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International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

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PAPER ID: 11A13N

DEMAND-SIDE RENEWABLE PORTFOLIO STANDARD: A CASE OF THAILAND

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ARTICLEINFO

Article history:
Received 24 March 2020
Received in revised form 19 June 2020
Accepted 10 July 2020
Available online 18 July 2020

Keywords:
Renewable portfolio standard (RPS); Electricity consumption; Demand-side renewable portfolio standard (D-RPS); Energy policy; Solar rooftop; Building sector; D-RPS policy; Time of Use (TOU) electric metering.

ABSTRACT

The electricity and heat generation sector have the highest proportion of greenhouse gas emission that comes from the combustion of fossil fuels. An increase in electricity production obtained from renewable energy resources is a key factor for a decrease in carbon emission. This paper introduces a new methodology for the Demand-Side Renewable Portfolio Standard (D-RPS) that focuses directly on electric power consumers. An effective implementation process is described for building owners to follow the novel D-RPS policy, which includes three stages - (i) numerical calculations of D-RPS value, (ii) assessment of target achievement, and (iii) corrective action to achieve the target. D-RPS can be applied for all types of buildings calculated by using data from monthly electricity bill measured in Kilowatt-Hour (kWh). The results show that D-RPS values of three different residential test-buildings are 332.7kWh, 587.35 kWh, and 694.05 kWh respectively. This shows the variation of D-RPS values based on the monthly electricity usage of each household. Residential building #1 could generate electricity upon the proposed criteria on a monthly basis. Meanwhile, residential buildings #2 and #3, applying the Time of Use (TOU) meter types have high electricity consumption and could not meet the proposed criteria in some months. As a result, these households must follow the D-RPS to meet the criteria. The simulation results illustrate that after implementing the D-RPS, the CO_2 emission caused by electricity consumption is reduced significantly in residential building #1 up to 164.35 kg-CO_2, residential building #2 up to 290.15 kg-CO_2, and residential building #3 at 342.86 kg-CO_2. It is envisaged that applying D-RPS policy in different buildings could potentially eliminate the carbon dioxide emission from traditional power consumption.

Disciplinary: Renewable Energy Policy, Sustainable energy, Environmental Engineering, Sustainability, and Carbon Management.

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1 INTRODUCTION

Electricity demand around the world has been increasing continuously. This causes the global warming problem due to the greenhouse effect. Further to the report by IEA in 2018, power demand has been increased since 2017 at 4 percent with different reasons including air conditioner usage in summer and heater usage in winter, and loads of demand for electricity from the industry, households, and different buildings. Most electricity is produced from coal and natural gas that causes increased Carbon (CO_2) emission at 2.5 percent in the power generation section. Since 2010, 2/3 of CO_2 emissions around the world have increased and come from fossil fuel production (IEA, 2018a; 2018b). Different countries have developed a power sourcing plan for country development and power distribution by increasing numbers of renewable energy sources for power generation. In 169 countries, states and provinces have a renewable energy promotion plan with precise targets, promotional amounts, and duration. Among these countries, 65 countries have determined 100% of renewable electricity targets. Nevertheless, most electricity demand comes from different buildings. Thus, law enforcement for effective power usage in different buildings is another method applied by some countries. For example, 69 countries have applied building energy code or BEC determined criteria for effective power consumption standards by 2018 (REN21, 2019). Renewable portfolio standard or RPS is applied by many countries along with renewable energy development plan and a developmental target is applied for developing renewable energy production proportion based on fossil fuel production with a penalty for those who could not generate or provide a determined amount of energy. In Asia, this policy is applied in seven countries including Bangladesh, China, Indonesia, Republic of Korea, Lao People's Democratic Republic, the Philippines (in policy drafting process), and Vietnam, which aims to develop renewable energy at 10-30 percent in 2020-2050 (Heeter *et al.*, 2019). Designing and development of renewable energy policy to replace fossil fuel-based on planned target and determination of renewable energy proportion are dependable variables for the increase or decrease of power consumption which would influence renewable energy replacement upon specified proportion. These could be applied to achieve the target of independent fossil fuel generation for all buildings. We, therefore, design the calculating method called Demand-Side Renewable Portfolio Standard (D-RPS) policy for different buildings or power users by using monthly electricity bills to produce, use and participate with the national renewable energy promotion.

