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Impacts of Feed-in Tariff and Metering Types on Electricity Consumption Efficiency in Australia

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Abstract: Small scale renewable energy technology mainly includes rooftop solar photovoltaic (PV) panels for electricity generation at household level. Solar feed-in tariff (FiT) is meant to encourage households to alleviate import from electricity grid especially during peak demand, via investment on on-site generation. We investigate the impact of FiT, net and gross metering types on household energy consumption, in Australia.

A macro level model is developed for New South Wales (NSW) using a recent Australian household energy consumption dataset. The results indicate that net metering is more effective than gross metering, in terms of curtailing electricity consumption. Additional micro level analysis is conducted for Queensland (QLD) and other states which also verify similar effects.

In the last four years the cost of production of solar panels has declined by 80 percent, which alongside high FiT would increase the number of prosumers. An immediate response is that most states have already reduced FiT to one third or less. However, further decline in technology cost and the advent of new technology are expected to lead to massive uptake. Today, more than 10 percent of Australians use solar power. The 8,000 rooftop solar systems in 2007 have increased to 1 million in 2013, a number first expected for 2030 (ABC, 2013). On the other hand, since the intermittent PV electricity is not fully reliable, the stable grid electricity has become more pricy. In Australia, average annual electricity price is now rising at 8% (ABS, 2013). Accordingly, households opt to either invest more on renewable technologies or adapt to lowered consumption.

Statistics show average annual electricity consumption decline by 5.8% since 2009 (AER, 2014). This reduction is at both households with or without renewable electricity technology (ABS, 2014b). An implication is that non-generating households now have to suffer from high price of grid electricity, while generating households have less difficulty. In fact high FiT would even make profit. The situation signifies the need for a minimal FiT that could still encourage sustainable uptake of the renewables.

In this article, we analyse and evaluate solar FiT in Australia since its introduction in 2008. Our focus goes on investigating the impacts of metering types (gross and net) with low and high FiTs on electricity efficiency behaviours in Australia, however regardless of Renewable Energy Target (RET) incentives and possible retail price-tariff structures. In gross metering (GM), imported electric energy (E_{in} kWh) and exported energy (E_{out} kWh) are metered separately and respectively equal to total consumption and solar generation, while in net metering (NM), the offset values are equal, i.e., E_{out}-E_{in} = generation minus consumption. Dwellings with no onsite electricity generation use non-generating meters (ngM). The notations, GM, NM, ngM, are used frequently in this article.

This study indicates that high FiT only encourages higher consumption and does not effectively alleviate demand from grid. This in particular applies to GM where FiT profit is more visible. In comparison, under high FiT, GM households tend to consume more electricity than NM households, while in general all generating households (whether GM or NM) consume more electricity than non-generating households. This could be further discussed with regards to the rebound effect. Another implication of this study is in line with maintaining low FiT. For example Victoria has reduced FiT per kWh from 60c to 25c and to 8c, from 2009 to 2014. The FiT currently offers minimum premium of 8c per kWh for excess electricity exported to the grid. Some electricity retailers may offer higher rates although not obligated to do so. The Essential Services Commission (ESC) has released a decision to adopt a minimum FiT of 6.2c per kWh from 2015 (FiT, 2014a). Other states have reduced FiT, capped generation capacity, or cut premiums.

