Global Commission to
End Energy Poverty

WORKING PAPER SERIES

Towards actionable electrification frameworks: Mini-grids under the grid

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I. INTRODUCTION

The role of mini-grids in the electrification of presently unconnected areas has been extensively studied, including their costs, possible business models, policy and regulatory challenges, financing gaps and needed and emerging technology innovations[1]. This technical paper focuses on mini-grid development in regions where the grid is already present. Deployment of mini-grids in these regions represents an important market segment for mini-grids as distribution companies strive not just for universal electrification within their license area, but also delivering reliable and sufficient supply to all consumers through a viable business model.

Depending on the country contexts, the portfolio of electrification solutions – stand-alone systems, mini-grids and grid-extension – will vary. However, these must be developed as part of a unified strategy rather than a silo-ed approach to ensure that sufficient and reliable access is delivered by 2030 and that no one is left behind[2]. A deep integration of the three modes of electrification is also a key feature of the Integrated Distribution Framework, together with a clear universal electrification mandate for an entity, permanence of energy access, harnessing external resources to improve viability of distribution in the long-term, and integration of electricity supply with productive end-uses[3].

Important initiatives – such as the Nigeria Electrification Project[4] – are already underway in low-access countries to accelerate electrification by developing mini-grids in unelectrified areas, however in limited coordination with the distribution companies.

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[1] See for example World Bank (2019), Mini-grids for Half a Billion People: Market Outlook and Handbook for Decision Makers; IRENA (2018), Policies and regulations for renewable energy mini-grids; IRENA (2019), Innovation landscape brief: Renewable mini-grids.

[2] SEforAll (2019), Integrated Electrification Pathways for Universal Access to Electricity: A Primer, https://www.seforall.org/sites/default/files/2019-06/SEforALL_IEP_2019.pdf

[3] Perez-Arriaga, et. al. (2019), Global Commission to End Energy Poverty: Inception Report, https://www.endenergypoverty.org/reports

[4] The Nigeria Electrification Project is being implemented by the Rural Electrification Agency in collaboration with the World Bank and aims to be the largest off-grid electrification project across 250 communities in 4 states in Nigeria (Niger, Ogun, Sokoto and Cross River). The Solar Hybrid Mini Grids component includes a minimum subsidy tender for private developers to electrify communities with high economic growth potential, and a performance-based grant for existing private mini-grid projects.

Thinking of the mid- and long-terms, as under the IDF perspective, the active involvement of distribution companies in the development of mini-grids is crucial for a scalable approach and for the benefits of distributed energy solutions to be fully realized. Potential conflicts between mini-grid developers and expanding distribution networks are usually addressed through dedicated regulations (e.g., in Tanzania, Nigeria, Kenya, Uttar Pradesh in India) that allow mini-grid operators to interconnect or be compensated for the residual value of the assets.

An important demonstration of the feasibility of the integrated distribution approach is the case of ECOF Kaduna Ltd. (also known as Konexa) in Nigeria, albeit at a reduced scale. The Nigerian regulator NERC has recently approved the sub-concession agreement between the distribution company, Kaduna Electricity Distribution Company (KAEDCO) and the private sector entity ECOF Kaduna Ltd. to make investments in network infrastructure that will guarantee 24/7 supply of electricity within the sub-concession area to all customers, roll-out new metering technology, deploy off-grid solutions such as mini-grids and solar home systems to serve unconnected populations, while creating embedded generation capacity[5].

Another interesting initiative to promote the integration of the incumbent distribution companies with off-grid solutions and mini-grids in particular, is the collaboration in Uganda between the private concession holder Umeme Limited and Utility 2.0 to develop pilots to establish whether the integration of utility operations with distributed renewable generation (DRE) can create more economically viable connections and faster[6]. This is mainly a capacity building measure to introduce the distribution company to the off-grid experience and to gather knowledge on customer behavior that could be helpful in larger scale initiatives.

These experiences involve the interaction of the mini-grids and the main grid “when the grid arrives” or the joint development of both electrification modes. However, in practice examples of mini-grids interconnecting with an existing main grid have been extremely limited in scale. This is the subject of this working paper.

Undergrid mini-grids

Grid extension has progressed at a rapid pace in several low-access countries, especially in South Asia. In 2018, India achieved electrification of all inhabited villages

[5] Echewofun. S. (2020), “FG okays partial concession of Kaduna DisCo to Konexa”, https://www.dailytrust.com.ng/fg-okays-partial-concession-of-kaduna-disco-to-konexa.html

[6] Umeme and Power for All (2020), “Umeme kicks off a global partnership pilot to identify new approaches to clean energy access in Uganda”, https://www.umeme.co.ug/umeme_api/wp-content/uploads/2020/03/U2-Press-Release-March-2.pdf

and in 2019 reported that all willing households have been electrified[7]. The majority of electrification drive has been based on grid extension with only remote, far-flung areas being electrified through off-grid technologies. Similarly, Bangladesh, which had been one of the fastest growing markets for stand-alone solar home systems, is now seeing a much greater focus on grid expansion to reach universal electricity access[8].

