www.rericjournal.ait.ac.th

The Economics of Net Metering Policy in the Philippines

Romeo Pacudan*[,1]

Abstract – *The Philippines is one of the first countries in Southeast Asia that introduced an incentivized self-consumption policy for small scale solar PV systems. Electricity tariffs in the country are the highest in the region and that costs of generating electricity from small scale PV systems have reached above grid parity. Incentivized self-consumption schemes include net billing and net metering arrangements, and in the literature these schemes are loosely described as net metering schemes. Both frameworks allow customers to generate their own supply and export surplus electricity to the grid. Under net billing arrangement, excess electricity receives monetary compensation while under net metering, customers receive energy compensation. The study assessed the two frameworks under Philippine conditions and the results show that net billing provides an attractive rate of return and encourages participants to self-consume rather than export electricity to the grid. Net metering on the other hand generates higher rate of return than net billing and encourages investments on larger systems that could also maximize electricity exports. Since the program implemented under the incentivized self-consumption scheme is supported by distribution utility customers, net metering would result in higher financial burden to ratepayers. The study results affirm that the government policy choice is more balanced, responding to the needs of program participants while not placing unwarranted burden to distribution utility customers.*

Keywords –incentivized self-consumption schemes, net metering, net billing, residential solar PV policy.

1. INTRODUCTION

Having experienced rapid economic transformation in the past decades, a number of Southeast Asian countries are aiming to balance rapid economic growth with long-term sustainability goals. Transitioning towards low carbon economic development has been slowly gaining momentum in their national political agenda. In the energy sector, several countries have aggressively pursued to increase the share of renewable energies in their national energy mix. With diverse national policy objectives to promote renewable energies, the focus in the past was on increasing deployment of utility scale renewable energy technologies. More recently the attention has broadened to cover deployment of small-scale renewable energy systems targeting commercial and residential sectors.

Among these countries, Indonesia, Malaysia, the Philippines, Singapore and Thailand have introduced policy frameworks that incentivize residential households to invest in rooftop solar PV systems. The choice of policy measures however has been disparate. With the continued decline of solar PV system costs and high financial obligations associated with feed-in tariff schemes, policies in the region converge towards incentivized self-consumption schemes. Indonesia recently introduced a net metering policy [61]; Malaysia and Thailand discontinued their feed-in tariff schemes, with Malaysia introducing a net metering scheme [41], [15] while Thailand pursuing a self-consumption policy [17]; the Philippines introduced a net metering framework [40]; and Singapore, net settlement policy [56].

Incentivized self-consumption schemes which include net metering and net billing frameworks, have been loosely described in the literature as net metering schemes but [32] and [14] have pointed out the main difference between these two schemes. In both cases, energy generated by solar PV systems is consumed first by residential households and excess generation is exported to the grid. Under a net metering arrangement, excess electricity receives energy compensation while a net billing scheme offers monetary compensation [32].

This study focuses on the policy framework implemented in the Philippines. For customers who participate in the net metering program under the net metering rules issued by the Philippine Energy Regulatory Commission (ERC) in 2013, their excess generation exported to the grid will be paid based on the distribution utilities' monthly generation charge. Following the above definitions of incentivized self-consumption schemes, the framework implemented in the country is therefore a net billing rather than a net metering framework. With regard to incentivizing households to invest in solar PV systems and in terms of overall management control from a policy implementation perspective, the key question raised in this paper is, how does the current net billing framework perform compare with the alternative net metering scheme?

*Energy Policy and Management, Institute of Policy Studies, Universiti Brunei Darussalam (UBD); and

Brunei National Energy Research Institute (BNERI), Science and Technology Research Building, Universiti Brunei Darussalam, Tungku Link Gadong, BE 1410 Brunei Darussalam.

[1] Corresponding author;
Tel: + 6737256850.
E-mail: romeo.pacudan@bneri.org.bn; romeo.pacudan@ubd.edu.bn; romeo.pacudan@gmail.com.

This paper is structured as follows. Section 2 provides an overview of residential solar PV policies. Section 3 reviews the renewable energy policy framework in the Philippines. Section 4 presents the data and methodology used in assessing technical and economic performances of residential solar PV technologies under the alternative policy frameworks. Section 5 presents the results and discusses its implications. Section 6 presents the study conclusion.

2. RESIDENTIAL SOLAR PV POLICIES

Feed-in tariff and incentivized self-consumption schemes are the main policy frameworks adopted by several countries and economies to close the gap between the cost of residential rooftop solar PV generation and retail electricity tariffs [31], [52]. Feed-in tariff schemes were widely adopted in European Union countries while incentivized self-consumption schemes were common frameworks adopted by various jurisdictions in the United States of America and in Australia [2], [38].

Under the feed-in tariff framework, residential households that installed rooftop solar PV systems are paid by utilities a tariff rate determined by authorities and guaranteed for a specific period of time [9]. A self-consumption scheme refers to a mechanism that permits generation of electricity mainly for self-consumption rather than for grid injection, while incentivized self-consumption schemes allow self-consumption and compensation for excess electricity exported to the grid over a longer time frame (up to 1 year or more) [14], [31]. As mentioned earlier, incentivized self-consumption policies include net metering and net billing schemes but these two are inaccurately described in literature as net metering schemes.

Historically, feed-in tariff schemes and to some extent net billing schemes have been responsible for jumpstarting solar PV markets and responsible for higher deployment rates in Europe and other industrialized countries as well as in a number emerging economies [2], [9], [31], [51], [55]. These schemes were financially attractive to investors due to the premium tariff rates set by early policy adopters. The consequence of this high success rate is the high financial obligations associated to feed-in tariff contracts. The financial attractiveness of 'net metering' schemes on the other hand is influenced by the costs of avoided electricity bills, but this could be improved if coupled with other financial incentives such as in the case of the USA [51]. The limited success of net metering schemes globally could be attributed, not on the inadequacy of the policy, but rather on the lack of additional incentive policies [51].

Since the past decade, feed-in tariff rates were regularly adjusted downwards due to market growth and rapidly declining solar PV prices [54]. Such reduction of feed-in tariff rates resulted a decline in solar PV deployment in Europe [31]. The narrowing of the cost gap (cost of electricity production from residential solar PV against retail electricity tariffs), and to some extent the achievement of grid parity in a number of countries have attracted interest from regulatory authorities, utilities and policy makers on incentivized self-consumption schemes as an alternative option for stimulating investments from residential consumers [6]. The increased competitiveness and the decentralized nature of solar PV systems would enable residential households to invest on rooftop PV systems to increase their energy savings and reduce their exposure to higher electricity prices.

Most studies that assessed the performance of alternative regulatory frameworks mainly focused on the comparison between feed-in tariff and net metering schemes [49]. Despite the recognition that there are various variants of net metering schemes [6], [50], there are limited studies comparing net metering and net billing frameworks. Case studies carried out by [59] for Chile, and [12] and [36] for Spain (countries that have achieved grid parity) show that net metering would result in higher profitability from investor households perspectives than net billing scheme. Ref [49] on the other hand, showed that in the case of Brunei Darussalam (country that have not reached grid parity), net metering and net billing schemes could be designed to provide the same level of incentives and that export tariff under the net billing scheme need to be set at a very high rate to compensate for the subsidized retail tariff rate. From a policy perspective, ref [36] concluded that net billing policies will result in minimum cost for the electricity system. In the case of California, [18] concludes that the current net metering program could be improved by introducing a net billing policy with compensation of export electricity based on locational net benefit analysis (LNBA). This would allow locationally differentiated compensation, improve grid cost recovery, and deeper decarbonization though storage-enabled alignment of solar supply and demand.