Keywords: *Solar feed-in tariff, net metering, solar panel uptake*

1. INTRODUCTION

A feed-in-tariff (FiT) (Couture and Gagnon, 2010) is an incentive to encourage uptake of renewable energy technology including photovoltaic (PV) so that users alleviate import from grid. An optimized FiT facilitates smooth uptake of renewable technology and at the same time promotes energy management and efficiency behaviours among households. Reversely, a high FiT ends up with more prosumer emergence (CSIRO, 2013), who are less concerned with energy efficiency and bill saving, and rather view FiT a profit making incentive. An Australian study analysed PV electricity price in all states using economical models to determine the accurate unit price of grid-connected rooftop PV electricity in \$/kWh throughout the year (Zahedi, 2009). Several configurations were considered depending on initial rebate and subsidies. For example, a case with \$2/W setup cost would return 15*c*/kWh worth of electricity in January. The estimated cost of generated electricity was then used to determine the base of FiT to justify the investment. A summary of recent estimations for setup cost (depending on capacity) across Australia is given in (SC, 2014). In China, Rigter and Vidican (2010) proposed a closed form equation that uses forecasts on future PV prices to derive an optimal FiT. King and Yu (2012) evaluated Taiwan's FiT scheme and Renewable Portfolio Standards (RPS), i.e., similar to Australian Renewable Energy Target (RET, 2014). A study in Ukraine, compared FiT against cost of energy production for different types of renewable energy. High FiT tariff and guaranteed access to grid were shown to be the main drivers toward green electricity production (Trypolska, 2012). However, excluding high FiT (due to its disadvantages), other studies showed a number of other drivers and motivational factors. These include both financial, e.g., insulation against rising energy prices, reduced outgoings in retirement, as well as non-financial factors, e.g., independence and self-sufficiency, resilience against outages, etc. The only study in favour of high FiT is about Thailand believing that high FiT laws create income opportunities for rural communities and offer significant potential to reduce imports of oil and coal (Greacen et al., 2003). However, as mentioned, most of the literature is against high FiT in particular in Australia (Martin and Rice, 2013) believing that low FiT still satisfies sustainable growth of renewable energy market, without disadvantages. Net metering scheme is supported in other literature to work along with low FiT. At last, the FiT itself can evolve to other measures, from social and environmental perspectives. For example, Eyre (2013) extended the concept of FiTs from power generation to energy saving called ESFiT. While FiT is a guaranteed price paid for each unit of energy produced, ESFiT defines a unit of saved energy, then pays a value depending on the public benefit and its worth. As an effective strategy, metering types (NM and GM) could play a role. In Australia, GM was first introduced in NSW in 2009, where costumers enjoyed FiT as high as \$0.60 to \$0.68 per kWh. However, only a year later (October 2010), the FiT was cut down to \$0.20, the lowest across Australia (AAP, 2010), on the realization of the faulty financial model with an over generous FiT (Martin and Rice, 2013). The NSW model had even triggered a movement among other PV owners in other states demanding for a national gross metering scheme. For example, 23000 households signed an online petition for a national gross feed in tariff (FiT, 2009). However by cutting FiT from higher than retail price (constant profit) to lower (constant loss), gross metering had to be replaced with net metering for the sake of social welfare. Therefore the trend is now toward net metering (NM) which makes a better balance between PV uptake (therefore PV panel imports) and expansion of Australian production (SFF, 2009). Analysis shows that under low FiT net metering is still profitable, especially when household electricity bill is taken into account (Poullikkas, 2013). High FiT allows for high profit leading to higher consumption (a rebound effect). Net metering is all about bill saving, efficient consumption, and occasionally profit making.

2. DATA EXPLORATION

A data driven methodology is implemented to analyse NM and GM under high and low FiT. The Australian Bureau of Statistics (ABS) published a public business survey of residential electricity distribution (ABS, 2014), based on experimental estimates in all Australian states, for 2010, 2011, and partially for 2012. The dataset includes electricity imported (E_{in}) as well as electricity exported (E_{out}) at residential meters. For dwellings with solar generation, in most states net import-export electricity is measured using a single meter. In NSW however, import and export electricity are measured separately. The summary of the data at state level is given in Table 1 which accordingly reveals several explicit facts especially about dwellings with GM and ngM. NM dwellings however require further processing. First, the supply data (supply mean (kWh) in Table 1) shows that average electricity imported by all NM, GM, and ngM classes has declined by almost 3%, 9%, 6% (from 2010 to 2011), and by 5%, 1%, 6% (from 2011 to 2012), respectively. Imported energy is directly proportional to electricity consumption at GM and ngM households. The fact that ngM households reduced consumption steadily by 6% per year indicates overall tendency towards low usage, regardless of generating solar electricity. GM consumption has less reduction in the second year, which implies that the high return from FiT in 2010 lead to rebound effect in 2011. Reversely, NM households seems to have consumed less energy in the second year (i.e., from 3% to 5% reduction), although imported energy is not directly related to household consumption. However, this is verified by main distributors in NSW that customers on NM try to cut consumption more often than GM customers (GE, 2014). Another fact is about uptake of solar technology within two years, from 2010 to 2012.