2 LITERATURE REVIEW

2.1 RENEWABLE PORTFOLIO STANDARD (RPS) IN THAILAND

RPS is the policy to determine renewable energy generation proportion applied for fossil fuel power generators, and it influences renewable energy development for power generators. Thailand started using the policy in 2003 by national competitive energy strategy as a part of alternative energy development strategy. Its target was revised for using 8 percent of alternative energy instead of 0.5 percent in 2015. According to Thailand's power development plan 2004, fossil fuel power generators established in 2010-2015 are subject to produce renewable energy at no less than 5 percent of fossil fuel production in the first year (IEA, 2016; REN21, 2005). If the power suppliers produce lower than this, they would pay a fine to the renewable energy development fund. Power suppliers who want to establish new power plants in 2010-2015 could choose to pay compensation for renewable energy generation at 1.3 times of maximum renewable energy price (EPPO, 2004). However, the policy was terminated already. Details of RPS were classified as elements based on the national renewable energy laboratory as the guidelines for designing the RPS policy. These include determining total installed power generation targets as percentage per annum, applicable renewable energy technology, importing alternative energy, and principles and regulations to ensure renewable energy investors (Heeter et al., 2019). Details of the RPS policy applied in Thailand in the past could be classified by its principle components as shown in Table 1 (IEA, 2016; REN21, 2005; EPPO, 2004).

Table 1: Key components of an RPS in Thailand.

Key component	RPS
Target	5% of the new power plant in 2010-2015 according to PDP2004
Interim schedule	8% of power consumption in the country in 2015
Eligible resource	solar photovoltaic, wind, biomass, waste and hydropower
Compliance entities	alternative power purchasing contact
Regulatory entity	Ministry of Energy
Penalties for noncompliance	1) fossil fuel power plant owner could pay compensation at 1.3 times of maximum renewable energy price.
	2) If the actual power generation was lower than 5% in a year, the owner was subject to pay a 5% fine to the alternative energy development fund.

To implement the RPS policy, some penalties are designated as the mandatory policy. The applied fine in Thailand is paid to the alternative energy development fund so that the fund would be paid for development upon the objective of this fund. Power generating entrepreneurs could decide to pay the fine instead of constructing a renewable power plant. Different penalties and types of renewable energy to be promoted are decided and considered by the national policymaker based on renewable energy generating potential.

2.2 ELECTRICITY CONSUMPTION IN THAILAND

Figure 1(a) shows that electricity consumption in Thailand has been increasing continuously. Most demands derived from power consumption in different buildings include residential, small, medium, and large commercial buildings and some specific businesses (see Figure 1(c)). Large commercial buildings consume the most power, followed by households. The 10-year statistics data show that power consumption in buildings is higher than 90 percent of total power consumption in the country (see Figure 1(b)). Most electricity is produced from natural gas and fossil fuel which makes the Thai government improve power generating development plans and increase more renewable energy. Thus, renewable energy has been increasing constantly as shown in Figure 1(d) (EPPO, 2019a; 2019b).

3 PROPOSED METHODOLOGY FOR D-RPS

We design a calculating method of D-RPS by using monthly electricity bills to apply it with renewable energy generation development. It focuses on power users with the fundamental principle to determine production proportion, power usage, and participation in promoting renewable energy production. The amount of electricity produced from renewable energy is used to substitute fossil fuel power. Dependent variables are increased or decreased based on the amount of electricity consumption in the electricity bill.