However, even as connections to the grid grow, it does not necessarily translate into access to reliable, sufficient and affordable electricity supply for all. Hundreds of millions of people presently live "under the grid" i.e., either they receive unreliable, inconsistent and low-quality power or receive no power at all[9]. Improving electricity services for those living *under the grid* would require distribution companies to make additional investments in the networks, billing and collection systems, as well as in bulk power supply, while ensuring cost-recovery and viability of long-term operation. With the financial health of distribution companies in majority low-access countries remaining weak, the capacity to mobilize investments to improve services is extremely limited.

Undergrid mini-grids could offer a solution in such contexts allowing distribution companies to attract external investments, potentially from private sources, while meeting multiple other objectives:

1. ***Increasing service quality:*** Electricity connection alone is usually not a guarantee for reliable, affordable supply, leading to consumers relying on traditional fuels (e.g., kerosene, diesel) and inhibiting existing (and the development of new) commercial and industrial activity.
2. ***Meeting rural electrification goals*:** Distribution licensees (concessionaires) in countries with low rural access rates with a universal electrification mandate could utilize undergrid mini-grids to expand connections within an existing area of network coverage, as well as to expand the network to unconnected areas.
3. ***Bringing back C&I customers:*** In contexts where a large number of C&I customers lie within grid connected areas but resort to captive generation for reasons such as lack of reliability of grid supply. With more reliable and cheaper electricity from mini-grids, C&I consumers would be willing to switch to and return to the grid, replacing more expensive and polluting alternatives.

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[7] PIB (2019), "Electrification of Villages", https://pib.gov.in/PressReleseDetail.aspx?PRID=1592833

[8] Fairley, P. (2020), Bangladesh Scrambles to Deliver Electricity to Its 160 Million Residents in 2021, https://spectrum.ieee.org/energy/fossil-fuels/bangladesh-scrambles-to-deliver-electricity-to-its-160-million-residents-in-2021

[9] Rocky Mountain Institute (2019), Electrifying The Underserved: Collaborative Business Models for Developing Mini-grids Under the Grid, https://rmi.org/insight/under-the-grid/

4. ***Reducing losses:*** Meeting ATC&C loss reduction targets in concession areas with high shares of rural population and low consumption.
5. ***Stimulating demand in rural areas:*** Demand can be created when mini-grids bring additional value in rural areas enabling the development of productive end-uses.

While undergrid mini-grids offer several benefits, developing these at scale will require tailored solutions to have a meaningful impact on the electricity services received by consumers while ensuring the long-term viability of the distribution companies. Building on case studies (primarily from India and Nigeria), this technical paper analyzes the various business models for undergrid mini-grids mainly from the perspective of effectively contributing to universal electrification, while also being consistent with the basic principles of the IDF approach.

II. OVERVIEW OF DIFFERENT MODELS FOR MINI-GRIDS UNDER THE GRID

Undergrid mini-grids can be configured in different ways – physically and functionally – to play various roles and unlock different amounts of value depending on the specific context. These include:

1. Mini-grids responsible for generation and distribution in a given service area under the grid with no interaction with the distribution companies' network. Such mini-grids have sprouted in locations, such as India, where the regulatory environment allows double-wiring among consumers and a reasonably large market exists of underserved consumers, in particular C&I, some of which might not even be connected to the main grid. Usually, the mini-grids (e.g., the case of Mera Gao Power, OMC Power in India) directly negotiate tariffs with end-consumers with limited regulatory protection[10].
2. Mini-grids undertaking generation and distribution while interacting with the grid. On the one hand, the interaction could involve mini-grids connecting embedded generation (and storage) assets to the existing distribution grid (for instance at a local MV/LV transformation node) and undertaking distribution activity based on regulated tariffs and defined remuneration agreements with the distribution company. On the other hand, less complex interaction may involve such mini-grids functioning as redundancy for when the main-grid fails. An example is the Wuse market case from Nigeria (Box 1)

[10] World Bank (2017), Mini Grids in Uttar Pradesh: A Case Study of A Success Story, http://documents.worldbank.org/curated/en/181781512395036596/pdf/ESM-fUttarPradeshMiniGridsCaseStudyConfEd-PUBLIC.pdf

Box 1: Interconnected mini-grids: the case of Wuse market in Nigeria promoted by Abuja Electric Distribution Company (AEDC.