Since on average, similar technology has been used regardless of NM or GM metering, the total number of all generating meters (whether GM or NM) reveals 89% and 24% annual uptake in 2010-11 and 2011-12, respectively. However, a closer look shows the effect is only on GM households, as solar uptake at NM households (122%) is much higher than GM households (2%) in 2011. The considerable decline in solar uptake at GM households (i.e., from 75% to 2%) is a response to reduced FiT. However, NM households sustain contribution to solar uptake. It is explicit that in general NM leads to sustainable consumption, alongside high uptake rate. At last, the higher average consumption at generating dwellings (compared to non-generating dwellings links with the rebound effect. For instance, a comparison between GM and ngM dwellings shows 12.6% higher consumption averaged over 3 million households in 2010-2012.

Table 1. Electricity consumption at generating and non-generating dwellings, NSW, 2010-2012 calendar years.

Dwellings		Dwellings with electricity generation capabilities						without electricity generation		
Metering standard		Net Metering (NM)			Gross Metering (GM)			non-generation Metering (ngM)		
Year		2010	2011	2012	2010	2011	2012	2010	2011	2012
Number of residential electricity meters		7,286	21,100	46,834	50,526	88,406	89,920	2,884,934	2,853,827	2,848,103
Proportion of electricity meters (%)		0	1	2	2	3	3	98	96	95
Electricity supplied to dwellings										
Supply mean (kWh)		6,667	6,458	6,127	7,716	7,018	6,950	6,815	6,418	6,038
Q1	Lowest quintile (kWh)	2,034	1,928	1,509	2,634	2,409	2,336	1,734	1,596	1,502
Q2	Second quintile (kWh)	3,773	3,787	3,157	4,804	4,333	4,190	3,876	3,598	3,342
Q3	Third quintile (kWh)	5,439	5,440	4,797	6,715	6,038	5,814	5,738	5,355	4,971
Q4	Fourth quintile (kWh)	7,737	7,571	7,070	9,131	8,232	7,971	8,164	7,679	7,159
Q5	Highest quintile (kWh)	14,321	13,546	14,091	15,292	14,073	14,435	14,560	13,862	13,215
Electricity supplied back to grid										
Supply mean (kWh)		736	711	np	829	1,969	np	na	na	na
Q1	Lowest quintile (kWh)	89	111	np	81	642	np	na	na	na
Q2	Second quintile (kWh)	354	336	np	304	1,119	np	na	na	na
Q3	Third quintile (kWh)	614	551	np	612	1,502	np	na	na	na
Q4	Fourth quintile (kWh)	867	828	np	963	2,043	np	na	na	na
Q5	Highest quintile (kWh)	1,756	1,728	np	2,182	4,531	np	na	na	na

3. METHODS AND RESULTS

NM consumption and solar generation is not as explicit as GM. A system of equations (1) is realized for net metering for all five quintiles (Q) within the dataset, where (d) represents dwellings demand in kW, (g) is renewable energy presumably from solar PVs (kW), (I) is hours or number of instances with $g > d$, and (J) is number of instances with $d > g$. Eq. (1) could be rewritten in form of (2), given the total number of instances in one year N equals to total hours in one year (i.e., 24×365), so that g and d would be in kW. Accordingly, there is an indication of average values of generation, demand, and number of instances where either transient generation or demand gets greater than the other, i.e., I (hours) and J (hours), respectively. On the other hand, for gross metering, Eq. (1-2) transform to (3) due to direct import and export of electricity. The last formulation is about non-generating metering where in absence of on-site generation, a single equation (4) describes the demand. The system is then analysed where index (Q) represents each of the quintiles, NM, GM, and ngM represent related metering standards, as formulated in Eq. (1-2), (3), and (4), respectively.