3. RENEWABLE ENERGY DEPLOYMENT POLICIES IN THE PHILIPPINES

3.1 *Overview of the Electricity Supply Industry*

The Philippine electricity supply industry has experienced wide-ranging transformation since the enactment of the Electric Power Industry Reform Act (EPIRA) in 2001 [7]. Structural, ownership and market reforms were introduced in the electricity supply industry to encourage greater competition and attract private sector investments [45]. A competitive market was expected to bring down electricity prices and provide more efficient services to end-users. The reforms separated different functions of the power sector (generation, transmission, distribution and supply), established the wholesale electricity spot market (WESM) and introduced retail competition. Generation, supply and grid operation represent the competitive segments of the industry while transmission and distribution constitute the natural monopoly segments [9], [30], [46].

Government bodies responsible for the transition and the governance of the restructured power industry were established and/or nominated under EPIRA, and this includes the following: i) Joint Congressional Power

Commission (JCPC) for guidelines and overall framework; ii) the Department of Energy (DOE) for policy; iii) the Energy Regulatory Commission (ERC) for economic regulation; iv) the Power Sector Assets and Liabilities Management (PSALM) Corporation for the privatization program; v) the National Power Corporation through its Small Power Utilities Group (NPC-SPUG) for missionary electrification; and the National Electrification Administration (NEA) for rural electrification promotion [7], [46].

Assets of the National Power Corporation (NPC), the then vertically integrated public utility responsible for generation, transmission and system of electricity, were broken down and its generating assets were privatized by PSALM. Generating assets were gradually sold to the private sector since 2004. The National Transmission Company (TRANSCO) was established by EPIRA to carry out high voltage transmission and sub-transmission functions. Transmission operations were then privatized through a 25-year concession. The National Grid Corporation of the Philippines (NGCP), was selected through competitive bidding to take over the operation, maintenance and development of the national grid in 2008. Distribution utilities, consisting of private distribution utilities and electric cooperatives, retained their functions and were required to provide open and non-discriminatory access to users of distribution wires and to charge ERC-determined wheeling rates.

The wholesale electricity market under the restructured industry consists of bilateral and spot markets. Under bilateral market, distribution utilities source its supply through medium to long-term contracts with generation companies, while under the spot market, through an hourly trading of electricity. During the first 5 years of WESM operation, distribution utilities were not allowed to source more than 90% of their supply from bilateral trade [7]. The Philippine Electricity Market Corporation (PEMC) was established in 2003 to prepare for the operation of WESM. With the establishment of market operational methodologies, the WESM commenced its commercial operation for the Luzon Grid in June 2006, for the Visayas Grid in November 2010 and for the Mindanao Grid in June 2017 [11]. PEMCO acts as the market operator while the NGCP is tasked to be the system operator of the WESM.

Retail competition and distribution network open access (RCOA) were introduced in June 2013 when the pre-conditions [2] that level the playing field set by the EPIRA were met. Under RCOA, the electricity market is categorized into contestable and captive markets. The former is defined as those end-users who have given the choice to select their supplier while the latter is defined as those who do not have a choice of a supplier of electricity [10]. The level of initial demand in the contestable market is 1 MW peak-demand and was reduced to 750 kW after two years of implementation.

3.2 RE Targets and Legal Framework

The Philippines is a net energy importing country, highly dependent on imported fossil fuels, and has always been affected by energy price volatility in the international markets. The development the country's renewable energy resources has been an integral part of the national strategy to enhance energy security and reduce harmful emissions from the use of fossil fuels. With the country's renewable energy resource potential estimated at around 250,000 MW, the Philippine Department of Energy under its National Renewable Energy Plan (NREP) set an ambitious target of increasing the total renewable energy installed capacity to around 15,300 MW by 2030 [37]. In a more recent policy document, the Renewable Energy Road Map 2017-2040, the Government aims to increase the renewable installed capacity to 20,000 MW by 2040 [53].

To achieve the above targets, the government enacted in 2008 a legal framework, the Renewable Energy Act, for the promotion and development of renewable energies in the country. The Act has specified frameworks that aim to incentivize private sector investments on renewable power generation. For grid-connected renewable energy systems, five main frameworks were outlined in the Act, and these are i) renewable portfolio standards, ii) feed-in tariff scheme, iii) green energy option, iv) green energy market, and v) net metering system [8], [46]. Among these measures, only feed-in tariff and net metering schemes are currently being implemented.

To further reduce the levelized cost of renewable power generation, the Act also specified fiscal incentives to be applied to renewable power investments such as income tax holiday; duty free importation of renewable energy machinery, equipment and materials; special realty tax rates on equipment and machinery; net operating loss carry-over; accelerated depreciation; zero percent VAT; cash incentive of renewable energy developers for missionary electrification; tax exemption of carbon credits; tax credit on domestic capital equipment and services. To address key financing barriers, the Act also stipulated that, with endorsement from DOE, government financial institutions (GFIs) will provide preferential financial packages for the development, utilization and commercialization of RE projects.

The Act also established the Renewable Energy Management Bureau (REMB) under the DOE and the National Renewable Energy Board (NREB). REMB is assigned to develop, formulate and implement policies, plans and programs to accelerate the development, utilization and commercialization of renewable energy resources and technologies; develop and maintain a database; conduct technical and impact studies; information, education and communication services. NREB on the other hand is tasked to recommend

[2] These conditions are the following: i) establishment of the wholesale electricity spot market; ii) approval of unbundled transmission and distribution wheeling charges; iii) initial implementation of the cross subsidy removal scheme; iv) privatization of at least 70% percent of the total capacity of generating assets of National Power Corporation (NPC) in Luzon and Visayas; and v) transfer of the management and control of at least 70% of the total energy output of power plants under contract with NPC to the Independent Power Producer (IPP) administrators [6].

policies, support in the implementation of renewable energy policies and in the management of the RE Trust Fund.

3.3 Net Metering Policy

As mentioned earlier, among the policy measures stipulated in the RE Act, only feed-in tariff policy and net metering schemes are currently being implemented. The DOE more recently has issued a draft circular and invited comments on the rules and guidelines governing the establishment of the renewable portfolio standards (RPS) [26].

Four years after the passage of the RE Act, NREB submitted to ERC the proposed Rules Enabling the Net Metering Program for Renewable Energy which was subsequently endorsed and approved by ERC in May 2013, and took effect in July 2013. Main features of the Net Metering Rules are the following [13], [26].

- Net metering allows customers of distribution utilities to install an on-site renewable energy facility for their own use and that surplus generation can be exported to the distribution grid;
- The capacity limit is 100 kW since the RE Law specified net metering facilities as distributed generation (DG). DG is defined as those systems with capacity not exceeding 100 kW;
- Eligible facilities include solar, wind, biomass or biogas systems or other RE systems installed within the customer's premises and must be compliant with technical standards;
- Only captive customers of distribution utilities are qualified for net metering program. Contestable customers and customers directly connected to the transmission grid are not eligible to join the said program;
- Pricing methodology would be finalized by ERC in consultation with industry stakeholders and participants, but initially fixed at the distribution utilities' monthly generation charge;
- The cost of RE exported to the grid will be included as generation cost of a distribution utility to be recovered from all its customers; and
- Distribution utilities are allowed to impose a net metering charge to all customers who avail of the net metering program which covers distribution utilities' incremental costs related to system enhancement, additional meter reading and other operating costs.

3.4 RE Deployment Status

Since the implementation of the policy measures and support mechanisms specified in the RE Act, significant progress has been achieved in terms of increasing the deployment of renewable energy technologies.

