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Rural Electrification through Mini-Grids: Challenges Ahead

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Rural Electrification through Mini-Grids: Challenges Ahead

Abstract

Recent debates on how to provide electricity to the roughly one billion still unconnected people in developing countries have identified mini-grids as a promising way forward. High upfront costs of transmission lines are avoided, and unlike home-scale solar, mini-grids can provide sufficient electricity for productive uses. This note outlines the challenges the mini-grid sector faces to achieve that potential. To date, few examples of sustainably working mini-grid programs exist. We identify regulatory issues, low electricity demand in rural areas, high payment default rates and over-optimistic demand projections as among the key challenges. Business models that account for high transaction costs in rural areas and are based on realistic demand forecasts could considerably increase the commercial viability of village grids.

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1. Introduction

A set of recent evaluation studies has cast doubt on the transformative effect that on-grid rural electrification could have on economic development in many parts of rural Africa, at least under prevailing circumstances (Chaplin et al. 2017; Lee et al. 2018; Lenz et al. 2017). While improved access to electricity does bring benefits to households, the costs per connection are high in grid roll-out programs, especially in sparsely populated areas (IEA 2010). Since the remaining one billion non-electrified households are mostly poor and located in rural areas, connection costs of these households need to be heavily subsidized. The micro-level evaluations referenced above also show that consumption of those who are connected is very low (see as well Taneja 2018) and impacts on incomes and jobs are modest.

The imbalance between costs of grid extension and the low demand indicates a need to consider lower cost alternatives to classical on-grid electrification. While off-grid home solar (Solar Home Systems and Pico-PV systems) yields considerable benefits for its users, its potential to provide sufficient energy for productive uses is limited (see for example Aklin et al. 2017; Grimm et al. 2017).

Against this background, high hopes have been pinned on village level mini-grids[1] that can walk the line between on-grid and home-scale off-grid electrification by providing sufficient capacities for productive uses (motive power) without incurring the high-investment costs of extending high-voltage transmission lines. Indeed, mini-grids play a crucial role in accomplishing the goal of the UN Sustainable Energy for All (SE4All) Initiative and Sustainable Development Goal 7 to provide universal access to electricity by 2030. The International Energy Agency (IEA) estimated that 42% of the additional electricity generation capacity to reach universal access can most economically be achieved through mini-grids (IEA 2010). For Africa alone, least-cost universal access requires around 350,000 mini-grids, according to the IEA.

It is technically feasible to build mini-grids in most parts of the developing world. Various technical solutions exist that are based on solar or wind power, sometimes combined with backup diesel generators in hybrid models. Moreover, agglomerations in hilly terrain and close to rivers lend themselves to electrification via hydro-powered mini-grids.

However, to date few examples of sustainably working mini-grid programs in Africa have matured beyond the installation of just one role-model mini-grid.[2] When expanded to a larger intended scale, many mini-grid programs fail for socio-economic or regulatory reasons. This underscores the need to look beyond technology to consider the economic incentives for building mini-grids, and the efficiency as well as effectiveness of policies that would strengthen those incentives (see Sovacool 2012). This note discusses key economic challenges of mini-grids, distinguishing between the two most common ownership models: commercially operated schemes that involve a private operator, and community-based schemes. It concludes by outlining ways how improved energy planning might help addressing these challenges.

[1] While IEA defines mini-grids as village or district level networks with loads of up to 500 kW, this note mostly addresses challenges of village-level mini-grids.

[2] See Tenenbaum et al. (2014: 25): "It is always possible for donors to provide the outside know-how to build an SPP in the occasional pilot village. When the project is inaugurated, it provides a good photo opportunity for an ambassador from a developed country or for a country's president before an election. But in the words of one observer, this is nothing more than `boutique electrification´".

2. Commercially operated mini-grids

Commercially-operated mini-grids include various arrangements from Public-Private-Partnerships, where a private company operates a subsidized network, to purely private endeavors, where private companies need to recover investment as well as operating costs through revenues. A model in Tanzania, for example, illustrates the case of public-private cooperation, where the government has developed a framework of political, regulatory, and legal support in order to facilitate private mini-grid development.[3] A Rural Energy Fund provides grants to co-finance the hardware. In Senegal, the government aims at electrifying remote villages by solar-diesel village grids.[4] Most projects are set-up as public-private arrangements where local private companies operate hardware financed by international development aid. Some few projects exist with purely private ownership, and companies financed by loans from development banks own and operate the grid.