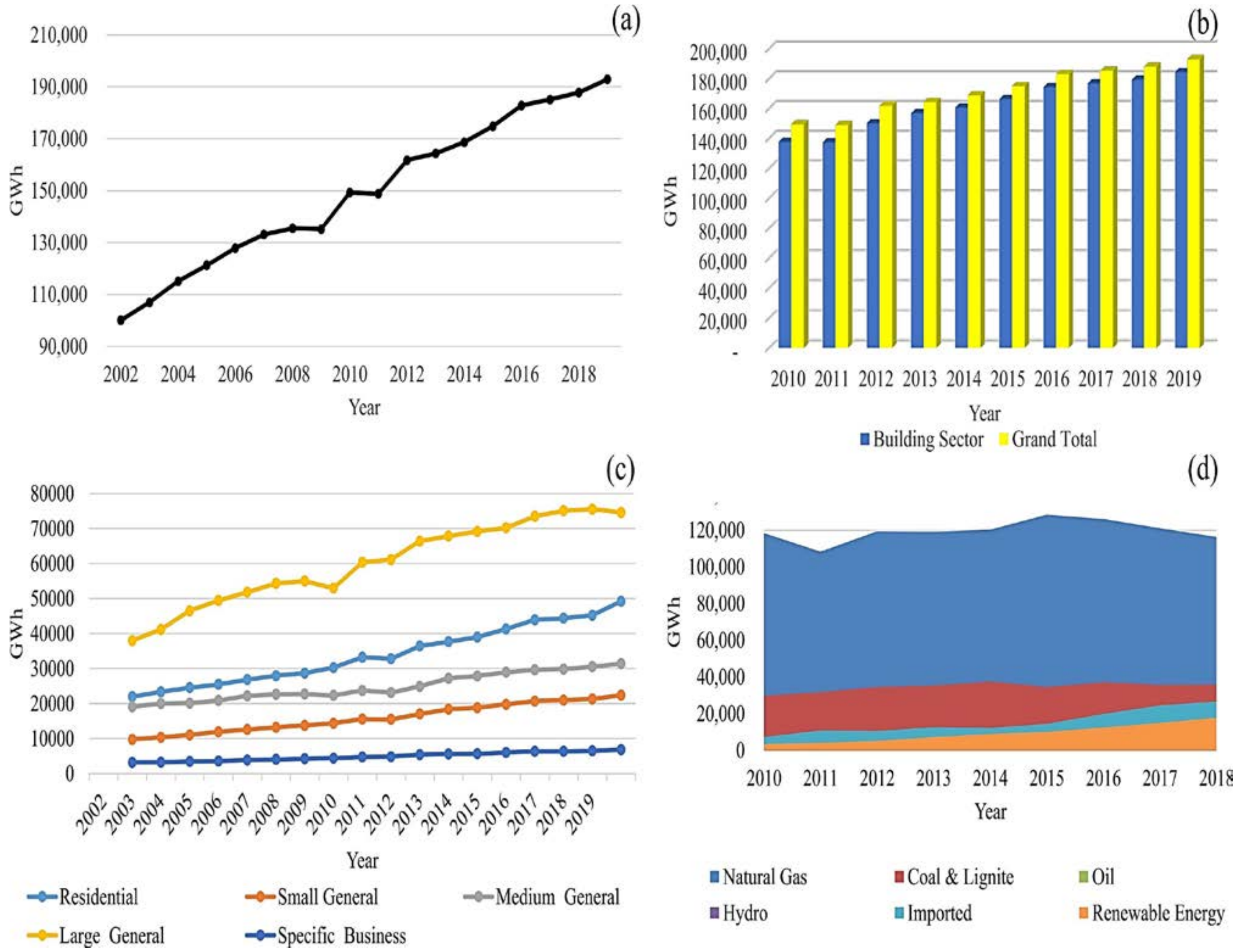

Figure 1: Overview of national power consumption and the proportion of fuel used to produce electricity. (a) Electricity consumption in Thailand (b) Electricity consumption in buildings compared to the total electricity consumption (c) Electricity consumption based on different sectors (d) The proportion of fuel used to produce electricity.

3.1 PROCESS OF CALCULATING METHOD

All kinds of building users could calculate D-RPS from monthly electricity bills as per the following process.

1) Find the Monthly electricity amount shown as kWh in the latest electricity bill before D-RPS policy announcement, denoted by Electricity Demand (ED)

2) Calculate the Percentage of renewable energy usage targets in the building (%$D\text{-}RPS$) as announced by the government or the organization.