As of mid-2017, the Philippine power system had a total installed capacity of 21,621 MW of which 32.55% were renewable power installations (16.83% hydropower, 8.82% geothermal, 3.90% solar PV, 1.97% wind and 1.04% biomass power). In terms of power generation, the total generation during the first half of 2016 amounted to 44.6 TWh with 27.6% generated by renewables (13.8% geothermal, 10.2% hydropower, 1.4% solar, 1.3% wind and 0.9% biomass).

During the period 2009 to 2017, around 1.876 GW of renewable power capacity was commissioned, its development directly linked to the incentives provided by the RE Act [3]. Solar PV capacity additions amounted to around 903.7 MW of which 8.2 MW was developed through net metering scheme while the remaining 895.5 MW was developed mainly through feed-in tariff policy.

4. DATA AND METHODOLOGY

This section describes and presents the methodology in assessing cost competitiveness and economic performance of rooftop solar PV in the Philippines. Section 4.1 presents the methodology in estimating energy yield of rooftop solar PV systems while Section 4.2 describes the methodology in calculating how much electricity is being consumed and exported by a typical household. Section 4.3 reviews electricity tariffs and its components. Section 4.4 presents the project cost assumptions while Section 4.5 explains the methodology used in estimating the levelized cost of electricity (LCOE).

4.1 Energy Yield Estimation

The energy yield of the rooftop solar PV power system used in the analysis was estimated following the methodology described in [48] which takes into account the regional climatic data and plant configuration. The study used the climatological database and program Meteonorm to derive the radiation data. Meteonorm is one of the sources of modeled datasets used by the solar PV industry in solar project analysis. Meteonorm's database are derived from more than 8,000 global weather stations, five geostationary satellite, and globally calibrated aerosol climatology and data period 1991-2010 [22]. The program uses long time datasets to calculate hourly values, monthly average values and yearly sums for various climate parameters such as radiation, temperature, precipitation and sunshine duration.

A specific site location, N14.54°, E121.05° and elevation of 27 meters above mean sea level, in Taguig City was taken as the representative location for meteorological conditions used in the analysis. The annual sum for global horizontal irradiation (GHI) in this location is 1,737.6 kWh/m².

The seasonal pattern of irradiation shown in Figure 1 indicates highest GHI values in spring and low during end of summer though this is the period with longest solar days. Summer however, is also the monsoon season with high degree of cloud cover, thereby negatively affecting the direct irradiation. The GHI also appears to increase in autumn which is explained by the onset of the dry season but will start to decline from September until December. The same pattern can be observed for inclined irradiation. The annual sum of inclined irradiation is higher than horizontal irradiation. Moreover, the inclined values from winter until middle of spring (April) as well as from autumn (September) are higher than the horizontal values.

The energy production software used in simulating plant energy yield is PVsyst [22]. Ref. [58] in their comparative performance assessment of solar PV production software packages used by industry stakeholders conclude that the radiation model components of the evaluated tools perform consistently and predicting similar plane-of-array irradiance from the same weather data. With respect to overall energy production, the most aggressive modelling tool generates 9% more than the most conservative one. The software packages evaluated were PV Watts, Solar Advisor Model, PV-Design Pro, PV*SOL and PVsyst.

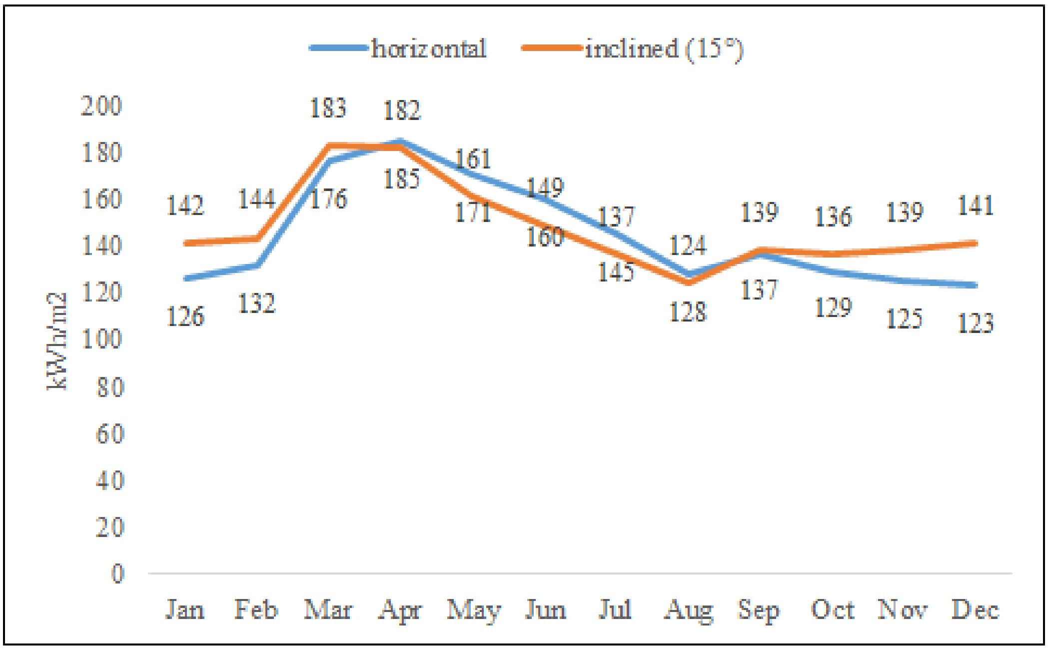


Fig. 1. Long-term average solar irradiation at site location N14.54°, E121.05°.

In estimating the solar PV power system energy production, the study used typical polycrystalline solar PV modules and string inverter available in the market. Three system sizes, 3 kWp, 5.5 kWp, and 10.5 kWp to simulate export scenarios were used in the analysis. Key model input parameters are shown in Table A1 of the Appendix. In the model, DC electricity is generated from PV modules and converted into AC electricity through a string inverter. In the simulation process, PV arrays are fixed to face south and inclined at 15° which corresponds to Taguig City's latitude [43].

The PVsyst simulation model endogenously estimates the technical losses of the system based on the technical parameters specified in the case study. In addition to this, the study exogenously estimated the loss in production due to PV module degradation and plant availability. An annual degradation of 0.5% was used in the study and an average of 99% availability based on string inverter manufacturers' guarantees.

Based on the climatic, physical and technical characteristics and assumptions presented earlier, the PVsyst model estimates the following: i) annual energy yield, ii) specific energy yield or yield factor (YF), and iii) performance ratio (PR). Yield factor refers to total annual energy generated per kWp installed. Various aspects affect the value of the specific yield such as location, weather conditions, module orientation, module type and balance of system efficiency [58], [62]. The performance ratio (PR) represents the ratio of the effectively produced energy with respect to the energy which would be produced by a perfect system continuously operating at standard test conditions (STC) under the same irradiance [42], [57].

The performance of the solar PV systems derived from PVsyst simulation (first year of operation and average performance for 20 years) for solar PV system with capacity sizes 3.0 kWp, 5.5 kWp and 10.5 kWp are shown in Table 1. Since the study used the same technical specifications for solar PV systems and meteorological condition, the technical performance of solar PV systems under different system sizes are almost identical.

4.2 Consumption and Export of Electricity

Under the current residential solar PV policy, Philippine distribution utilities encourage production and consumption of electricity from solar PV systems, and offer to purchase surplus generation at a rate set by the Energy Regulatory Commission (ERC).

