Crowdfunding Investment for Renewable Energy (Extended Abstract)

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ABSTRACT

This paper studies a new renewable energy investment model through crowdfunding, which is motivated by emerging community solar farms. In this paper we develop a sequential game theory model to capture the interactions among crowdfunders, the solar farm owner, and an electricity company who purchases renewable energy generated by the solar farm. By characterizing a unique subgame-perfect equilibrium, and comparing it with a benchmark model without crowdfunding, we find that although the farm owner reduces its investment level under crowdfunding, the overall green energy investment level is increased due to the contribution of crowdfunders.

Categories and Subject Descriptors

J.4 [**SOCIAL AND BEHAVIORAL SCIENCES**]: Economics

General Terms

Economics, Management

Keywords

Renewable Energy, Crowdfunding, Game Theory

1. INTRODUCTION

A special *crowdfunding* green energy investment has been recently introduced in the form of community shared renewable energy projects. A typical example can be found in three community shared solar projects launched by Clean Energy Collective (CEC) in Colorado[2]. The newly emerging investment pattern in green energy— crowdfunding, can benefit all stakeholders (e.g., individual investors, the solar farm owner who represents traditional investors, electricity company). However, few research has been done about this new business model and its impact on green energy investment. Our paper aims to fill the gap by studying the optimal crowdfunding mechanism and the impact of the presence of crowdfunding on both the green energy investment and the penetration of green energy in the total energy consumption. We develop a game theory model to represent the strategic interaction between three players: a group of individual crowdfunders, the owner of a solar farm who initiates the crowdfunding, and an electricity company who purchases green energy generated by the farm through a wholesale contract. We compare the equilibrium under crowdfunding with a benchmark model without crowdfunding. We find that though the farm owner's investment level decreases under crowdfunding, the overall green energy investment level as well as the penetration of green energy in consumption increases due to the contribution of crowdfunder.

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2. PROBLEM FORMULATION

There are multiple players in the model: the owner of the farm, a group of crowdfunders and the electricity company. The sequence of events is as below:

1. The electricity company offers the wholesale price of the green generation, $w \in \mathbb{R}^+$;
2. The firm offers a contract to the crowdfunders, which specifies the unit panel investment cost c and the return r for per unit green energy generation, and also determines its own investment level $N_0 \in \mathbb{R}^+$.
3. Based on the contract, the crowdfunders determines their investment levels $n_i \in \mathbb{R}^+$.
4. The green generation is realized, the electricity company purchases from the market to satisfy the demand that cannot be satisfied by green generation.

3. EQUILIBRIUM ANALYSIS

3.1 Benchmark: No Crowdfunding

In the benchmark model without crowdfunding, the electricity company determines the wholesale price and then the green farm owner chooses the investment level. Using backward induction, we first characterize the farm's optimal investment decision $N_0^\sharp(w)$ for a given wholesale price w, then derive the optimal wholesale price $w^\sharp$ set by the electricity company anticipating the optimal investment strategy of the firm owner, $N_0^\sharp(w)$.

3.2 Crowdfunding Model

In the crowdfunding model, in addition to the direct investment by the farm owner, the farm also raises funding from crowdfunders. Using backward induction, we first solve the investment decision of individual small investors $n_i^*(c, r)$ given the contract offered by the farm owner, (c, r), then derive the farm owner's optimal crowdfunding contract $(c^*(w), r^*(w))$ and investment decision $N_0^*(w)$ given the wholesale price offered by the electricity company, w, finally we analyze the electricity company's optimal decision on wholesale price, i.e., w^*.

3.3 Comparison

We look at the impact of the crowdfunding through comparing the sub-game perfect equilibrium with crowdfunding with the sub-game perfect equilibrium without crowdfunding.