In all models of commercially operated mini-grids, a degree of profitability is required to make the approach financially sustainable. This is challenging in three respects:

First, households and small enterprises in rural areas of developing countries typically have a very low ability to pay. Household electricity demand in rural Africa therefore tends to be very low, given the tariffs charged and the modest income levels (see for example D'Agostino et al. 2016; Lenz et al. 2017; Taneja 2018). Electricity in rural areas often is used only for lighting, charging mobile phones, and operating a few small appliances plus radios and sometimes TV sets.[5] Especially in Africa, the potential scale of electricity-using productive activities in rural areas is limited, so demand from enterprises is quite low. Moreover, in most of those rural areas, electricity is not the major bottleneck that impedes business development. In the absence of roads and market access, electricity can only be used for productive purposes that serve the local market. Profitability of these businesses is mostly low and so is accordingly the business demand for electricity (Chaplin et al. 2017; Neelsen and Peters 2011; Peters et al. 2011; Peters and Sievert 2016; Lenz et al. 2017). In addition, income often fluctuates seasonally since in many parts of the developing world the incomes of rural populations depend heavily on agricultural production.

Second, institutional and political challenges often impede setting electricity consumption tariffs high enough to cover operating costs, let alone capital costs so that investments into mini-grids become attractive. One important reason is that today, hardly any grid-based rural electrification project aims to recover investment costs; instead, they are largely or entirely funded by Governments or international donors. In most countries, consequently, rural tariffs for electricity from the national grid do not cover costs (see Trimble et al. 2016) and are often highly cross-subsidized by urban consumers. Accordingly, regulatory bodies or the incumbent utility interested in extending grid service typically will resist imposition by commercial mini-grids of higher tariffs needed to cover their costs. In addition, local traditional leaders, like village chiefs or religious leaders, sometimes intervene if very high tariffs compared to the national grid are proposed for commercial mini-grids. Rural dwellers themselves are aware of tariffs in grid-connected areas through family ties or other networks. While mini-grid operators or project developers can try to overcome resistance to higher tariffs by communicating in a sensitive way the necessity to charge higher tariffs to get such access to electricity, social and political tensions are nonetheless likely.

Third, and related to the second point, the local population (including local leaders) is not naturally enthusiastic about investment into a mini-grid. Depending on the proximity of the national grid they

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[3] See for example www.minigrids.go.tz.

[4] This happened previously under the rural electrification program ERSEN (see for example Bensch et al. 2012) and today as part of the Programme Nationale D'Electrification Rurale du Senegal (DEEC and ASER 2016).

[5] See for example IEG (2008), and Peters and Sievert (2016) for multi-country reviews.

may not perceive a mini-grid as providing *real* electricity. Proximity of the national grid can lead to aspirations (realistic or not) to be connected soon to it; a mini-grid connection may even be perceived as an impediment to a future grid connection (see Fowlie et al. 2018 for an example from India).

To resolve these impediments, especially in countries with a rapidly expanding national network, a policy framework is needed to "address the dynamic relationship between microgrids and the grid" (Fowlie et al. 2018). This includes an approach for future integration of mini-grids and their generation capacities into the national grid (IFC 2017; Tenenbaum et al. 2014) and, hence, agreements with the utility and the regulatory authority. For India, Comello et al. (2017) emphasize that if no legal framework exists for resolving the fate of the mini-grid when the central grid is extended to the village where the mini-grid is located entrepreneurs abstain from making the investment in the face of that risk.

3. Community operated mini-grids

In community operated schemes local communities own, manage, operate, and maintain the mini-grids. In many cases, the communities receive external help with designing, financing, and installing the mini-grids. For example in Indonesia, the governmental Green PNPM program supported micro-hydro rural electrification projects (Peters and Sievert 2015). Here, investment costs for installing the systems were almost completely funded by governmental grants (communities only had to add a minimum amount of local material and manpower). After installation, the mini-grids were handed over to the communities that were then in charge of the operation.

For mini-grids operated by a community, several additional challenges emerge. Tariffs are often set way below a level that ensures financial and technical sustainability, and fees are not rigorously collected (Peters and Sievert 2015). Several factors can explain this phenomenon.

The absence of an external operator makes it more difficult for a community-based mini-grid to pursue a quasi-commercial approach which at least yields enough revenues to pay for maintenance and replacement investments. Ability to pay is low for the same reasons as given above for customers of commercially operated mini-grids. In addition, users perceive the grid as community property and are not always convinced of the need for paying prices that would be required to cover costs. For example, if mini-grids run on renewable energies (solar, hydro, wind) so that no operational cost for fuels exists, the population may think the service should be provided for free. Moreover, in the typical design of community operated mini-grids, investment costs do not have to be recovered from users due to external grants, and the community is aware of this. The need to accumulate funds for maintenance and repair is often not fully understood or under-appreciated. The capacity to pay operational staff also may seem dispensable in rural subsistence communities where paid labor is an exception rather than the rule.

In addition, incentives and obstacles to enforce payment rigorously are different for community members than external staff members of a commercial operator.[6] Most importantly, social entanglements complicate rigorous enforcement. Since the management team members themselves are inhabitants of the community, it is very difficult for them – due to social relations among the villagers – to apply sanctions against neighbors and friends, especially if those people are encountering financial problems. Only if a strong shared consent exists among households in the community, and

[6] Fowlie et al. (2018) report on similar problems for the case of private local operators in India who were unwilling to take actions against electricity theft in the community.

only if this consent is emphasized repeatedly during community gatherings the management of the community-operated mini-grid can enforce sanctions without marginalizing themselves socially.