$$\begin{cases} \sum_{i=1}^{I}(d-g)_i = E_{in} \\ \sum_{j=1}^{J}(g-d)_j = E_{out} \end{cases} \tag{1}$$

$$\begin{cases} I(\overline{d-g}) = E_{in} \\ J(\overline{g-d}) = E_{out} \\ N = I + J \end{cases} \tag{2}$$

$$\begin{cases} \sum_{n=1}^{N}(d)_n = E_{in} \\ \sum_{n=1}^{N}(g)_n = E_{out} \end{cases} \Rightarrow \begin{cases} \bar{d} = E_{in}/N \\ \bar{g} = E_{out}/N \end{cases} \tag{3}$$

$$\sum_{n=1}^{N}(d)_n = E_{in} \Rightarrow \bar{d} = E_{in}/N \tag{4}$$

$$\begin{cases} D\colon\ \bar{d}_{GM\{Q_q\}} \approx \bar{d}_{NM\{Q_q\}} \\ G\colon\ \bar{g}_{GM\{Q_q\}} \approx \bar{g}_{NM\{Q_q\}} \\ O\colon\ (\overline{d-g})_{NM\{Q_q\}} \approx (\overline{d-g})_{GM\{Q_q\}} \end{cases} \tag{5}$$

Solving Eq. (2) for NM dwellings, the values of I_{NM}, J_{NM}, and average of $\pm(g\text{-}d)_{NM}$ will be obtained. On the other hand, Eq. (3) directly reveals values of average d_{GM} and g_{GM} for GM households. Now, let us make an assumption about households within quintile Q_q as a subset of the entire NM sample set ($Q_q \subset$NM, q=1...5) having similar demand and generation behaviour as households belonging to corresponding quintiles of the GM sample set (5). The evidence is that all samples have been pulled out of the same population (NSW) with only different metering protocols. We employ a linear regression based on the supervised learning in neural networks. A single layer perceptron is formed with nodes D representing demand and G generation at input, and node O representing their offset at output. The network is first loaded with known values $\{D, G, O\}$, i.e., D and G from GM, and O from NM (left hand side values in (5)). The trained system is then used to guess on unknown values of D and G from NM, through deduction from known value of O from GM (right hand side values in (5)).

Table 2. NSW representing main Australian demographics (2006-2009) ABS census (ABS, 2014).

Demographics	Australia	Newcastle		Demographics	Australia	Newcastle
Age:				Median family income:	1171	1132
0-4	0.06	0.06				
5-14	0.14	0.11		Occupied private dwelling:		
15-24	0.14	0.15		Separate house	0.75	0.73
25-54	0.42	0.41		Semi-detached house	0.09	0.11
55-64	0.11	0.1		Flat, unit or apartment	0.14	0.15
65+	0.13	0.16				
				Tenure:		
Family characteristics:				Fully owned or being purchased	0.65	0.61
Couple families with children	0.45	0.4		Rented	0.27	0.32
Couple families without children	0.37	0.38				
One parent families	0.16	0.19		Internet connections:	0.58	0.53

3.1. NSW Renewable Electricity Generation and Consumption

New South Wales (NSW) hosts one third of the Australian population; and is well representing the demographics. Table 2 shows Newcastle city located in east NSW, against Australia (EA, 2014). In particular the related dataset of this study (NM and GM) are from NSW. We apply the process on the three household sectors (NM, GM, ngM) of NSW dataset in Table 1, so that instead of E_{in} and E_{out}, average demand (d) and renewable generation (g) are obtained (Table 3). Additionally, the expected values of I_{NM} (hours without renewable energy generation) and J_{NM}, (hours of renewable energy generation) is included. To estimate unpublished NM and GM values of E_{out} for year 2012 we estimate $(g\text{-}d)_{NM}$ and $(g\text{-}d)_{GM}$ for year 2012, and with the available values of E_{in}, NM and GM values of E_{out}. At the first glance, Table 3 reveals the same fact that electricity demand at households with generation capability is on average 10-20% higher than demand at households without generation capability. This is attributed to psychological factors mainly household's confidence in its electricity generation capability leading to lavish consumption. Second, the ratio of GM demand over NM demand has reduced from >1 in 2010, to <1 in 2011. This verifies the fact that in 2010, GM households relatively consumed more energy due to higher FiT= 20-68c compared to NM FiT which was often in effect equal to electricity price (FiT≤ 26c). This in particular relates to GM installations prior to October 2010 with all connection enjoying the ~60c rate. However, 2011 values, and expected values for 2012 (underlined values in Table 3) indicate that new households (and those dragged from 2010 to 2011) changed trend due to FiT changes in favour of net metering. After April 2011, with new FiT, net metering is preferred by most new customers, reported by a NSW distributor (GE, 2014). Investigation on I (hours of $d>g$) and J (hours of $g>d$) reveal overall demand and generation profiles. However, this is a rough estimate and may not reflect exact hours. A limitation is about the assumption for $|g\text{-}d|_i = |d\text{-}g|_j = |g\text{-}d|_N$ which might be far from the reality. Another limitation over time dimension is about unknown sequence of instances $i \in I$ and $j \in J$. From another perspective, J values can be used to infer solar capacity. For example, in 2010 the NM-Q_1 households had on average J=338 hours of $g>d$ (~1 hour per day), while Q_5 households had ~3 hours of $g>d$ per day. With equal average hours of solar radiation, it seems that J could reflect the size of solar panels S_{Q_q} (kW) used on average by each quintile (6). Further micro analysis is needed to obtain coefficient γ, e.g., Residential Building Electricity Efficiency (RBEE) dataset of individual households (Ambrose et al., 2013).

