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Investing in Mini Grids Now, Integrating with the Main Grid Later: A Menu of Good Policy and Regulatory Options

THE BOTTOM LINE

Mini grids can economically supply electricity to people in areas that the main grid is unlikely to reach soon. Mini grids can be quickly deployed and are increasingly price-competitive against traditional sources of energy. They can attract private financing and operate without subsidies when allowed to charge cost-recovery tariffs. Moreover, the arrival of the main grid does not mean that the investment in mini grids will be wasted: their generation and distribution assets can generally be reused in an integrated system. The key is to define—in advance—technical standards and commercial options for integration once the main grid arrives.

This Live Wire was prepared by the Global Facility on Mini Grids, a program of the World Bank's Energy Sector Management Assistance Program (ESMAP).

Why is this issue important?

Investing in mini grids with an eye to their eventual integration into the main grid can quickly advance electrification while avoiding the risk of stranding assets

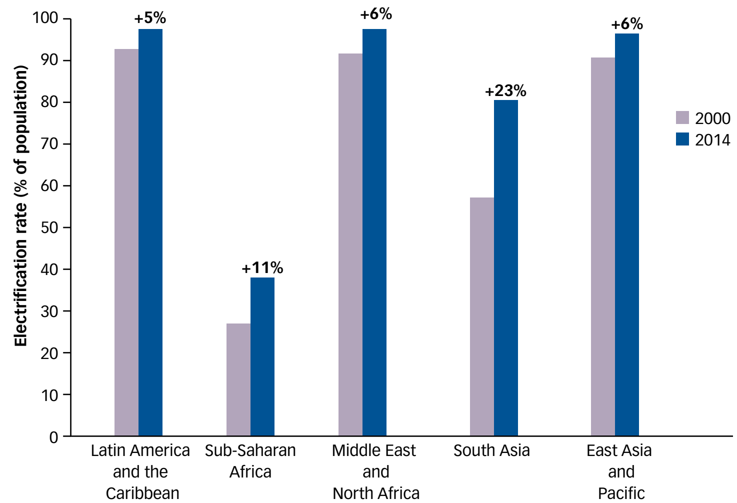
A fully integrated power system is the optimal solution for electrifying most countries. Such power systems minimize the cost of supply by allowing for economically efficient planning, investment, and operation of assets with significant economies of scale. Several developing countries have made efforts to build and expand an integrated power system that includes mini grids and other distributed generation, often with good results. For example, Ghana has constructed an interconnected grid that provides power to 85 percent of its urban population and 41 percent of the rural population.

But most electrification efforts have focused on expanding the main grid to rural areas. South Asian countries have done fairly well with this strategy: electrification rose from 57 percent in 2000 to 80 percent in 2014, an increase of 23 percent (figure 1). Other regions have increased electrification by 5–11 percent over the same period. Sub-Saharan Africa remains the least electrified region (World Bank 2017: 5).

Slow expansion has left millions of people without reliable power, or any power at all. More than 566 million people in Sub-Saharan Africa, and 250 million in India, remain without electricity (IEA and others 2018).

Expanding the main grid can be difficult owing to institutional, economic, and financial barriers, where they are found, that are well

Figure 1. Improvement in electrification rate by region, 2000–14



Source: World Bank (2017).

understood but hard to overcome—and those barriers are likely to remain in place in the near future. Expanding the main grid in rural areas demands significant investment; the long distances and scattered, remote customer bases increase the time and capital required to get the job done. Expanding the grid in rural areas costs $1,100 per connection in Vietnam, for example, and $2,300 in Tanzania, whereas a single connection in urban areas costs $570 and $600–1,100 in the same countries (Castellano and others 2015: 24).

Power utilities have difficulty raising the capital required for new assets (or allowing private investors to do so) owing to their poor

Developing countries that promote investment in mini grids in the right way today may be able to bypass the costly retrofitting that several countries with a centralized system already face or will soon be facing.

financial and operating performance. Indeed, electricity sales on the main grid often cannot even cover operating costs, let alone finance rapid grid expansion. Meanwhile, government budgets can rarely accommodate the full costs of realizing grid extension investments because they are fiscally constrained.

