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Policies and Regulations for

Private Sector Renewable Energy Mini-grids

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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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Access to electricity is a central building block of socio-economic development. It empowers people and communities to increase their income and productivity, enhance their access to healthcare, water and education, and improves their overall well-being. Without universal access to modern energy services, achieving the Sustainable Development Goals set for 2030 will be nearly impossible.

Extending power to everyone, especially at such a rapid pace required, cannot be done solely through national electricity grids. An estimated 60% of the additional power generation needed to achieve universal access must come from off-grid solutions. Most of these will involve mini-grids – isolated, community-level power grids, which can eventually be absorbed into the main grid or may continue to operate autonomously.

In business terms, the case for either mini-grid or standalone systems to supply renewable power to underserved communities has never been stronger. Costs have fallen dramatically – over 80% since 2010 for solar photovoltaics (PV) – while technologies have continued improving.

Renewable energy mini-grids have a proven track record of delivering cost-competitive electricity services in rural areas. Traditional deployment models led by public utilities, non-governmental organisations and communities, are being complemented with private sector approaches. From local entrepreneurs to large international utilities, interest in the development, financing and operation of mini-grids is growing.

Policies and regulations for private sector renewable energy mini-grids aim to support policy makers in the design of enabling policy and regulatory frameworks. The report examines licencing, tariff regulation, risks related to main-grid arrival, and access to finance – the key factors investors in mini-grids consider. The report finds that mini-grid configurations respond differently to the policy and regulatory environment. It analyses the specificities for mini-grids based on solar, biomass, wind and small hydropower, or a combination of these with other energy sources. These should be fully understood to develop the right policy mix.

This report comes as part of a broad stream of work by the International Renewable Energy Agency on how to expand energy access through the accelerated deployment of renewables. I am confident that it will inform policy making on mini-grid deployment and support the achievement of both electrification and development goals.

Adnan Z. Amin
Director-General
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ABBREVIATIONS

AC	Alternating current
AEPC	Alternate Energy Promotion Centre (Nepal)
ARE	Alliance for Rural Electrification
BOOM	Build, own, operate and maintain
BOM	Build, operate and maintain
CAPEX	Capital expenditure
DC	Direct current
EIA	Environmental impact assessment
ESIA	Environmental and social impact assessment
ESMAP	Energy Sector Management Assistance Program
EUEI PDF	EU Energy Initiative Partnership Dialogue Facility
EWURA	Energy and Water Utilities Regulatory Authority (Tanzania)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IDCOL	Infrastructure Development Company Ltd. (Bangladesh)
IPP	Independent power producer
kW	Kilowatt
kWh	Kilowatt-hour
MNRE	Ministry of New and Renewable Energy (India)
MW	Megawatt
NERC	Nigerian Electricity Regulatory Commission
O&M	Operation & maintenance
PPA	Power purchase agreement
PPP	Public private partnerships
PV	Photovoltaic
REA	Rural electrification agency
RERA	Regional Electricity Regulators Association
RURA	Rwanda Utilities Regulatory Authority
SDG	Sustainable Development Goal
SE4All	Sustainable Energy for All
SHS	Solar home system
TA	Technical assistance
TEDAP	Tanzania Energy Development and Access Project
UPERC	Uttar Pradesh Electricity Regulatory Commission
UPNEDA	Uttar Pradesh New and Renewable Energy Development Agency
USD	US dollars
VAT	Value added tax

EXECUTIVE SUMMARY

Off-grid renewable energy solutions will be key to achieve universal access to electricity. Rapidly decreasing technology costs, increasing reliability, and a growing track record of deployment has strengthened the case for accelerated adoption of stand-alone and mini-grid solutions. Off-grid solutions are estimated to supply nearly 60% of the additional generation needed to achieve universal access; mini-grids will account for the majority.

Renewable energy mini-grids tap into locally available resources to deliver electricity services. Relying on a single energy source (*e.g.*, solar, wind, hydro, biomass) or a combination (*e.g.*, solar-diesel hybrids), mini-grids provide varying electricity service levels (or tiers). Traditionally, government agencies, state-owned utilities, community groups, nongovernmental organisations, and, in some cases, local private firms have driven mini-grid development. While successful in bringing electricity to a large number of areas, limited economic sustainability and scalability have remained key challenges for growth.

Private sector involvement will accelerate growth in mini-grid deployment. From local entrepreneurs to large international utilities, there is growing interest from the private sector in the development, financing, operation and management of mini-grids. Combining technology with new business and financing models, the private sector is deploying mini-grid solutions utilising diverse financing options.

Governments have an important role in facilitating private sector participation. Mini-grid development is closely tied to national policy decisions and regulatory frameworks. Supporting mini-grids requires an adaptation of the power system framework, traditionally based on a centralised model. Mini-grid solutions are diverse, and so are the accompanying business and financing models. In recognition of these specificities, a number of countries have turned to dedicated policies and regulations that cater specifically to mini-grid development.

KEY POLICY AND REGULATORY CONDITIONS FOR PRIVATE SECTOR MINI-GRIDS

The policy and regulatory landscape for mini-grids is highly dynamic as governments introduce dedicated measures, gain experience and incorporate learning towards a more effective framework for mini-grid development. This is essential to successfully adapt to local conditions and address deployment barriers. Recent developments point to some general policy and regulatory conditions related to legal provisions, tariff regulation, main grid arrival and financing, to support private sector mini-grids.

LEGAL AND LICENSING PROVISIONS

The private sector must have the legal right to generate, distribute and sell electricity to consumers. Obtaining the required licenses and permits can be a lengthy, risky and costly process, at times exceeding 10% of a project's capital costs. As a general guideline, fees and other development costs should not exceed 1–2% of the total cost of a project. Although there is no single 'right way' to design an enabling legal and licensing environment, some general principles should be followed.

Clear processes and procedures are needed to reduce barriers to market entry. A common approach to facilitate mini-grid licensing and other regulatory requirements is to establish a single-window clearance facility hosted at a rural electrification agency or similar body. The Indian state of Uttar Pradesh, for example, has established a one-stop shop for all mini-grid projects at the New and Renewable Energy Development Agency). Coordinating stakeholders, managing the approval process, facilitating capacity building, and administering financial incentive schemes can significantly reduce transaction costs. Information on processes and procedures should be easily accessible (*e.g.*, Tanzania's online information portal, minigrids.go.tz).

Streamlined regulatory requirements can reduce development costs. Regulatory requirements need to strike a balance between ensuring that the actors participating in the market are reliable and compliance is affordable. A segmented approach linked to mini-grid sizes and technology is increasingly common. In Tanzania, for example, mini-grids with a capacity of less than 1 MW need not apply for a generation license. Simplified registration for mini-grids, solely for information purposes, are also used in some countries. Non-energy requirements, such as environmental impact assessments, can be simplified and standardised for projects.

Provisional licenses and concessions can mitigate project-development risks. These measures help avoid two or more developers carry out preparatory activities on the same site. Provisional licenses provide exclusivity for a few years, while concessions grant a private entity the exclusive right to build, operate, and maintain assets to supply electricity in a specific area for a defined time (*e.g.*, 15 years) and service quality. Holding a concession typically comes with preferential tariff arrangements and financial incentives. Concessions are usually awarded for large areas through tendering, whereas provisional licenses are more suitable for bottom-up mini-grid development.

COST RECOVERY AND TARIFF REGULATION

Tariff regulation has a strong influence on the viability and sustainability of mini-grids, notably by affecting the operators' ability to set end-user tariffs. This affects project cash flows, the availability of funds for management, operation and maintenance, and cost recovery. Expectations of cost-recovery vary. Typically, grant-financed systems require tariffs to cover at least management, operation, and maintenance costs, while private operators strive to also cover capital costs plus a risk-equivalent return.

Cost-covering tariffs are one way of ensuring economic viability for private sector mini-grids. Mini-grid tariffs tend to be higher than those for the main-grid – this disparity is often viewed through the lens of equality and fairness between rural and urban consumers. In this light, some countries impose national uniform tariffs (or keep mini-grid tariffs close to those of the main-grid), that are usually too low to allow sustainable mini-grid operation. With decreasing costs of renewables, the case for differentiated tariffs has strengthened. Mini-grid solutions are increasingly competitive compared to the cost of grid extension and current expenditures on conventional energy. Add to this the social cost of no electricity access. The Southern Africa Electricity Regulators Association emphasises that mini-grid tariffs be high enough to cover costs (thus invariably higher than main grids), and structured to reflect current spending on energy. It recommends that authorities provide provisions for communities to appeal, without directly regulating tariffs. In Tanzania, tariffs are reviewed if 15% of the consumers appeal. In Rwanda, comparison between mini-grid and main-grid tariff is not a valid cause for review.

A tailored approach to tariff regulation is effective for catalysing private sector mini-grid development. Increasingly, small-scale systems (*e.g.*, under 100 kW in Tanzania and Nigeria) are being exempted from tariff approvals, allowing operators to set tariffs in consultation with the communities. Under these circumstances, project developers can test flexible tariff structures in a light-handed regulatory space. At the same time, regulatory agencies save resources and time. As systems become larger, operators prefer some form of official tariff approval to mitigate the risk of future tariff disputes. In this case, regulators are advised to standardise and define, to the greatest extent possible, the tariff setting methodology.

Tariff caps and standardised tariff-calculation methodologies as elements of an enabling approach to tariff setting. Caps limit tariffs to a certain maximum, with the operator free to apply any tariff up to that level. Caps should be set accounting for local conditions (*e.g.*, the technology used, village area, capacity). In some cases, tariff caps are applied by financing institutions such as in Bangladesh. Although a step in the right direction, tariff caps do not protect operators completely from local tariff disputes as they only indicate an upper limit. Tariff determination through standardised methodologies (*e.g.*, a cost-plus approach) allows for systematic assessment and approval by regulators, and provides the basis for brief negotiations. Countries, such as Senegal and Nigeria, are using cluster approaches (determining tariff caps by applying the cost-plus approach to groups of mini-grids) and information technology to minimise tariff approval costs. Policy makers are encouraged to identify the most suitable tariff-determination approach in consultation with local stakeholders and to formalise its adoption.

MITIGATING THE RISK POSED BY THE UNEXPECTED ARRIVAL OF THE MAIN GRID

Unexpected arrival of the main-grid is a major risk faced by mini-grid operators. Encroachment of the main grid can siphon off customers and strand investments. The risk is particularly acute in the years before the mini-grid is fully amortised. The absence of, or lack of adherence to, grid-extension plans makes it difficult to internalize the risk in the preparatory and project-development phase of mini-grids.

Rural electrification master plans provide valuable guidance to public authorities and private mini-grid developers. Information on the location and timeframe for grid extension, as well as population density, productive loads (telecom towers, mines, etc.) and existence of other licensees, can inform decision making. Kenya's National Energy and Petroleum Policy (2015), for instance, provides the basis for the development of a comprehensive electrification strategy towards universal access by 2020. Generally, non-transparency, uncertainty in funding and coordination issues pose challenges to developing and following a coherent master plan.

If defined ahead of time, interconnection and/or compensation mechanisms allay risks associated with main grid arrival. When the main grid reaches a mini-grid before its assets have been amortised, two main choices could be presented: the mini-grid may be connected to the main grid (subject to technical compatibility) and/or the operator may be compensated. In the case of interconnection, the mini-grid operator may sell its electricity in bulk to the grid (converting into a small power producer); it may supply its customers with electricity bought from the national grid (making it a small power distributor); or it may provide tail-end support, running in 'island mode' when the grid is down. In Cambodia, 250, formerly isolated diesel mini-grids, small power distributors are licensed by the Electricity Authority of Cambodia. Operators may also be compensated for the residual value of the mini-grid assets rendered uncompetitive by the main grid, as is the case in Rwanda and Tanzania, where regulators assign a depreciation scenario for fixed assets. To ensure the success of either mechanism, full information about the applicable tariffs, depreciation scenarios, and other matters should be available ahead of time to allow proper planning (financial and otherwise).

POLICY MEASURES TO FACILITATE ACCESS TO FINANCE

Private mini-grids pass through different phases with varying financing needs. Governments can take several measures to facilitate access to equity, debt and grant financing for mini-grids. During the project-development phase, equity and grants can be attracted by improving access to information needed to perform initial market assessments and by cooperating with regional and global funding facilities to attract early-stage grants. In 2015, Rwanda was awarded a USD 840 000 grant by the Sustainable Energy Fund for Africa to co-finance feasibility studies of 20 micro-hydro sites, as well as rollout and implementation plans that include tariff and business models for mini-grids. Easy repatriation of funds and low withholding tax and indexation of tariffs to key variables (*e.g.*, diesel price, foreign exchange rate, inflation) help attract investors for follow-on phases. To tackle specific financing gaps (*e.g.*, access to debt), dedicated funds can be established that pool together public and donor finance and guarantee tools can be used to leverage private capital. Local commercial banks can be engaged to make available low-cost, local-currency loans. An example is the Inter-American Development Bank's USD 9.3 million programme implemented by Bancoldex, a commercial bank in Colombia that aims to deliver long-term concessional financing for private entities engaged in mini-grid development.

Efficient design and delivery of public financial support is paramount for market development. Grants, a widely used form of financial support, should be carefully designed to ensure project sustainability over the lifetime. Ongoing support is perceived as risky, given unforeseeable changes in policy and underfunded budgets. For this reason, support towards capital expenditures is generally preferred, but this should not reduce the operators' incentive to ensure long-term operation. Moreover, grants for generating assets may lead to sharp increases in end-user tariffs when system capacity is expanded.

Grants may be delivered on a step-by-step basis (with developers seeking grants at the end of each project phase) or integrated into a single process (wherein the support linked to a phase is unlocked upon achievement of the preceding phase). The Guided Idea Competition approach implemented by the Nigerian Energy Support Programme is an example of the latter. In general, financial support should be designed to leverage capital from commercial financial institutions. Nepal's Renewable Energy Subsidy Policy, for instance, is designed to cover approximately 40% of the total cost, with the remainder expected to come as private investments and in-kind contributions from communities.

