Prosumer Empowerment through Community Power Purchase Agreements: A Market Design for Swarm Grids

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1. Motivations Underlying the Research

Between 2010 and 2019, the population without access to electricity decreased from 1.2 billion to 759 million. Electricity access can be provided in two ways: either through top-down, centralized electrification via national grid extension or bottom-up, decentralized through decentralized renewable energy solutions (DREs), that is, standalone solar systems, mini grids, and swarm grids.

The IEA estimates that the number of people connected to DREs between 2010 and 2019 more than doubled, reaching 11 million people, while GOGLA et al. calculate that by 2019, 105 million people had access to off-grid solar systems (lanterns and solar home systems). To achieve the United Nation's Sustainable Development Goal 7 in a bottom-up dominated approach, Tilleard et al. estimate that in Africa alone, by 2030, more than 290 million people could be connected to mini grids (this translates to more than 4,000 mini grids). DREs represent the most economically viable option for servicing the part of the population that is too remote or for which the national grid extension is too expensive.

Advancing the top-down electrification process, countries of the Global South, with support of international aid and development funding, are accelerating their national grid expansion. As the national grid reaches their customers, the private sector (DRE companies) is put at danger of having to either relocate their assets or abandon them. At the same time, the DRE end-user, reached by the national grid, faces several challenges due to being exposed to a double infrastructure. The challenges can be of technical and financial nature caused by assets that are becoming abundant or need additional equipment to be suitable for national grid and DREs.

2. Research Performed

This paper investigates a technically and economically viable solution for the co-existence of the national grid–a centralized infrastructure–with the decentralized, renewable energy infrastructure in Global South countries, with a case study on Bangladesh. At the intersection of these two electrification pathways the question arises if the two approaches can be integrated to the benefit of society by maintaining existing assets. For this paper we assume the technical link to be a bidirectional inverter and a battery representing the point of common coupling (PCC) between national grid and currently off-grid systems. We then suggest to apply a cost recovery approach to calculate the economic value of a community power purchase agreement (C-PPA) that allows the community to enter into a trade agreement with the national grid to export at a specified rate. To verify and assess the feasibility we run an optimization model to simulate allocation of revenues and track trade activity for a case study using both, a mixed complementarity problem (MCP) and a linear problem (LP) formulation. In this analysis, we find that the C-PPA would bring economic benefits to end-users (consumers, prosumers) by decreasing network

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charges and increasing revenue from additional sales of electricity. Based on the indication of this being beneficial we suggest a framework where the private sector and national utilities work in a collaborative effort through a public-private partnership.

3. Main Conclusions and Policy Implications

The results demonstrate a series of co-benefits: (a) the prosumer is monetarily rewarded for the utilization of her assets and for electricity trading with no additional infrastructure investment; (b) if the state utility takes over the investment costs with the interconnection infrastructure and outsources the integrated grid operations and maintenance to the private sector, the otherwise high grid expansion costs can be saved and repurposed in other infrastructure investments; (c) the operations of the decentralized renewable energy company are no longer threatened by the grid expansion and it can become an Integrated Grid Operator.

State utilities need to define the grid interconnection requirements (i.e. delivery voltage, special requirements and conditions, point of supply, interconnection arrangement) so that the C-PPA can be accurately calculated. The private sector needs to be informed about the range of services it can provide to the national grid and the discussion to differentiate between a feed-in tariff and the C-PPA tariff need to be taken up. Finally, due to its better access to financing, the state utility should take over the cost of the DRE interconnection–in our case analysis, the cost of the PCC. Our estimations show that the cost of the PCC is lower than that of the grid extension and that its CAPEX can be recovered faster if the risk is taken over by the national utility. As the scenario analysis shows the OPEX of the newly interconnected infrastructure can be priced in the C-PPA.

As the C-PPA is a derivation of a standard PPA, energy regulators (such as energy ministries or renewable energy agencies) need to ensure that the contractual framework is defined and standardized. Moreover, regulators could also consider setting up utility concessions that can allow the IGOs to obtain the rights to provide services under the C-PPA, under public sector oversight or public-private partnership (PPP). These PPPs are a means to leverage private capital and must have a clear legal structure balancing between ensuring adequate financial returns and meeting the public objectives of the governing agency, particularly given that the fundamental economics of grid-based rural electrification remain difficult. Finally, tracking and making public the costs incurred with the national grid extension and individual consumer interconnection could enable researchers, international development organizations, and policymakers in further investigating the cost-benefit analysis of centralized vs. decentralized electrification, in quantifying the investment required to reach the remaining unelectrified population, and in supporting more targeted policy recommendations.