UNIVERSITY OF CAMBRIDGE | Energy Policy Research Group

On the viability of energy communities

EPRG Working Paper 1716

Cambridge Working Paper in Economics 1740

Ibrahim Abada, Andreas Ehrenmann & Xavier Lambin

The notion of energy communities has received increased interest over the past few years, triggered by better information and communication technologies and an increase in environmental awareness. These communities are sometimes seen as a viable business model that will foster local production and consumption of renewable energy. However, despite the potential profits made by such communities, there is no guarantee that they will be viable as a subset of participants may find it profitable to exit the community and create another one of their own if not properly remunerated. Our main goal in this paper is to analyze some conditions under which an energy community will remain stable.

We consider households of a common building or close geographical area that may decide to combine their effort in a community, and jointly build solar panels on their roofs (or windmills in a nearby field). We then consider two sources of potential gains: aggregation gains, in the form of decreased network fees, and energy gains, as the renewable energy can be consumed at zero marginal costs or re-injected in the network at a feed-in tariff. The challenge of the community is to find a proper, stable and fair (these notions are rigorously defined in the paper) way to share these benefits among its members.

We treat this problem within the framework of cooperative game theory. An array of results is found, depending on the cost structure of renewable installations. We show that the most basic sharing rules (per-capita, pro-rata of consumption or peak demand) usually fail to provide adequate remuneration to all players. In that case, some households may decide to opt out from the community. They may then try to create another smaller community with other unsatisfied households or may remain on their own. We find that diversified households with different generations, family size, occupation status, under the same roof create more value, and are therefore more likely to stick together as a community. More elaborate sharing rules, such as the Shapley value or the minimum variance allocation, though slightly more complex, have desirable properties and are more likely to enable communities to share their gains, thereby enabling them to be viable. When the community cannot be stable, the intervention of a social planner or a change in network tariffs may be required to restore efficiency. If such an intervention is not desired, we propose a way to optimally split the whole energy community into smaller stable groups of consumers, so that the lost value when splitting is minimized.

At this stage of our research, we will restrain ourselves to only assessing the game-theoretical implications of communities, inasmuch as they are motivated by financial incentives. Non-economic motivations, as well as potential externalities will not be explicitly modelled.

The present paper is related to at least two strands of the literature. The first pertains to the literature on cooperative games. Clear expositions of how cooperative game theory can be applied to costs and surplus sharing in many sectors can be found in Young (1994), Moulin and Shenker (2001) and Moulin (2002). These elements have been applied to a wide variety of topics in the energy sector (Massol and Tchung-Ming 2010; Hagspiel, 2016, etc.). The second is related to the literature on decentralized energy systems. Substantial applied research has been done on decentralized generation, from an engineering or optimization perspective. For example, Ahn https://www.gov.uk/government/publications/gas-security-of-supply-strategic-assessment-and-review (2013) and Kraning (2013) provide insights into the optimal dispatch of decentralized generation. Likewise, operational research on energy communities and micro-grids has also been very active recently, showing an increased interest in these business models (Olivares et al. (2014), Basak et al. (2012), Steinheimer et al. (2012), etc.), of which the benefits have been widely stressed, both theoretically and empirically. All of the previously mentioned papers envisage rather sophisticated energy communities endowed with technologies such as storage or demand-response. In contrast, we do not explicitly model these aspects so as to focus on the issue of gain sharing within the community. Indeed, the literature has so far restricted the analysis to the technically achievable benefits yielded by such communities, while very little research has been made to date on the actual viability of the community seen as a coalition. We believe that our study is the first to apply cooperative game theory within energy communities as such, which is our main contribution. The other important contribution of this work is to propose an optimal stable partitioning as a way to treat the instability of the energy community. Each sub-group might then create a smaller viable community on its own.

Contact ibrahim.abada@engie.com

Publication October 2017