A portfolio of financing instruments and innovative delivery models can catalyse private investments. Instruments, such as subordinated debt and third-party collateralization, when tailored to the sector could make it easier to attract debt and equity investors. Central banks, for instance, can set up subordinated debt facilities at low interest rates and with long tenures. Examples of such structures are the Micro, Small and Medium Size Enterprise Development Fund of the Central Bank of Nigeria, and Nepal's Himalayan Bank and the Clean Energy Development Bank. Traditional infrastructure development models, such as public-private partnerships, can also be applied to reduce risks and enhance project bankability. To promote public-private partnerships, the Rwandan government leased 22 micro-hydro projects to be developed or upgraded and managed by private sector for 25 years.

POLICIES FOR VARIOUS COMBINATIONS OF TECHNOLOGY AND SERVICE TIER

Tailored mini-grid policies and regulations can allow investment streams to be directed into certain combinations of technology and tier. Policies can influence not only the pace of rural electrification, but also the level of access, public spending, and, to some extent, customer satisfaction. All these aspects are related, such that improvements in one may come at the expense of another. For instance, a policy focus on solar DC mini-grids will result in fast-paced electrification with low government spending, but a relatively low level of electricity service. In contrast, a policy focus on micro-hydro would yield a higher level of service, but at a slower pace. The right policy mix can optimise development of the mini-grid sector, but an understanding of how policies affect different technology-tier combinations is essential.

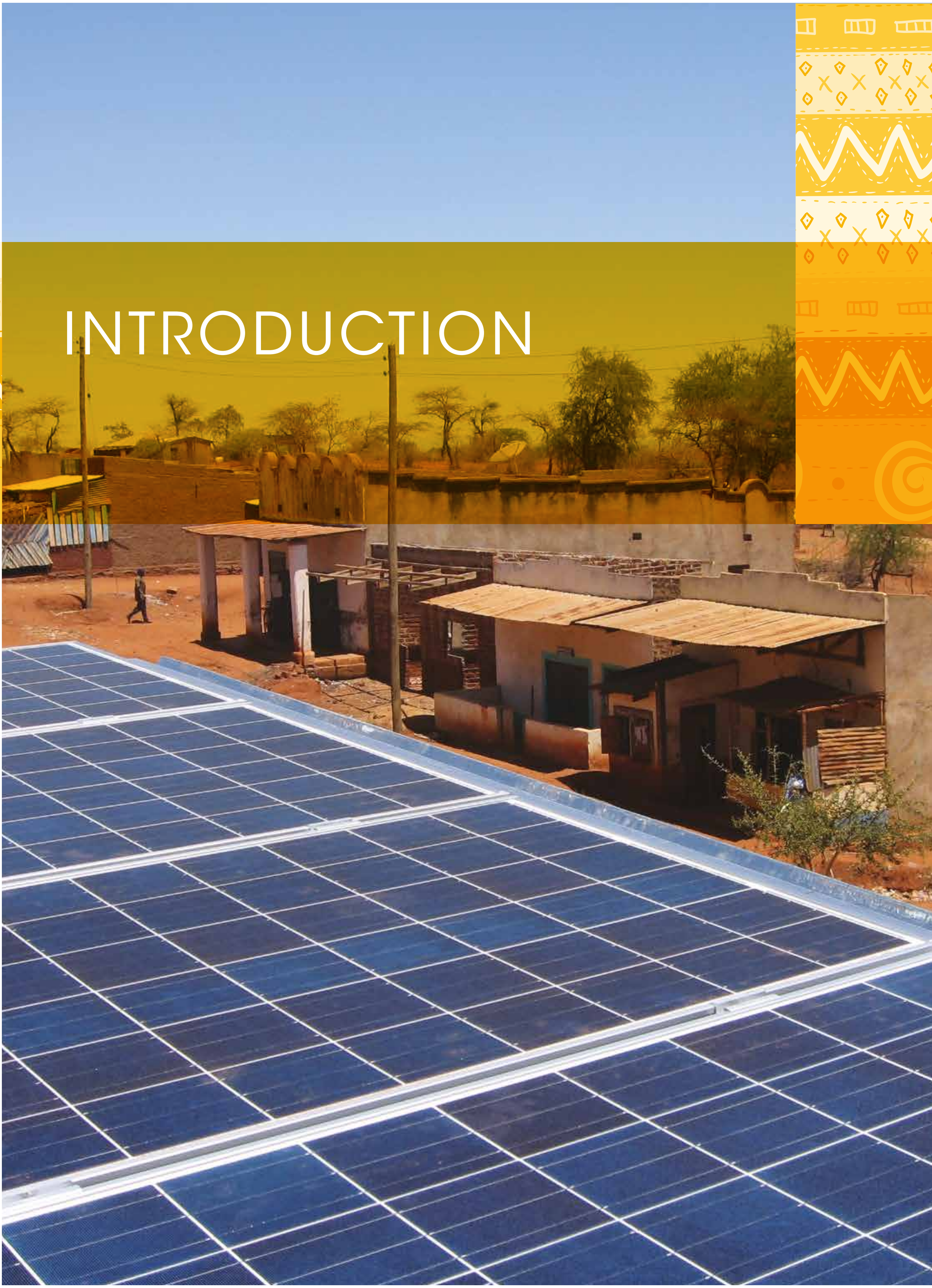
Various mini-grid configurations respond differently to the policy and regulatory environment. Solar DC mini-grids, for instance, are highly modular, low-capacity systems with predominantly movable assets and are, therefore, less susceptible than, say, small-hydro plants to main-grid encroachment. With fixed costs spread over fewer units of electricity, solar DC mini-grids are particularly sensitive to project development costs. On the operational-side, incentives targeting appliances could reduce costs and enhance the services available. Large mini-grids can benefit from de-risking measures, including power purchase agreements. Energy resource risks also vary: solar resources are better understood and more easily estimated than wind, biomass, or hydro. Targeted policy actions to mitigate this risk, such as siting and data gathering initiatives, would help diversify the portfolio of mini-grid solutions available.

TRANSLATING RECOMMENDATIONS INTO POLICIES AND REGULATIONS

Mini-grid policies and regulations need to continuously be adapted to ensure effectiveness. The renewable energy mini-grid sector is highly dynamic and therefore policies evolve as they are introduced, applied and calibrated. Furthermore, to create enabling conditions for private mini-grid development, measures are needed in energy and non-energy sectors (*e.g.*, financial, data and statistics, and rural development). This report provides examples of different measures, as a starting point for the development of a central repository of policy and other legal documents that can be easily accessed by sector stakeholders and policy makers.

A well-designed policy and regulatory framework improves project sustainability and maximises socio-economic benefits. Access to electricity has substantial forward linkages for rural development, marked by considerable improvements in productivity, income, and livelihoods, all of which produce spill-over effects. In fact, renewable energy solutions have the potential to advance many Sustainable Development Goals. Given these interlinkages, policy makers are encouraged to examine the opportunities that mini-grid solutions offer for both electrification and other facets of sustainable development.

INTRODUCTION



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Access to modern energy services is now at the forefront of the development agenda. With their capacity to transform livelihoods, modern energy services can improve incomes, education and health services, food and water security, employment, and gender equality (Figure 1.1). An estimated 1.1 billion people today live without access to electricity and are deprived of these opportunities.

The Sustainable Development Goals (SDGs) propose to achieve universal access to electricity by 2030. To reach this goal, efforts will need to be redoubled; the traditional approach of extending the grid will not be enough. With demand outpacing capacity in most urban and semi-urban areas, extending the electrical grid to rural areas remains economically, technically or physically infeasible for most utilities. As a result, rural electrification is proceeding too slowly to address the deficit. In Sub-Saharan Africa, for example, the average electrification rate is around 17%; rapid population growth outpaces efforts to provide electricity (IEA, 2015; IEA, 2014).

Decentralised solutions have recently gained prominence as cost-effective alternatives to traditional approaches. Solutions range from small-scale household systems to isolated mini-grids that service a few households or a village of several hundred houses as well as community centres and small businesses.

Figure 1.1 Meeting multiple Sustainable Development Goals through renewable energy

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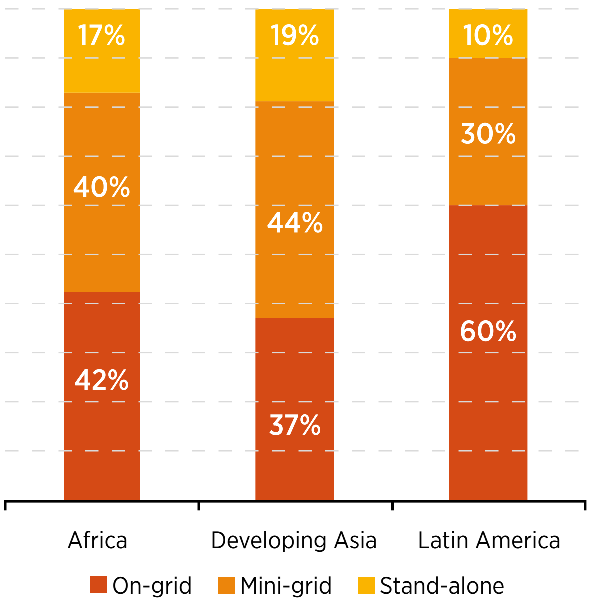
It is estimated that off-grid solutions will supply nearly 60% of the additional generation needed to achieve universal access (IEA, UNDP, and UNIDO, 2010); mini-grids are expected to supply most of the need in Africa, developing Asia, and Latin America (Figure 1.2). Advances in efficiency and reliability, together with sharp decreases in cost, mean that most mini-grids would be powered by renewable energy sources. Solar photovoltaic (PV) modules, for instance, cost three-quarters less today than in 2009 (IRENA, 2015), making renewable energy–based mini-grid solutions the most competitive option for expanding access in many rural areas.

Figure 1.2 Additional generation needed for universal electricity access by 2030 (by region and source)



Sources: Based on IEA, UNDP, and UNIDO, 2010.

Mini-grids have generation capacities from around 1 kW up to 10 MW, supplying electricity to customers who are off the national grid. Relying on a single energy source (*e.g.*, solar, wind, hydro, biomass, diesel) or a combination of sources (*e.g.*, solar-diesel hybrids), with or without storage, mini-grids provide varying electricity service levels. "Micro-grids"[1] and "pico-grids" are mini-grids with generation capacity less than 10 kW. Mini-grids[2] are often seen as a bridge solution until the main grid arrives. In remote rural areas, they may be the most economical long-term solution.

With flexible sizing, resource utilisation, and management options, mini-grids are highly adaptable to local conditions. Solar–based DC mini-grids can be used for basic lighting and mobile-phone charging; biomass mini-grids for powering electric appliances and motors in workshops and homes; and mini–hydro systems for providing grid-quality electricity. Because mini-grids rely on local resources and networks to generate and supply electricity, technical management is less complex than for national utilities. But owing to their limited generation capacity, mini-grids require greater Customer demand management and optimisation than main grids.

With an array of stakeholders engaged in the deployment, operation and management, the track record for mini-grid development is growing. The private sector is showing greater interest in the sector. By combining the cost reductions available through renewable energy technologies with innovative models for finance and business, private players are unlocking new markets to bring electricity to rural areas, working alongside government efforts. The highly decentralised approach requires private entities —ranging from large consumer-goods conglomerates and private utilities to local energy entrepreneurs —to participate in the rural energy sector, bolstering traditional efforts to expand access through mini-grids (Section 1.1). This chapter analyses the rationale for increased focus on private sector involvement in the mini-grid sector (Section 1.2) and describes the steps taken by governments in this direction (Section 1.3). Finally, section 1.4 presents the objectives of this report and provides context for the development cycle of mini-grid policy and regulation.

1. *In OECD countries, the term 'micro-grid' refers to a distribution and generation system, with generation capacities in the MW or hundreds of kW range, that can operate independently or in conjunction with the area's main electrical grid. These micro-grids are often installed to achieve exceptionally high levels of reliability for applications, such as data farms or industrial processes, for which a power outage could prove very costly.*
2. *Throughout this report, the term 'mini-grid' is used to refer to all forms of mini-grids, including micro- and pico-grids. Only when the distinction becomes relevant is further classification specified (e.g. micro-hydro).*

1.1 TRADITIONAL APPROACHES TO MINI-GRID DEVELOPMENT

Electrification through mini-grids in developing countries has historically been driven by government agencies, state-owned utilities, cooperatives, community groups, nongovernmental organisations, and, in some cases, small, local private firms. Either by developing, managing, or operating new systems, such entities managed to bring electricity to individual villages or a few households. Using grants and soft loans, governments and international development organisations have made large investments in equipment; in-kind contributions from the beneficiaries have also played a role. Consumers themselves have often paid minimal tariffs, leaving little financial resources for system expansion to meet growing demand. Limited economic sustainability and scalability are major drawbacks to the traditional business models, which, in many cases, have involved communities and utilities.

In the community-driven deployment model, tariffs generally are designed to cover only operations and maintenance (O&M) and sometimes reinvestment costs. Tariffs are almost always set too low, so only the most minimal management costs are recovered—a situation worsened if management oversees multiple mini-grids in the same area. Without qualified oversight, local operation often leads to early breakdowns of equipment, which creates the need for repairs earlier than anticipated. As a consequence, maintenance costs are underestimated and community-run mini-grids struggle with repairs. This makes the long-term operation of mini-grids nearly impossible without funds to replace equipment or expand system capacity when needed.

Community-owned mini-grids have nevertheless been widely deployed and have a long track record, specifically with micro-hydro development (discussed in detail in Section 2.3.3). To overcome the challenges described above, community groups can be integrated into capacity-building programmes. These in turn can create strong local teams and structures able to undertake basic O&M and system management, including tariff collection and dispute resolution.

In the utility-driven model, tariffs set at national levels lead to mini-grid projects that are cross-subsidised by grid-connected customers. With tariffs that do not cover costs, however, utility budgets become strained, worsening insolvency risks. Moreover, the cost of managing isolated systems is prohibitive given the high cost of operation and management of fossil-fuel based mini-grids which are common. Utilities limit their involvement in building mini-grids, focusing instead on establishing more grid-based connections in urban or peri-urban areas, which have a higher return on investment at lower additional costs of connection. This negatively impacts the pace at which the main grid expands to reach rural areas where consumption levels and ability to pay are low. A number of governments are therefore taking measures to open up the rural electrification sector to private participation (Box 1.1).

Box 1.1 Why is private mini-grid development being promoted?