3) The calculation of $D\text{-}RPS$ using data from steps 1) and 2) is as

$$D\text{-}RPS = ED \times \%\, D\text{-}RPS \qquad (1).$$

4) Building owners or users apply the $D\text{-}RPS$ value to consider installing renewable power generating system in the building

3.2 TARGET ACHIEVEMENT REVIEW

Since D-RPS is a compulsory policy, there should be a target achievement assessment as

$$D\text{-}RPS_{Status} = ERE_{PVR} - D\text{-}RPS \quad (2),$$

where

$D\text{-}RPS_{Status}$ = D-RPS policy target achievement,

ERE_{PVR} = electricity produced from the solar photovoltaic rooftop in the building each month and shown in kWh unit.

If $D\text{-}RPS_{Status}$ assessment < 0, this means "unachievable". If $D\text{-}RPS_{Status}$ assessment ≥ 0, it is considered "achievable".

3.3 REVISION OR CORRECTION TO ACHIEVE THE TARGET

If the amount of electricity produced from renewable energy does not meet the target, the owners should consider an alternative to promote or increase additional production capacity of renewable energy or purchase additional renewable power from other buildings.

4 DATA DETERMINATION AND SIMULATION

We can calculate D-RPS from the percentage using monthly electricity bills for all kinds of buildings. In this research, we determine input values from Table 2 (EPPO, 2018; REN21, 2005) and Table 3 with a 5% proportion. This method is based on the RPS policy data in Thailand (REN21, 2005) which is adjustable according to the policy and plan. We apply rooftop solar power technology to generate renewable energy in the building. We simulate generated power by using PVWatts® software by NREL (NREL, 2016) which has the function to simulate power output generated by rooftop solar power generating system (Pabasara, *et al*., 2019), and apply research simulation by determining system value as shown in Table 3 (Chaianong, *et al*., 2019).

Table 2: Input data for the simulation of D-RPS

Key component	D-RPS
Target	5%
Interim schedule	2018-2037
Eligible resource	Solar Photovoltaic Rooftop
Electricity Bill	Electricity consumption(kWh), Residential Type 1.2 and 1.3(TOU)

Table 3: Technical input data of PV rooftop system for the simulation

PV System Specifications (Residential)	Input
System Size	0.5 -10 kW_p
Module Type	Standard (Crystalline Silicon)
Array Type	Fixed (roof mount)
Array Tilt	13.7°
Array Azimuth	180°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.1

5 RESULTS

Tables 4-6 show the results when we apply D-RPS applications with three residential buildings with installed rooftop solar energy power generation system. They reveal D-RPS values that comply with the regulation criterion varied from the amount of electricity usage each month. The proportion is constant at 5%, and the replacement could help reduce the CO_2 emissions from electricity usage. Since electricity consumption of residential buildings increases constantly, if we apply D-RPS, it would encourage the installation of a rooftop solar energy power generation system. It is possible to reduce produced electricity in the system based on D-RPS value each month.

Table 4: Result of D-RPS application with residential building #1 (meter type 1.2)

Unit: (kWh/month)

Month-Year	ED	$D\text{-}RPS = ED \times \%D\text{-}RPS$	ERE_{PVR} (AC Output of PV systems)	$ED_{D\text{-}RPS}$ $(ED - D\text{-}RPS)$	$D\text{-}RPS_{Status} = ERE_{PVR} - D\text{-}RPS$	
					≥0,(+)	**< 0,(-)**
May-18	672	33.6	59.51	638.40	25.91	
Jun-18	579	28.95	57.24	550.05	28.29	
Jul-18	516	25.8	67.63	490.20	41.83	
Aug-18	519	25.95	60.17	493.05	34.22	
Sep-18	552	27.6	55.08	524.40	27.48	
Oct-18	536	26.8	53.79	509.20	26.99	
Nov-18	515	25.75	52.58	489.25	26.83	
Dec-18	512	25.6	48.94	486.40	23.34	
Jan-19	460	23	51.47	437.00	28.47	
Feb-19	506	25.3	52.52	480.70	27.22	
Mar-19	554	27.7	56.66	526.30	28.96	
Apr-19	733	36.65	59.09	696.35	22.44	
Total	**6,654**	**332.7**	**674.66**	**6,321.30**	**341.96**	