In this context, mini grids can be a low-cost and timely solution to supply electricity to people in areas that the main grid is unlikely to reach in the medium term (five to ten years). In such regions, mini grids have an edge over main-grid expansion in several ways.

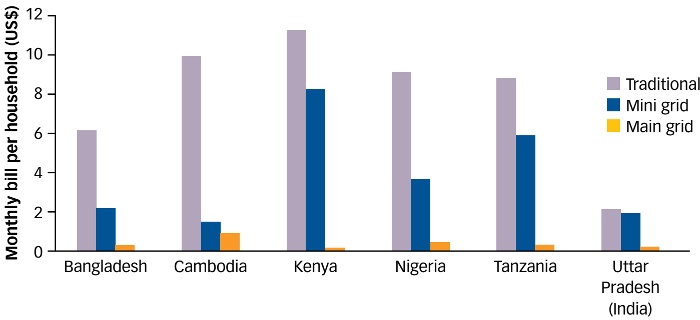
Mini grids can be deployed more rapidly than the main grid. Their planning and implementation are more conducive to spontaneous entrepreneurial development, while grid expansion involves several institutions (ministries, utilities, rural electrification agencies) in a longer and more complex series of steps.

Mini grids are now more than ever price-competitive against traditional sources of off-grid energy (diesel self-generation, kerosene, and dry cell batteries) thanks to the significant improvements in the cost and performance of renewable and storage technologies, coupled with innovative business models. The latest generation of low-cost, rapidly deployable "solar hybrid" mini grids source their energy from solar photovoltaic (PV) systems coupled with battery storage and diesel backup. They make use of smart in-home meters and offer convenient payment options, such as mobile money.

Mini grids can access private financing and operate without subsidies when the regulatory framework allows them to charge full cost-recovery tariffs. Even at cost-recovery levels, users can save money in comparison with traditional sources of energy. For example, mini grids could save Nigeria's off-grid and underserved consumers up to $2.4 billion annually on diesel self-generation (REA 2017: 7). Figure 2 compares households' cost of energy from mini grids, the main grid, and traditional sources of energy in six Sub-Saharan and Asian countries, for equivalent "Tier 2" consumption.[1] Main-grid supply would be cheapest—but the main grid might not arrive anytime soon.

Policymakers may view investing in mini grids as a waste of resources in the longer term if they are meant to be replaced by a cheaper, more cost-efficient main grid. But the arrival of the main grid does not necessarily mean that the investment in mini grids would be wasted. Indeed, mini grids' generation and distribution assets can be reused in an integrated system, either separately or together. Solar hybrid and small hydro mini grid systems can improve the stability and quality of the main grid by providing backup and frequency stability; and they can do so without significantly lowering efficiency, since their levelized costs are close to those of larger solar PV and hydro plants that would be built as independent power producers. Reusing mini grids' generation and distribution assets can enable developing countries to shape their power system into a centralized grid that integrates fractal systems,[2] in line with socioeconomic trends toward the creation of smaller-scale energy markets. Developing countries that promote investment in mini grids in the right way today may even be able to bypass the costly retrofitting that several countries with a centralized system already face or will soon be facing.

Figure 2. Comparison of households' monthly energy bill for Tier 2 consumption by sources, 2017



[1] "Tier 2" access to electricity allows for consumption of 6 to 21 kWh/month (Bhatia and Angelou 2015). We use the lowest end of the range (6 kWh/month) to calculate the monthly bill for the main grid and for mini grids.

[2] Fractal grids refer to nested system operations—at the appliance level, in the home, at the household level, at the distribution level, at the national or regional level, and between national or regional levels.

Requiring compliance with main-grid standards may be useful where the main grid is likely to expand soon; so-called light standards may be enough where the main grid is not likely to expand soon.

What can be done to attract investments in mini grids in areas unlikely to be reached by the main grid?