THE INCREASING PACE OF ELECTRIFICATION

- Mini-grids are a decentralised solution that can be scaled up rapidly to expand access via diverse, locally available renewable energy resources.
- The decentralised approach allows adaptation of mini-grid technology, operation, and management structures involving the private sector, local communities, and nongovernmental organisations.

BETTER VALUE FOR MONEY

- Private investment in mini-grid development decreases pressures on public funds and increases scalability of interventions. Private project development and innovative public-private partnership models are both options.
- With mini-grid development, governments and utilities are spared the cost of building expensive medium-voltage lines to areas with limited loads and avoid losses.

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BALANCING PUBLIC UTILITY BUDGETS

- Many utilities charge non-cost-covering tariffs for grid electricity, an approach that creates high debt and low operational budgets. When utilities are freed from having to invest in and operate rural mini-grids, they can focus on expanding the national grid to improve electricity services in more densely populated areas with a higher return on investment.

RURAL DEVELOPMENT

- Mini-grids can be installed in remote rural areas, allowing governments to strike a balance between urban and rural development. Privately driven mini-grids lay more emphasis on productive uses, building sustainability into the system, and boosting the socioeconomic benefits of access.

1.2 INCREASED FOCUS ON THE PRIVATE SECTOR

Private sector involvement in mini-grid deployment has a number of advantages, chief among them access to financing and established management practices that make it possible to deploy and maintain infrastructure assets over the long term. The private sector's focus on customers, concern for cost optimisation, decentralised decision-making, local presence, flexible management structures, real time pricing and innovative and entrepreneurial thinking all contribute further to strong and effective operations.

Mini-grid business models combining local expertise and decentralised management structures are already available and have been proven through pilot projects in several countries (IRENA, 2015). The track record of large-scale private mini-grid rollout, however, is rather limited—as rural electrification has only recently piqued private sector interest by appearing to be potentially profitable. Recent interest is fuelled by a number of factors, among them:

- the lower cost of renewables
- more reliable technologies
- greater business innovation in customer finance (*e.g.*, pay-as-you-go)
- better customer-management technologies (*e.g.*, mobile payment, remote monitoring, load management, and metering)
- more dedicated donor/public financial support programs for mini-grids
- dedicated private sector policies and regulations, in some countries.

Governments play a key role in facilitating private sector involvement in mini-grid development. Particularly important is the development of a pipeline of sustainable and, in some cases, commercially viable projects with a reasonable risk-return profile.

Recognising the opportunity that mini-grids offer and the potential for private sector engagement, more countries have been introducing policies, and regulations that support mini-grid development. Some recent examples are described below.

1. In March 2016, the **Tanzania** Energy and Water Utilities Regulatory Authority (EWURA) unveiled its Development of Small Power Projects Rules 2016, which laid out licensing and tariff regulation requirements for mini-grids. Under the rules, very small power producers (< 100 kW) are exempted from licensing or tariff regulation requirements. The rules also provide clarity on the consequences of main grid arrival and offer a standard power purchase agreement and a standard methodology for computing tariffs for electricity fed into the main grid (Tanzania EWURA, 2016).
2. In June 2016, **India** released its draft national policy on renewable energy–based mini-grids. The objectives include mainstreaming mini-grid solutions to improve access, streamlining project development procedures, providing frameworks for operating with local distribution companies, optimising access to finance and fostering innovation in mini-grid business models (India MNRE, 2016).
3. In 2015, the **Rwanda** Utilities Regulatory Authority established a simplified regulatory framework to exmpt or expedite licensing for mini-grid projects. The regulation differentiates requirements for large,

medium, small, and very small mini-grids, while also providing greater clarity on tariff determination and the consequences of grid arrival (RURA, 2015).

It is increasingly clear from these examples (and from others not covered here) that to facilitate mini-grid development, a number of policy and regulation design elements must work in a concerted manner—notably those related to licensing, licensing, tariff regulation, main grid arrival risk mitigation and financial support. Mini-grid policies and regulations are developed in continual processes that depend on successful adaptations to local conditions, including barriers to deployment.

1.3 THE DEVELOPMENT CYCLE FOR MINI-GRID POLICY AND REGULATION

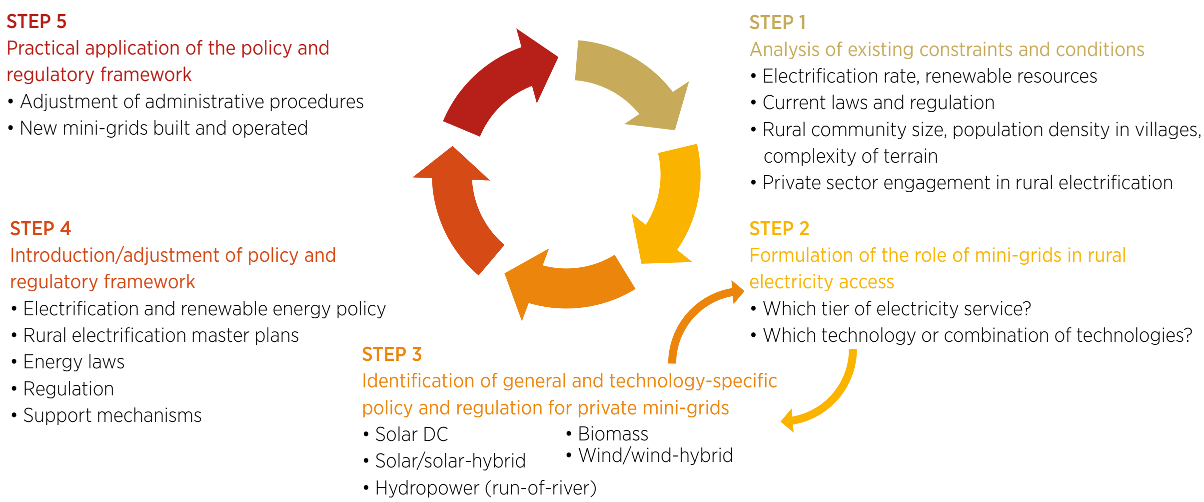
A typical development cycle for mini-grid policy and regulations (see Figure 1.3) begins with an analysis of current conditions—including the electrification rate, present laws and regulations, the characteristics of the targeted rural areas (location, size, type of demand, and density), and constraints on private mini-grid implementation and operation. In a second step, the role of mini-grids in achieving universal electricity access is specified. The target level of electricity service and the generation and distribution technologies to be used are defined. In a third step, general and technology-specific policy and regulatory needs are identified to inform the design process. Step 4 translates the identified requirements into actual policies, master plans, laws, regulations, and support instruments. Step 5, the final step, involves the practical application of the policy and regulation and the incorporation of field experience into the development cycle.

Well-designed policies and regulations maximise the economic and social benefits of a project and make them sustainable. There is an inherent trade-off, though. Given the diverse nature of deployment approaches, a one-size-fits-all policy approach can be ineffective in unleashing the full spectrum of technological, management, and financing options. At the same time, policies and regulations cannot be customised to every conceivable combination of mini-grid technology, business model, and local conditions.

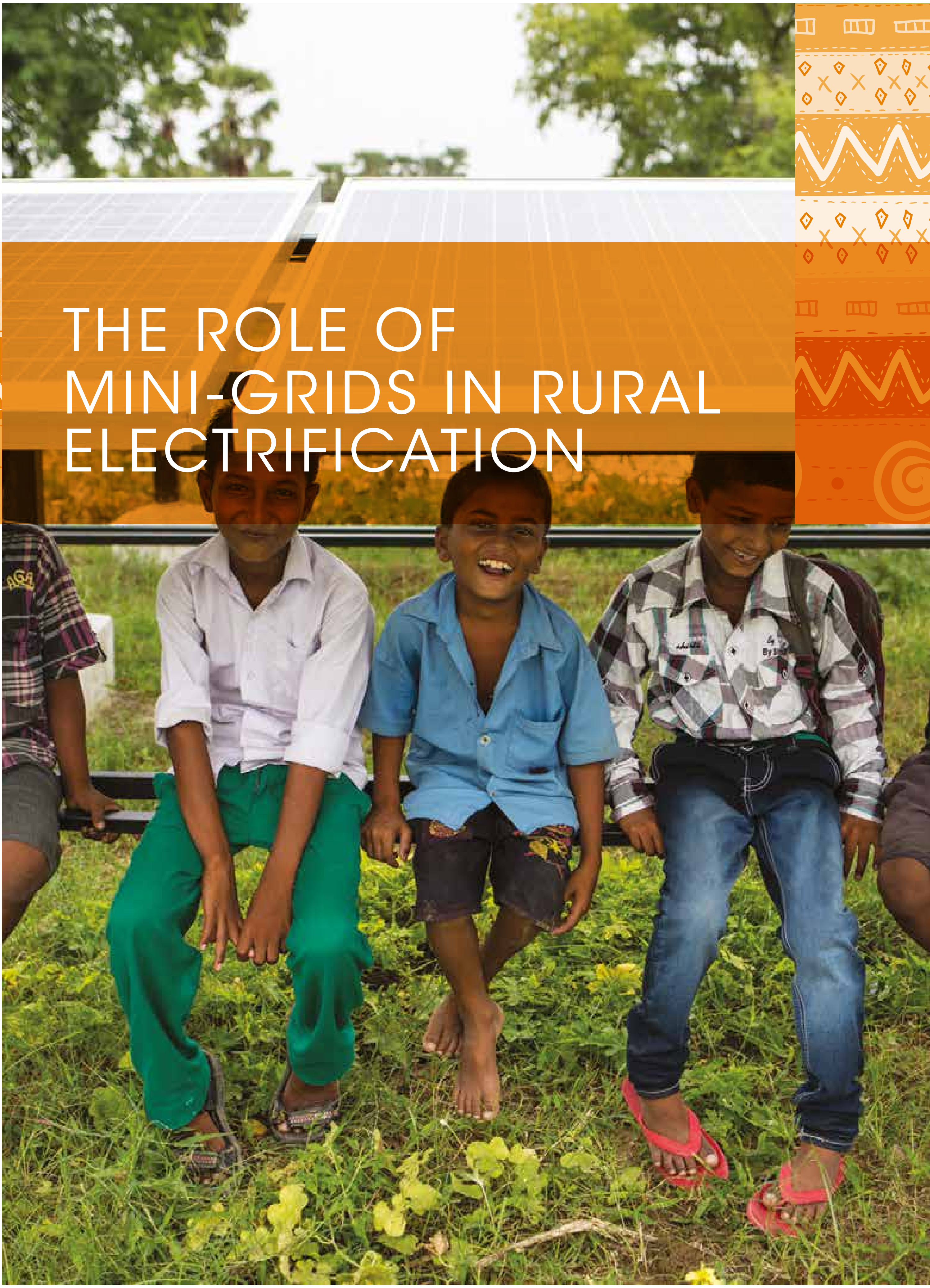
Achieving the right balance requires an in-depth understanding of the specificities as well as the policy and regulatory needs (or sensitivities) of different mini-grid deployment models. Building on earlier analysis (*e.g.* EUEI-PDF (2014), Tenenbaum *et al.* (2014)), as well as IRENA's work on the topic (*e.g.* IRENA, 2013 and 2015), this report is meant to support that effort by:

1. Presenting case studies of mini-grids to illustrate their role in rural electrification strategy (Chapter 2);
2. Analysing best practices in policy design, as well as in the policy and regulatory needs of different mini-grid technology solutions (Chapter 3);
3. Showcasing measures that governments are taking to develop the policy and regulatory framework needed to scale up mini-grid deployment (Chapter 4).

Figure 1.3 Policy development cycle for the mini-grid sector



THE ROLE OF MINI-GRIDS IN RURAL ELECTRIFICATION



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Mini-grids powered by renewable energy provide a wide range of electricity services in unconnected areas. A growing track record of projects, falling costs, and continued pressures to expand electricity access are compelling policy makers to mainstream mini-grids within national rural electrification strategies. A first step in that direction is to understand what services mini-grids can provide and the different technologies and business models that are driving their deployment. This chapter will analyse the multi-tier framework classifying electricity access to show which mini-grid solutions can deliver what type of access. Case studies will then be used to analyse the various deployment models.

2.1 A MULTI-TIER FRAMEWORK TO CLASSIFY ELECTRICITY ACCESS

Traditionally, governments have defined access in terms of the number of households that have electrical connections or that live within a certain distance of distribution infrastructure. Such definitions usually do not take into account service quantity and quality. Many connected households are supplied with electricity for limited hours of the day (or night), and with low reliability (ESMAP, 2015). Until very recently, a common framework to classify electricity access has been lacking. As a consequence, definitions varied greatly.

From a socio-economic perspective, the benefits of electricity access are realised when reliable, cost-effective, and sufficient electricity is available for a range of uses, including productive uses. As the global community convenes around the recently adopted Sustainable Development Goal 7 (SDG 7), defining electricity access in terms of quantity and quality will be vital to meeting the development objectives.

The *Global Tracking Framework 2013* was the first of a series of reports on progress towards the three objectives of the Sustainable Energy for All (SE4All) initiative. The framework introduced a comprehensive measurement and evaluation system that categorises access according to the quality and quantity of services customers can access.[3] In this tiered framework, households fall into one of six different classes, depending on the services offered (lighting, phone charging, television, fan, electric motors, etc.), as well as the peak capacity, duration of electricity supply, evening supply, affordability, legality, and quality. These categories, their definitions and ranges, and the applicable technology are illustrated in Table 2.1. Some key features include:

- Tier 0 describes non-existent or completely unreliable supply. Customers get less than four hours of electricity per day—and less than an hour in the evening.

3. *Access pertains to usability of supply rather than actual use of energy (ESMAP, 2015).*

- Tier 1 customers receive basic, reliable electricity for lighting and phone charging—at least one hour in the evening; electricity is available for at least four hours each day.
- Tier 2 provides more than 50 W of power, enough to run televisions and fans.
- Tier 3 allows for low-power appliances requiring at least 200 W and provides more than eight hours of electricity per day, or 50% of working hours for productive users.
- Tiers 4 and 5 supply electricity at near-grid or grid-quality levels.