Table 5: Result of D-RPS application with residential building #2 (meter type 1.3)

Unit: (kWh/month)

Month-Year	ED	$D\text{-}RPS = ED \times \%D\text{-}RPS$	ERE_{PVR} (AC Output of PV systems)	$ED_{D\text{-}RPS}$ $(ED - D\text{-}RPS)$	$D\text{-}RPS_{Status} = ERE_{PVR} - D\text{-}RPS$	
					≥0,(+)	**< 0,(-)**
May-18	966	48.3	59.51	917.70	11.21	
Jun-18	1,098	54.9	57.24	1,043.10	2.34	
Jul-18	1,037	51.85	67.63	985.15	15.78	
Aug-18	1,068	53.4	60.17	1,014.60	6.77	
Sep-18	1,407	70.35	55.08	1,336.65		–15.27
Oct-18	812	40.6	53.79	771.40	13.19	
Nov-18	880	44	52.58	836.00	8.58	
Dec-18	863	43.15	48.94	819.85	5.79	
Jan-19	778	38.9	51.47	739.10	12.57	
Feb-19	822	41.1	52.52	780.90	11.42	
Mar-19	926	46.3	56.66	879.70	10.36	
Apr-19	1,090	54.5	59.09	1,035.50	4.59	
Total	**11,747**	**587.35**	**674.66**	**11,159.65**	**102.59**	**–15.27**

Table 6: Result of D-RPS application with residential building #3 (meter type 1.3)

Unit: (kWh/month)

Month-Year	ED	$D\text{-}RPS = ED \times \%D\text{-}RPS$	ERE_{PVR} (AC Output of PV systems)	$ED_{D\text{-}RPS}$ $(ED - D\text{-}RPS)$	$D\text{-}RPS_{Status} = ERE_{PVR} - D\text{-}RPS$	
					≥0,(+)	**< 0,(-)**
May-18	1,174	58.7	59.51	1,115.30	0.81	
Jun-18	1,195	59.75	57.24	1,135.25		–2.51
Jul-18	1168	58.4	67.63	1,109.60	9.23	
Aug-18	1,096	54.8	60.17	1,041.20	5.37	
Sep-18	1,059	52.95	55.08	1,006.05	2.13	
Oct-18	1,122	56.1	53.79	1,065.90		–2.31
Nov-18	1,199	59.95	52.58	1,139.05		–7.37
Dec-18	1,094	54.7	48.94	1,039.30		–5.76
Jan-19	1,007	50.35	51.47	9,56.65	1.12	
Feb-19	1,238	61.9	52.52	1,176.10		–9.38
Mar-19	1,255	62.75	56.66	1,192.25		–6.09
Apr-19	1,274	63.7	59.09	1,210.30		–4.61
Total	**13,881**	**694.05**	**674.66**	**13,186**	**18.65**	**–38.03**

