Consortium for Development Policy Research

Policy Brief PB1703 | Energy | January 2017

Decentralized electric power delivery for rural electrification in Pakistan

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About the project

Funded by: IGC

Key Counterpart: Punjab Energy Department

Impact

Dissemination of the findings occurred at a major Energy Roundtable held in February 2017 at LUMS on the Future of Energy in Pakistan. The roundtable included numerous thought leaders from Government, Industry and Non-Profit Organisations working in the area. In February 2018 the team met with the CEO of Ignite – National Technology Fund, Mr. Yusuf Hussain, during which they proposed their idea of decentralised energy generation for rural electrification, discussed the findings of the project and briefed the CEO on the demand side of the market segment. The interaction was positive and there was a possibility for further engagement as a funding partner for a pilot microgrid deployment.

International Growth Centre

This policy brief is based on a study conducted by Dr. Hassan Abbas Khan (LUMS), Dr. Husnain Fateh Ahmad (Sewanee: The University of the South), Mashood Nasir (LUMS), Muhammad Fatiq Nadeem (LUMS) and Nauman Ahmed Zaffar (LUMS). It has been compiled by Zara Salman.

In brief

- A microgrid can provide isolated communities with electricity. It requires a marginally higher up-front cost but has a significantly lower long-run cost.
- The willingness to pay for different bundles of electricity services was determined through a household census across 6 villages. The cost for meeting the demand was also determined by l0oking at alternative solutions.
- It was found that what people are willing to pay is higher than the cost of providing the service, particularly when using decentralized microgrids. This demand could be met by local entrepreneurs with minimal government intervention.

Access to electricity is now widely considered a basic right, but there are still many citizens who remain excluded from it. In particular, those in isolated communities have to rely on unreliable and unhealthy alternatives for their energy needs, like kerosene oil. This is because large upfront costs of electrification through the national grid makes expansion prohibitively expensive for governments in developing countries. Therefore, as a solution to this problem, the use of low cost renewable resources such as solar photovoltaics (PV) to power these communities have gained momentum in recent years.

A recent innovation is the solar direct current (DC) microgrid. A microgrid is generally built around a centralized solar generation mechanism that provides multiple households with electricity through a DC cable network. While it requires a marginally higher up-front setup cost, a microgrid allows the provision of basic electrification (defined as high quality lighting and charging a mobile phone), to multiple households in a single community at a significantly lower long run cost compared to traditional power provision mechanism. It is also a promising alternative to standalone solar systems and fossil fuel generation, as it presents a low cost, sustainable and green alternative.

The presence of microgrids is not that common in Pakistan. In the paper that his policy brief draws on, it is established that there is both a demand for electrification in off-grid areas, and this demand can be met through new decentralized solar microgrid architectures.

Demand assessment methodology for rural electrification

To ascertain the demand for micro-grids, the willingness to pay for different bundles of electricity services was elicited, by conducting a household census across 6 villages in the Multan district of Punjab, Pakistan.

Households were asked about three different levels of service, which were chosen to replicate services provided by existing commercial low-power microgrids, such as Mera Gao Power, and those made available using decentralized microgrids architecture. Households could choose amongst the option of lights only, lights plus fan or lights, fan and communal load. The prices at which these services were offered were randomized between three rate plans, which presented increasing prices for each level of service.

Supply assessment methodology for rural electrification

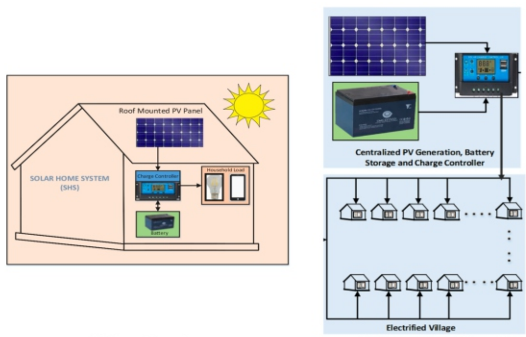
To analyze the feasibility of rural electrification through solar power, three distinct systems are proposed 1) standalone or isolated solar home systems, 2) traditional low voltage microgrids (central generation e.g. Mera Gao Power), and 3) New distributed and decentralized microgrids (with decentralized resources i.e. generation and/or storage separate for each home but sharable load with neighbours).