Table 2.1 Access to household electricity: A multi-tier matrix

ATTRIBUTES		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Capacity	Power[4]		Very low power Min 3 W	Low power Min 50 W	Medium power Min 200 W	High power Min 800 W	Very high power Min 2 kW
	And daily capacity		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
	Or services		Lighting of 1,000 lumen-hours per day and phone charging	Electrical lighting, air circulation, television, and phone charging are possible			
Duration	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening		Min 1 hrs	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration < 2 hours
Quality						Voltage problems do not affect the use of desired appliances	
Affordability					Cost of a standard consumption package of 365 kWh per annum is less than 5% of household income		
Legality						Bill is paid to utility, prepaid card seller, or authorized representative	
Health and safety						Absence of past accidents and low perception of risk in the future	

Source: Adapted from ESMAP, 2015.

The tier-based system describes the service levels experienced by customers, not the demand for energy. So, for example, low-tier electrification in a well-developed area may result in unmet demand. By the same token, a remote and undeveloped region with high-tier electrification will be unprofitable because the few customers will not be consuming all the electricity generated.

Theoretically, almost any tier can be reached. But this depends on the government (or a mini-grid developer/operator) developing infrastructure, providing loans for productive appliances, training customers on

4. The minimum power capacity ratings in watts are indicative, particularly for Tier 1 and Tier 2, as the efficiency of end-user appliances is critical to determining the real level of capacity, and thus the type of electricity services that can be performed.

electricity usage and business practices, and so forth. Setting the tier(s) for which the mini-grid framework will be designed is a strategic decision on the part of the government. At any chosen level, a well-designed policy framework will deliver customer satisfaction at low tariffs, while keeping government expenditures as low as possible.

2.2 RENEWABLE ENERGY–BASED MINI-GRIDS AND THE MULTI-TIER SYSTEM

The Sustainable Energy For All (SE4All) multi-tier system is technology-neutral (ESMAP, 2016). It does not distinguish among different sources of generation (solar, wind, hydro, fossil) or different distribution options (grid, mini-grid, or stand-alone). A number of configurations can be envisaged for mini-grids that tap into one energy source or several to deliver service at certain tiers.

As noted earlier, mini-grids can be designed for the highest service tiers. The solution is closely tied, however, to (i) demand, (ii) available energy resources, and (iii) local conditions. In most unconnected areas, the systems are designed to meet current and projected demand.[5] Modular, flexible options for electricity generation, such as solar photovoltaic (PV), are considered the most suitable for household loads. Generating energy for the higher tiers and overcoming intermittency challenges requires storage or hybridisation with other energy options, such as diesel generators. Small-hydro can deliver high-tier service; it is typically the least costly option where water resources are available and sufficient demand exists to amortise the investment. Similarly, biomass is an attractive option in regions where there are abundant resources and sufficient demand.

Local demand heavily influences the choice of mini-grid technology. The existence of sufficient residential load and commercial (or anchor) load (*e.g.*, from rural industries, water pumps, and agro-processing machinery) justify capital investments in assets that can provide higher tiers of electricity services.

Technology choice can also be driven by other exogenous factors—for example the uncertainty and risk surrounding the arrival of the main grid, an event that strands investments and diminishes consumer bases. As a hedge, some mini-grid developers deploy flexible, modular systems, generally based on solar PV, which can quickly be assembled and disassembled, reducing losses when the main grid arrives. Others build systems that comply with the national grid standards. This enables the mini-grid operator to become a small power distributor that purchases electricity at wholesale from the main grid when it arrives, an arrangement that would be subject to existing policy and regulations (see Chapter 3). Private mini-grids are using various deployment models and technologies, adapted to the local conditions, to deliver services across all tiers of electricity service.

2.3 DEPLOYMENT MODELS FOR DIFFERENT COMBINATIONS OF TECHNOLOGY AND TIER

This section describes typical deployment models for different technology-tier combinations using practical examples and cases. The combinations presented here are known to be the common approaches for renewable energy–based mini-grid electrification. In the case of hybrid systems, a portion of the electricity supplied may come from other generation technologies (notably diesel generators) or from storage.

The combinations analysed are as follows:

- Solar direct current (DC)—tiers 1–3
- Solar and solar-hybrid alternating current (AC)—tiers 1– 5
- Hydro (run-of-river) AC—tiers 1–5
- Biomass AC—tiers 1–5

The deployment models for these combinations are analysed across the six components illustrated in Figure 2.1. For each combination, each component is analysed through case studies, stakeholder consultations, and a literature review.

5. *Future demand is based on the number of households expecting to be connected, in addition to aspirational demand or growth in demand that may occur at a household level. The latter is often difficult to project with accuracy.*

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Figure 2.1 Components of deployment model analysed

Ownership

Site selection

Financing

Technology

Operation & management

Tariff design and collection method

2.3.1 SOLAR DC (TIERS 1–3)

Solar DC mini-grids typically have a capacity of less than 3 kW^p and provide low to medium-tier services. They cater to electricity loads at times of high demand (evening) and integrate battery capacities ranging from 1 to 30 kWh. Depending on the configuration of the system, access of up to tiers 2–3 can be provided. Service covers lighting, mobile charging, and low power loads such as radios. Some solar DC mini-grids are able to power TVs, stereos, sewing machines, and limited refrigeration and grain milling.

Direct current is preferred in such systems, where electricity is distributed across short distances, generally only a few hundred meters from the generating plant (Palit and Malhotra, 2015), and efficiency losses at the inverter (that is, in converting DC to AC) can be avoided. Such mini-grids distribute electricity using DC from the battery at different voltages, which usually range from 12 to 120 V depending on the network configuration and site details. Most DC grids are set up as not readily compliant with the main grid, using house-to-house wiring or ground cabling that can be easily removed when the main grid arrives.

Solar DC mini-grids can be deployed rapidly and, given low installed capacities, with low capital costs. Within a broader rural electrification strategy, these mini-grids deliver levels of service that could over-lap with those of solar home systems (SHSs). From a system operation and management perspective, however, there are differences between the approaches, especially considering the range of ecosystem services needed for sustainable SHS dissemination. Initiatives are in place to convert swarms of SHSs deployed in dense areas into a solar DC mini-grid (Box 2.1).

Box 2.1 The case of SOLshare in Bangladesh

Bangladesh hosts one of the most dynamic markets for solar home systems (SHSs) in the world, having deployed more than 4 million systems as of June 2016. The IDCOL SHS programme has, by all measures, been a tremendous success—providing electricity to more than 18 million people, or 11% of the population. The programme has helped to create a sustainable local industry that has improved the system's long-term operational soundness. Equally important, it has demonstrated that through financial innovation even the poorest households can afford off-grid solutions. Collection efficiency, although decreasing, remains high at over 95% — a figure higher than that of many banks in the developed world.

From an end-user perspective, a key challenge is for the SHS to cope with increasing demand. In the current environment, either the household is constrained by the existing SHS or has to secure another SHS (an inefficient option, with total capacity not necessarily increasing in linear fashion with the addition of each new system). SOLshare, a private enterprise operating in Bangladesh, has developed a smart-village grid in Shariatpur, Bangladesh, that interconnects existing SHSs into a peer-to-peer electricity-trading network. This ingenious micro-grid allows users to both buy and sell electricity, allowing those with a PV system to generate income, while those without one can access affordable electricity. In this manner, households are also able to maintain productive loads that would otherwise be impossible using their SHSs alone. SOLshare energy supply is provided in different packages through a flexible prepaid payment system, similar to pay-as-you-go methods for mobile phones.

To gain a better understanding of the deployment model behind solar DC mini-grids, Figure 2.2 presents an overview of the different components, with the remainder of the section analysing each of those in more detail. The analysis is based on the case of three private enterprises operating in the solar DC mini-grid market segment:

- Mera Gao Power (India) has more than two thousand solar DC mini-grids each connecting 30–50 customers.
- Devergy (Tanzania) is in early start-up phases. As of May 2016, it had electrified 14 villages with solar DC mini-grids, with dozens more in the pipeline.
- Solaric (Bangladesh) provides electricity in about 40 villages, connecting 40–50 customers in each.

The three enterprises were selected for diversity across geography and electricity services (tiers) they provide (Table 2.2). The analysis is further strengthened with other cases from the literature.

Figure 2.2 Deployment model for solar DC mini-grids; tiers 1–3

Tier 0	**Tier 1**	**Tier 2**	**Tier 3**	Tier 4	Tier 5

Ownership
- Private, sometimes with a village ownership component, BOOM and BOM

Site selection
- Small villages with high population density
- Typically low income customers
- Clusters of villages to facilitate logistics
- Strong customer training component

Financing
- Mainly corporate finance, grants, possibly debt
- CAPEX subsidies to reduce tariffs

Technology
- Low cost PV-battery <5 kW
- Non main-grid compliant distribution networks - Flat rates, load limiters or pre-paid meters
- Highly efficient DC appliances

Operation & management
- Strong local presence of operator
- Low cost overhead structure
- Low cost logistics
- Intermittent operation with flat rates/load limiters, continuous operation with meters, mobile money

Tariff design and collection method
- Flat weekly or appliance-based tariffs
- Pre-payment meters or load limiters
- Pay-as-you-go

BOOM = build, own, operate, and maintain;
BOM = build, operate, and maintain;
CAPEX = capital expenditure.

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Table 2.2 Selected solar DC mini-grid case studies analysed in the report

Enterprise	Mera Gao Power	Devergy	Solaric
Type	For-profit social enterprise	For-profit social enterprise	For-profit social enterprise
Country of operation	India	Tanzania	Bangladesh
Systems implemented	>2 000	Grids in 14 villages with more than 2 000 customers	40
Technology	Solar DC mini-grids connecting 30–50 customers on 24V distribution with strong local presence of operator	Solar DC mini-grids for 5–6 customers per networked tower on a 24V network	Solar DC mini-grids connecting 40 –50 customers on a 220V DC distribution network
Tariff design and collection method	Manual collection of flat-rate tariffs	Prepayment meters with fully automated payment and monitoring via mobile money	Mobile money collection (from head office to entrepreneur) and prepaid system (for end-users)
Tiers covered	1	1–3, maximum 250W (time and service level tariffs)	1–3 with a focus on 2
Business model	Private sector with company subsidies from international donors for accelerated rollout	Private sector with company subsidies from international donors for accelerated roll-out	Private operator approach
Sector regulation	Unregulated	Below 100 kW and therefore categorised as a “very small power producer” and exempt from license and tariff review by the regulatory authority	Unregulated for small systems; new PPP approach wherein government provides funds for public services (*e.g.*, electrification of a hospital) to private operator

Ownership. Solar DC mini-grids are typically owned and operated by a private entity (sometimes including a village-ownership component) and amortised through sales of electricity over a period of two to seven years. The model has been adopted by developers such as Solaric in Bangladesh and Devergy in Tanzania. Mera Gao Power takes a micro-utility approach when implementing its solar DC mini-grids. The firm designs, installs, operates, maintains, and provides the service to consumers for a fee or tariff (Palit and Malhotra, 2015), forming joint liability groups, with all users of a given micro-grid acting as a group to ensure timely collection. The ownership model may vary in other cases. Uttar Pradesh New and Renewable Energy Development Agency (UPNEDA), for instance, installed more than 23 solar DC mini-grids in 2011–12 under a build, operate, and maintain model, wherein the technology providers install the micro-grids and then local operators run them. The local operators are paid a salary from the monthly user fee, and UPNEDA does the monitoring (Srivastava, 2013).

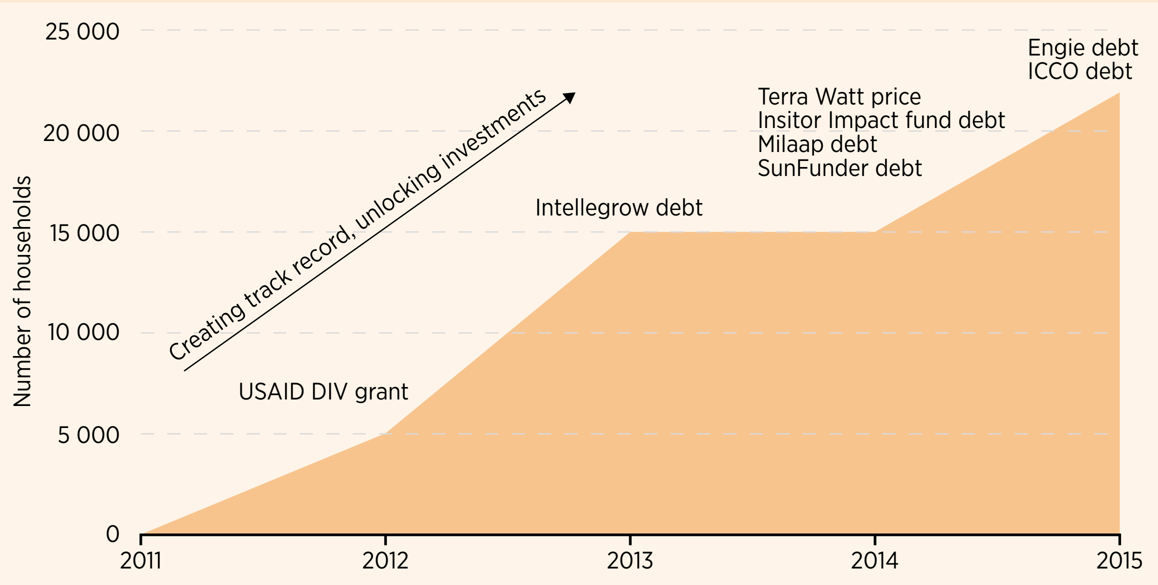
Site selection. Solar DC mini-grids are easily deployed in villages with high population densities. The system can be installed on the ground or a rooftop, or be distributed across multiple rooftops. As with most mini-grids, sites farther away from the grid are preferred, as these avoid untimely main-grid arrival. There have been cases, though, such as for Mera Gao Power, when the systems have continued to operate in villages where the grid has arrived but supply is unreliable. Local socio-economic conditions and evidence of community engagement also influence site selection. A minimum number of customers is needed to justify initial investments. In the case of Devergy, for instance, which uses distributed, networked solar DC grids, four or five clustered houses are required for the product to be technically and financially viable. Another important component in site selection and development involves understanding what electricity services the community desires, its willingness to pay, and local capacity to undertake periodic O&M and collection. This is particularly important for solar DC mini-grids, given their limited generation capacity, as they are shared by at least 50 households. Therefore, community expectations need to be carefully managed.