The Wuse market comprises of over 2,100 shops of which 68% have electricity supply and the majority rely on fuel-based generators to meet needs. The willingness to pay for reliability is high with shop-owners paying up to ₦120 – 300 per kWh as against AEDC's average tariff of 32/kWh. Through a partnership between the Rural Electrification Agency, a private developer, AEDC and the Market Association, an interconnected 1 MW solar-diesel-storage project with 0.7 MWh of battery storage has been deployed. It comprises three independent hybrid PV solar systems of 450kWp, 350kWp and 200kWp to serve the 3 distinct segments of the market.

Besides lower costs for shop owners and reliable supply, the adoption of interconnected mini-grids have reduced ATC&C, increased revenues for AEDC (including the Distribution Use of System Agreement, DUoS charges of N12/kWh). The project serves as a pilot for a dedicated program for deploying distributed energy solutions, including interconnected mini-grids, franchisees/concessions and embedded generation projects, to augment grid supply and investments in unserved and under-served areas. A dedicated regulation for electricity distribution franchisee in Nigeria is under development and is likely to be passed soon.

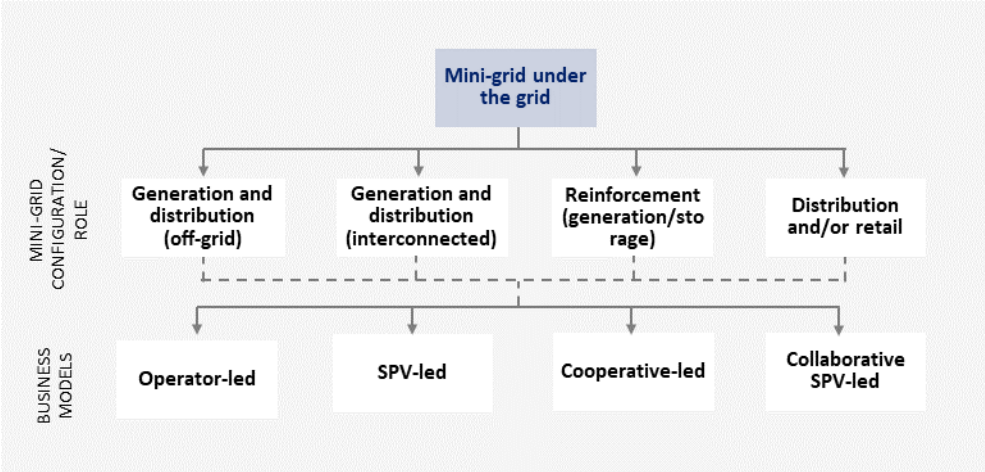
3. Mini-grids providing reinforcement through generation or storage or combination of the two at the local MV/LV sub-station to improve the power quality at the tail end of the rural feeder. In this case, the private operator would sign an agreement with the distribution company without engaging in any distribution activity.
4. Mini-grids engaged in billing and collection, as well as complementary activities such as development of productive end-uses to support demand stimulation. The primary objective of such a model is to reduce commercial losses and support demand growth in rural areas with low consumption to improve viability of electricity distribution.

The various configurations described above can be deployed in a given context dynamically as the local conditions change, such as improvements in grid supply. In India and other countries, for instance, combinations of approaches are seen involving off-grid and grid-interactive mini-grids, as well as distribution franchisees responsible for metering, billing and collection.

To develop the mini-grids under any of the above laid out configurations, the following business models are possible, as also illustrated in Figure 1[11]:

1. Mini-grid operator-led wherein a private operator is responsible for the development and operation of the mini-grid in consultation with the distribution company and/or community.
2. Special purpose vehicle (SPV)–led wherein the development is led by a consortium comprising of the distribution company while certain functions are sub-contracted to a private mini-grid operator.
3. Cooperative-led which involves a cooperative formed by the community which leads mini-grid development and operation.
4. Collaborative SPV-led wherein ownership and operation functions are shared among the mini-grid operator, community cooperative and DisCo investors.

Figure 1 Overview of mini-grid under the grid configurations and business models



III. ASSESSING SCALABLE CONFIGURATIONS FOR UNDERGRID MINI-GRIDS TO SUPPORT UNIVERSAL ELECTRIFICATION

Each configuration of undergrid mini-grid discussed in the previous section is different from the perspective of the actors involved, the business for distribution companies, the exposure to regulatory requirements, as well as the potential for scalability and demand stimulation. Further, the permanence of electricity access under each configuration also varies. This section analyses these differences for each configuration with a view to better understand which works better under what condition, and what are the configurations that have the highest potential for scale-up and to support electrification.