Defining clear technical standards and commercial options for integration can address key concerns of mini grid developers and entice them to invest

What happens when the main grid arrives is a major concern for mini grid developers. Investors face two risks: The first is that their assets will be stranded. This can occur when the main grid builds over the mini grid, pulling customers to the cheaper or better service the main grid offers. The second risk is expropriation of assets, which occurs if the utility or the government takes over the mini grid assets without adequate compensation. Governments that are serious about increasing electricity access will want to mitigate these risks to foster mini grid investments and hasten electrification.

Two sets of actions can reassure potential mini grid investors. The first set would define clear technical standards for mini grids, enabling them to connect to the main grid. The second would establish clear rules on commercial options available to mini grids when the main grid arrives. The two sets are intertwined, so they need to be dealt with together.

Setting clear technical standards is key to allowing future connection of mini grids to the main grid at minimal cost. Setting main-grid standards and granting a right to connect, subject to compliance with standards, may be useful where the main grid is likely to expand soon; light standards may be enough where the main grid is likely to expand later.

Technical standards for connection with the main grid should cover the following aspects:

- Equipment (distribution network poles, conductors, and insulators) that ensures the network can handle the quantities of electricity that flow when energized by the main grid
- Generation synchronization, to ensure the safe and reliable operation of the grid when connected to the mini grid generator
- Interoperability, which refers to the capability of two or more networks, systems, devices, or components to interact, communicate, and exchange information securely and effectively.

Guaranteeing mini grids the right to connect, subject to compliance with standards, can further reassure investors. Without a legal requirement, the operator of the main grid may be tempted to exert discretionary power and reject the connection of a mini grid.

Table 1 presents three options for standards in case expansion takes place within the lifetime of the mini grid; these are illustrated with country examples.

Table 1. Three options: Technical standards for grid expansion *within* mini grids' lifetime

Standards	Description	Examples
Main-grid standards	Mini grids must comply with main-grid technical standards.	• *Nigeria*. "Relevant Technical Codes and Standards" for mini grids with permits (above 100 kW), conferring the right to interconnect • *Cambodia post-2001*. Grid codes and standards for all mini grids • *Kenya*. Grid code for connection and distribution applies to all mini grids
Mandatory grid-compatible standards	Mini grids must comply with specific standards (lower than main-grid standards) that achieve safety and allow connection when the main grid arrives.	• *Uttar Pradesh*. For connection, mini grids must comply with 2013 CEA regulations (Technical Standards for Connectivity of the Distributed Generation Resources).
Optional grid-compatible standards	Mini grids that comply with grid-compatible standards (lower than grid standards) may choose an economically attractive option when the main grid arrives. Safety is also regulated.	• *Tanzania*. For connection or asset buyout, distribution assets must comply with grid-compatible standards set by the Tanzanian bureau of standards.

A lighter approach to standards may foster the development of mini grids in communities where subsidies are limited, and where the ability to pay for the desired service level rules out the use of technology compatible with the main grid.

Setting grid-compatible or main-grid standards can be useful when the grid is expected to be expanded within the lifetime of a mini grid's assets. At that point, a mini grid operator may well not have received the required return. Having the option to connect to the main grid may allow a mini grid operator to earn the expected revenue, preserving the value of the investment.

Grid-compatible or main-grid standards enable mini grids to integrate without jeopardizing the safety, stability, and reliability of the power system. Mandatory standards guarantee the stability of the power system and ensure higher equipment quality and safety. But stability of the power system can be preserved even with optional standards, while offering flexibility to mini grid operators. Operators can choose either to follow the standards to guarantee later connection or not do so and risk being denied the right to connect if they are unable to upgrade their infrastructure when the main grid arrives.

Grid-compatible or main-grid standards entail relatively high costs both for developers and governments for several reasons:

- Equipment that meets these standards is typically more expensive. For example, in Bangladesh one developer reported that compliance with pole standards accounted for 25 percent of the total mini grid's capital expenditure, compared with 5 percent for an unregulated project in Nigeria. Grid-compatible or main-grid standards may also prevent innovation that could decrease costs.
- Governments may need to provide subsidies to cover the added costs and attract investments in communities where incomes are too low to charge a cost-recovery tariff.
- Designing and enforcing grid-compatible standards requires significant human resources from governments. For example, in Cambodia the regulator advises developers on how to build mini grid systems so that they can integrate with the main grid later (Tenenbaum 2018: 30).