Financing. An energy service approach is capital intensive. Solar DC mini-grid business models rely on a rapid scale-up. Short project-development cycles and relatively low capital outlay for each project (anywhere between USD 1 000 to USD 10 000) mean that enterprises can scale up rapidly, generate adequate cash flows, distribute fixed costs over a large number of projects, and develop a track record to attract further financing—a key challenge for many enterprises operating in this space. At present, enterprises rely mostly on equity and corporate-guaranteed debt capital. Because these companies are typically small enterprises, their ability to acquire on-balance-sheet financing with corporate guarantees is limited. Early-stage grant financing plays a crucial role in building enterprise-level institutional capacity and during the scale-up stage, as evidenced by the case of Mera Gao Power (Box 2.2).

Box 2.2 Mapping the investment milestones in Mera Gao Power (India)

Mera Gao Power has secured financing at different stages. Grant funding from the U.S. Agency for International Development in 2011–2012 (USD 300 000) financed the first phase of scale-up and was crucial as the company sought to build institutional capacity. It also helped create a track record to attract further investment. In 2013, Mera Gao Power raised equity of about USD 1 million from Insitor Management, which helped Mera Gao Power reach 15 000 households by the end of 2013. As with most new business models, it took some trial and error. But with its new service geographies, Mera Gao Power raised additional funding from ICCO (USD 500 000 debt) and Engie, which helped it to expand to 22 000 households in 2015. Mera Gao Power has also tapped into crowdfunding raising, on one occasion, USD 30 000 debt with a 36-month term using SunFunder. Figure 2.3 presents an overview of the different components, with the remainder of the section analysing each in more detail.

Figure 2.3 Major financing milestones for Mera Gao Power



Source: Shaad, 2014.

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Access to low-cost debt with flexible terms remains a key barrier. Debt is important for rapid scale-up because it comes at a lower cost than equity financing. Local commercial banks in most developing countries have yet to fully grasp the investment opportunity that solar DC mini-grids represent; they often require collateral, if they agree to lend at all.[6] In Bangladesh, Solaric is facing this challenge because banks will not accept solar DC mini-grid components as collateral . The collateral that young enterprises can provide is usually minimal; as a result, banks offer lower debt portions and less-attractive conditions. An alternative to local commercial banks is international debt, if local regulations permit it. Currency risk could be a major challenge, although hedging[7] may be a possibility. Solaric is able to benefit from available hedging partners, owing to the high volumes of garment exports from Bangladesh.

Technology. The mini-grid is a PV system tied to a battery pack, charge controller, and distribution network. The network itself is not, generally speaking, main-grid compatible, but, otherwise, differences in configurations can be seen across the three cases analysed. Devergy configures its mini-grid with distributed, networked solar PV; it has battery storage coupled with smart metering and a cloud-based monitoring system, thus minimising losses that would occur with centrally located generation and 24V distribution. In this manner, while many users in a typical village consume at tier 1, larger customers consume at tier 3, which powers appliances that include refrigeration and grain-grinding equipment. Mera Gao Power distributes electricity through a 24V DC network serving tier 1, with each connection having two 1W LEDs and one mobile charging point. Solaric mini-grids distribute at 220V, enabling customers to use televisions, laptops, satellite receivers, and so on (in other words, tiers 2 and 3).

Innovation is growing on the metering and appliance side. Both Solaric and Devergy integrate prepaid meters into the mini-grid, allowing end-users to pay for services beforehand. To reduce operational and collection costs, the payment process has been integrated with mobile money platforms. Remote monitoring and load limiters also enable operators to assess consumption and act on nonpaying consumers and those that are drawing too much power. On the appliance side, highly efficient DC appliances are allowing end-users to watch television, refrigerate food, and use grain-grinding equipment, even on smaller mini-grids. Devergy equips households with meters that allow for real-time monitoring of usage and credits or consumption. Load monitoring helps operators allocate power according to demand. In each village, a centralised Global System for Mobile communication (GSM) unit communicates information through General Packet Radio Service (GPRS) about mini-grid operations to a central server.

Operation and management. As deployment scales up, a key challenge is the post-installation management of the mini-grids to ensure efficient payment collection and reduce operational costs. A combination of approaches has been adopted. First, emphasis is placed on handing over day-to-day operation to a local operator and identifying clusters of villages served by the same operational hubs that look after collection, monitoring, and servicing. Second, regional technicians are notified of problems by mobile-enabled monitoring systems. Third, shifting to prepaid or pay-as-you-go tariff methods addresses concerns about nonpayment and better management of generation.

Tariff design and collection method. Solar DC mini-grids compete with conventional lighting solutions such as kerosene and batteries. While lighting powered by electricity from mini-grids costs far less than power from kerosene or batteries, tariffs must be cost-reflective and allow for a certain return if

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6. *Lack of safety standards for DC distribution are known to hinder financing of DC mini-grid projects. However, efforts are underway to address this challenge. For instance, the IEC/TS 62557 series (Recommendations for small renewable energy and hybrid systems for rural electrification) addresses many of the concerns and is being used by the World Bank Group's Lighting Africa initiative (together with UN SE4All). Additionally, the IEC 60364 series (Low voltage electrical installations) have been revised to include low voltage DC installations in buildings.*
7. *Hedging is a technique for reducing foreign exchange risk using the money market, the financial market in which highly liquid and short-term instruments such as Treasury bills, bankers' acceptances, and commercial paper are traded.*

the mini-grid is privately operated. At the same time, the tariff must be tailored to the income patterns of rural communities.

Mera Gao Power charges a connection fee of INR 50 (USD 0.75)[8] and a prepaid weekly tariff of INR 25 (USD 0.37); the joint liability group made up of consumer households assures that the payment is made every week. The tariff is designed to deliver a 15% return on investment over three years (Palit and Malhotra, 2015). Devergy uses a time- and service-level tariff and collects customer payments via its mobile money technology and remotely switchable connections, reducing the need for a local presence but increasing the initial investment cost. There are pros and cons to both the flat monthly or weekly model and the payment for time and service model. The fixed charge is a fairly simple method, but users get no information about the amount of energy they can use; as a consequence, users tend to overwithdraw from the network. Payment for service discourages excessive use, reduces commercial losses, and addresses capacity constraints, but it also requires more expensive metering and monitoring systems.

2.3.2 SOLAR AND SOLAR-HYBRID AC (TIERS 1–5)

Solar and solar-hybrid (AC) mini-grids can deliver higher-tier services than can solar DC mini-grids, distributing electricity on a low- or medium-voltage AC grid. In fact, they can reach up to Tier 5 but often stay at tiers 3–4. Solar hybrid mini-grids may additionally include a diesel generator to cover peak demand and to back up intermittent solar. These mini-grids are also well suited to cover the demand of larger productive users and small industrial loads such as mills, wood and metal shop machines, and telecom towers. With demand and load management, operators can achieve proper daytime consumption of solar-generated electricity. The solar and solar-hybrid mini-grid market segment is attracting more private project developers owing to the steep reductions in prices for PV modules and a positive outlook for lower equipment costs.

Figure 2.4 Deployment model for solar/solar-hybrid mini-grids; tiers 1–5

Solar/solar-hybrid | Tier 0 | **Tier 1** | **Tier 2** | **Tier 3** | **Tier 4** | **Tier 5**

Ownership
- Private, often public-private partnership or partly subsidized model

Site selection
- Small industries and other anchor loads
- Good productive use potential
- High population density
- Clusters of villages to facilitate logistics
- Strong customer training component
- Areas with low risk of main-grid connection

Financing
- Striving to acquire project finance
- CAPEX subsidies to reduce tariffs

Technology
- Mostly main-grid quality 24/7 AC power
- Usually high renewable penetration with generator as backup
- Generator: mostly diesel, sometimes biomass or biofuel
- Often main-grid compliant distribution networks
- Smart meters, pre-paid meters, sometimes load or load and time limiters

Operation & management
- Strong local presence of operator
- Low cost overhead structure
- Low cost logistics
- Social theft and vandalism protection mechanisms like split of assets

Tariff design and collection method
- Regulated by authorities or through negotiations with the users
- Pay-as-you-go (PAYG)
- Pre-payment meters or load limiters,
- Appliance-based tariffs

8. *USD 1 = INR 67.05*

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The three private enterprises analysed for this market segment are listed below and in Table 2.3.

- *ACCESS SA (Mali)* is a for-profit company with 15-year concessions in 32 villages, of which 12 are operational; 9 of these are solar hybrid systems. The company uses 30–70% public finance; the rest is private finance for initial investments. The concessions protect from main-grid con-nection, although villages near the national grid are susceptible to takeover by the national elec-tricity grid operator, EDM SA. If this happens, EDM is to pay an agreed compensation to the company. Tariffs are adequately regulated.
- *OMC (India)* has implemented approximately 100 systems through 2015 by using solar-battery-diesel systems and telecom towers as anchor loads. They supply tiers 1–4 service to public, commercial, and household customers close to telecom towers. Stand-alone mini-grids in India fall outside tariff regulations, so tariffs are decided mutually with consumers.
- *JUMEME (Tanzania)* is a social business with the installation of one 90 kW solar-diesel-battery system under its belt. It plans to install about 25 systems over the next two years. Financing is based on a capital grant of about 50%; the remaining 50% will come through private finance, both equity and debt. Electricity is sold via prepaid meters and gives access to household, community, commercial, and productive users at tiers 3–5. At under 100 kW, the pilot system is exempted from regulatory tariff approval.

Table 2.3 Selected solar and solar-hybrid AC mini-grid case studies analysed in the report

Enterprise	ACCESS	OMC	JUMEME
Type	For-profit private company	For-profit private company	Private social business
Country of operation	Mali	India	Tanzania
Systems implemented	>12	~100	1
Technology	AC solar-diesel-battery hybrid	AC solar-diesel-battery hybrid	AC solar-diesel-battery hybrid
Tariff design and collection method	Mixture of post and prepaid metering	Prepayment metersw	Prepayment meters
Tiers covered	Tiers 2–4	Tiers 1–4	Tiers 3–5
Business model	30–70% public subsidy, 15-year concession	Mostly telecom towers as anchor customers, financing mostly private	50% grant mostly from ACP-EU, 20% equity, 30% debt
Sector regulation	Concessions and tariffs adequately regulated	Stand-alone mini-grids in India are outside tariff regulations, so tariffs are decided mutually with consumers	Systems below 100 kW exempted from regulatory tariff approval

Ownership. The assessed solar mini-grid deployment models involve owning and operating a cluster of mini-grids. Clustering helps achieve economies of scale and reduces tariffs for end users. Amortization times depend on the business model and the terms and conditions of the financing in place.

Site selection. Site selection for solar and solar-hybrid mini-grids depends on a range of factors. Local factors include the type of loads available (*e.g.*, domestic, rural productive, commercial), ability and willingness of people to pay, and projections of how the load might evolve. Solar and solar-hybrid mini-grids are capable of reaching high tiers of services, but if the electricity generated is not utilised, then viability is difficult. The presence of productive or anchor loads in (or around) the village, therefore, becomes an important deciding factor in site selection, as shown in the Indian case described in Box 2.3. These loads could range from local agro-equipment (*e.g.*, milling machines, water pumps) to social infra-structure (*e.g.*, rural health-care centres) to telecom towers. OMC, as well as others such as DESI Power and Gram Power, uses telecom towers as anchor loads while supplying power to rural communities (Bhattacharyya and Palit, 2016). Integration of solar PV into existing diesel-powered mini-grids is an increasingly attractive way to reduce O&M costs, as demonstrated in Mali, where at least 30 hybrid mini-grids exist. The World Bank recently funded a project to integrate solar PV into existing diesel-powered mini-grids in about 50 locations (Rai *et al.*, 2016).

Box 2.3 Tying generation to domestic, commercial, and productive loads: The case of solar-hybrid mini-grids in India

In India the Mlinda Foundation has installed more than 270 pico- and micro-grids totalling 90kWp and serving approximately 1,900 homes, 365 small businesses, and 3 schools. Recently, it commissioned four solar-hybrid mini-grids in the Gumla district of Jharkhand covering 254 tribal households. Each mini-grid is powered by a solar PV array, inverter, and battery bank supplemented by diesel generator as backup for peak-load management. These systems are supplying energy for domestic, commercial (*e.g.*, village shops and poultry units), and productive loads (*e.g.*, farm loads like irrigation pumps and rice-hulling machines). At present, 46 farmers have switched from diesel-powered irrigation pumps and rice hullers to solar-powered electric machines.

Round-the-clock electricity from the solar-powered mini-grids gives villagers the flexibility to pursue productive activities. The units power their farm-based productive loads and light their poultry coops through the night. The savings they accrue by eliminating kerosene and diesel increase their disposa-ble income, which they can further invest in energy-efficient devices.

Source: GSES, 2016.

Financing. Privately owned and financed solar/solar-hybrid mini-grids require project financing that features medium tenures and low interest rates. The financing demand for project development and equipment falls beneath a low double-digit million-dollar range per cluster (*e.g.*, <USD 10 million). Low "ticket size" is one reason that financing institutions are generally disinclined to fund mini-grids. Unless several similar projects can be clustered, mini-grids do not meet the size requirements that financing institutions prefer to fund. The relative novelty of the technology and the mini-grid market itself also dampen interest among financial institutions. With inadequate information on the business model and associated risks, financiers lack confidence in the projects.

Technology. Typically a solar mini-grid system consists of PV panels, an inverter, supervisory control, switchgear and protection equipment, batteries, and a distribution network. Within hybrid power systems, diesel generator sets, or gensets, are dispatchable. They improve the quality of service and the security of supply because they balance the intermittent production of renewable energy technologies. In addition, diesel backups allow the mini-grid operator to fully charge the batteries at least once a month, thus increasing battery life. It is important to keep in mind that in developing countries, especially in rural areas, provisioning of fuel is an arduous and costly undertaking.

For a hybrid power system to be cost-efficient, its design must match production capacity with local demand. A trend to slightly oversize the PV generator

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has been observed to increase the life of batteries at similar LCOE or even lower. In the case of diesel generation sets, oversizing shortens the life of the engine. The higher rate of fuel consumption is also a factor, as diesel generation sets need to run at 60–80% capacity for optimal efficiency (Power Water, n.d.). Given the site-specific nature of the technology and the financial and technical implications of over- and undersizing, significant onsite data and optimization tools are required for system design. With technological advancements, new systems are more energy efficient, with smart supply-load management systems that are often main-grid compliant. Automatic communication systems, custom-made smart meters, and built-in load control all provide tailor-made solutions for customer billing and collection services. Earthspark International and Gram Power, for example, are using smart metering and pay-as-you-go and prepaid models to make their systems technically robust and financially attractive to the users.