[11] Rocky Mountain Institute (2019), Electrifying The Underserved: Collaborative Business Models for Developing Mini-grids Under the Grid, https://rmi.org/insight/under-the-grid/

1. Generation and distribution (off-grid)

There are a number of contexts where un- or under-served grid consumers are connected to independent, non-grid interactive mini-grids. Such mini-grids usually have their own generation assets (including storage) and a distribution network that services consumers in a given area or even a specific large consumer. The distribution company does not play any active role in the development or operation of such mini-grids, including the use of its network infrastructure. The mini-grids organically sprout in contexts, such as India and Nigeria, where the regulatory environment is favorable and a reasonably large market exists to service consumers that are under-served by the grid.

Business model and actors involved

Sensing an opportunity to provide electricity services to underserved grid consumers, the private sector has been a key driver of developing undergrid mini-grids. In India, several hundred mini-grids have been developed in the states of Uttar Pradesh and Bihar, by private sector entities such as Mera Gao Power, OMC Power and Husk Power. While Mera Gao Power focused on delivering basic electricity services, such as lighting and mobile charging, primarily to households through a DC network, OMC Power focused on telecommunication towers as anchor customers while also servicing households and other public buildings[12].

The business model of independent undergrid mini-grids is based on a relatively short investment timeframe (around 5-7 years) compared to the economic lifetime of the assets. To reduce payback periods and risks on revenue generation, generally the mini-grids focus on maximizing C&I customers and other productive end-uses (e.g., irrigation pumps, agro-processing equipment) either already connected to the main-grid or not. With a sizeable volume of such anchor loads, the capacity of the mini-grid to cover additional numbers of residential consumers and public infrastructure is enhanced.

The distribution companies are traditionally not part of the business model and it is purely a mini-grid operator-led approach. Often, other stakeholders may be involved especially anchor load customers (e.g., telecom towers, public buildings such as health centers, agri-loads). The recently launched Tata Power Renewable Microgrid

[12] World Bank (2017), Mini-grids in Uttar Pradesh: A Success Story, http://documents.worldbank.org/curated/en/181781512395036596/pdf/ESM-fUttarPradeshMiniGridsCaseStudyConfEd-PUBLIC.pdf

Pvt. Ltd. supported by the Rockefeller Foundation is following a similar business model for the first phase of roll-out[13].

Business case for distribution companies

The business case for distribution companies to be involved in, or support, mini-grid development through this approach is limited. Such mini-grids are largely private sector-driven initiatives with short-/medium-term investment outlook. While some involve the development of redundant non-grid compatible networks, others have focused on grid-compatible infrastructure. For instance, mini-grids being rolled-out in the first phase by the Rockefeller Foundation-supported TP Renewable Microgrid Pvt. Ltd. in Uttar Pradesh (India) will involve the development of grid-compatible distribution network in areas with already existing infrastructure. The investments in *double-wiring* in areas already covered by the grid raise important questions for the efficiency and scalability of such models at the overall distribution-sector level, nothwithstanding the viability of the independent mini-grids themselves.

The focus of independent mini-grid operators on demand stimulation through C&I customers and other productive and consumptive loads, does support growth in electricity consumption in rural areas addressing one of the key barriers for distribution companies to invest scarce resources in improving services.

Regulatory landscape

Independent undergrid mini-grids are seen to develop in countries/regions where regulations do not explicitly keep any actor from undertaking generation/distribution/retailing activities in specific areas. In India, for instance, the Electricity Act of 2003 exempts rural electricity service providers from price regulation and licensing requirements. Privately-financed mini grids may sell electricity directly to consumers through unregulated distribution agreements[14].

Tariffs are mutually decided between consumers and the operator. Regulations provide minimal security for the investors in the event of improvements in the quality of grid supply leading to loss of consumers, or due to customers reneging on tariff agreements. Further, the regulations generally do not dictate the service standards and the quality of distribution infrastructure (e.g., meters, networks, household wiring), although certain health and safety norms may apply. This results in a diversity of

[13] Tata Power (2019), “Tata Power Launches TP Renewable Microgrid”, https://www.tatapower.com/products-and-services/micro-grids.aspx

[14] World Bank (2017), http://documents.worldbank.org/curated/en/181781512395036596/pdf/ESM-fUttarPradeshMiniGridsCaseStudyConfEd-PUBLIC.pdf

network infrastructure, from grid-compatible ones to basic wiring and distribution poles.

Dedicated regulation has been developed in a number of countries/regions that dictates the interface between the main-grid and the mini-grids. The assumption in most cases is that the mini-grid arrives first, followed by the grid reaching its territory thus requiring a range of exit options for the mini-grid operator such as interconnection or compensation, or permanence under prescribed conditions. This has been the case in Nigeria, Kenya, Tanzania as well as in Uttar Pradesh (India)[15]. The regulatory landscape for undergrid mini-grids is less developed and conducive interaction with the grid will require active involvement of the distribution companies, as discussed further in the next section.