A lighter approach to setting standards may be appropriate for areas where grid expansion is expected to occur *after* developers and investors have recouped their investments. A lighter approach includes options that range from safety standards only (and no technical standards), or technical standards specific to mini grids. Table 2 presents these options and illustrates them with examples.

Table 2. Three options: Technical standards for grid expansion *beyond* mini grids' lifetime

Standards	Description	Examples
No technical standards	Mini grids are free to set their own standards.	• *Cambodia*. No technical standards before 2001
Safety standards only	Only safety standards are regulated.	• *Nigeria*. Recommended safety standards for registered mini grids (in practice, all mini grids as of 2017) • *Uttar Pradesh*. Safety standards only for mini grids below 50 kW
Technical standards specific to mini grids	All mini grids are bound to comply with specific technical standards. Compatibility with the main grid is not required.	• *Nigeria*. Health and safety standards for all mini grids • *Sri Lanka.* Government-subsidized mini grids must comply with technical standards that are less stringent than the main-grid standards

Setting lighter standards can save resources for both developers and governments:

- This option gives developers more flexibility to design mini grids with their target market and local conditions in mind—and it encourages innovation. For example, developers might design their mini grids to operate on direct current, which is cheaper than operating on alternating current.
- Governments may save on subsidies. No subsidy is generally required when there are no technical standards; safety standards require minimal subsidies. A lighter approach may foster the development of mini grids in communities where subsidies are limited, and where the ability to pay for the desired service level rules out the use of technology compatible with the main grid.

Even lighter standards require some administrative capacity and resources. In the case of safety standards only, regulators still need to be able to define and enforce those standards. Designing and enforcing mini grid-specific standards is a "time-consuming process that requires extensive research" as well as a sufficient level of subsidies (USAID 2017: 174). Regulators may also have to carry out costly and time-consuming connection studies if a mini grid operator wishes to connect to the main grid (USAID 2017: 165). Without administrative capacity, entrepreneurs who use substandard equipment may fail to provide reliable power, damaging their reputation as service providers or the reputation of the entire mini grid sector. Before Cambodia enforced technical standards, a quarter of mini grids had service interruptions every day due to equipment breakdowns (EDC 2001).

Clear commercial arrangements for generation and distribution assets make up the second set of actions that can be taken to encourage investments in mini grids by providing investors greater clarity about the continuation of revenues after the main grid arrives.

Far-sighted arrangements for generation and distribution assets provide investors greater clarity about the continuation of revenues after the main grid arrives. These arrangements include integration and exit options, such as conversion to a small power distributor (SPD), a small power producer (SPP), or both (SPD+SPP); or an asset buyout.

Table 3. Options that allow mini grid investors to continue to earn revenues after the main grid arrives

Option	Description	Examples
Small power distributor (SPD)	• Mini grid operator retains its distribution assets and purchases electricity wholesale from the utility, selling to its customers. • Generation assets are transferred to the utility, sold to a third party, moved to another location, abandoned, or decommissioned.	• The *Cambodian government* let mini grid operators keep their distribution business, seeing that mini grids would be more efficient at achieving the objectives of rapid electrification and better service than the national utility, which was focusing on transmission and generation expansion. Cambodia's regulation provides for an automatic conversion of mini grids to SPDs when the main grid arrives; the operator must decommission its generation assets and buy from the grid. To compensate for the loss of value of the generator, the tariff that an operator may charge is kept above cost-recovery levels for more than one year. The tariff then adjusts from the level of a diesel mini grid to the lower level of the SPD buying from the national utility.
Small power producer (SPP)	• Distribution network is transferred to the utility or abandoned. • Mini grid operator retains its generation assets, becomes an independent SPP, and sells power to the utility. • Batteries may also be used to provide services.	• *Uttar Pradesh*. Isolated mini grids can convert to SPPs and sell power at a feed-in tariff determined at the state level. • *Tanzania*. One option available to mini grids is to convert to an SPP, provided they comply with connection standards. • *Bangladesh*. Mini grids must convert to SPPs, and the tariff at which they can sell power is determined upon negotiation with the power purchaser on a cost-plus basis.
Small power producer and small power distributor (SPP+SPD)	• Mini grid operator retains both its distribution network and generation assets. • It meets its customers' needs by buying from the grid, running its generator, or both. • It can sell its excess power to the main grid. • The utility purchases and operates the mini grid assets. • Variants include partial asset buyout (of distribution assets only)..	• *Nigeria*. Mini grids have the option to convert to SPD and SPP, whereupon they are deemed "interconnected." • *Tanzania*. Mini grids have the option to convert to SPP and SPD.
Asset buyout	• The utility purchases and operates the mini grid assets. • Variants include partial asset buyout (of distribution assets only).	• *Uttar Pradesh.* Mini grids have the option to sell their distribution assets to the utility at the "cost determined on mutual consent between the utility and developer by the estimation of cost/profit loss of the project installed by the developer" (UPNREDA 2016). • *Nigeria*. Mini grids have the right to sell part or all of their assets to the distribution company at the depreciated value of the assets plus 12 months of revenue.