Operation and management. Operators have a strong local presence, often involving communities in O&M to reduce costs and minimise downtimes. For instance, Mlinda conducts dedicated trainings for local technicians in the installation and operation of plants. Technology innovation can also play an important role in minimising costs associated with O&M, including tariff collection. Remote monitoring, in particular, can allow operators to observe clusters of mini-grids and develop centralised O&M capacity to bring down overhead, as well as transaction and logistics costs. In some cases, community ownership of certain assets is also preferred to protect against theft and vandalism.

Tariff design and collection method. Various tariff models have already been tried for solar or solar hybrid mini-grid systems in different regions of the world. Tariff design mainly depends on a country's regulatory framework. In an unregulated market, the private sector identifies the site and then develops and implements the projects, determining tariffs through negotiations with the end users. This approach gives operators the flexibility to design tariff schemes suited to a system's cash flow and a community's willingness to pay. The most common methods of tariff collection are pay-as-you-go, prepayment meters or load limiters, appliance-based tariffs, and fixed weekly or monthly tariffs.

OMC has a prepaid system based on subscription, where a rural consumer is charged a monthly rental of USD 2. Gram Power has also adopted a prepaid credit model for tariff design and collection. Local entrepreneurs purchase prepaid bulk energy credits from Gram Power, then wirelessly transfer the prepaid recharge into consumers' meters, again on a prepaid basis. The meter also has the ability to indicate the quantum of load operable for certain hours. For instance, around USD 1 could purchase 200 hours of compact fluorescent lighting or 50 hours of fan operation. Local entrepreneurs make a profit of around 10 percent on the overall sale of energy credits. In under-regulated environments, mini-grids may need to set tariffs per kWh on a consumed-energy basis, in accordance with the national tariff or at a level set through negoti-ations with the regulatory body (*e.g.*, AMADER in Mali). Different models for tariff regulation are dis-cussed in greater detail in Section 3.1.

2.3.3 HYDRO (RUN-OF-RIVER) (TIERS 1–5)

Small-scale hydropower plants are capable of supplying electricity 24 hours a day for all different tiers at a cost that is less than that of most other renewable energy technologies. Depending on capacity, run-of-river hydropower systems are usually classified into pico- (< 1 kW), micro- (< 100 kW), and mini- (up to 1 MW). Pico- and micro-hydro systems feed into an isolated grid to electrify remote rural areas, with possible future connection to the main grid if and when it arrives. Larger mini-hydro systems are developed in both isolated and grid-connected settings depending on local loads and proximity to national grids. Both micro- and mini-hydro systems have been deployed at

9. *Classifications of pico-, micro-, and mini-hydro vary from context to context. There is also no standard classifica-tional distinction between small- and large-scale hydropower. Different countries adopt different thresholds, rang-ing from 5 MW to 50 MW (in China).*

scale in several countries, demonstrating what works and does not work. Micro-hydro development has been particularly strong in South and Southeast Asian countries, such as Nepal, Indonesia, Malaysia, Myanmar, and Sri Lanka, where systems of tens and hundreds of kWs capacity have been widely deployed to expand electricity access. In Nepal, for instance, more than 1,400 micro-hydro plants are in place, accounting for close to 25 MW of total capacity. The plants can vary from anywhere between 12 kW to 140 kW, with the average capacity of plants added between 2011 and 2013 being 30 kW (World Bank, 2015).

In micro-hydro development, communities, in the form of cooperatives or community-based organisations, are known to play an important role in project development, ownership, and operation. In fact, most programmes are designed for communities to have some form of ownership stake in the systems. Other private entities active in the sector include local practitioners, nongovernmental organisations, and faith-based organisations. Given the small scale, and often the remoteness, of micro-hydro systems, the private sector has yet to fully engage in segments other than equipment manufacturing, site preparation, and installation. Much stronger engagement is seen in the mini-hydro space where the deployed capacity is large enough to provide economies of scale and more predictable cash flows. Such projects also often enjoy policy support such as feed-in tariffs and power-purchase agreements (PPAs).

Because much of the micro- and mini-hydro development takes places at a project-by-project level and because of the wide range of private actors involved, this section deviates from the approach adopted for other technology-tier combinations, where selected cases are analysed. Instead, this section addresses the different components of the micro- and mini-hydro deployment model while using specific cases as examples. These components are summarised in Figure 2.5.

Figure 2.5 Deployment model for hydro (run-of-river); tiers 1–5

Tier 0 | **Tier 1** | **Tier 2** | **Tier 3** | **Tier 4** | **Tier 5**

Ownership
- Strong community-ownership component with growing private participation, especially for larger mini-hydro projects

Site selection
- Excellent hydro potential throughout the year
- High population in a region that can be covered with a medium voltage grid

Financing
- Usually mainly grant funded with reserve accounts for turbine replacement and repair
- Option for non-recourse project finance especially if a large anchor customer is connected

Technology
- Construction and turbine prepared to last >20 years
- Main-grid compliant medium and low voltage distribution networks
- Flatrates, load limiters or pre-paid meters
- AC off-the-shelf appliances

Operation & management
- High project development cost and long process (ESIA, water rights, etc.)
- 24/7 electricity supply
- Often local management by community or by anchor load owner for distribution and professional operator for generation

Tariff design and collection method
- Regulated by authorities or through negotiations with the users
- Pay-as-you-go (PAYG)
- Pre-payment meters or load limiters,
- Appliance-based tariffs

ESIA = environmental and social impact assessment.

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Ownership. Diverse ownership models are seen for micro- and mini-hydro development. A number of nongovernmental entities, ranging from private enterprises to communities, are involved at different stages of project development. Eventually, ownership usually rests with the communities alone or together with a private entity (in a public-private partnership). The dominant role of community entities in the ownership and O&M of micro- and mini-hydro plants is considered a reasonably sustainable model that ensures continued operation among thousands of communities globally. There are several reasons for this. First, communities see great value in the social benefits arising from these projects, which are otherwise not financially attractive for the traditional private sector to invest in.[10] Second, community projects have the benefit of building local capacity in management and leadership. This capacity building is difficult to quantify. Nevertheless it remains clear that communities that together build and operate these projects also bond together. By building trust in each other, community members strengthen the community's collective ability to respond to adversity. This is vital for the sustainable operation of the small-hydro system, especially in the remotest of rural areas.

The community-ownership model is paving the way, moreover, for the private sector to play a greater role. A combination of factors is at work. First, community-owned systems developed under national and international programmes are financed primarily through grants or concessional public financing, with partial contributions from communities. There is limited technical capability at the community level, and the financing structures (discussed later) offer little incentive for community-owned systems to maximise productive uses or increase the load factors.[11] Tariffs are often set to recover the general expenses, leaving little for additional investments (*e.g.*, unscheduled repairs). Second, if and when the main grid reaches, the small-hydro systems are many times simply abandoned in the absence of additional investment to integrate with the grid.[12] Third, private sector involvement would allow of programmes that currently depend on public financing from governments or development. Finally, successful markets (in Nepal, Indonesia, and Sri Lanka, for example) have shown that, under the right conditions, local turbine manufacturing can thrive and in turn drive deployment of small-hydro solutions.

Site selection. Small-hydropower development is highly sensitive to physical site characteristics, including seasonal water flow rates, head (pressure), and the distance to load centres. The best geographical areas are usually hilly or mountainous regions with a continuous flow of water throughout the year. Wherever these conditions prevail and nearby demand is high, the hydro-powered mini-grid is preferred. Compared with other options (*e.g.*, diesel, solar), it is often the least costly way to expand electricity access (World Bank, 2015; ARE, 2014). Information about resource availability and physical sites is rarely available, however. Because of this, potential sites must be assessed individually, and each system designed for the local environment. Site selection, feasibility studies, preparation, development (*e.g.*, the design of weirs and penstocks), and installation are all resource intensive and have long lead times. The timeframe is also affected by regulatory requirements—the need for licenses, for example, or environmental and social impact assessments (discussed in detail in Chapter 3). For instance, most countries set conditions, such as weir height, that determine the regulatory requirements that projects must meet. These processes must be factored into the site selection and system design.

Financing. Micro- and mini-hydro plants are largely financed by grants from government programmes or through bilateral or multilateral development agencies, corporate social responsibility (CSR) programmes, or philanthropic organisations. The communities also

10. *Social benefits are not limited to energy access alone. Community hydropower projects often also include a watershed-management component in which community members work together to protect against deforestation and farming practices that increase erosion.*
11. *Building social capital and mobilization comes at a cost—up to 30% of the project cost in the case of REDP in Nepal.*
12. *Important to note is that some community-owned projects in Sri Lanka and Indonesia are interconnected with the national grid (PUCSL 2013).*

contribute financially or through in-kind contributions (*e.g.*, labour, material). In Nepal, a survey of projects supported by the Alternate Energy Promotion Centre (AEPC) showed that community support was nearly a third of the total capital expenditure, with the rest of the financing coming in the form of grants from various sources, including a subsidy offered under a government-led programme (World Bank, 2015). The government, together with other stakeholders, is trying to reverse this trend. It has begun some projects with revolving funds that pool financial resources to develop multiple micro-hydro projects. In some cases, the systems can be transferred for O&M to the local communities on a lease-to-own basis, paying back the cost of the system to the revolving fund, such as in Peru (Box 2.4).

Box 2.4 Revolving fund for micro-hydro: IDB-ITDG fund in Peru

In Northern Peru, more than 50 micro-hydro schemes have been deployed to provide electricity to around 5 000 families, averaging about 33 kW. About 40% of the cost of the micro-hydro scheme is paid by the community members, partly through a loan from the Inter-American Development Bank (IDB). Most schemes are run by a local management group, which sets a suitable tariff structure so that payments will cover O&M costs and loan repayment. A village micro-enterprise oversees the day-to-day O&M. The Micro Hydro Promotion Fund (MPF) was a revolving fund; IDB contributed USD 120 000 in 1992, followed by USD 300 000 in 2000. Generally, the MPF credit experience has been positive. Loans totalling USD 783,718 were made to partially finance the construction of 31 micro-hydro units up to January 2005. The MPF lent up to USD 50 000 per project (about 25–30% of the average investment cost), with a repayment period of up to five years. Average payback times were about three years, which results in high monthly instalments averaging about 13–14% of current municipal revenues. A longer repayment period substantially reduces the value of these instalments and reduces the risk of default.

Source: Practical Action, 2005.

The small size of micro-hydro projects, together with the higher risks associated with returns on capital investments, has hindered commercial financing. Some national programmes, as in Sri Lanka, have been able to leverage commercial financing for isolated, micro-hydro projects (Box 2.5). The experience of Myanmar is also interesting. There, local practitioners have self-financed community-owned projects, allowing communities to repay capital costs from tariff collection within about five years of commissioning. The technology has remained underdeveloped, however, in order to keep costs low enough to allow rural communities to self-finance (HPNET, 2015). This is one drawback of the approach.

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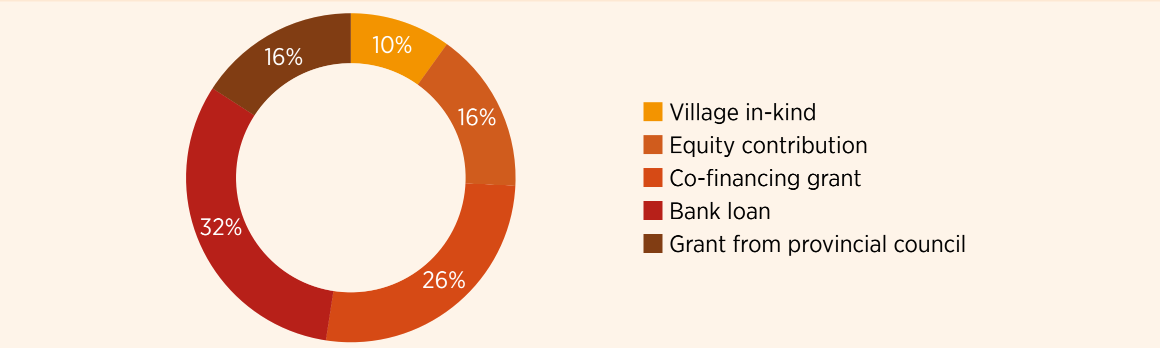
Box 2.5 Financing of micro-hydro plants in Sri Lanka

Most micro-hydro projects in Sri Lanka were supported by the Renewable Energy for Rural Economic Development (RERED) project funded by the World Bank's International Development Association (IDA) and the Global Environment Facility (GEF). Until its culmination in 2012, the RERED project had helped deploy more than 173 projects with an aggregated capacity of about 1,748 kW. Plant capacities of the micro-hydro schemes range from 3 kW to 50 kW, with 17 to 116 consumers. A project is built, owned, and operated by a society formed by the village consumers, called the Electricity Consumer Society (ECS). The ECS acts either as a registered company or a cooperative to access loan funds from a participating credit institution (PCI) (mostly private commercial or development banks and finance companies). Subject to meeting the PCI's assessment of creditworthiness, the ECS obtains medium- or long-term subloans from the PCI.

Two special dollar accounts (SDAs) are maintained at the Central Bank of Sri Lanka to deposit the proceeds of IDA credit and GEF grant. The credit in the SDA is used to refinance PCIs, which approve subloans to project beneficiaries. As the PCI disburses funds against the approved subloan amount, a loan disbursement request form is forwarded by the PCI to obtain a maximum refinancing of 80% of the amount disbursed. Release of grant funds is based on evidence of work done. Technical assistance funds are available for a project facilitator (a consulting company) to assess the water source, produce technical designs, and develop a feasibility study and a bankable proposal. Typically, these companies support the community from inception to project commissioning. This mediation is crucial for a project to get off the ground, as there is limited capacity at the community-level to initiate projects.

Figure 2.6 Typical distribution of capital by source



Source: DFCC, 2016.

Mini-hydro projects have typically been financed commercially; especially if they are backed by strong anchor loads and utility-backed PPAs, which make for more predictable cash flows, more bankable projects, and possible nonrecourse project financing. In Indonesia, for instance, feed-in tariffs are offered to mini-hydro projects (up to 10 MW) with operators signing PPAs with the local utility (Baker and McKenzie, 2015).

