Applied Energy Symposium 2019: Low carbon cities and urban energy systems
October 16-18, 2019, Xiamen, China
Paper ID: 0030

ECONOMIC ANALYSIS OF DIFFERENT BUSINESS MODELS FOR ENERGY PROSUMERS: FOCUSING ON THE ROOFTOP SOLAR PV SYSTEM

Jongbaek An[1], Taehoon Hong[2,*], Minhyun Lee[1], and Hakpyeong Kim[1]

1 Department of Architecture and Architectural Engineering, Yonsei University, Seoul, 03722, Republic of Korea

2* Department of Architecture and Architectural Engineering, Yonsei University, Seoul, 03722, Republic of Korea (Corresponding Author)

ABSTRACT

Many countries have introduced various renewable energy sources to reduce carbon emissions. However, installing the renewable energy system without any energy storage system often fails to consume all of the produced energy, which then ends up being wasted. This study evaluated the economic performance of the surplus electricity trading of energy prosumer through three different business models. The proposed method can help energy prosumers to determine the business model with the highest profits and to evaluate the economic feasibility of peer-to-peer electricity trading for the future improvement.

Keywords: Energy prosumer; Net-metering; Power Purchase Agreement (PPA); Peer-to-Peer (P2P) electricity trading; Economic analysis; Rooftop solar PV system

NONMENCLATURE

Abbreviations	
KEEI	Korea Energy Economic Institute
KEPCO	Korea Electric Power Corporation
P2P	Peer-to-Peer
PPA	Power Purchase Agreement
PV	Photovoltaic
REC	Renewable Energy Certificate
SMP	System Marginal Price

1. INTRODUCTION

Approximately 80% of the energy consumed globally is supplied from fossil fuel, and two thirds of the global greenhouse gas emissions are from the energy section [1]. Accordingly, the South Korean government announced the "2030 New Energy Industry Promotion Strategy," aiming to reduce greenhouse gas emissions of up to 55 million tons by 2030. In the energy prosumer sector, the strategy strived to establish an energy prosumer market and promote energy prosumer businesses, that aim to create a market in which anyone can produce and/or sell electricity. Furthermore, it hopes to make inroads into the low-carbon electricity generation market through the continuous expansion of renewable energy generation [2].

In such a context, Peer-to-Peer (P2P) electricity trading has emerged which enables the direct trading of electricity between energy prosumers and consumers without requiring the intervention of third parties [3]. P2P electricity trading allows energy prosumers to sell the surplus electricity to nearby energy consumers, instead of electric utilities. Currently, P2P electricity trading is available in the United Kingdom [4], Germany [5], and the Netherlands [6], and its pilot projects are in progress in South Korea [7].

This study compared the economic performance of the current business models for energy prosumers to that of the P2P electricity trading. Toward this end, this study analyzed the economic performance of each business model based on the electricity billing system in South Korea, according to the following procedures: (i) residential electricity billing system; (ii) profit structure of business model; (iii) definition of assumptions; and (iv)

Selection and peer-review under responsibility of the scientific committee of CUE2019
Copyright © 2019 CUE

economic analysis of business models for energy prosumers.

2. MATERIAL AND METHOD

2.1 Step 1: Residential electricity billing system

Since the 1973 Oil Crisis, South Korea has implemented a progressive billing system in residential electricity billing to promote energy savings and protect low-income families. A progressive billing system applies higher fees sequentially according to the increase in the electricity used by the consumer. Currently, the three stages shown in the following table are used (refer to Table 1). The final residential electricity bill is generated by adding the electricity industry-based fund and VAT to the basic and progressive charges based on the electricity consumption [8].

Table 1. Residential electricity bill

Basic charges (US$/household)		Progressive charges (US$/kWh)	
Under 200kWh	0.76	To the first 200kWh	0.08
201~400kWh	1.34	To the next 200kWh	0.16
Over 400kWh	6.11	Over 400 kWh	0.23

2.2 Step 2: Profit structure of business models

In South Korea, there are three business models in which energy prosumers install a renewable energy system for self-consumption and make additional profits by trading the surplus electricity: (i) net metering; (ii) power purchase agreement (PPA); (iii) P2P electricity trading. Table 2 shows the characteristics of the three different business models including their target and scope [9].