For this analysis, a typical middle-income household with daily electricity consumption amounting to 50 kWh (1,500 kWh per month) and whose average daily consumption profile is shown in the Figure 2, was used. This load profile is based from [49] which is a yearly average and has taken into consideration weekend fluctuations and seasonal variations of demand. The household electricity demand peaks 3 times during the day (at around 6 o'clock, at noontime and at around 5 o'clock in the evening) but the highest peak occurs in the evening. Electricity consumption between 5 in the morning and 5 in the afternoon could be supported by the rooftop solar PV plant.

Table 1. Technical performance of solar PV systems.

		3.0 kW_p	5.5 kW_p	10.5 kW_p
Peak Power	kW_p	3.0	5.5	10.5
Irradiation on horizontal plane	kWh/m^2	1738	1738	1738
Irradiation on inclined plane	kWh/m^2	1775	1775	1775
Plant availability	%	0.99	0.99	0.99
First Year Performance				
Energy yield (after inverter)	kWh/year	3866	7083	12891
Overall yield factor	$kWh/kW_p/year$	1289	1288	1287
Overall performance ratio	%	72.6	72.5	72.5
Average Performance (20 years)				
Energy yield per year (average 20 years)	kWh/year	3688	6756	12891
Total yield for 20 years	kWh	73761	135119	257817
Overall yield factor	$kWh/kW_p/year$	1229	1228	1228
Overall performance ratio	%	69.3	69.2	69.2

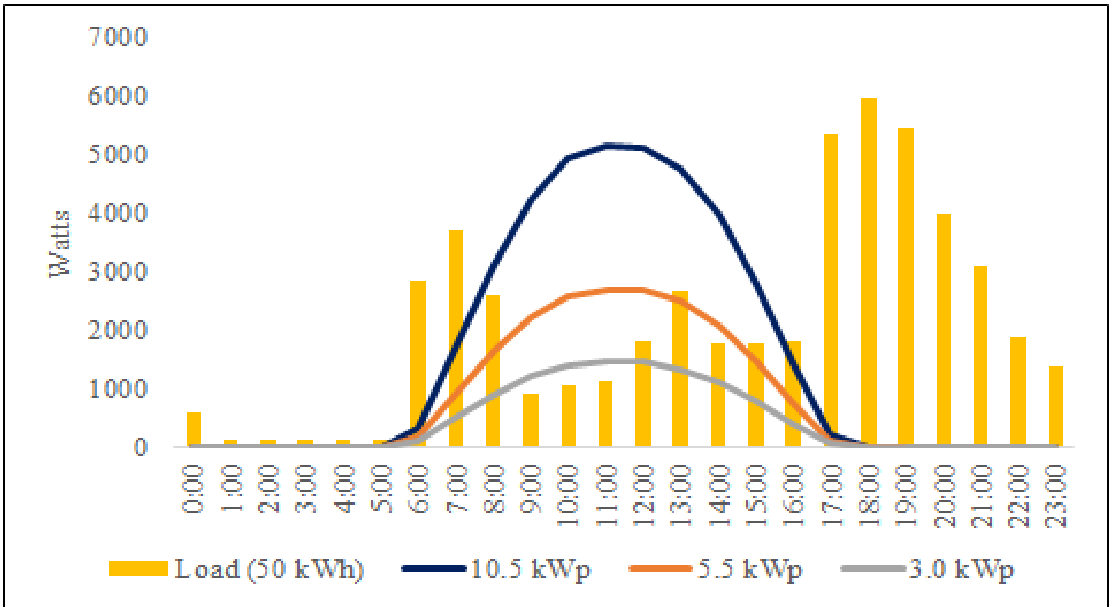


Fig. 2. Typical middle class household consumption pattern and average solar PV production profiles.

The average daily production curves of the three solar PV systems (3.0 kW_p, 5.5 kW_p and 10.5 kW_p) derived from PVsyst simulation software are also shown in the same figure. The PVsyst model which uses Meteonorm's 19-year average global irradiation datasets estimated solar PV systems' hourly production of the 3 selected solar PV systems for 365 days and presented the average hourly yield for a typical year.

Within this time range, the area under the solar PV production curve and below the load profile represents the electricity consumption that would be covered by the solar PV plant while the area above the load profile but under the solar production curve represents the amount of electricity that could be exported to the grid. As shown in the same Figure, if the household would use a smaller 3 kWp system with average daily production of 10.6 kWh, around 91% of the electricity generation would be self-consumed. If the household would install bigger systems, 5.5 kWp (production of 19.71 kWh per day) and 10.5 kWp (production of 37.62 kWh per day), around 71% and 46% of the energy generated would be self-consumed, respectively.

4.3 Electricity Tariff Rates and Generation Charges

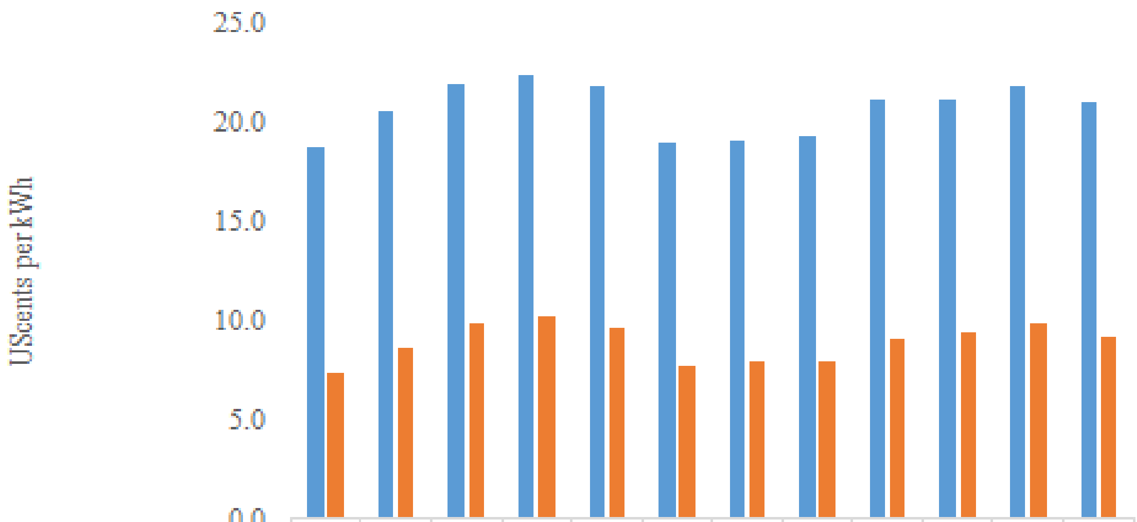
The opportunity cost of self-consumption under the incentivized self-consumption schemes, is the electricity tariff rate the residential household is paying to the distribution utility. Taking the tariff rate of MERALCO, the largest electricity distribution utility in the Philippines, as the reference, the average tariff rate for a household with 1500 kWh monthly consumption in 2017 was US$ 0.2103 per kWh.

Electricity exports, as stipulated in the implementing rules and regulation, have compensation rate fixed equal to the distribution utilities' generation charge. In 2017, the average generation charge amounted to US$ 0.08899 per kWh representing around 43% of the total electricity tariff rate. The monthly evolution of the tariff rate and generation charge in 2017 are shown in Figure 3.

4.4 Project Costs

Installed system prices of solar PV technologies have been rapidly declining over the past years. System prices below US$1 per Wp have been observed in competitive tenders for large-scale utility projects in 2016 [31], [33]. For rooftop systems, prices have also been declining though installed costs are still higher than those of ground-mounted systems. Installed system costs for rooftop systems vary by country but a number of countries have installed costs between US$1 and US$ 2 per Wp in 2015 [31].