$$S_{Q_q} \propto J_{Q_q} \qquad (6)$$

3.2. NSW, a Top-Down Review

To obtain NM demand and generation values in Table 3 we assumed that Q_1-Q_5 households in terms of demand match with Q_1-Q_5 households in terms of generation. This assumption is controversial as it may not apply to many cases, e.g., dwellings with high demand but low generation. Therefore, in this section, we repeat the analysis for individual NSW statistical areas level 2 (SA2) (ABS, 2014a), which eliminates the previous assumption for quintiles. Fortunately, in addition to the data summary (as shown in Table 1), the ABS dataset also includes E_{in} and E_{out} down to SA2 levels for NM, GM, and ngM dwellings, and for all Australian territories. We use these values to directly calculate ngM demand, and GM demand and generation. Values of NM demand and generation are inferred indirectly using similar neural inference mechanism. Fig. 1 shows the method of extracting these values from known GM and NM, E_{in} and E_{out}. Given the fact that all generating dwellings within the same SA2 (i.e., most likely within similar dominant climate zone), have similar solar generation on average, the difference between electricity demand is inferred using neural regression, with known values of d_{GM}, g_{GM}, and $(d\text{-}g)_{NM}$. As a result, Eq. (7-8) show ratios of d_{GM}/d_{NM} and g_{GM}/g_{NM} respectively for years 2010 and 2011, averaged over nearly 400 SA2s. The results show that 20% extra d_{GM} in 2010 has reduced to comparable value of d_{NM} in 2011. The ratios of d_{GM}/d_{NM} in (7) and (8) are shown for all SAs in Fig. 2 (a) and (b), respectively.

$$2010: \begin{cases} d_{GM}/d_{NM} = 1.189 \cong 1.2 \\ g_{GM}/g_{NM} = 0.987 \cong 1 \end{cases} \quad (7) \qquad 2011: \begin{cases} d_{GM}/d_{NM} = 0.962 \cong 1 \\ g_{GM}/g_{NM} = 1.021 \cong 1 \end{cases} \quad (8)$$

Table 3. NSW, consumption and domestic generation. GM and ngM demand is directly imported from grid. NM demand could be imported from grid or from PV. Underlined values show unpublished values for 2012.