First, net-metering enables the energy prosumers to self-consume the electricity from the renewable energy generation, and any surplus electricity is sent back to the grid so as to obtain reductions in the electricity bill. Net-metering is only possible by making a contract with Korea Electric Power Corporation (KEPCO), the only electric utility that provide electricity in South Korea, and the regulation was revised in 2016 to allow net-metering for up to 1,000kW system capacity. Shown below is the electricity bill savings through net-metering (refer to Eq. (1)).

$$EBS_{NM} = \mathrm{C}(E_1) - \mathrm{C}(E_1 - EG) \quad (1)$$

Table 2. Characteristics of different business models for energy prosumers

Classification	Net-metering	PPA	Peer to Peer (P2P) electricity trading
Application type	All type	All type	Residential
Eligible system size	≤ 1000kW	≤ 1000kW	≤ 1000kW
Profit structure	Electricity bill saving	Electricity bill saving Selling surplus electricity Selling REC	Electricity bill saving Selling surplus electricity

Second, PPA allows the energy prosumers to sell the surplus electricity with KEPCO based on the system marginal price (SMP). Unlike net-metering, PPA additionally make profits by selling the surplus electricity to KEPCO instead of a reduction in the electricity bill, and a contract of up to 1,000kW system capacity is possible for a building. Since 2016, PPA allows additional profit from selling renewable energy certificate (REC), however, this can make PPA economically more advantageous. Thus, to analyze only the business model mechanism of treating surplus electricity and to consider the balance with the other two different business models, this study did not consider the profit from selling REC for the economic analysis. Shown below is the electricity bill savings through the PPA (refer to Eq. (2)).

$$EBS_{PPA} = \mathrm{C}(E_1) - \mathrm{C}(E_1 - E_2) + SMP \times (EG - E_2) \quad (2)$$

Third, P2P electricity trading, unlike PPA, allows the energy prosumers to sell the surplus electricity directly to nearby consumers within the same electricity grid, instead of selling to KEPCO. Compared to net-metering or PPA, it does not require any trading with KEPCO, and the trading price is not fixed and can differ according to several parameters. Shown below is the electricity bill savings obtained via P2P electricity trading (refer to Eq. (3)).

$$EBS_{P2P} = \mathrm{C}(E_1) - \mathrm{C}(E_1 - E_2) + PETP \times (EG - E_2) \quad (3)$$

Here, EBS_{NM}, EBS_{PPA}, and EBS_{P2P} refer to the monthly electricity bill savings of the energy prosumer under net metering, PPA, and P2P electricity trading, respectively. $C_{(x)}$ is the electricity bill for the electricity consumption x, E_1 is the total monthly electricity consumption of the energy prosumer, and E_2 is the monthly electricity self-consumption of the energy prosumer. EG is the monthly electricity generation of the energy prosumer, SMP is the

Copyright © 2019 CUE

system marginal price, and PETP is the P2P electricity trading price. Here, EG>E_2, and E_1>E_2.

2.3 Step 3: Definition of assumptions

In Step 3, various assumptions to analyze the economic performance of each business model are defined. First, Seoul in South Korea was selected as the target region where one fifth of the total population live with the largest electricity consumption in the country. Second, residential building was selected as the target facility type. Third, the rooftop solar PV system was selected as the target renewable system since it accounts for the largest cumulated capacities among the distributed generation system in South Korea. Fourth, South was selected as the orientation since the electricity generation is at its maximum in southwards. Fifth, the system capacity was set to 3 kW in this study, as it is the maximum capacity required for receiving government subsidies for installing a residential rooftop solar PV system in South Korea. Sixth, monthly electricity consumption was set to 230 kWh based on the database offered by Power Big Data Center in South Korea. Seventh, the SMP, which is used for the economic analysis of the PPA, was set to US$ 0.08/kWh based on the annual average SMP offered by KEPCO [11]. Eighth, the P2P electricity trading price, which is used for determining the P2P electricity trading profit, was set to US$ 0.21/kWh, by referring to the "Study on the Improvement Plan for Energy Prosumer Activation" published by Korea Energy Economic Institute (KEEI) [12].