Privately owned and financed mini-grids require project financing approaches with long tenures and low interest rates in case no external collateral or guarantees are available. The financing demand for project development and equipment, per project site, typically falls beneath the single-digit million-dollar-range. Export credit agencies are known to play a role in mini-hydro project financing, helping equipment suppliers and developers source long-term concessionary credit to deploy projects in developing countries. But privately financed mini-grids lead to higher electricity-generation costs than plants financed largely through grants because the equity or debt needs to be paid back as well as the administrative cost and the risk assumed by the investors. Public-private partnership models are seen to overcome this challenge. In Indonesia, for instance, IBEKA (a not-for profit social enterprise) develops micro- and mini-hydro projects where low-income community members pay for electricity at the national tariff level (Box 2.6). The sales income (which must cover operating and maintenance costs) can be sufficient to attract private investment for a hydro plant—particularly from socially motivated investors who do not require a high financial return.

Box 2.6 Public-private partnerships: The case of a 120 kW micro-hydro system in Indonesia

Cinta Mekar, a 120 kW micro-hydro system, was developed through a public-private partnership. The total project cost was borne equally by three parties: a multilateral agency, a private company, and IBEKA. The plant is equally owned by the community and the private company. Mekar Sari Cooperative represents the community. The joint venture sells the electricity generated to PLN, the state-owned electricity company, under a power-purchase agreement at a fixed tariff (IESR, 2013).

Technology. Small-scale hydro mini-grids are generally designed to provide grid-quality AC power supply. The key components—waterway, penstock, powerhouse (turbine, load controllers), transformers, and transmission lines—all involve mature technologies. Although the technology is available, a principal challenge is to adapt it to local conditions. Efforts are underway in some markets to localise the fabrication, development, and installation of key components (*e.g.*, electronic load controllers). Where it is likely that the main grid will arrive in the near future, or where feed-in incentives are available (*e.g.*, Indonesia), additional investment could make systems compatible with the grid. In most other cases, especially for micro-hydro, the objective is to minimise development costs as much as possible.

The success of a micro- or mini-hydro systems relies heavily on the design and sizing of the system. Oversizing or undersizing the system, or inaccurate assessment of demand or willingness to pay, can all prove costly for the overall viability and sustainability. Sizing the system is tied particularly to resource availability across seasons. Micro- or mini-hydro production during dry months can be orders of magnitude lower than production during wet months. This means that, in addition to a robust resource assessment, community engagement is key. The system design process has to strike a balance between how much power can be generated over a year and what the demand is and is projected to become. It is easy to quantify existing demand; projected demand is largely unknown. Experience, not just from Nepal but also from Indonesia and Malaysia, has shown that in the short term, household demand increases substantially along with commercial loads (*e.g.*, agro-processing units of 7–12 kW) (World Bank, 2015). As a result, the plant cannot meet peak demand. In addition, the capital subsidy in Nepal is designed for systems providing 100–200 W/household. The system is designed for those load conditions. So technol-ogy options such as electronic load controllers are used against unregulated fluctuations in the load on the demand side. Otherwise, there is long-term damage to plant components and, ultimately, more regulation on the consumer side.

Regarding end-use metering, the technology depends on the tariff structures that are in place. Tier 1 and 2 customers use low quantities of energy, which complicates the amortization of costs associated with connection and in-home installation. When

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peak demand in the community exceeds the energy supplied by the power plant, operators try to regulate consumption by shifting towards load limiters and prepaid meters. With solar micro-grids, operators have more influence over consumer choice of end-use appliances. But micro- and mini-hydro customers can buy off-the-shelf AC appliances. The diffusion of appliances has a significant impact on the ability of the power plant to provide continuing levels of electricity services as households and rural enterprises move up the energy ladder, oftentimes quickly.

Operation and management. The plant O&M generally rests with community-based entities for micro-hydro systems and with private operators for mini-hydro plants. Local capacities need to be developed to undertake minor O&M of the system (*e.g.*, clearing debris from ducts) as well as basic troubleshooting. For IBEKA's systems in Indonesia, the operator visits twice daily to check the system, switch it on or off, and clear any debris from the intakes. Minor maintenance, such as greasing the bearings, is conducted weekly; major overhauls take place every three or four years. Grid-connected schemes usually have an onsite operator. Two or three people share the work (IBEKA, 2012). To the extent possible, expertise is localised to keep downtimes and maintenance costs low. Training is also provided to the community on household energy management.

The management of micro- and mini-grids is made particularly complex given the evolution of demand over time. An additional aspect to consider is that although systems may be unable to meet peak demand, the average plant load factors can be surprisingly low. In Nepal, for instance, the average load factor can be anywhere between 18% and 33% owing to negligible nonpeak demand. Raising plant load factors, thereby distributing costs over more kWhs, would require greater local development of commercial loads and productive uses. But such loads require reliable supply. Sometimes this dilemma can be resolved by connecting several mini-grids (Box 2.7).

From an O&M perspective, a significant challenge is restoring supply after unscheduled breakdowns. The remoteness of these plants makes them vulnerable to damage from extreme weather conditions. It is not uncommon, for instance, to see penstocks damaged by large boulders after a landslide or earthquake. In these cases, operators (usually the community) have to mobilise additional financial resources to undertake repair work because tariffs provide minimal cost recovery.

Box 2.7 The advantages of connecting mini-grids: The example of Nepal

In 2011, seven isolated mini-grids were connected together with combined capacity of 132 kW in Baglung, Nepal. Mini-grid connection vastly improved energy utilization over the day, increasing the plant load factor of these micro-hydropower plants from 42% to 67%. This cost-effective and sustainable power system encouraged local entrepreneurship, in turn improving several other socioeconomic dimensions. The community formed the Energy Valley Mini-Grid Cooperative and in time developed rules, regulations, and other legal documentation. This model enhances communal responsibility for project sustainability among the members or the beneficiary households. The executive body of the cooperative has ultimate power over the operation, maintenance, expansion of transmission and distribution lines, as well as for setting the power-purchase agreement rate, the tariff structure, and related issues (Pokharel *et al.*, 2013).

Tariff design and collection method. Several different approaches to tariff design are being adopted for isolated micro-hydro projects. These include consumption-based, flat rate, and wattage-based subscription tariffs. Charging a tariff based on consumption benefits all end-users equally, whereas flat rates usually benefit customers who can afford more appliances. A third approach is a wattage-based subscription tariff, which works like the flat rate but with different maximum consumption levels. Consumers who wish to have higher maximum consumption pay a higher monthly subscription fee. This is an effective way to charge for what is valuable in a hydro-based mini-grid system (power) and not charging for what is abundant (energy). It also saves on costs. As with other mini-grids, meters in small-hydro mini-grids are being designed to handle prepayment transactions and serve demand- and load-management tasks.

2.3.4 BIOMASS (TIERS 1–5)

Biomass resources are widely available in rural Africa and Asia, where the electricity-access challenge is concentrated. Agriculture and livestock production is a livelihood for most people in these regions, giving them access to a range of biomass feedstocks. These locally available resources represent an opportunity for mini-grid development. The technology itself is mature and scalable, ranging from several kWs to MWs, capable of supplying 24/7 electricity at tiers 1–5, meeting both basic and peak loads.

Biomass digestion and gasification are mature technologies used in mini-grids in South and Southeast Asia, with projects in other world regions as well. Husk Power Systems (EUEI PDF, 2015) and Desi Power (UN Foundation, 2014) are prominent examples. Both operate several biomass mini-grids in India (Box 2.8). Among other examples that could be cited is SME Renewables in Cambodia (SME Renewables, 2005). Mini-grids powered by sugar companies or timber mills (or other forest-product processors) are common in Africa.

The fuel component is a distinguishing feature of biomass-based mini-grids. The available feedstocks (type, amount, quality, and cost) determine the suitability and viability of the mini-grids, as well as the choice of technology and system design. For the biomass-powered mini-grid, sustainable access to fuel supply is an essential, and sometimes the most difficult, aspect of deployment.

Figure 2.7 presents an overview of the different components, with the remainder of the section analysing each in more detail. The three private enterprises analysed for this market segment are described below and in Table 2.4.

Figure 2.7 Deployment model for biomass mini-grids; tiers 1–5

Tier 0 | **Tier 1** | **Tier 2** | **Tier 3** | **Tier 4** | **Tier 5**

Ownership
- Private (BOOM), sometimes with entrepreneur ownership (BOM)

Site selection
- Large villages with high density
- Anchor loads preferred
- Clusters of villages to facilitate logistics
- Strong operator training component

Financing
- CAPEX subsidies to reduce tariffs
- Corporate or concessional finance

Technology
- Gasifier (5 kW to 1.5 MW); direct combustion (>1 MW); anaerobic digestion (>5 kW); biodiesel (>5 kW)
- Can involve pre-pay metering
- Standard AC appliance

Operation & management
- Fuel supply arrangements are key
- Minimize environmental impacts
- Local operator

Tariff design and collection method
- Regulated by authorities or through negotiations with the users
- Pay-as-you-go (PAYG)
- Pre-payment meters or load limiters,
- Appliance-based tariffs

BOOM = build, own, operate, and maintain;
BOM = build, operate, and maintain;
CAPEX = capital expenditure.

Box 2.8 Biomass gasification-based electrification in Bihar (India)

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Saran Renewable Energy Pvt Ltd. (Bihar, India) received the 2009 Ashden Award for replacing diesel generators with biomass gasification. The business model was to install gasification equipment with a dual fuel generator supplying up to 128 kW of electricity to small businesses, farms, and households in Bihar through a local grid spanning about 1.5 km. The plant costs were USD 170 000, about 90% of which was spent on the gasifier and generator and about 10% on the distribution line. The plant was financed by personal equity, a bank loan of USD 40 000 (INR 2 million), and a government subsidy. Paying off the investment (appr. 50%) constitutes the greatest part of the running costs, followed by fuel costs (35%) and O&M (15%). USD 0.04 per kg is paid to local farmers for supplying biomass, mainly stems of a locally grown tree named 'dhaincha'. To ensure proper ignition, gas from the gasifier is mixed with 10–15% diesel fuel. Customers are charged about USD 0.15 per kWh. With this tariff structure, the plant is expected to recover the capital costs within six years. Small-business customers who previously used electricity from diesel generators (including grain mills, cold stores, sawmills, welding workshops, and farmers) are crucial to the economic success of this plant. These businesses reportedly save 40% by switching to electricity produced from the gasifier.

Source: UNIDO, 2014; Ashden, 2009.

- *Husk Power Systems (India)* has nearly 60 plants in operation, each with a capacity of 25–50 kW and serving 200–600 households and 5–10 small businesses (including irrigation pumps) across 2–4 villages within a radius of 2 km.
- *DESI Power (India)* has developed six biomass-based mini-grids in India.
- *Pamoja Cleantech (Uganda)* develops biomass-based mini-grid projects in Uganda providing electricity at tiers 2–5.

Table 2.4 Selected biomass mini-grid case studies analysed in the report

Enterprise	Husk Power Systems	Desi Power	Pamoja Cleantech
Type	For-profit energy service company	Private developer	Private developer
Country of operation	India	India	Uganda
Systems implemented	~60 plants (2015)	6 mini-grids (2014)	2
Technology	Biomass gasification systems	Biomass gasifier-powered mini-grids	Biomass gasifier-powered mini grids
Tiers covered	Tiers 1–3[13]	Tiers 1–3	Tiers 2–5
Business model	Different models applied	Installing systems in communities with anchor businesses	Installing systems in communities with anchor businesses and small businesses
Sector regulation	Subsidies for biomass gasification projects, no clear strategy for grid interconnection; tariff regulation in India does not allow cost-covering operation for biomass mini-grids	Grants for capital cost required for feasibility	Systems below 100 kW exempted from regulatory tariff approval

13. Electricity is available for 6–8 hours a day to meet tier 1 demand for about 60% of the consumer base: two lights and mobile charging (30W). For the few consumers with higher demand (fans, televisions, refrigerators), Husk Power Systems supplies tier 2–3 power.

Ownership. Biomass-based mini-grids have various ownership models—private entities (*e.g.*, energy service companies, or ESCOs) or communities that own, operate, and maintain the systems, collecting tariffs for the electricity supplied. In some cases, the systems are owned and operated by different private entities, with the likely involvement of a local entrepreneur/operator. In fact, Husk Power System wholly owns most of the plants but also has a portfolio of plants under franchise or partnership agreements (Ashden, 2011). Additionally, Husk Power now also operates as an equipment supplier in East Africa, seeking other community-based enterprises to own and operate the mini-grid.

Site selection. Site selection for biomass-based mini-grids is largely determined by access to sufficient amounts of quality feedstocks and proximity to villages with enough aggregated electricity demand (SADC RERA, 2013). Because of the overriding need for sufficient available biomass, biomass mini-grids need detailed resource assessments—essentially a cropping-pattern study of agriculture in the area—in order to design a proper system. This resource assessment must take harvest cycles into account; some fuels may not be available during certain parts of the year. Biomass-based solutions have been deployed in both green-field and brownfield contexts (Box 2.9).

Box 2.9 Direct combustion of biomass in an island grid: The case of Mafia Island in Tanzania

On Mafia Island in Tanzania, the Ngombeni Biomass Project fires a 1.4 MW steam turbine with waste wood from a large, aging coconut plantation. Under a long-term power-purchase agreement, the project sells 1 MW of electricity to the national electric company, TANESCO, at TSH 490 per kWh ($0.22 per kWh). The electricity is distributed across the island by TANESCO's mini-grid and sold to about 8 000 retail customers at national uniform tariffs (TSH 60 per kWh if less than 50 kW per month; TSH 273 per kWh for electricity greater than 50 kWh) (TANESCO, 2016). Purchasing electricity from Ngombeni allows TANESCO to shut off its own expensive diesel generators during the daytime, saving TANESCO considerable amounts of fuel. The evening load exceeds 1 MW, so the utility switches the distribution system over to its large diesels. Diesel generation by TANESCO is estimated to cost TSH 819 per kWh (about USD 0.37 per kWh).

Source: EWURA, 2015.

Technology. Depending on the feedstocks and the capacity of the system, biomass-based power production can take different forms (Box 2.10). The technology itself, while mature, has relatively higher O&M requirements compared with, for instance, solar. In addition, small-scale gasifiers are known to be ill-suited to the variable loads offered by mini-grids.