Compensation model

The revenue for independent mini-grids is from electricity sales. Developers may secure concessional debt or equity financing or grants from foundations, non-governmental organizations or other donor agencies. There is usually no regulatory oversight on capital investments in such mini-grids and, accordingly, no guarantee of return on investments. In some cases, capital subsidies may be provided by the government. Uttar Pradesh's mini-grid policy has provisions for securing capital subsidies from the state government, however availing of this would require operators to set a pre-set tariff for the consumers. In the specific case of Uttar Pradesh, the pre-determined tariff was not sufficiently high for mini-grids to be developed under the subsidy route. Generally, the business models of independent mini-grids are designed to recover investments in a short-/medium-time frame (far less than the economic lifetimes of assets). No transferable assets are developed as part of the mini-grid, or compensated by the distribution company in the event of closure of mini-grid.

Demand stimulation potential

The demand stimulation potential is high in the case of such undergrid mini-grids, as the operator seeks to increase revenue to recover investment costs. In some cases, operators work in partnerships with productive end-use appliance suppliers, MFIs and NGOs to support demand growth. The Mini-Grid Innovation Lab, established by CrossBoundary Advisory and The Rockefeller Foundation in 2018, supported seven mini-grid developers to finance 663 appliances on credit across 25 sites in East Africa and Nigeria. Appliance purchasers consumed nearly twice as much electricity for the

[15] IRENA (2018), Policies and regulations for private sector mini-grid, https://www.irena.org/publications/2018/Oct/Policies-and-regulations-for-renewable-energy-mini-grids

first five months following adoption with average revenue per user growing 18% above baseline levels after 11 months in East Africa; in Nigeria, the figure was 25% after five months[16].

Scalability potential

Off-grid undergrid mini-grids mainly address gaps posed by an unreliable grid electricity supply. With some exceptions where small-scale DC mini-grids have been deployed to provide basic electricity access (lighting and mobile charging), such mini-grids strongly rely on the availability of anchor loads in the form of C&I consumers that are already paying (or are willing to pay) a premium for reliable service. Only in the presence of C&I consumers can the mini-grids connect households and other loads while ensuring viability of the business model.

While in some countries, such as Nigeria, the market to service C&I consumers is large, there are some inherent risks in the business model of such mini-grids especially from a scalability perspective. Improvements in the reliability of grid supply, usually under subsidized tariffs, will render the mini-grid businesses unviable. The absence of regulatory safeguards and non-involvement of distribution companies mean that investment timeframes for such mini-grids is around 4-6 years even though assets have much longer economic lives, resulting in higher negotiated tariffs.

Further, the development of a large number of undergrid mini-grids with negotiated tariffs and duplication of network infrastructure is less efficient compared to an approach that involves a more dynamic and collaborative interaction between the undergrid mini-grid and the grid, although it may be more complex to organize (with regulators, distribution companies, private sector).

2. Inter-connected mini-grids (generation and distribution)

With inter-connected mini-grids, a physical connection exists between the mini-grid and the incumbent distribution network. Mini-grid generation assets (including storage) are connected to the local distribution network and can be configured to offer different services. A fully integrated mini-grid would service consumers within a specified distribution area and be responsible for supply, distribution, metering, billing and collection. It includes its own generation asset with agreements to procure or sell electricity with the distribution company. Due to regulatory limitations, a fully integrated mini-grid may not be feasible resulting in other models for interconnected mini-grids. Where grids are unreliable, for instance, mini-grids may take on a limited role of

[16] Lovin et. al. (2019), “Low Energy Consumption = Unprofitable Mini-Grids. Is Appliance Financing the Answer”, https://nextbillion.net/mini-grids-and-appliance-financing/

serving as a back-up to ensure reliability of supply especially in the case of C&I customers, which in some cases could be directly supplied by the mini-grid.

In many contexts, distributed interconnected mini-grids may offer the opportunity for distribution companies to address important gaps in their services by leveraging private sector capital and expertise, improve reliability of supply, reduce losses and, importantly, retain or attract large consumers within their networks. Such mini-grids are likely to be operating in a regulated environment that guides tariff setting, compensation and service delivery.

Business model and actors involved

A centerpiece of the business model of an interconnected mini-grid is the partnership between the distribution company and the developer/operator. The structure of the partnership may vary from context to context, depending on the extent of involvement by the distribution company. At the very least, distribution companies would allow interconnected mini-grids to service a given area/consumer(s) and utilize the distribution network by paying a distribution use of service charge. This is the approach that is being supported as part of Nigeria's distribution franchisee model under consideration.