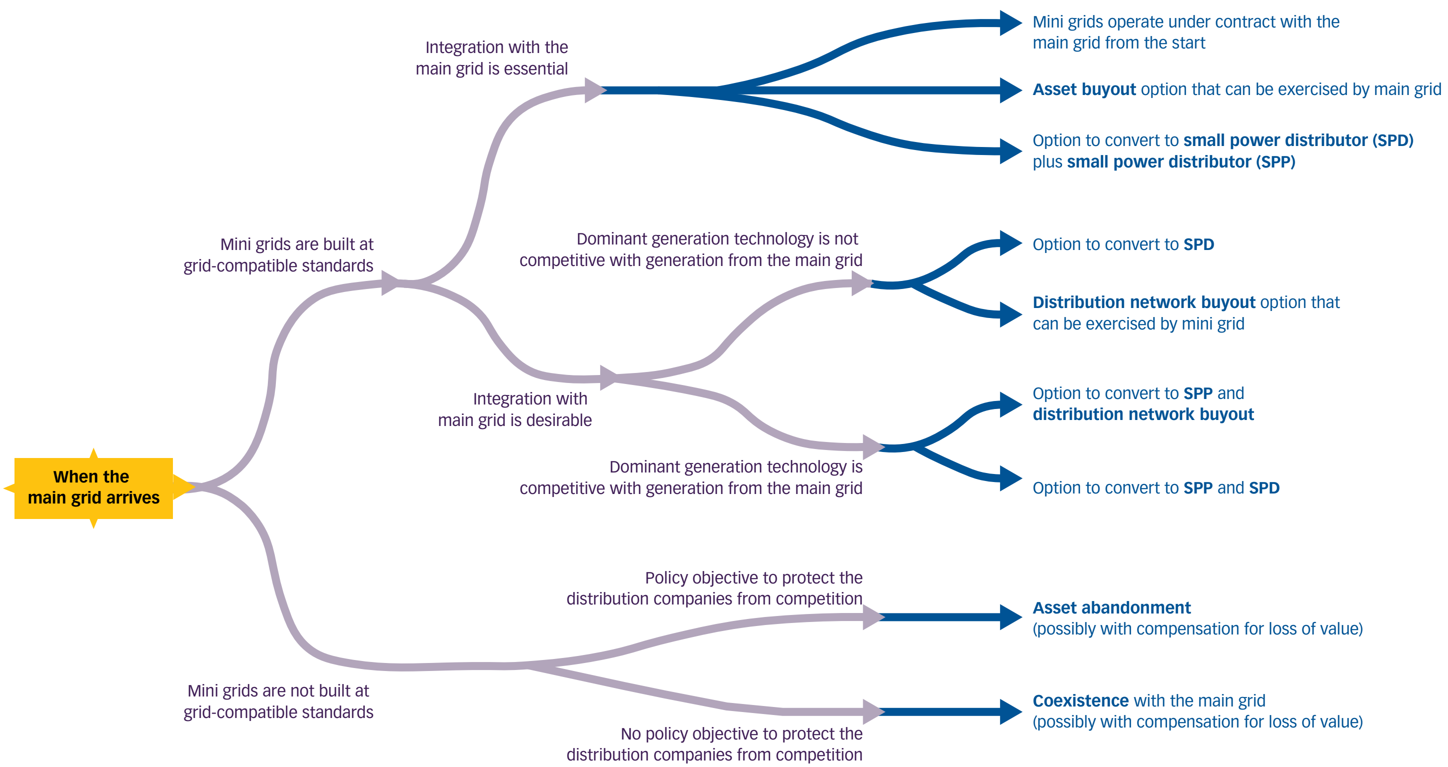
How mini grids integrate with the main grid will depend on the compatibility and competitiveness of their assets.