Rooftop solar PV system dealers in the Philippines are offering system installed cost ranging from US$ 1.5 – 2.0 per Wp [21], [25], [28] for system sizes ranging from 3 kWp to 10 kWp. For this analysis, the study used an average system cost of US$ 1.75 per Wp. The installed system costs include consulting services, licenses and permits; installation; equipment (module, balance of systems which include inverters and others); design and engineering; transport costs and grid connection costs.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
tariff for 1500 kWh	18.7	20.5	21.9	22.3	21.7	18.9	19.0	19.3	21.0	21.1	21.8	21.0
generation charge	7.4	8.6	9.8	10.2	9.7	7.7	7.9	8.0	9.1	9.4	9.8	9.2

Fig. 3. Tariff rate for household with 1500 kWh consumption per month.

4.5 Levelized Cost of Electricity

The levelized cost of electricity (LCOE) is one of the measures used in assessing the cost competitiveness of a technology. The levelized cost is defined as the value for which an equal-valued fixed revenue delivered over the life of asset's generating profile would cause the project to break-even [34]. This can be roughly calculated as the net present value of all costs over the lifetime of the asset divided by the total electricity output of the asset. LCOE is estimated by the following equation:

$$LCOE = \frac{\sum_{n=1}^{N} \frac{C_n}{(1+d)^n}}{\sum_{n=1}^{N} \frac{Q_n}{(1+d)^n}} \quad (1)$$

where: C_n stands for total costs, in the year n; Q_n stands for energy generation, in the year n; n stands for year; N stands for the project life; and d stands for the discount rate. This study used the before tax weighted average cost of capital (WACC) as the discount rate.

Based on the above methodology, the LCOEs for solar PV systems were estimated. Three alternative installed costs were considered in estimating the LCOE: i) US$ 1.5 per Wp (low value), ii) US$ 1.75 per Wp (most likely value), and iii) US$ 2.0 per Wp (high value). This range of installed costs for small-scale systems is consistent with those in the ASEAN [1] and in IEA PVPS reporting countries [31]. The study considered only the capital and O&M costs. The latter is taken to be 1% of the system installed cost. Decommissioning and other costs were not considered in the analysis. The debt share used in the study was 70% and the project lifespan was 20 years. Additional project parameters are shown in Table A2 of the Appendix.

Based on these costs and technical parameters, the LCOE values are the following: US$ cents 11.4 per kWh for installed cost of US$ 1.50 per Wp; US$ cents 13.3 per kWh for installed cost of US$ 1.75 per Wp, and; US$ cents 15.2 per kWh for installed cost of US$ 2.0 per Wp. The LCOE for 3.0 kWp, 5.5 kWp and 10.5 kWp systems are the same since the study used the same financial parameters and that the technical performance of each systems (shown in Table 1) are identical.

5. RESULTS AND DISCUSSIONS

5.1 Grid Parity

To assess the competitiveness of rooftop solar PV in the Philippines, the LCOE of a solar PV unit is compared with the average retail electricity price. The use of electricity consumption costs rather than power generation costs is considered appropriate since small-scale solar PV projects are connected to low voltage level network as opposed to large-scale projects that are connected to either medium or high voltage grid network. When the LCOE of a given technology equals the average price the consumer is paying to the distribution utility, the said technology is known to reach 'grid parity' [31]. If the LCOE equals the average cost of generation, the 'fuel parity' is said to have been achieved.

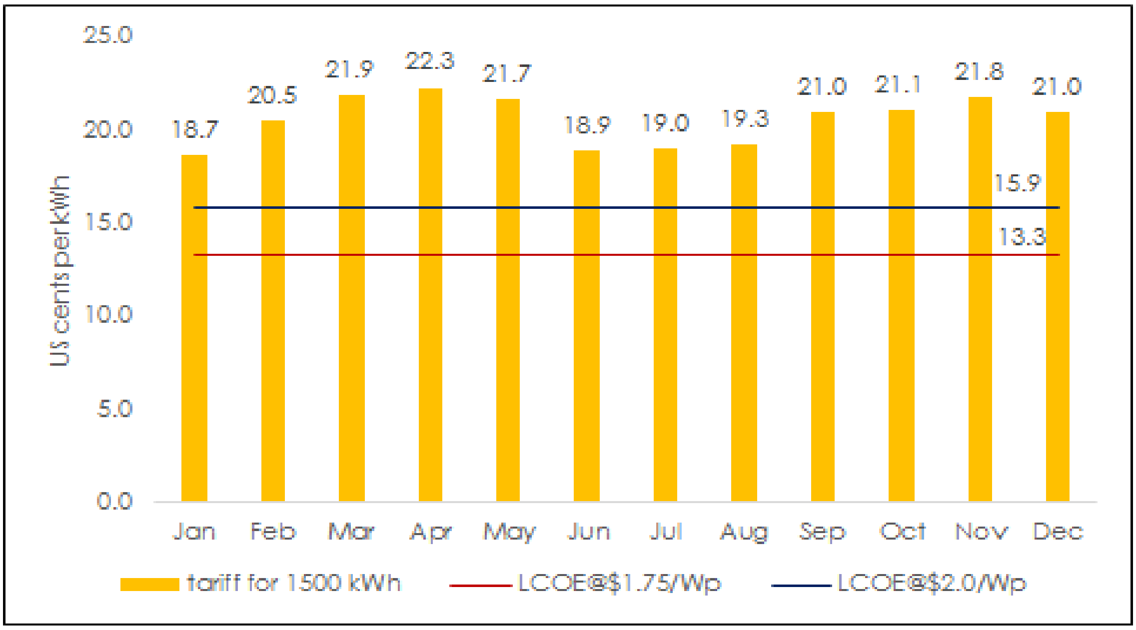


Fig. 4. LCOE vs. monthly tariff for household with consumption of 1500 kWh per month.

The solar PV power plant would displace grid generation hence the opportunity cost of power from solar PV installation is represented by the retail price of the grid power. MERALCO's monthly retail tariffs for households with electricity consumption of 50 kWh per day (1,500 kWh per month) are shown in Figure 4 [37]. The figure shows that small-scale power generation has reached above grid parity in the Philippines. The LCOE of the solar PV systems with installed cost of US$2.0 per Wp amounts to US$0.159 per kWh while monthly prices for 2017 were all above US$0.18 per kWh (the monthly average is US$0.21 per kWh). The results indicate that with existing electricity retail tariffs and solar PV system prices, households have sufficient financial incentives to invest in rooftop solar PV technologies.

5.2 Incentives under Alternative Policy Scenarios

5.2.1 Net Billing Scheme

Under the net billing arrangement, the opportunity cost of self-consumption (Psc) is the electricity retail price (Prp) (equation 2). The export tariff (PexNB) on the other hand is equal to the generation charge, as fixed by ERC (equation 3). The project revenue for any given year would have the form presented in equation 4, where (QscNB) and (QexNB) denote electricity self-consumption and export volumes respectively. Following the assumptions in [16], the study considered that both the retail price (Prp) and generation charge (PGC) would increase annually by 3% throughout the project lifespan.

$$P_{sc} = P_{rp} \tag{2}$$

$$P_{exNB} = P_{GC} \tag{3}$$

$$R_n = (P_{rp,n} * Q_{scNB,n}) + (P_{GC,n} * Q_{exNB,n}) \tag{4}$$

Based on these, the economic performance of PV installations are shown in Table 2. The results show that at current solar PV costs and electricity tariff rates, the three system sizes would provide positive economic benefits to households whose daily electricity demand profile were presented earlier. The project internal rate of returns (IRRs) are higher than the weighted average cost of capital.