Table 3. Main assumptions for benefit analysis by business model

Classification		Description
Region	Country	South Korea
	City	Seoul
Facility type		Residential building
System	Type	Rooftop solar PV system
	Orientation	South
	Capacity	3kW
Monthly electricity consumption		230kWh
Electricity price	SMP	US$ 0.08/kWh
	P2P electricity trading price	US$ 0.21/kWh

Note: The exchange rate (KRW/US$) is 1193.80 won to a U.S. dollar (as of 22 May 2019)

2.4 Step 4: Economic analysis of business models for energy prosumers

Table 4 shows the economic analysis results on the annual electricity bill savings by business model when the self-consumption rate of the energy prosumer is 20%, 40%, 60%, and 80%, respectively. First, the net-metering showed constant electricity bill savings (US$ 285.26) regardless of the self-consumption rate. This is because, in net-metering, energy prosumers are billed only for their net electricity consumption assuming that all of the monthly electricity generation has been used regardless of actual self-consumption rate. Second, in PPA, the higher the self-consumption rate, the higher the electricity bill savings (US$ 375.11 to US$ 391.09). This is because, the annual average SMP is low (US$ 0.08/kWh), so the self-consumption gives a larger profit. Third, in P2P electricity trading, the higher the self-consumption rate, the lower the electricity bill savings (US$ 785.25 to US$ 576.11). This is because the P2P electricity trading price was set high (US$ 0.21/kWh), so it is more profitable for the energy prosumer to sell the surplus electricity to the nearby consumers through the P2P electricity trading than to self-consume the electricity.

Table 4. Economic analysis results of business models for energy prosumers

Classification	Electricity bill savings (US$/year)		
Self-consumption rate	Net-metering	PPA	P2P electricity trading
20%	285.26	375.11	785.25
40%	285.26	380.44	715.54
60%	285.26	385.76	645.82
80%	285.26	391.09	576.11

Note: The exchange rate (KRW/US$) is 1193.80 won to a U.S. dollar (as of 22 May 2019)

3. CONCLUSION

This study analyzed the economic performance of various business models for energy prosumers based on the electricity billing system in South Korea. Toward this end, this study calculated the annual electricity bill savings from a total of three business models (i.e., net metering, PPA, and P2P electricity trading). First, PPA and P2P electricity trading generated large profits by selling the surplus electricity in addition to self-consuming the electricity generated from the rooftop solar PV system, and therefore, their profits were higher than those from net-metering. However, the surplus electricity trading via PPA was more advantageous when the self-consumption rate was higher, because of the low SMP, whereas in P2P electricity trading, it was more advantageous to lower the self-consumption rate as

Copyright © 2019 CUE

much as possible. Also, in P2P electricity trading, higher economic performance is shown with a lower self-consumption rate, and therefore, the energy prosumer tends to trade the surplus electricity via P2P electricity trading rather than self-consuming it. Therefore, further research is necessary on the methods and policies for determining appropriate prices for P2P electricity trading.

Based on the calculation results of this study, it is expected that P2P electricity trading would be more economical than net-metering and PPA that are currently implemented in South Korea. Furthermore, the methodology used in this study can be implemented in estimating the profits in P2P electricity trading based on the different conditions of energy prosumers and consumers and in supporting decision making on entering the P2P electricity trading market. Future research should be conducted to determine the suitable electricity trading price that is economically feasible for energy prosumers and consumers to enter the P2P electricity trading market.

ACKNOWLEDGEMENT

This work was supported by a grant (19CTAP-C151880-01) from Technology Advancement Research Program (TARP) funded by Ministry of Land, Infrastructure and Transport of Korean government.

REFERENCE

[1] IRENA, Renewable energy: a key climate solution; 2017.

[2] Ministry of Trade, Industry & Energy, Energy New industry proliferation strategy; 2015

[3] Liu T, Tan X, Sun B, Wu Y, Guan X, Tsang D. Energy management of cooperative microgrids with P2P energy sharing in distribution networks. In: IEEE international conference on smart grid communications (SmartGridComm); 2015.

[4] Piclo-Building software for a smarter energy future, Available from: https://piclo.energy/

[5] SonnenCommunity, Available from: https://sonnen group.com/sonnencommunity/

[6] Vandevron: Duurzame energie can Nederlandse bodem, Available from: https://vandebron.nl/

[7] Ministry of Science and ICT, Available from: https://english.msit.go.kr/english/main/main.do

[8] Korea Electric Power Corporation, Available from: http://home.kepco.co.kr/kepco/EN/main.do

[9] M. Lee, T. Hong, K. Jeong, J. KimA bottom-up approach for estimating the economic potential of the rooftop solar photovoltaic system considering the spatial and temporal diversity, Appl Energy, 232 (2018), pp. 640-656

[10] Power Big Data Center, Available from: https://bigdata.kepco.co.kr/cmsmain.do?scode=S01

[11] Korea Power Exchange, Available from: https://www.kpx.or.kr/eng/index.do

[12] Korea Energy Economic Institute, Study on the institution improvement plan for energy prosumer activation, 2016

Copyright © 2019 CUE