In theory, the same mechanism can also work the other way around. Social cohesion might lead people to feel more obliged to pay their contributions on time since non-payment challenges the financial sustainability of the whole system, and loss of financial sustainability can lead to a loss of the electricity service for the whole community. However, our experience indicates that in practice, this mechanism is only rarely observed. Once one customer starts delaying payment or even defaults without any consequence, bad payment practices spread rapidly among customers.

4. A key role for improved electricity planning

Effective planning tools to design electrification strategies are pivotal to define the most suitable electrification strategy for different sub-national regions, comparing the extension of the national grid to the establishment of a mini-grid or other off-grid systems. Recently, electrification planning tools such as spatially explicit GIS-based models (see Mentis et al. 2017; Moner-Girona et al. 2016; Parshall et al. 2009; Sanoh et al. 2012) and Network Planner software (see Kemausuor 2014; Ohiare 2015) have been designed for and applied to different countries in Africa. They identify the distance to the already existing grid, topography, population density and growth, solar irradiance, cost of diesel provision, electricity demand, and potential connection rates after electrification as the most important factors driving decisions on which investments for electrification are least-cost for meeting demands. These new quantitative approaches have significant potential to improve national electrification masterplans or provide the necessary basis where such plans do not exist hitherto.

Yet, as Trotter et al. (2017a) argue, there also is considerable scope for improving these existing tools, especially by increasing the accuracy of medium-term demand forecasts. Those forecasts are not just useful for planning electricity distribution they also can have a significant impact on location, sizing and timing of centralized generation and transmission infrastructure vis-à-vis decentralized generation and distribution through mini-grids. In fact, the sensitivity analysis in Kemausuor (2014) reveals the heavy dependence of these models on demand assumptions: as connection rates and average demand projections decrease least-cost strategies noticeably shift from on-grid to mini-grids and off-grid home solar. In addition, the models do not yet account for potential productive use hubs, for example potential rural industrial zones or other types of areas with business potential. Another missing ingredient is the higher transactions costs per unit of service provided that typically arise with managing mini-grids, as discussed above.

Finally, to the degree lower carbon energy development objectives play a role in a country's policy agenda, this can also be included in improved planning tools (Trotter et al. 2017b). Since currently planned mini-grids largely rely on renewable energies incorporating such objectives into planning tools would give additional weight to options for renewable mini-grids. A next generation of planning tools might also be designed for considering dynamic strategies yielding better-calibrated responses to potential changes over time in terms of economic development (and hence electricity demand), investment costs, and governmental electrification rate targets

5. Concluding Remarks

Village level mini-grids can offer great potential for good-quality electricity provision at lower costs than grid extension in sparsely populated areas, where demand density is lower than in more settled areas. However, there are many practical challenges, and business plans must be scrutinized not just in terms of technology but also with respect to socio-economic dimensions. Demand projections are oftentimes overstated not least because of excessive optimism in growth of electricity demand for productive uses. As Taneja (2018) notes "planning should depend on reasonable electricity demand growth projections that are produced by parties without incentives to overstate growth.". To this end, planning tools have to be improved, and data-driven projections of electricity consumption in the future need to be used.

Furthermore, currently used planning tools do not adequately account for the difficulties operators face in sustainably running mini-grids. These difficulties translate into higher transaction costs that need to be better understood to foster mini-grid development. In order to improve this understanding, RMI (2017) advocates experimental pilots to generate systematic knowledge on different options for configuring and managing mini-grids. Such pilots can be used to better calibrate technological, operations and management models in order to address the socio-economic challenges that expanding mini-grid investments face. Moreover, current tools also need to better account for what happens as the central grid is extended into the territory of the mini-grid but also in terms of inequities resulting from heavy subsidization of the central grid (Fowlie et al. 2018).

In sum, mini-grid programs have to be embedded in a holistic approach to electrification that addresses regulatory and political issues at the national as well as local levels of government (see Sovacool 2012).[7] In particular, cost-covering tariffs have to be communicated and agreed upon with the local population at a very early stage and clearly labelled as a pre-condition for the investment. They need to be accompanied by a rigorous payment regime in which customers are fully aware of the consequences of not paying their bill. In this context, consumption subsidies for poor customers, as for example proposed by Urpelainen (2018) in form of vouchers, might increase the commercial viability of mini-grid investments as well as addressing equity issues induced by subsidization of the central grid.

[7] Tenenbaum et al. (2017) present three insightful case studies of what occurred for mini-grids once the main grid arrived in Cambodia, Indonesia, and Sri Lanka. In the latter two countries, several factors undercut the mini-grid operators including a price of electricity from the main grid below the cost of supply. In contrast, in Cambodia the regulatory system facilitated transition of mini-grid operators to providers of electricity to the main grid. Tenenbaum et al. also note that policies toward mini-grids have been evolving in several countries in Sub-Saharan Africa, including Kenya, Nigeria, Rwanda, and Tanzania.

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