Dwellings		Dwellings with electricity generation capabilities												without solar generation		
Metering standard		Net Metering (NM)						Gross Metering (GM)						non-generation Metering		
Year		2010		2011		2012		2010		2011		2012		2010	2011	2012
Average dwellings demand			I (h)		I (h)		I (h)		I (h)		I (h)		I (h)			
mean (kW)		0.7729	7793	0.8750	7007	0.8465	5507	0.881	7910	0.801	6841	0.793	5236	0.778	0.733	0.689
Q1	Lowest quintile (kW)	0.2321	8422	0.2802	6951	0.2648	2775	0.301	8499	0.275	6917	0.267	2756	0.198	0.182	0.171
Q2	Second quintile (kW)	0.4255	8091	0.5200	7051	0.4903	4561	0.548	8239	0.495	6962	0.478	4417	0.442	0.411	0.382
Q3	Third quintile (kW)	0.6218	7862	0.7272	7107	0.6877	5526	0.767	8028	0.689	7015	0.664	5361	0.655	0.611	0.567
Q4	Fourth quintile (kW)	0.8958	7790	0.9993	7124	0.9530	5857	1.042	7924	0.940	7018	0.910	5675	0.932	0.877	0.817
Q5	Highest quintile (kW)	1.6847	7627	1.8419	6911	1.8361	5731	1.746	7666	1.607	6627	1.648	5303	1.662	1.582	1.509
Average dwellings generation			J (h)		J (h)		J (h)		J (h)		J (h)		J (h)			
mean (kW)		0.0959	967	0.219	1753	0.5000	3253	0.095	850	0.225	1919	0.534	3524	na	na	na
Q1	Lowest quintile (kW)	0.0093	338	0.0729	1809	0.5710	5985	0.009	261	0.073	1843	0.581	6004	na	na	na
Q2	Second quintile (kW)	0.0352	669	0.1261	1709	0.4515	4199	0.035	521	0.128	1798	0.470	4343	na	na	na
Q3	Third quintile (kW)	0.0711	898	0.1691	1653	0.4024	3234	0.070	732	0.171	1745	0.421	3399	na	na	na
Q4	Fourth quintile (kW)	0.1116	970	0.2296	1636	0.4724	2903	0.110	836	0.233	1742	0.495	3085	na	na	na
Q5	Highest quintile (kW)	0.2503	1133	0.4928	1849	0.9702	3029	0.249	1094	0.517	2133	1.074	3457	na	na	na

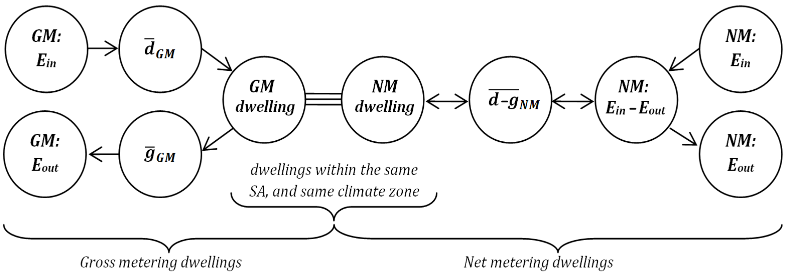

Figure 1. Assuming on average (over SA2 level) that GM and NM dwellings are equivalent in terms of solar technology and capacity, solar radiation and climate (i.e., GM dwelling ≡ NM dwelling), for all NSW SA2s, average d_{NM} and g_{NM} can be extracted from average $(d\text{-}g)_{NM}$, guided by known average values of d_{GM} and g_{GM}.

3.3. QLD, a Bottom-Up Review

Residential Building Electricity Efficiency (RBEE) is a nationwide research project for analysis of energy efficiency behaviours, consumption, solar generation, and other characteristics at individual dwellings, for a wide range of dwelling typologies, household types, and occupancy patterns. Among catchment areas, south east Queensland (SEQ) has the closest characteristics to both states of QLD and NSW, by population, demographics, and climate zone. The time series consumption and generation data, i.e., at 30 min resolution, is available for tens of non-generating as well as generating dwellings, from November 2012 to February 2013. At the first glance, average hourly electricity demand is measured at ≃0.79 kW at non-generating dwellings, and ≃0.87 kW at generating dwellings (in 2012). The difference shows ≃10.1% higher consumption at generating dwellings. Similarly, macro level analysis suggests more accurate value of 12.6%.