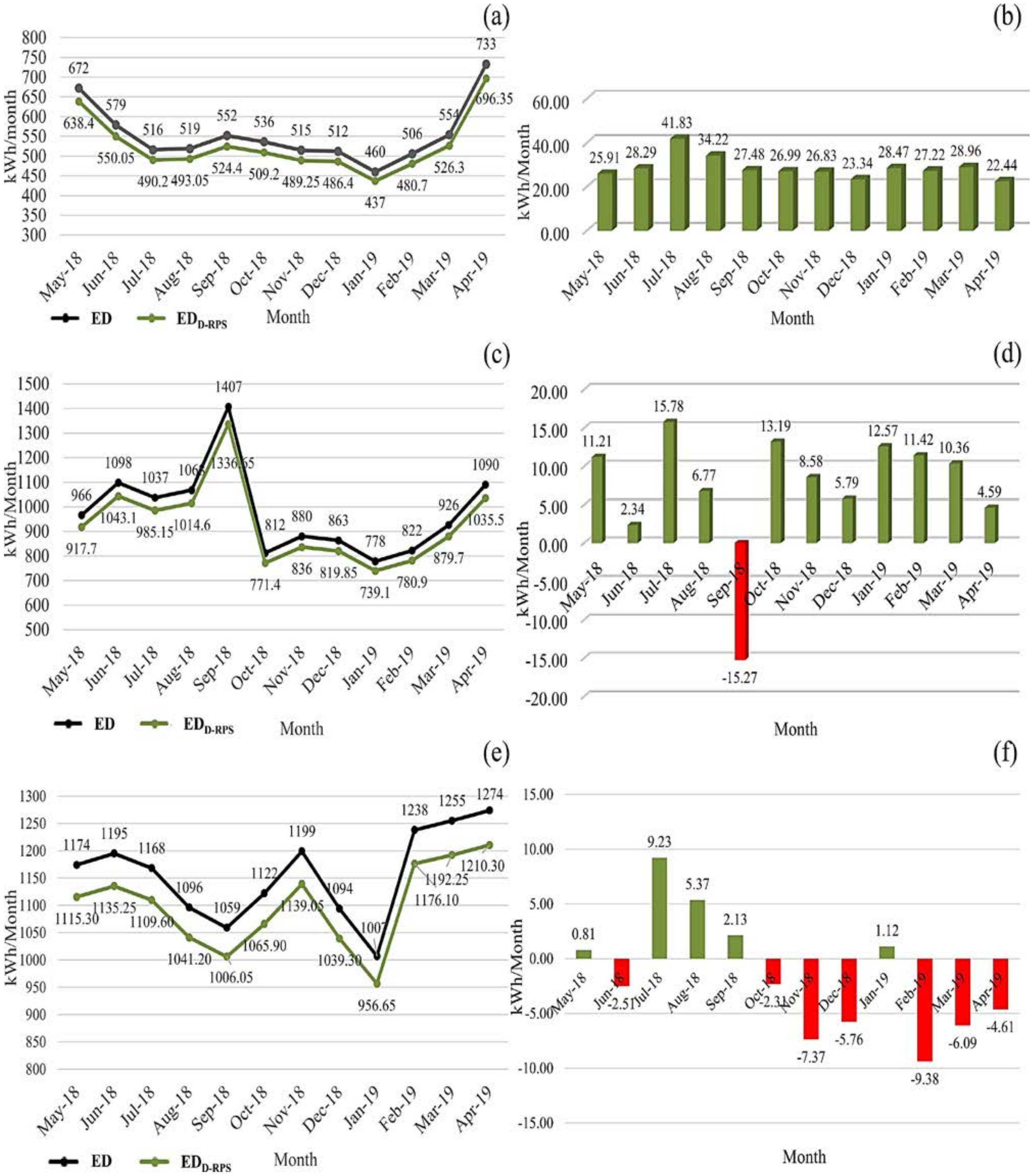

Figure 2: Results of D-RPS application and assessment of target achievement each month of the three residential buildings (a and b) residential building #1 (meter type 1.2), (c and d) residential building #2 (meter type 1.3 (TOU)), and (e and f) residential building #3 (meter type 1.3 (TOU)).

Figure 2 depicts the same results graphically. The D-RPS values of residential buildings #1, #2, and #3 are 332.7kWh, 587.35 kWh, and 694.05 kWh respectively. This shows the variation of D-RPS values based on the monthly electricity usage of each household. Of the overall electricity usage at 5% of power generation system in different households and assessment of status, using 500 watt-peak (W_p) power generation capacity based on PVwatts® assessment, we find that the system could generate 674.66kWh electricity per year. Residential building1 could generate electricity upon the criteria every month, whereas residential buildings #2 and #3 that use Time of Use (TOU) electric metering type have high electricity usage and could not meet the criteria in some months. As a result, residential buildings #2 and #3 have to increase installed generation capacity. This data shows the importance of providing opportunities for households that follow D-RPS but could not meet the criteria. These households should increase their power generation capacity or have an alternative to promote and compensate electricity units that could not meet the target by using different methods. Due to the 10 kWp power generation capacity for different households in Thailand, the systems of these households should be evaluated and compared with the monthly electricity usages to select the proper size of the system.