Commercial arrangements include integration and exit options such as conversion to a small power distributor (SPD), a small power producer (SPP), or both (SPD+SPP); or an asset buyout. Table 3 presents these four options and illustrates them with country examples. Figure 3 illustrates how to navigate the options for integration or exit in specific contexts.

These options allow mini grids to efficiently integrate with the main grid in a manner consistent with their assets' compatibility and competitiveness. Converting to an SPD may be appropriate for a mini grid whose distribution network is in good condition and grid-compatible but whose generator is not competitive with power from the grid. However, where a mini grid's distribution network is not in good condition or grid-compatible, but the generator is competitive with power from the main grid, converting to an SPP may be appropriate. Finally, where the mini grid's distribution network is in good condition and grid-compatible, the generator is competitive, and the main grid does not provide reliable service, the SPP+SPD option may be appropriate.

Commercial arrangements affect how investors earn revenues. For SPDs, a good option is to factor a return on investment into the

Figure 3. Decision tree for integration and exit options



distribution margin (that is, the difference between the retail tariff and the wholesale tariff) charged by the SPD. However, once a mini grid is connected to the main grid, its customers may well expect to pay the same tariff as the main grid customers. Subsidies may then be needed to respond to this expectation while preserving the value of investment in the mini grid. For example, after years of differentiated, cost-reflective tariffs for SPDs, Cambodia introduced a subsidy that equalizes mini grid tariffs with those on the main grid while preserving a return on investment for the SPD.

Feed-in tariffs may not protect small power producers if there are no clear rules about how producers should deliver power and be paid. A power purchase agreement with a creditworthy utility solves this problem.

For SPPs, a feed-in tariff (FiT) would guarantee a fixed price over a long period for every kWh generated and fed into the grid (Tenenbaum 2014: 174). FiTs can be set based on either:

- **Avoided-cost tariff.** This method requires estimating the value of the energy to the purchasing utility based on avoided financial, economic, or social costs. It allows competitive SPPs to recover their costs.
- **Technology-cost tariff.** At this level, a well-run SPP would earn a reasonable profit using a technology specified in the tariff. This method requires an estimate of the cost-recovery tariff, based on assumptions about the capital structure, capacity factor, capital costs, and cost of debt. It allows SPPs to recover their costs.

For SPDs+SPPs, as seen above, mini grids can be protected by a return on investment in the distribution margin, and a FiT for the sale of power to the utility.

FiTs may not be enough to protect the SPP if there are no clear rules about how the SPP should deliver power and be paid. Signing a power purchase agreement (PPA) with the utility can achieve this. The utility also needs to be creditworthy.

The development of standard PPAs that the utility is legally bound to honor can further protect mini grid investors. Standard PPAs balance the bargaining power between the mini grid and the utility. The utility is often the only available buyer. In its position of monopoly buyer, it may, in the absence of standards, try to dictate the terms and conditions of the PPA, which may not allow developers to recover their investment in the mini grid's assets. In Tanzania, recent rules require the main grid to enter a standard PPA if an isolated mini grid is eligible to convert into an SPP (EWURA 2018).

Appropriate enforcement of defined rules and commercial arrangements is essential to investment stability. Ideally, discretionary decisions by the government or the regulator should not block a mini grid operator from choosing an integration or exit option or interfere in the enforcement of the defined compensation rules.

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