PROPOSITION 1. *After introducing crowdfunding, we have: (a) the farm owner's sales revenue from green energy generation stays the same, but the investment cost is reduced;(b) the overall investment in solar panel increases;(c) the procurement cost saving from green energy procurement increases.*

Proposition 1(a) suggests that by setting the return of crowdfunding lower than the wholesale price, the farm owner achieves the same revenue while reducing his own investment cost in solar panels. Proposition 1(b) shows that the overall investment in solar panels is always larger than that under the traditional investment setting without crowdfunding. This indicates that crowdfunding does help ramp up the green energy generation. The increase in the overall solar panel investment is mainly contributed by the crowdfunders. Proposition 1(c) indicates that the electricity company also benefits from crowdfunding. This is driven by the penetration of green energy increased by crowdfunding. Since the average cost of green energy generation is lower than the average market price, the wholesale price is lower than the market price. Therefore, more green energy supply implies more procurement cost saving for the electricity company, which also increases the welfare of energy consumers.

4. SIMULATION

In this section we aim to demonstrate the effects of variable parameters on the benefit of crowdfunding in increasing green energy generations through simulations with real data.

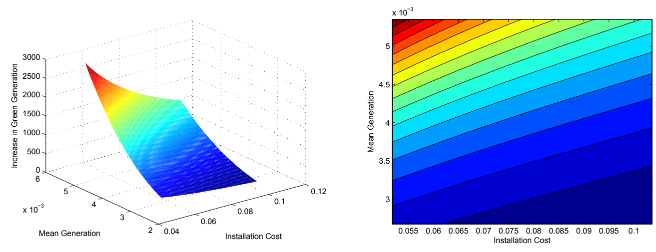
We use real data to determine the parameters in our model. For the average market price q, we use the daily average price in Southern California of 2013 based on the data provided by U.S. Energy Information Administration (EIA)[1], which is $\$48.45$ per MWh. According to the report by solar energy industry association, in 2013 the installation cost for solar photovoltaic (PV) with capacity of 1 Watt is \$2.59, the mean and variance of energy generation of solar panel with capacity of 1 Watt is $\mu_g = 0.0027$ MWh per year and $\sigma_g = 4.9 \times 10^{-5}$ MWh per year[1]. Following literatures in economics, we choose the risk tolerance of the farm owner ρ to be 5 and the average risk tolerance of the crowdfunders β to be 20.

With the simulation results, first, we conduct comparative analysis. Figure 1 plot the increment in total green energy generation caused by crowdfunding against the installation cost b and the mean generation μ_g. From Figure 1 we can observe that the improvement of green energy generation introduced by crowdfunding increases as the installation cost b decreases and as the mean generation g increases. In order to compare the sensitivity of the increment with respect to the installation cost b and the mean generation μ_g, Figure 1b shows a set of iso-curves. Each iso-curve is represented by combinations of the installation cost b and the mean generation μ_g under which crowdfunding generates the same increment in green energy generation. From the iso-curve plots we can see that per unit raise in mean generation brings about a higher increment in green energy generation than per unit reduction in installation cost does. Therefore we conclude that it is more efficient to increase mean generation than to reduce the cost.

[1]See http://www.eia.gov/electricity/wholesale/

Table 1: Net capacity factor (%) of a solar photovoltaic (PV) farm during 2008-2012

Year	2008	2009	2010	2011	2012
Capacity	31	30.5	29.6	30.7	30.9



(a) (b)

Figure 1: Impact of installation cost b and mean generation μ_g on increment in green generation introduced by crowdfunding

5. CONCLUSION AND FUTURE WORK

In this paper, we studied an emerging investment pattern in green energy—crowdfunding, which is motivated by emerging community shared renewable energy projects represented by community solar farms. The pattern of crowdfunding investment for renewable energy has various merits but calls little attentions from (quantitative) researchers. Our paper filled the gap by analytically showing how crowdfunding benefits the stakeholders and increases the overall renewable energy investment level and hence the the green energy penetration in consumption. We also numerically estimate the potential impact of crowdfunding in practice through simulations based on real data.

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