Distribution companies may even take up equity in a consortium to monetize further from servicing a given area/consumer(s) especially where high potential for economic opportunities and demand generation exists. This is the case of an initiative named DESSA by Abuja Electric Distribution Company (AEDC), which is described later. The case of ECOF Kaduna Ltd. (Konexa), also in Nigeria, goes beyond this interconnected mini-grid model, as it is in fact a closer approximation – at a reduced scale level – of the IDF model itself. ECOF Kaduna Ltd. is a sub-concessionaires of the incumbent disco Kaduna Electric that will take on the responsibility of generation and all distribution activities within a specific concession area with a view to provide universal electricity access in this area and to scale up later to the entire distribution company.

Besides the private sector and the distribution companies, third entities may also be involved. In the case of the Wuse market interconnected mini-grid, for instance, the traders association was also part of the agreement. In some cases, the operator may even be a community-based organization (e.g., cooperative). In the case of the distribution company DASURECO in the Philippines, for instance, an interconnected mini-grid is owned and operated by a cooperative which services nearly 600

households while exporting surplus generation to the grid under a net metering agreement[17].

Business case for distribution companies

There is a strong business case for distribution companies to adopt interconnected mini-grids. Depending on key priorities, including improving reliability, voltage quality, billing, metering and reducing AT&C losses, mini-grid business models and services can be adapted. Identifying and developing clusters of service areas where interconnected mini-grids could add maximum value for distribution companies, external private capital can be attracted to improve network infrastructure and service delivery, thereby reducing the defection of consumers especially large C&I customers and also attracting others that had defected in the past or that were never connected to the grid. Recognizing the value of interconnected mini-grids, Abuja Electric Distribution Company is developing the Distributed Energy Solutions Strategy (DESSA), which aims to deploy interconnected mini-grids, storage and embedded generation to improve reliability and quality of supply across parts of its concession area that have high economic potential.

Regulatory landscape and compensation

An interconnected mini-grid can be implemented in several ways and the necessary regulatory frameworks will vary. In the case of a fully integrated mini-grid (which offers generation and carries out all distribution activities), different scenarios can be seen:

- A distribution company may determine that the least-cost approach to improving reliability of service and reducing losses in a given concession area is through mini-grids. Should the regulations allow for the distribution company to consider CAPEX investments in mini-grids to determine its revenue requirements, then the distribution company may directly invest and operate mini-grid, or engage private operators. The tariffs for consumers connected to the mini-grid will be regulated and in line with other consumers within the entire concession area of the distribution company.
- Where CAPEX investments in local generation or storage are not covered under RAB (e.g., as is the case in the new concession in Odisha, India), distribution companies may still decide to invest should the resulting reductions in ATC&C losses (and growth in revenues from large consumers) is sufficient

[17] Guya, G. (2019), The Case of Dalupan Micro Hydro Power Plant, http://asiacleanenergyforum.pi.bypronto.com/2/wp-content/uploads/sites/2/2019/06/1-GM-Guya-Presentation_Microhydro-Dalupan_Revised_FORMATTED.pdf

to recover investment costs (presuming they have the capacity to make the initial investments). Otherwise, distribution companies may engage different partnership models, such as sub-concession agreements and franchisees (Box 2), to engage private sector in the financing, development and operation of interconnected mini-grids. Here, tariffs for consumers serviced by the mini-grids may be regulated (based on the terms of the agreements with the distribution company/regulator) or unregulated and directly negotiated (e.g., as proposed under the AEDC's DES strategy)18. A key shortcoming with directly negotiated tariffs is the emergence of multiple tariff regimes within a concession area.

- If the reliability of the main grid is poor and difficult to fix in the medium-term, some agreement must be reached between the distribution company and the mini-grid operator to upgrade reliability and voltage level at a cost lower than reinforcing the main grid upstream.

Box 2: Input-based franchisee model for interconnected mini-grids.

Distribution companies may adopt the input-based franchisee (IF) model to engage private mini-grid operators to service a given territory under the grid. IF can be structured in several ways: traditional IF approach involves a private operator receiving input energy from the distribution company at a pre-determined price. Operators commit to reduce ATC&C losses through limited CAPEX investments and realise higher revenues for a given fixed input energy price. In an IF Incremental Revenue Sharing (IF-IRS) model, the input-energy is free for operators in order to alleviate demand and price fluctuation-related risks. Instead, the incremental revenue realized by the private operator through loss reductions and CAPEX investments is shared with the distribution company at a pre-defined ratio.