The results also indicate diminishing returns relative to increasing system sizes. This is due to the fact that the export tariff rate is much lower than the opportunity cost of self-consumption. The net billing policy design therefore has established a built-in disincentive to households to oversize their solar PV system installations. Higher economic benefits would be achieved with systems that satisfy mainly the household's daytime electricity demand.

Table 2. Economic performance of solar PV systems under net billing scheme.

	3.0 kW_p	5.5 kW_p	10.5 kW_p
Electricity export	9%	29%	54%
Internal rate of return (IRR)	17.9%	15.3%	11.8%
Payback period (years)	6	7	8

Note: weighted average cost of capital = 7.2%

5.2.2 Net Metering Scheme

This section evaluates the economic attractiveness of the solar PV installations under the alternative net metering scheme.

$$P_{exNM} = P_{rp} \tag{5}$$

$$R_n = (P_{rp,n} * Q_{T,n}) \quad (6)$$

As presented earlier, net metering will have only energy compensation. The electricity exported to the grid will be used to offset the household's electricity imports from the grid. In this case, the opportunity cost of self-consumption expressed in Equation 2 would remain valid. On the other hand, the opportunity cost of exported electricity would be equal to retail electricity tariff (Equation 5). The project revenue at any given year under the net metering scheme is shown in equation 6, where (Q_T) is the sum of export and self-consumption volumes.

Similarly, based on [16], the electricity retail price (Prp) was projected to increase by 3% annually throughout the lifespan of the project.

With these, the economic performance of each system was estimated and the results are shown in Table 3. The results indicate that under the net metering scheme, the economic performance of each system is higher than those under the net billing scheme. This is due to the fact that electricity exports under the former are valued at the retail tariff while those under the latter are priced at discounted rate (generation charge). In addition, given the same project technical and financial parameters, the project IRRs and payback periods for systems with varying capacity sizes would be the same. This creates an incentive for households with financial resources or with access to financing, to invest in much bigger systems. The net metering scheme therefore provides an incentive to oversize PV system installations.

5.2.3 Sensitivity Analysis

To identify and address key risks, a sensitivity analysis was carried out on key parameters that could significantly affect the viability of a solar PV project from residential households' perspective. These parameters include: i) capital costs, ii) O%M costs, iii) solar PV capacity factor, iv) module degradation, v) electricity tariff and v) generation charge.

The internal rate of return is the indicator used to assess the sensitivity of the above parameters on project profitability. The results of the analysis are summarized in Table 4. The overall results show that for both policy frameworks even with high increase in project costs, reduction of electricity generation (the study reduced the capacity factor and increased the module degradation rate), and reduction of project benefits (the study reduced the annual increase of electricity tariff and generation charge), the project IRR will not significantly diverge from the baseline case.

Under the net billing scheme as presented earlier, larger PV systems have lower IRRs than the smallest system and that despite the increase of project costs, decrease of electricity generation and decrease in project benefits, the IRRs will remain attractive. Under the net metering scheme, all system sizes have the same level of sensitivity for all variations of the identified parameters.

Table 3. Economic performance of solar PV systems under net metering scheme.

	3.0 kW_p	5.5 kW_p	10.5 kW_p
Electricity export	9%	29%	54%
Internal rate of return (IRR)	19.2%	19.2%	19.2%
Payback period (years)	6	6	6

Note: weighted average cost of capital = 7.2%

Table 4. Sensitivity analysis.

	Internal Rate of Return (IRR) (%)		
	3.0 kW_p	5.5 kW_p	10.5 kW_p
Net Billing Scheme			
1. Base	17.9	15.3	11.8
2. Capital Cost (from US$ 1.75/W_p to US$ 2/W_p)	15.1	12.7	9.6
3. O&M (10% increase)	17.8	15.2	11.7
4. Capacity factor (10% output decrease)	15.7	13.2	10.0
5. Module annual degradation (from 0.5% to 1%)	17.2	14.6	11.1
6. Electricity tariff (from 3% to 1%)	15.7	13.3	10.3
7. Generation charge (from 3% to 1%)	17.9	14.9	11.1
Net Metering Scheme			
1. Base	19.2	19.2	19.2
2. Capital Cost (from US$ 1.75/W_p to US$ 2/W_p)	16.2	16.2	16.2
3. O&M (10% increase)	19.1	19.1	19.1
4. Capacity factor (10% output decrease)	16.8	16.8	16.8
5. Module annual degradation (from 0.5% to 1%)	18.5	18.5	18.5
6. Electricity tariff (from 3% to 1%)	16.8	16.8	16.8
7. Generation charge (from 3% to 1%)	19.2	19.2	19.2

5.3 Implications on Distribution Utility Customers

The program implemented under the incentivized self-consumption scheme in the Philippines is a customer-supported program and that the 'net metering' rules considered the payments to program participants as generation cost and allowed distribution utilities to recover these payments from all its customers. The previous sections show that the alternative net metering scheme provides better returns to program participants than the current net billing framework. This implies that the net metering scheme requires higher contributions from all customers than the current net billing policy.

For demonstration purposes, the study assumed 1000 participants for the incentivized self-consumption scheme and that these participants are using either the 3 kWp or 5.5 kWp system. Ref [19] reported that the current program participants of MERALCO have an average installed capacity of 4 kWp and that the number of participants have reached more than 1000 as of end of 2017 [20]. Table 5 shows the financial requirement of program participants for both schemes and that the alternative net metering framework would require around 2.3 times that of the current net billing arrangement. The financial burden to customers would be higher under the alternative net metering scheme.

Table 5. Amount to be supported by distribution utility customers for 1000 participants.

	For 3.0 kW_p unit Total of 3.0 MW_p		For 5.5 kW_p unit Total of 5.5 MW_p	
	current net billing ('000 US$)	alternative net metering ('000 US$)	current net billing ('000 US$)	alternative net metering ('000 US$)
First year	31	73	181	419
Cumulative 20 years	802	1857	4615	10867

6. CONCLUSION

The Philippines is one of the pioneering countries in Southeast Asia that introduced an incentivized self-consumption policy for both residential and commercial customers. The residential 'net billing' program is gaining popularity and the number of program participants have been increasing. This is mainly driven by declining solar PV costs and that small solar PV systems have reached above grid parity in the country. The levelized cost of electricity (LCOE) of a system with installed cost of US$ 2 per Wp, given the financial and meteorological conditions of the country, is estimated to be below US$0.16 per kWh while households with electricity consumption above 200 kWh per month have an average tariff rate of over US$0.18 per kWh. For a PV system price scenario of US$1.75 per Wp, the LCOE would be around US$0.13 per kWh which is lower than the average tariff of US$0.15 per kWh for households consuming around 100 kWh per month. Middle income households therefore have sufficient incentives to invest in rooftop solar PV systems.

Net billing and net metering schemes have been loosely described in the literature as net metering scheme. Both frameworks allow customers to generate their own electricity through decentralized renewable energy systems and export their surplus electricity to the grid. The main difference is that under the 'net metering' scheme, participants are not financially compensated for exports but allowed to offset their consumption during the time when their systems are not operating or their generation is insufficient compared with their demand. On the other hand, 'net billing' schemes compensate program participants financially. In the case of the Philippines, the Energy Regulatory Commission (ERC) initially set the tariff rate equal to the distribution utility's generation charge.

This study compares the two alternative policy frameworks with respect to the level of incentives they provide to program participants, and in terms of overall management control from policy implementation perspective. Three solar PV system sizes were considered in the study: 3.0 kWp, 5.5 kWp and 10.5 kWp while a middle income household with daily consumption of 50 kWh (1500 kWh per month) with a typical load profile was used in the analysis. The electricity that could be exported to the grid would be 9%, 29% and 54% for the respective system sizes.