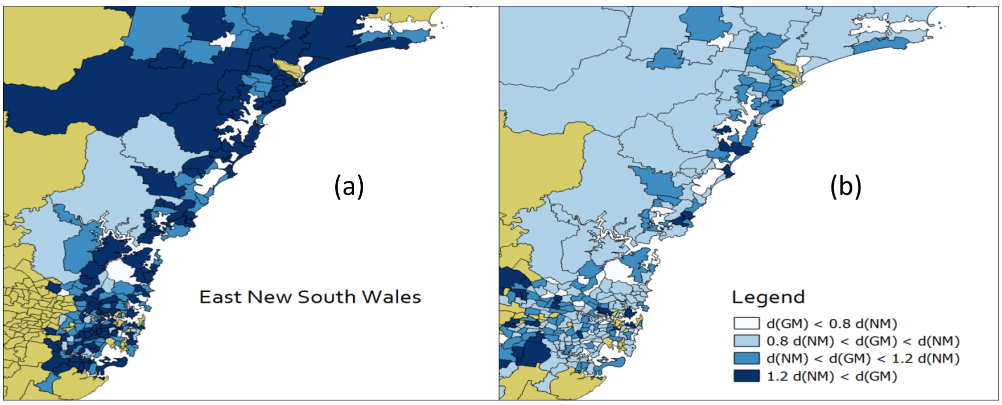

Figure 2. d_{GM}/d_{NM} in SA_2 in NSW. (a) in 2010, d_{GM} is 20% higher than d_{NM}, (b) in 2011, d_{GM} is close to d_{NM}.

For generating dwellings, the hourly solar generation is averaged at 0.45 kW, which accounts for ≃52% of household hourly demand. Knowing that QLD practices NM, this high proportion signifies the effectiveness of NM. On the other hand, we obtained d_{GM}/d_{ngM}=12.6% (in 2010-2012 NSW), while here d_{NM}/d_{ngM}=10.1% is obtained (in 2012 in QLD). And since on average both states had almost similar FiTs over the given periods, i.e., QLD FiT= 44c, and NSW FiT= (60+20)/2= 40c, the ratio of d_{GM}/d_{NM} could be obtained from

$(d_{GM}/d_{ngM})/(d_{NM}/d_{ngM})$= 12.6/10.1≃ 1.25. In other words, generating dwellings in QLD would have consumed 25% more electricity under GM. It is apparent from both macro and micro analysis that, given the FiT circumstances, GM households simply consume more electricity than NM households, while on average they use similar solar technology, and receive similar solar radiation. A positive feedback is then made by higher investment on PV technology in quest for higher return from FiT which in turn entails unleashed PV uptake. This reinforcing cycle could be best harnessed with lowered (minimised) FiT, while the reducing cost of technology sustains solar uptake.

4. OTHER VIEWPOINTS

We showed that net metering leads households towards energy efficient behaviours. However, net metering is subject to criticism from several perspectives. Existing and potential users of solar (and other renewable energy) technology argue that lowered FiT discourages sustainable PV uptake. They often raise that national gross feed in tariff programs have been established around the world, resulting in increased uptake of solar and wind power systems among home owners and businesses (FiT, 2014). In this part, a quick example case is given to prove the otherwise. We consider two Australian territories, one QLD with constant FiT of 44c for most of 2010-2012 (i.e., until July 2012), and South Australian (SA) with FiT= 44c (until September 2011), which was then lowered to ≃26c (EM, 2014). The choice of QLD and SA is due to similar initial FiTs (44c per kWh) and consistent net metering programmes in both states. However, the fact that SA changed tariff almost exactly in the middle of the 2010-2012 duration, allows for a meaningful comparison with QLD which retained tariff for the entire duration. Fig. 3 shows the summary of the consumption-generation data in QLD and SA.