The objective of interconnected mini-grids is so far seen mainly to improve reliability of service and reduce ATC&C losses. Should electrification (both in terms of adding connections and increasing supply/consumption) be added as an objective, additional subsidy may be needed to bridge any revenue gap due to high cost of service delivery and conducting distribution and demand stimulation activity. Depending on the nature of partnership between the distribution company and the mini-grid, the subsidy would need to be tailored and directed at either of these entities.

Traditional, performance-based subsidies (e.g., for each incremental connection) as advocated by the Africa Mini-grid Developers' Association and SE4All modeled on the Nigeria NEP experience, may not be the most suitable approach for undergrid mini-

[18] The private operator may also be allowed to negotiate tariffs with respective consumer groups, although the total revenue requirement is regulated to ensure appropriate cost-recovery. The case of the sub-concessionaire ECOF Kaduda Ltd. (Konexa) in Nigeria appears to follow this approach.

grids especially in contexts where majority connections have already been made. However, an element of performance-based subsidies may still be needed to incentivize operators to ensure universal coverage within the area of service.

With interconnected mini-grids utilizing own generation assets to ensure quality and reliability of supply, the IF-IRS model is likely to be more relevant. It offers adequate incentive to reduce ATC&C losses, support demand creation and increase connections, with the distribution company also monetizing from growth in revenues.

Demand generation potential

The long-term nature of investments associated with interconnected mini-grids entails that the operators have an intrinsic motivation to increase demand within their area of operation. In cases like Abuja Electric, the clusters identified for interconnected mini-grid development are those with high economic potential and, therefore, offer substantial opportunities for demand creation.

Scalability potential

The scalability potential of interconnected mini-grids is high given the strong incentives for distribution companies to utilize distributed energy resources to improve service quality and retain/strengthen its core large consumers that value reliability of supply. The model further advances efficiency in the overall development of the distribution sector by minimizing investments in redundant infrastructure and leveraging the synergies between the main-grid and off-grid solutions.

While the complexities may of interconnected mini-grid may be non-trivial (e.g., defining the business models, agreements between the distribution companies and mini-grids), it has the potential to provide for win-win solutions for all stakeholders, while also supporting the broader viability of the distribution sector and electrification objectives.

3. Reinforcement (embedded generation and storage)

Undergrid mini-grids may also be deployed to fulfill a reinforcement function where quality and reliability of electricity supply is a primary concern. This requires private sector entities to deploy generation and storage assets connected to the distribution network (at 33kV/11kV or 11kV/400V). The private sector entity in this case is not responsible for undertaking any distribution-related activities.

Actors involved

Reinforcement mini-grids usually involve an agreement between the distribution company and the private sector operator to deliver specific grid services through embedded generation and storage assets. Where a generating asset is involved, the agreement likely takes the shape of a Power Purchase Agreement with a determined tariff for electricity fed into the distribution network, as well as remuneration for any other grid services provided.

Business case for distribution companies

Distribution companies may require reinforcement at the tail-end of the grid to improve quality of supply especially in the presence of C&I consumers who would value reliability and quality of supply. Such consumers may either be utilizing their own expensive captive generation to cope with an unreliable grid, or may not be connected to the grid at all. Improving quality of grid can bring back/avoid defection of such consumers, while also reducing energy costs for captive generation.

Further, countries have also considered deployment of embedded generation in rural distribution feeders where agricultural loads are high. Agricultural tariffs are generally highly subsidized in developing countries **resulting in** a substantial burden for distribution companies and industries (against whom agriculture tariffs are cross-subsidi**z**ed). In India, for instance, a draft policy was announced in 2019 to added solar-based embedded generation (at 33/11kV) to meet agricultural load and reduce losses[19].

Regulatory landscape and compensation

The regulatory landscape and compensation arrangements for such mini-grids essentially involves distribution companies being able to legally procure power from multiple generation sources and the negotiation of agreements with the various generators. Tariffs for generated electricity fed into the grid may be pre-determined in a Power Purchase Agreement, while any other grid services (e.g., voltage control) delivered **could** also be remunerated. The model for development could be to identify points in the distribution network that require reinforcement and tender out areas close by to be developed as generating plants with private sector participation.

[19] MNRE (2019), Guidelines for the development of Decentralised Solar Power Projects, https://mnre.gov.in/img/documents/uploads/file_f-1580894745068.pdf

Demand generation potential

The demand growth potential of such mini-grids is limited. An organic increase in consumption may be expected as a result of improvements in electricity supply among existing and new consumer groups such as residential, commercial and industrial.