5.1 RESULTS OF CO_2 EMISSION REDUCTION

We find a decrease in electricity usage in building #1 at 164.35 kg-CO_2, building #2 at 290.15 kg-CO_2, and building #3 at 342.86 kg-CO_2, which represents D-RPS policy application in different buildings. This could help reduce CO_2 emission (EPPO, 2019c) and provide variation based on the amount of renewable energy usage. Because more than 90% of power consumption in Thailand is from the buildings sector each year (97% in 2019), D-RPS policy application in the buildings sector would reduce CO_2 emission from electricity usage significantly.

6 CONCLUSION

D-RPS is designed to encourage more renewable energy usage at different buildings. This work employs DPRS using the amount of electricity usage shown on monthly electricity bills. The numbers used are therefore based on actual data of power users as kWh unit, and renewable energy sources could be applied accordingly based on the potential of renewable energy, technology, and cost in different countries. This complies with the fundamentals of the RPS design principle. Increased usages of renewable energy in buildings are advantageous in terms of environmental friendliness and target achievement of greenhouse effect reduction in different countries. D-RPS can also be used for the microgrid development system as part of an intelligent power generation system in the future.

7 AVAILABILITY OF DATA AND MATERIAL

Data can be made available by contacting the corresponding author.

8 REFERENCES

Chaianong, A., Tongsopit, S., Bangviwat, A., Menke, C. (2019). Bill saving analysis of rooftop PV customers and policy implications for Thailand. *Renewable Energy*, 131, 422-434.

EPPO. (2004). *Regulations for purchasing electricity from small power producers Renewable Portfolio Standard (RPS)*. Energy Policy and Planning Office. http://www.eppo.go.th/index.php/th/eppo-intranet/item/1707-nepc-thaksin97 Accessed January 2020. (in Thai).

EPPO. (2018). *Thailand Power Development Plan 2015-2037 (PDP2018)*. Energy Policy and Planning Office. http://www.eppo.go.th/images/POLICY/ PDF/PDP2018.pdf Accessed January 2020.

EPPO. (2019a). *Electricity Consumption for the Whole Country (Classified by Tariff)*. Energy Policy and Planning Office. http://www.eppo.go.th/index.php/en/en-energystatistics/electricity-statistic Accessed January 2020. (in Thai).

EPPO. (2019b). *Power Generation Classified by Fuel Type (Detail)*. Energy Policy and Planning Office. http://www.eppo.go.th/index.php/en/en-energystatistics/electricity-statistic Accessed January 2020.

EPPO. (2019c). *CO_2 Emission per kWh*. Energy Policy and Planning Office. http://www.eppo.go.th/index.php/en/en-energystatistics/co2-statistic Accessed January 2020.

Heeter, J., Speer B., Glick, M. B. (2019). *International Best Practices for Implementing and Designing Renewable Portfolio Standard (RPS) Policies*. National Renewable Energy Laboratory (NREL). https://www.nrel.gov/docs/fy19osti/72798.pdf Accessed January 2020.

IEA. (2016). Strategic Plan for Renewable Energy Development: 8% Target. International Energy Agency. http://www.iea.org/policies/4873-strategic-plan-for-renewable-energy-development-8-target?country=Thailand&qs=Thailand Accessed March 2020.

IEA. (2018a). *Global Energy & CO_2 Status Report The latest trend in energy emissions in 2018*. International Energy Agency. http://webstore.iea.org/global-energy-co2-status-report-2018 Accessed July 2019.

IEA. (2018b). *Key World Energy Statistics 2018*. International Energy Agency. http://webstore.iea.org/key-world-energy-statistics-2018 Accessed July 2019.

NREL. (2016). PVWatts Calculator®. *National Renewable Energy Laboratory*. http://pvwatts.nrel.gov Accessed March 2020.

Pabasara, W.M., Wijeratne, U., Yang, R.J., Too, E., Wakefield, E.R. (2019). Design and development of distributed solar PV systems: Do the current tools work?. *Sustainable Cities and Society*, 45, 553-578.

REN21. (2005). *Renewables 2005 Global Status Report*. Renewable Energy Policy Network. http://www.ren21.net/wp-content/uploads/2019/05/GSR2005_Full-Report_English.pdf Accessed January 2020.

REN21. (2019). *Renewable Global Status Report 2019*. Renewable Energy Policy Network http://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf Accessed January 2020.

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