A 'net billing' scheme would yield IRRs of 17.9%, 15.3% and 11.8% for 3.0 kWp, 5.5 kWp and 10.5 kWp systems, respectively. These are higher than the weighted average cost of capital of around 7.2%. The results show that returns are higher for smaller systems that mainly cater for household's daily demand compared with larger systems that export more energy to the grid. This framework disincentivizes oversizing of the solar PV installations. An alternative 'net metering' arrangement would yield IRRs of 19.2% for all system sizes which is higher than those under the 'net billing' arrangement. Since the IRRs for different system sizes are the same, this encourages program participants to install larger systems and oversize their solar PV installations.

The incentivized self-consumption program in the Philippines is customer-funded hence payments to program participants need to be recovered from all customers as part of the generation charge. The 'net metering' program which provides better returns to participants would also require higher contribution from customers. The 'net metering' program requires 2.3 times more contribution than the 'net billing' program.

The study results affirm that the policy choice of the government balances the needs of the program participants and funding customers. The framework does not provide excessive benefits to program participants nor placing unwarranted burden to the paying customers.

These results are consistent with the findings presented in the literature review. In countries that achieve above grid parity, net metering programs would provide higher returns to participants. On the other hand, net billing programs would deliver reasonable returns at lower electric system costs.

ACKNOWLEDGEMENT

This study is funded by the internal research grant on the 'Deployment of Low-Carbon Energy and Transport Technologies: Options and Implications for Brunei Darussalam' from the Universiti Brunei Darussalam.

REFERENCES

[1] ACE, 2016. *Levelized Cost of Electricity of Selected Renewable Technologies in the ASEAN Member States*. ASEAN Centre for Energy. Jakarta, Indonesia.

[2] Campoccia A., Dusonchet L., Telaretti E., Zizzo G., 2009. Comparative analysis of different supporting measures for the production of electrical energy by solar PV and wind systems: Four representative European cases. *Solar Energy* 83(3): 287-297.

[3] Capongcol M., 2018. *Introduction on Renewable Energy Act.* Retrieved May 16, 2018 from the World Wide Web: https://www.doe.gov.ph/sites/default/files/pdf/announcements/02-rembd-re_act_intro.pdf.

[4] Celdran A., 2016. *The ADB Solar Rooftop Project: Boosting Solar Energy Growth in the Philippines.* Retrieved November 16, 2017 from the World Wide Web: http://k-learn.adb.org/materials/20160801/adb-solar-rooftop-project-boosting-solar-energy-growth-philippines.

[5] Christensen J.M., Denton F., Garg A., Kamel S.M., Pacudan R., and Usher E., 2006. *Changing climates. The role of renewable energy in a carbon-constrained world*. A paper prepared for Renewable Energy Policy Network for the 21st Century (REN 21) by the United Nations Environment Program (UNEP). Retrieved May 16, 2018 from the World Wide Web: http://unpan1.un.org/intradoc/groups/public/documents/apcity/unpan031637.pdf.

[6] Christoforidis G., Panapakidis I., Papadopoulos T., Papagiannis G., Koumparou I., Hadjipanayi M., and Georghiou G., 2016. A model for the assessment of different net-metering policies. *Energies* 9(4): 262.

[7] Congress of the Philippines, 2001. Republic Act 9136. *An Act Ordaining Reforms in the Electric Power Industry, Amending for the Purpose Certain Laws and for Other Purposes*. Philippines.

[8] Congress of the Philippines, 2008. *Republic Act 9531. An Act Promoting the Development, Utilization and Commercialization of Renewable Energy Resources and for Other Purposes.* Philippines.

[9] Couture T., Cory K., Kreycik C., and Williams E., 2010. *A Policy Maker's Guide to Feed-in Tariff Policy Design.* National Renewable Energy Laboratory Technical Report. Golden, Colorado.

[10] DOE, 2012. Department Circular No. DC2012-05-0005, *Prescribing the General Policies for the Implementation of the Retail Competition and Open Access*. Department of Energy, Philippines.

[11] DOE, 2017. Department Circular No. DC2017-05-0009, *Declaring the Launch of the Wholesale Electricity Spot Market (WESM) in Mindanao and Providing for Transition Guidelines.* Department of Energy, Philippines.

[12] Dufo-López R. and J.L. Bernal-Agustín. 2017. A comparative assessment of net metering and net billing policies. Study cases for Spain. *Energy* 84: 684-694.

[13] ERC, 2013. *Resolution No. 09, Series of 2013. A Resolution Adopting the Rules Enabling the Net-Metering Program for Renewable Energy*. Energy Regulatory Commission, Philippines.

[14] European Commission, 2015. *Best Practices on Renewable Energy Self Consumption.* Commission Staff Working Document. European Commission.

[15] SEDA. 2018. *Feed-in Tariff Dashboard.* Retrieved January 6, 2018 from the World Wide Web: http://seda.gov.my.

[16] GIZ, 2013. *Net-Metering Reference Guide: How to avail solar roof tops and other renewables below 100 kW in the Philippines*. German International Cooperation. Manila, Philippines.

[17] GIZ, 2017. *Thailand Solar PV Policy Update January 2017*. German International Cooperation. Bangkok, Thailand.

[18] Gridworks 2018. *Sustaining Solar Beyond Net Metering.* Retrieved May 15, 2018 from the World Wide Web: http://gridworks.org/wp-content/uploads/2018/01/Gridworks_SustainingSolar_Online.pdf.

[19] Rivera D., 2016. *More MERALCO customers shift to net metering.* Retrieved January 6, 2018 from the World Wide Web: http://beta.philstar.com/business/2016/06/25/1596294/more-meralco-customers-shift-net-metering.

[20] Rivera D., 2018. *Over 1000 MERALCO customers drawn to net metering scheme.* Retrieved January 6, 2018 from the World Wide Web: http://beta.philstar.com/business/2018/01/02/1773747/over-1000-meralco-customers-drawn-net-metering-scheme.

[21] Meister Solar, 2017. *Solar PV Package.* Retrieved November 16, 2017 from the World Wide Web: http://www.meister-solar.com.

[22] Meteonorm, 2018. *Irradiation data for every place on Earth.* Retrieved January 6, 2018 from the World Wide Web: http://www.meteonorm.com.

[23] PVsyst, 2017. *Photovoltaic software.* Retrieved November 16, 2017 from the World Wide Web: http://www.pvsyst.com/en/.

[24] National Renewable Energy Laboratory, 2017. *System Advisor Model.* Retrieved November 16, 2017 from the World Wide Web: https://sam.nrel.gov.

[25] Spectrum, 2017. *Spectrum Solar Calculator.* Retrieved November 16, 2017 from the World Wide Web: https://spectrum.net.ph/.

[26] Department of Energy, 2017. *Promulgating the rules and guidelines governing the establishment of the renewable portfolio standards for on-grid areas.* Retrieved January 2, 2018 from the World Wide Web: https://www.doe.gov.ph/announcements/request-comments-draft-department-circular-entitled-promulgating-rules-and-guidelines.

[27] Department of Energy, 2013. *Net metering guide.* Retrieved January 6, 2018 from the World Wide Web: https://www.doe.gov.ph/net-metering-home.

[28] Solar Philippines, 2017. *Solar PV Price List.* Retrieved November 16, 2017 from the World Wide Web: https://www.solarphilippines.ph/solar-panel-home/.

[29] Department of Energy, 2017. *Power Supply and Demand Highlights.* Retrieved May 16, 2018 from the World Wide Web: https://www.doe.gov.ph/power-sector-situation.