Scalability potential

Reinforcement mini-grids have an important role to play in ensuring reliability and quality of supply at the tail-end of the distribution network. Its scalability is highly dependent on the local conditions**,** such as **the status** of infrastructure, existing and potential loads, and consumers valuing the reliability. There is also a likelihood of interconnected mini-grids transforming into reinforcement ones with time**,** as investments in networks and customer engagement bring down losses and distribution activities are handed back to the distribution company.

4. Distribution and retail

Private sector entities may also be engaged to carry out metering, billing and collection activities within a defined concession area of a distribution company. In such cases, no generation is involved. Such a model can also be referred to as a collection-based distribution franchisee, and usually the primary motivation is to reduce commercial losses related to metering, billing and collection, especially in rural and less dense areas.

Actors involved

Distribution companies engage private sector entities to undertake tasks limited to billing, revenue collection, complaint redressal and facilitating new connections. In some cases, non-governmental entities have also been involved in undertaking these tasks such as in the case of CESU in Odisha (see box below).

Box. Sustainable Model Distribution Zone: Joint initiative of Smart Power India and the Central Electricity Supply Utility of Odisha (CESU).

The Model Distribution Zone (MDZ) covers more than 630 villages catering to the electricity needs of over 550, 000 people. These areas have high electricity access with 90% of the households connected to the grid but with poor reliability, quality and customer service, which has resulted in unviable rural electricity supply. The program focuses on a) improving the reliability and quality of grid electricity supply; b) enhancing customer experience; and c) engaging communities in building localised sustainable business models in rural electricity supply. As part of the

initiative, Women Self Help Groups (WSHGs) are engaged as micro-franchisees involved in metering, billing & collection activities[20].

Business case for distribution companies

The mini-grid/franchisee acts as a facilitator and enabler for increasing revenue collection for the distribution company by improving metering, billing and collection efficiency. It is particularly relevant in contexts where commercial losses are high, especially dispersed rural areas with dominant residential loads. Such mini-grids/franchisee are able to develop a local ecosystem to improve metering, and raise awareness and enforce timely collection through community groups.

Regulatory landscape and compensation

The franchisee agreement would usually be signed between the distribution company and the mini-grid/franchisee. As with most franchisee agreements, the regulator will have limited oversight over the implementation of the agreement itself. The mini-grid/franchisee would be appointed for a given area with a target for revenue collection every month based on a baseline collection in the area. The operator is primarily remunerated through franchisee margins (which will be a percentage of collections) and any incentives for exceeding the target[21].

Demand generation potential

The potential is moderate. As the mini-grids compensation is linked to additional revenue generated for the distribution company, there is an incentive to support demand growth within the concession area. However, such a model is mostly used in cases where collection efficiencies are low and, therefore, majority of revenue growth is anticipated to come from improved billing and collection, rather than from demand growth efforts.

Scalability potential

An important drawback of collection mini-grids/franchisees is that its incentive is to increase revenues through improving collection efficiency and not through technical loss reduction. Therefore, the overall objective of loss reduction is usually not achieved

[20] Smart Power India (n.d.), “Model Distribution Zone (MDZ) Program”, http://www.smartpowerindia.org/model-distribution-zone-program

[21] AERC (2018), Discussion Paper on ‘Distribution Franchisee Framework’, http://www.aerc.nic.in/Discussion%20Paper%20on%20Distribution%20Franchisee%20Framework.pdf

fully. Its use is broadly limited to contexts with low collection efficiencies. It does not have a significant impact on increasing electrification.

IV. CONCLUSIONS

- If the objective is to electrify everyone in a country with a mix of electrification solutions, then undergrid mini-grids will have a role to play as long as there is a sufficiently strong business case for distribution companies and the viability of mini-grid companies is ensured. Stand-alone/silo-ed approaches will not be able to provide the scale necessary to meet the ambition.
- Distribution companies can utilize the undergrid mini-grid opportunity to meet a number of different objectives (e.g., service quality improvement, reduce ATC&C losses, demand generation, etc.). The precise role undergrid mini-grids can play in a given concession area will depend on a comprehensive analysis that identifies least-cost approaches to service existing consumers, as well as meet electrification targets.
- Based on a review of the different configurations, interconnected mini-grids have significant potential to enable distribution companies to improve reliability of supply and services, especially to large C&I consumers. Further, such mini-grids also allow distribution companies to attract private sector capital. The right partnership model between the distribution company and the private mini-grid operator will depend on the regulations.
- The regulations have to allow for cost recovery, so the mini-grid business is viable and regulated, as well as permanence in incentivized. At the same time, distribution companies should also be in a position to monetize from the opportunity, beyond simply leasing distribution assets. Tariffs need to ensure cost-recovery and must converge in a given concession area, however where rural electrification objectives are added subsidies will be needed. These subsidies will ideally need to be designed to reflect the cost of service delivery and not be OPEX oriented.