Standalone systems are generally suboptimal for rural deployment due to the generation and consumption profile of most rural communities. Solar panels produce most power around noon, whereas consumption is likely to be higher in the early mornings and late evenings or nights. Thus, as generation and consumption does not match, there is limited storage and lot of wastage. Higher autonomy and larger loads may be met through the use of storage capacity; however, such systems would require very high upfront costs.

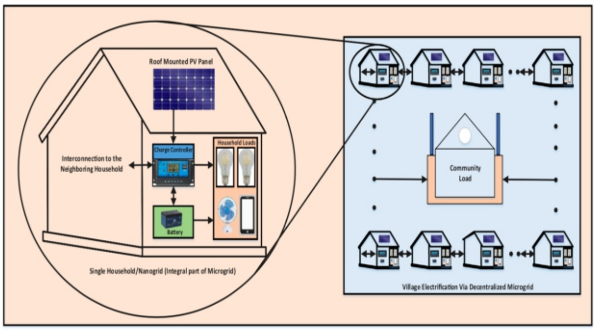
Centralized microgrid implementations (Fig 1(b)), on the other hand, are more energy efficient than standalone systems (Fig 1(a)) due to resource sharing capabilities. Subscribers share resources that are both generated and stored at a central facility. Since there is some flexibility, gained through diverse usage across households, the system yields the same power delivery in a smaller size, when compared to standalone systems. For low-cost deployments, traditional microgrid systems rely on low voltage DC distribution. These largely self-sustained implementations typically allow for up to 8 hours of electricity provisions per day. However, the primary deterrent to scaling up are the considerable line losses at low voltages.

An alternative to traditional microgrids are decentralized microgrids (Fig. 1(c)) which can cater to many of the issues with traditional microgrids. Decentralized microgrid systems rely on the distribution of resources in terms of generation, as well as storage where most of the power produced is consumed locally with any surplus power shared between neighbors. It therefore allows for the possibility of powering a shared communal load. Such a system has the inherent tendency of resource sharing to extract benefits of usage diversity, thereby lowering wastage and increasing efficiency.

Figure 1: Explaining standalone systems, centralized and decentralized microgrids



(a) Standalone System (b) Centralised Microgrid



c. Decentralized Microgrid

Results

By examining the data collected on reported willingness to pay and by estimating the cost of meeting this demand, it can be demonstrated that there is surplus to be exploited. That is, the value respondents put on these services (captured through willingness to pay), is higher than the cost of providing it using solar systems. This surplus if met, would not only by definition be welfare increasing, but could also be met by local entrepreneurs, with minimal government interventions.

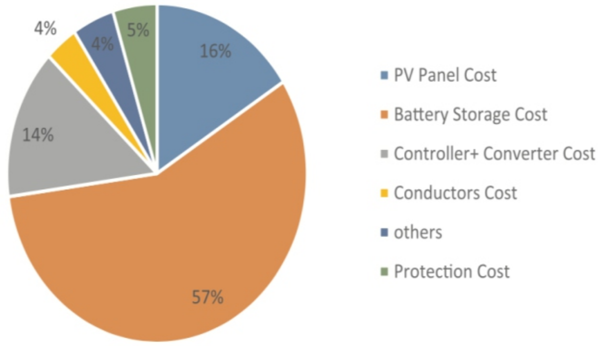
There is significant difference for all services beyond those provided by traditional micrograds (lights and mobile charging). Households are willing to pay almost twice as much for the addition of a fan, and about 2.5 times more for both a fan and communal load. This means that solar power, in particular decentralized microgrids, present a viable alternative to grid electricity even for loads beyond high quality light. It is also sized to provide electrification well beyond a traditional setup (24 h compared to 8 h).