[30] Hunt S., 2002. *Making Competition Work in Electricity*. John Wiley & Sons, Inc.

[31] IEA PVPS, 2017. *Trends 2017 in Photovoltaic Applications*. International Energy Agency. Paris, France.

[32] IEA PVPS, 2016. *A Methodology for the Analysis of PV Self-Consumption Policies.* International Energy Agency. Paris, France.

[33] IEA, 2016. *World Energy Outlook 2016.* International Energy Agency. Paris, France.

[34] IEA/NEA, 2010. *Project Costs of Generating Electricity 2010*. International Energy Agency and Nuclear Energy Agency of the Organization for Economic Cooperation and Development. Paris, France.

[35] IFC, 2015. *A Project Developer's Guide to Utility-Scale Solar Photovoltaic Power Plants.* International Finance Corporation.

[36] Prol J.L and K.W. Steininger. 2017. Photovoltaic self-consumption regulation in Spain: Profitability analysis and alternative regulation schemes. *Energy Policy* 108, 742-754.

[37] MERALCO, 2017. *Electricity Rates.* Retrieved December 6, 2017 from the World Wide Web: https://company.meralco.com.ph/news-and-advisories/rates-archives.

[38] Motlagh O., Grozev G., and Foliente G., 2015. Impacts of feed-in tariff and metering types on electricity consumption efficiency in Australia. In *21st International Congress on Modelling and Simulation, Gold Coast*, Australia. 29 November – 4 December 2015.

[39] Department of Energy, 2011. *National Renewable Energy Program*. Retrieved January 2, 2018 from the World Wide Web: https://www.doe.gov.ph/national-renewable-energy-program.

[40] Ocampo R., 2013. *How net metering works: Understanding the basics of policy, regulation and standards.* Retrieved January 6, 2018 from the World Wide Web: https://www.doe.gov.ph/net-metering-home.

[41] SEDA, 2018. *Overview of Net Energy Metering.* Retrieved January 6, 2018 from the World Wide Web: http://seda.gov.my.

[42] Nordmann T., van Sark W., and Green M., 2014. Analysis of long-term performance of PV systems: different data resolution for different purposes. IEA PVPS Task 13, Subtask 1, Report IEA-PVPS T13-05:2014. International Energy Agency. Paris, France.

[43] NREL, 1990. *Shining On: A Primer on Solar Radiation Data.* National Renewable Energy Laboratory. Golden, Colorado.

[44] Pacudan R.B., 1998. Natural gas pricing policies in Southeast Asia. *Natural Resources Forum* 22(1): 27-36.

[45] Pacudan R. and E. de Guzman. 2002. Impact of energy efficiency policy to productive efficiency of electricity distribution industry in the Philippines. *Energy Economics* 24: 41-54.

[46] Pacudan R., 2006. Chapter 11 Power Sector Liberalization and Access to Energy in the Philippines, in: OECD/World Bank, *Liberalization and Universal Access to Basic Services*. Paris, France.

[47] Pacudan R., 2014. *'Electricity Price Impacts of Feed-in Tariff Policies: The Cases of Malaysia, the Philippines and Thailand'*, in Han, P. and F. Kimura (eds), Energy Market Integration in East Asia: Energy Trade, Cross Border Electricity, and Price Mechanism, ERIA Research Project Report FY 2013, No. 29 Jakarta: ERIA, pp 283-319.

[48] Pacudan R., 2016. Implications of applying solar industry best practice resource estimation on project financing. *Energy Policy* 95: 489-497.

[49] Pacudan R., 2018. Feed-in tariff vs. incentivized self-consumption: Options for residential solar PV policy in Brunei Darussalam. *Renewable Energy*. 122: 362-374.

[50] Poullikkas A., 2013. A comparative assessment of net-metering and feed-in tariff schemes for residential PV systems. *Sustainable Energy Technology Assessment* 3: 1-8.

[51] Ramalho M., Câmara L., Pereira G., Pereira da Silva P., and Guilherme D., 2017. *Photovoltaic energy diffusion through net-metering and feed-in tariff policies: Learning from Germany, California, Japan and Brazil.* Retrieved November 16, 2017 from the World Wide Web: http://www.gesel.ie.ufrj.br/app/webroot/files/public

ations/01_ELAEE 2017 - Camara_Ramalho_Pereira_Silva_Dantas.pdf

[52] REN 21, 2017. *Renewables 2017, Global Status Report.* REN 21 Renewable Energy Network for the 21st Century.

[53] Department of Energy, 2017. *Renewable Energy Road Map 2017-2040.* Retrieved January 2, 2018 from the World Wide Web: https://www.doe.gov.ph/pep/renewable-energy-roadmap-2017-2040.

[54] Rickerson W., Couture T., Barbose G., Jacobs D., Parkinson G., Chessin E., and Belden A., 2014. *Residential prosumers – drivers, and policy options (RE Prosumers).* IEA-Renewable Energy Technology Deployment.

[55] Rodrigues S., Torabi R., Faria F., Cafôfo N., Chen X., Ramezani A., Mata-Lima H., and Dias M., 2016. Economic feasibility analysis of small scale PV systems in different countries. *Solar Energy* 131: 81-95.

[56] Energy Market Authority, 2017. *Solar Photovoltaic Systems.* Retrieved January 6, 2018 from the World Wide Web: https://www.ema.gov.sg/Solar_Photovoltaic_Systems.aspx.

[57] Tamizh Mani G., Paghasia K., Kuitche J., Vemula M., and Sivaasubramanian G., 2011. *Photovoltaic Module Power Rating per IEC 61853-1 Standard: a Study under natural Sunlight.* Solar America Board for Codes and Standards.

[58] PVsyst, 2012. *User's Guide, PVsyst Contextual Help.* Retrieved November 16, 2017 from the World Wide Web: http://files.pvsyst.com/pvsyst5.pdf.

[59] Watts D., Valdés Jara D., and Watson A., 2015. Potential residential PV development in Chile: The effect of net metering and net billing schemes for grid-connected PV systems. *Renewable and Sustainable Energy Reviews* 41: 1037-1051.

[60] Yates T. and B. Hibberd. 2010. *Production Modelling for Grid-Tied PV System. Solar Pro (Issue 3.3 April/May).* Retrieved November 16, 2016 from the World Wide Web: https://solarprofessional.com/articles/design-installation/production-modeling-for-grid-tied-pv-systems/page/0/13#.W0Anu9Uzapo.

[61] Yosiana B., 2016. *The Rise of the Energy Prosumers in the ASEAN.* Retrieved January 6, 2018 from the World Wide Web: http://www.aseanenergy.org/blog/the-rise-of-the-energy-prosumers-in-asean/

[62] Zhang T., 2017. *What's a good value for kWh/kWp? An overview of specific yield.* Retrieved November 16, 2017 from the World Wide Web: https://www.solarpowerworldonline.com/2017/08/specific-yield-overview/

APPENDIX

Table A1. Solar power plant technical parameters.

Module Orientation			
Module inclination		15°	
Azimuth		0	
Module-inverter configuration			
Installed module capacity	3.0 kW_p	5.5 kW_p	10.5 kW_p
Module type	polycrystalline	polycrystalline	polycrystalline
Number of modules	12	22	42
Nominal capacity of modules	250 W_p	250 W_p	250 W_p
Number of modules per string	12	11	14
Number of strings in parallel	1	2	3
Inverter capacity	2.75 kW AC	4.6 kW AC	4.6 kW AC
Number of inverters	1	1	2
Installed inverter capacity	2.75 kW AC	4.6 kW AC	9.2 kW AC