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

through simulations with real data. We aim to compare the effect of government policies and technology improvement in solar panels without crowdfunding with the benefit of crowdfunding in increasing green energy generations.

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)[4], 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[Association, 2013]. Since the majority of manufacturers offer the 25-year standard solar panel warranty, we assume that the lifespan of a solar panel is 25 years, so the annual investment cost for solar photovoltaic (PV) with capacity of 1 Watt is $b = \$0.1036$ per Year. As for the generation parameter of solar farms, we calculate the statistics of solar generation based on a 5-year solar farm's annual average capacity factor. Capacity factor is the ratio of the system's actual energy output during a fixed period to the potential output if the system ran at full capacity for the entire period[U.S. Department of Energy, 2011]. Capacity factor of solar photovoltaic (PV) is primarily determined by solar insolation, so it varies with locations, weather and time of day, etc. during 2008-2012 (Table 1), which suggest that 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.

There are no standard and well accepted values for the risk tolerance degree of the farm owner ρ and the average risk tolerance degree of the crowdfunders β. According to the values of absolute risk aversion of managers used in [Haubrich, 1994], we choose the risk tolerance of the farm owner ρ to be 5. Similarly, we let the average risk tolerance of the crowdfunders β to be 20 following [Choi *et al.*, 2007].

We compare the impact of crowdfunding with that of government policies and technology improvement aiming to boost green generation. For government policies, we consider government subsidy and carbon tax. Subsidy is characterized by θ, meaning that for \$1 collected by the green farm, $\$\theta$ is from government subsidy, and $\$(1-\theta)$ is from the electricity company. In other words, under the government subsidy of θ, if the wholesale price is w for per unit green energy the green farm still receive w per unit but the electricity company only needs to pay $(1-\theta)w$ per unit. The carbon tax results in an increase in the average market price q. Specifically, a carbon tax τ results in the average market price increasing by τ. For technology improvement, we consider both increasing capacity factor and reducing installation cost. Figure 1 plots the green generations in five scenarios: (1) no crowdfunding with subsidy, (2) no crowdfunding with carbon tax, (3) no crowdfunding with increased capacity factor, (4) no crowdfunding with reduced installation coast, and (5) crowdfunding only. Figure 1 shows that crowdfunding can achieve the same green generation as that under 34% of government subsidy, i.e., $\theta = 34\%$, or under 51% of carbon tax, i.e., $\tau = 51\%$ or with 13% increased in capacity factor, or with 19% decreased in installation cost. The result indicates that crowdfunding is a simple but effective way to boost green generation compared with government policies and technology improvement.

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

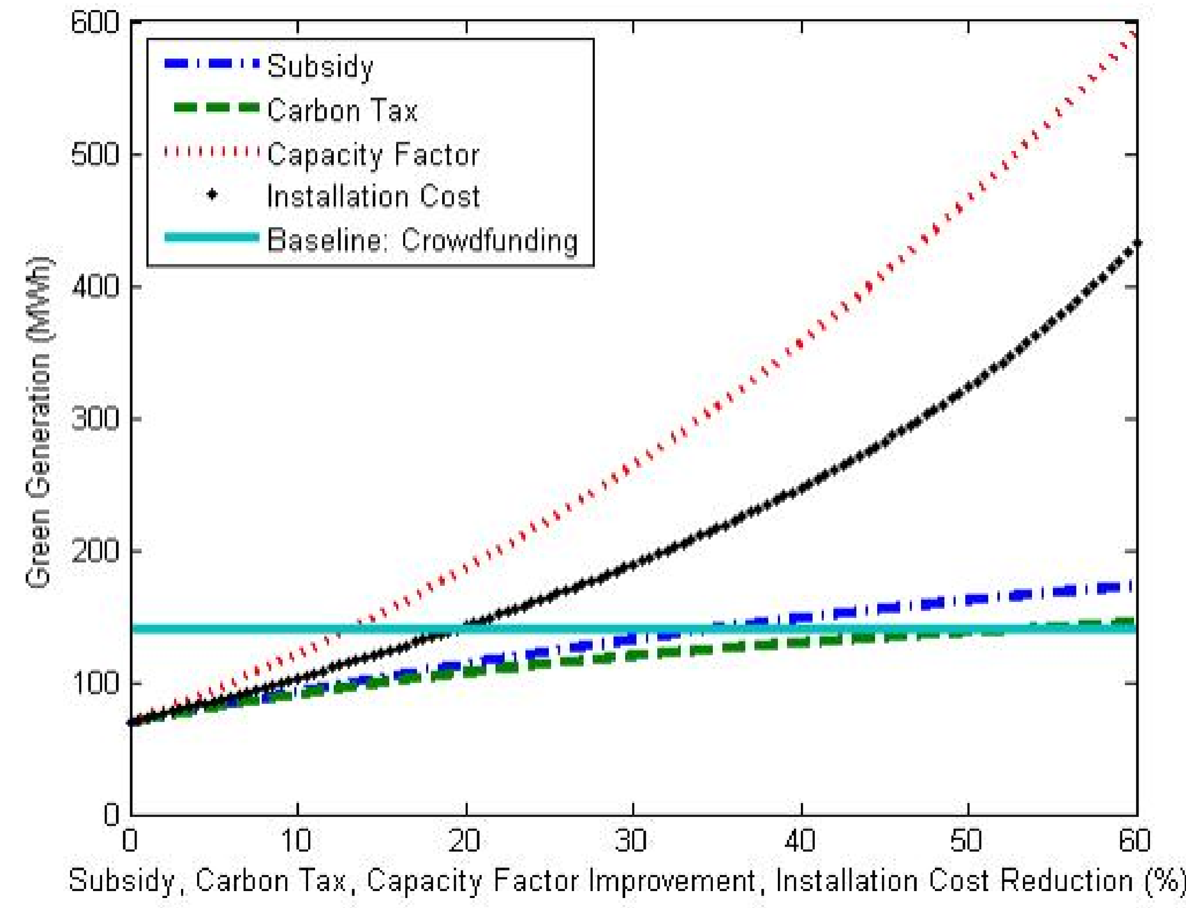

Figure 1: Comparison of Green Energy Generation under Subsidy, Carbon Tax, Increased Capacity Factor, Reduced Installation Cost, and Crowdfunding as a Baseline

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 and made the following contributions. First, we developed a sequential game model to capture the strategic interactions during crowdfunding and derived a unique subgame-perfect equilibrium to the three-player sequential game. Second, from the equilibrium we obtained the optimal cost and reward allocation rule in crowdfunding. Thirdly, by comparing with a benchmark model without crowdfunding we analytically showed how crowdfunding benefits the stakeholders and increases the overall renewable energy investment level and hence the green energy penetration in consumption. Finally, we numerically estimate the potential impact of crowdfunding in practice through simulations based on real data and find that crowdfunding is a simple but effective way to boost green generation compared with government policies and technology improvement.

References

[Association, 2013] Solar Energy Industries Association. Solar energy facts: 2012 Year-in-review. pages 2013–2015, 2013.