Moreover, assuming a non-profit loan structure (0%), a system can be made viable at nominal fixed monthly prices. Given the average willingness to pay results from households in our data, the system can break even within 9 years for a system with lights and fans.

In terms of cost, a 75% subsidy, i.e. approximately 6800 USD (PKR. 750,000) per village is required to sustain a decentralized microgrid. This is much lower than the electrification costs through the national grid in most areas. Therefore, while decentralized microgrids may not be attractive to entrepreneurs under the current cost structure, they offer a low-cost system to governments and non-profits, who can, with very low levels of subsidies, make this an enticing proposition for local entrepreneurs.

Finally, it is important to highlight that the major component to the cost of any off-grid solar PV system is the cost of storage. Batteries are both expensive, have short life spans and are generally inefficient. As an example, for a case of a decentralized microgrid, it is demonstrated that the cost of storage highly dominates the overall cost of the system in its lifespan of 25 years (Fig. 2), at current market prices. However, recent developments in battery technology suggest that the overall cost of such a system is likely to come down in future, which will make these microgrids (or other solar PV backup applications) even more viable.

Figure 2: Life Time (25 years) operation cost break-up of a decentralized micro-grid



Overall the data shows that willingness to pay varies with income, respondent education and by standard of living indicators. Interestingly, the willingness to pay decreases for a monthly income regardless of the level of service offered, though it decreases at a decreasing rate. Similarly, increases in the consumption of fruit (a proxy for standard of living and wealth) also lowers willingness to pay across the board. This may suggest that those with higher levels of income and wealth have more readily available access to alternative sources of energy.

It was also found that respondents with more years of education were more open to the use of solar technology, reflected in their higher willingness to pay. This suggests the need for familiarity with new technology, and the need for demonstrations and free trials as part of any on the ground intervention. Similarly, the existence of anchoring by price plan, as households offered the highest price plan (3), reported higher willingness to pay, both practically and statistically.

Policy Recommendations

As the data suggests even traditional microgrid setups would fare well in Pakistan. The lack of pre-existing implementations may then be attributed to the inflexible nature of laws governing electricity generation and distribution in the country. A review of the current legal framework shows that it is illegal for private parties to sell electricity to other private agents. Exceptions to the law exist, but do not apply to a typical microgrid setup. A private entity cannot set up a distribution system for a rural community to sell electricity without a prior license for generation, as well as approval from the regional distribution company. The system is in its current formulation too complicated for local entrepreneurs or even larger entities to be able to operate microgrids at the community level. While net metering is now allowed in which individual consumers are only allowed to 'sell back' to the grid, it is not allowed for selling to other private consumers. Therefore, a major recommendation is to allow private parties (microgrid owners) to sell electricity to consumers in parallel with distribution companies. This should be allowed by law and the requirement for a separate distribution license should not be imposed to facilitate this process.

The law should also allow private parties to generate and distribute electricity through renewable sources up to 100 kW in off-grid and bad grid areas at a village level. The upper bound of 100kW is recommended to minimize potential legal challenges from distribution companies (DISCOs) in Pakistan, which have the sole right to distribute power in the current regulatory regime. Since the suggestion includes a potential law change, then necessary protection must be given to existing entities while ensuring that new players (entrepreneurs who setup local microgrids) have a pathway to entry. Furthermore, such entities should require a single license from a local authority (e.g. the Union Council), instead of the multiple licenses required from multiple parties, at various levels of government. Some movement on this front has been seen and based on discussions with law-makers (National Electric Power Regulatory Authority – NEPRA), there is a definite move towards removal of exclusivity of DISCOs for providing energy services. This will materialize in due course.