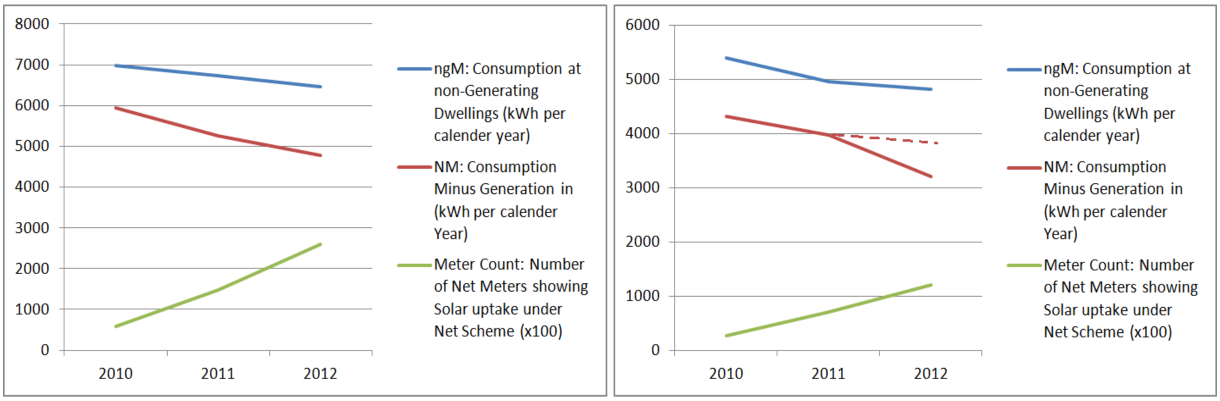

Figure 3. Annual data for NM count (green), average consumption minus generation (red), and average ngM consumption (blue), over 2010-2012 period: in Queensland (left) and in South Australia (right).

For non-generating dwellings, reduction of electricity consumption is apparent in both states, which also applies to whole country. It is proven that Australians now tend to use less electricity, mainly due to efficiency, and mindfulness. In terms of impact of FiT, Fig. 3(a) for QLD with constant FiT shows constant solar uptake rate (meter count), and constant rate of net metering (i.e., offset of consumption and generation at NM dwellings). A different situation is realised for WA in Fig. 3(b) where reduction of FiT in 2011 gives an elbow to net metering, as well as non-generating metering, however not to solar uptake rate. In other words, with or without FiT reduction, solar uptake in 2011-2012 continues to grow at the same rate as in 2010-2011 or even slightly higher. The interpretation about elbows in ngM and NM characteristics in SA is apparently due to the impact of FiT changes in 2011. It could be observed that from 2010 to 2011, the energy consumed by non-generating dwellings (blue) has the same reduction as the offset of imported and exported energy at net metering dwellings (red). The difference of about 1000kWh between the two curves is therefore interpreted as the average solar generation (9) provided both ngM and NM households have similar average demand for electricity. In fact, we have previously shown that generating households often tend to consume more electricity (an excess of E_c kWh) compared to non-generating ones (10), i.e., a rebound effect. Fig. 3(b) is used to establish a qualitative analysis. Consumption at ngM dwellings is presumably independent from solar FiT. Given this, without any changes to FiT from 2011 to 2012, NM should have remained parallel to ngM (perforated red in Fig. 3(b)). Accordingly, the deviation of NM from ngM in 2011-2012 (i.e., to approximately 600 kWh lower) could be interpreted as being either due to lowered NM consumption or increased NM solar generation capacity, both in response to FiT reduction. While both scenarios are favourable, the answer more likely lies in higher generation capacity (solar uptake), alongside positive rate of meter counts. The impacts of changes are rather absorbed by households in terms of consumption behaviour (lowered consumption) and increased generation capacity. It is seen that solar uptake rate has remained positively increasing despite lowered FiT. Solar investment continues to grow with or without FiT as most users find it a viable asset, not only for electricity supply, but for the environment. As described in (6), for similar annual patterns of average solar radiation and average household consumption, J is supposed to remain constant along years and across quintiles of sample dwellings, i.e., number of hours of *g*>*d*. In contrast, by interpreting *J* as solar capacity, a conclusion could be made about average panel size to increase year by year and from lower quintile to higher quintile. Individual dwellings have different *J* value; therefore, using data of individual dwellings in this example, we infer the value of coefficient γ to elaborate Eq. 6 to Eq. 11. Accordingly, with γ≃ 0.48, average panel size is obtained 2.3 and 4.3 kW in 2011 and 2012, respectively. A limitation however is about duration of micro data limited to the summer months.

$$ngM \equiv NM: \; E_{in} - 1000 = E_{in} - E_{out} \quad (9) \qquad ngM \not\equiv NM: \; E_{in} + (E_c - 1000) = E_{in} - E_{out} \quad (10)$$

$$S = \gamma J + \varepsilon \;, \; \gamma = 0.478 \;, \; \varepsilon(0,0.01) \quad (11)$$

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