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Box 2.10 Biomass-to-electricity conversion processes

Biomass gasification a thermo-chemical process in which biomass materials, such as rice husks and wood waste, create "producer gas." The producer gas, in turn, is cooled, cleaned, and piped to one or more internal combustion engines. Biomass gasifiers are available as small as 5 kW and can reach MW scales. Gasifiers require frequent maintenance because of tar and residue buildup.

Direct combustion/steam turbine is the combustion of biomass in a boiler to create steam that turns a turbine. Steam turbines are cost-effective at scales of 1 MW or more and are therefore suitable only for larger mini-grids. Maintenance requirements are generally lower than those of biomass gasifiers, and they accommodate a range of fuels: rice husk, wood waste, empty bunches of oil palm fruit, and so on.

Anaerobic digestion is the decomposition of organic waste to produce biogas, which is used to power a modified engine. Digested sludge from the digester can generally be used as a fertiliser. The simplicity and modularity of design, construction, and operation, as well as the many uses for the biogas product, make this technology well-suited for rural applications. Typical feedstocks in off-grid applications are livestock wastes (*e.g.*, manure) and waste from agricultural processing, such as palm waste or effluents from palm oil mills , tapioca factories, and distilleries (REAP, 2014).

Biodiesel from nut and seed crops is burned in a diesel generator. Biodiesel is commonly made from coconut (copra) oil, soybean, palm, and seeds from the Jatropha curcas plant, as well as from used cooking oil. Biodiesel can be used in pure form or blended with diesel for use in small- and large-capacity systems.

Financing. Small-scale biomass mini-grid projects are generally financed through a mix of project-level and corporate financing. Husk Power System managed to raise a grant of USD 2 million, equity from several investors totalling USD 6.65 million, and debt of around USD 750 000. The company receives subsidies from the Indian government of USD 7,100 per system (EUEI PDF, 2015). In Cambodia, biomass gasifier developer SME Renewables received funding for initial projects from the Canada Fund and USAID. After receiving equity investment through E+Co, the company was able to offer competitive five-year financing for turnkey projects (SME Renewable Energy, 2016). SME installs rice-husk gasifier systems for commercial clients (rice mills, etc.), which power commercial loads, and for projects funded by grant organizations, including the Energy and Environment Partnership and the Centre d'Etude et de Développement Agricole Cambodgien.

The price of feedstocks poses business risks for the biomass-based mini-grid. In several cases, the price for biomass feedstocks for gasifiers is steadily rising because of higher demand on the part of mini-grid operators and other users. Crop yields fluctuate from year to year, and dry spells or heavy rainfall further affect prices for biomass feedstocks. There are no standardised schemes available yet to hedge this risk, but improved agricultural models (technology and management) may help to stabilise prices (ARE, 2015). Appropriate risk mitigation strategies could be:

- Establishing close relationships to local biomass sources
- Creating dependency by offering feedstock suppliers with, for example, waste ash to use as fertiliser (see Box 2.11)
- Offering bargain prices for electricity to biomass suppliers in return for biomass.

Box 2.11 Risk-mitigation strategies for biogasification: The case of Novis in Senegal

A cooperative project involving a 32 kW biomass gasifier provides 24/7 electricity to 1,200 villagers of Kalom in Senegal. The Stadtwerke Mainz Foundation: Energy for Africa, owns 70% of the project, and another nine local owners hold 2–5% each. The use of biomass has established a new market, as biomass becomes a valuable good. Twelve hundred villagers benefit from the electrical power, improving their livelihoods and supporting micro-entrepreneurship. The by-product of electricity generation, known as biochar, is used to fertilise nearby farms. By creating downstream linkages for a by-product that has productive uses, operators indirectly reduce the risk of nonpayment. And by involving local stakeholders in different phases, the project has encouraged social acceptance. The project has also generated seven direct jobs in the village, as local staff have been trained for daily operations, maintenance, and accounting.

Source: ARE, 2015.

Operation and management. Biomass mini-grids have high O&M requirements because of issues related to fuel quality and quantity as well as environmental concerns.

- Fuel quality and quantity. Developers that do not own the fuel source must arrange a credible long-term supply, either through long-term agreements (>3–5 years) or some other means. Many schemes remain at the pilot stages (*e.g.*, Zambia) (GVEP, 2011). Some biomass fuel supplies (*e.g.*, rice husks, sugarcane) are seasonal, and alternative fuel supplies for the off-season must be compatible with the project's gasifier, boiler, or digester technology. The plants of Husk Power Systems, for example, have a typical capacity ranging from 25 to 50 kW. Each 32 kW gasifier requires approximately 50 kg of rice husks per hour or 12 000 kg rice husks per month, assuming eight hours of operation per day. The company tries to source fuel from within a radius of 10–20 km from its plants (EUEI PDF, 2015).
- Environmental protection. Biomass power, even at mini-grid scales, involves risks to the environment, which developers need to heed. Fuel collection must avoid excessive impact on local forests. Biomass power projects need to be operated in ways that minimise pollution, including airborne particulates and liquid and solid effluents.

Maintenance of biomass combustion equipment can be significant, especially with biomass gasifiers. Gasifiers are particularly sensitive to variations in fuel quality (levels of moisture and size of the fuel units). The gasification of agricultural residues usually produces a good deal of ash waste. The gas produced through biomass gasification usually contains unacceptable levels of tar, causing environmental and process-related problems. Tar from fuel gas condenses at low temperatures, and the residue then corrodes, erodes, and abrades engines and turbines. In addition, the removal of by-products such as hot gas particles, alkali, chlorides, and ammonia is costly and has a significant effect on the economy of the system. If environmental and technical standards are not enforced, these pollutants are improperly discarded. The daily operation and handling of these by-products require trained and skilled manpower. Taken together, these maintenance issues have proved to be major barriers to the deployment of biomass gasification.

2.3.5 WIND AND WIND-HYBRID AC (TIERS 2–5)

The use of wind power for mini-grids remains an underutilised technology. A key reason is the intensified competition between solar and wind-based solutions for powering isolated mini-grids. Rapid decreases in the cost of solar technologies, combined with solar's modularity, no moving parts and a better understanding of resources, have meant that mini-grid developers often prefer solar over wind-based solutions. Another reason has to do with physics: because captured wind power depends on the swept area of the rotor, the doubling of wind-turbine blade length quadruples the amount of wind power generated. This leads to engineering economies that favour large wind turbines.

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Despite a market trend towards larger grid-tied systems, off-grid applications, such as telecommunication stations, offshore generation, and hybrid systems with diesel and solar continue to play an important role in remote areas of developing countries (WWEA, 2016). Hybridisation, in particular, is emerging as a key market for small-wind growth driven by incentives to reduce diesel fuel use or to provide electricity services at higher tiers. Hybrid mini-grids combining electricity generation from different renewable-energy sources with diesel generation have the potential to slash energy costs (Frankfurt School—UNEP, 2015). In areas with strong and consistent resources, wind power is being integrated into particularly large mini-grids (hundreds or thousands of kW of load), as well as in remote areas at high altitudes where solar electricity is precluded by long, dark winters.

Wind and wind-hybrid systems can provide electricity services across all tiers, with tier 5 the most prevalent, because wind turbines are generally installed in large mini-grids that run diesel generators and/or solar systems that are already providing tier 5 service. Given the limited knowledge base on the deployment of small-scale wind for electricity access, this section touches on the literature covering key aspects of the deployment model in diverse settings. Figure 2.8 presents an overview of the different components of the deployment model; the rest of the section analyses each component in more detail.

Figure 2.8 Deployment model for wind and wind-hybrid mini-grids; tiers 1–5

Tier 0 | **Tier 1** | **Tier 2** | **Tier 3** | **Tier 4** | **Tier 5**

Ownership

- Generally conventional isolated rural electrification utility (state utility, investor-owned utility or cooperative)

Site selection

- Requires at least one year of anemometer data collection to prove local resource
- High and steady wind speeds, high price of diesel fuel
- Economies of scale favor larger mini-grids (hundreds of kW of typical load)

Financing

- At this stage of industry development generally requires grant component
- Financed using debt and equity channels available to utilities

Technology

- Integrated with existing diesel generation
- Low penetration requires few modifications
- Medium penetration requires advanced controls, synchronous condensers, dispatchable loads
- High penetration requires all of the above plus storage able to respond rapidly to changes in wind power output levels

Operation & management

- Maintenance not frequent but requires special skills and equipment for climbing or lowering towers

Tariff design and collection method

- Regulated by authorities or through negotiations with the users
- Pay-as-you-go (PAYG)
- Pre-payment meters or load limiters,
- Appliance-based tariffs

Ownership. Most rural mini-grids utilising wind-power are operated by traditional small-scale utilities in remote areas that have added wind turbines to cut the fuel costs of their diesel generators or by community-operated, grant-funded projects. Wind turbines have also been added to diesel-powered mini-grids by utilities in Indonesia, Fiji (Mario, 2009), Bonair (Bunker, 2015), Vanuatu (UNELCO Engie, 2015), and the Falkland Islands (Falkland Islands Government, 2015) (Table 2.5). In Alaska, ten mini-grid cooperative utilities use wind power. These projects have received support from the U.S. government and from the Denali Commission, an agency of the Alaskan state government (Baring-Gould and Dabo, 2009).

Table 2.5 A sample of wind-diesel hybrid mini-grids

Village name	Country	Year installed	Wind kW	Solar kW	Diesel kW	Main stakeholder	Status
Nusa Penida	Indonesia	2006	800	80	3 650	State utility	Wind no longer functioning
Nabouwalu	Fiji		53.6	37	200	State utility	Wind no longer functioning
Nazareth	Colombia	2010	425			Government implemented	Wind no longer functioning
Port Vila	Vanuatu		3 025		>5 000	Investor-owned utility	Operating
Kotzebue	USA		915		11 000	Cooperative utility	Operating
Stanley	Falkland Islands		1 980		6 600	State utility	Operating
Bonair	Bonair		11 000		14 000	State utility	Operating

A few nonprofit organizations and mini-grid-specialized ESCOs have entered the field, either building new wind-powered mini-grids or retrofitting existing brownfield sites. In India, for instance, Practical Action partnered with Gram Vikas to develop wind-solar hybrid energy systems that cater to 60 households in two villages in the Indian state of Orissa (Box 2.12).

Box 2.12 Small wind-solar hybrid energy systems in India

Practical Action partnered with Gram Vikas to establish small wind-solar hybrid energy systems in the rural areas of Kalahandi district in the Indian state of Orissa. This project is designed to fulfil the light-ing requirements of every household in the two villages. Each of the 60 households (35 in Kamlaguda village and 25 in Tijmali) now have two light bulbs and one charging point for mobile and other acces-sory charging.

In developing the project, the community came together and agreed to operate and maintain the systems in the future. Separate committees and bank accounts have been formed in each village. Each household pays agreed user fees to the village committees (Kamlaguda, INR 60, or USD 0.9, per month; Tijmali, INR 30, or USD 0.45, per month) towards the operation and maintenance costs. The project has succeeded in transferring skills so that the community can now fabricate and install the wind-solar hybrid system independently.

Source: Practical Action, 2014.

Government-funded or CSR wind-hybrid projects are not uncommon. In Colombia, hybrid wind-diesel or wind-solar-diesel mini-grid projects account for over 2% of off-grid electricity. USD 152 million for these projects came from the Instituto de Planificación y Promoción de Soluciones Energéticas para las Zonas No Interconectadas (IPSE) (Rodriguez, 2012).[14] A couple of greenfield wind mini-grid projects have been installed in Nepal under a collaboration between the Asian Development Bank and Nepal's AEPC (ADB, 2014; Kathmandu Post, January 6, 2016) (Box 2.13). In Argentina, a CSR project installed a wind-diesel hybrid system near the remote Patagonian town of Chorriaca (GSEP, 2013).

Box 2.13 Community-operated wind-hybrid systems in Nepal and Malawi

The Wind-Solar Hybrid Energy Project, implemented in Bhorleni, Nepal, by the Alternative Energy Promotion Centre (AEPC) has an installed capacity of 25 kW (10 kW wind and 15 kW solar). The project provides electricity to a village with 131 households. The 25 kW hybrid system was installed in 2015 at an estimated total cost of USD 120 000, with AEPC providing USD 90 000 and the community contributing USD 20 000 in cash and USD 10 000 in labour (sweat equity) and fixed assets. It is the country's first wind-solar pilot project, and AEPC has handed over responsibility for system operations and management to the local consumer committee.

In 2007, the Malawi government, through its Department of Energy, implemented a hybrid system (60% solar and 40% wind) in Ulunyeni to provide electricity to unelectrified villages. A total of 150 households benefited from the system, the total cost of which, for each village, was approximately USD 150 000). The project is managed by the community through a committee; the Department of Energy provides technical services. Each household has five lighting points and one socket outlet and pays a minimum of MWK 200 per month (about USD 0.56) towards security for the system and the salary of the operator. The system is also used to run a water pump to meet basic needs.

Source: Pandit, 2015; UN, 2013.

Site selection. Wind and wind-hybrid mini-grids need stable wind speeds of above 5m/s at a height of 30 meters for the turbines to produce electricity cost-effectively. Power output depends on stable wind speeds. Because power varies with the cube of the wind speed, a turbine that produces 25 kW at 5 m/s will produce more than 40 kW at 6 m/s (and vice versa). Proper site selection is thus a key requirement. In general, suitable wind conditions can be expected in regions above a certain latitude on the coast or on islands (ARE, 2012). If data on wind speed and wind direction are unavailable, wind measurements become necessary. These wind assessments are best carried out over at least one year in order to map seasonal variations; this remains a key disadvantage of wind compared with solar.

Financing. Financiers see a high resource risk in wind mini-grids above and beyond the demand risk that exists in every greenfield mini-grid. Wind assessments contribute to high project-development costs, especially for small projects. Thus far, most wind mini-grids add wind generators to existing (brownfield) diesel mini-grids with known demand-load curves, reducing at least one element of risk. Risks posed by hurricanes, storms, and lightning strikes are significant. Vanuatu's wind installation helps mitigate this risk by using tilt-up towers for its turbines.

14. *The wind portion of the IPSE flagship, a 425 kW wind-diesel hybrid project in Nazareth, Colombia, installed in 2008, is no longer functioning (García, Trujillo, and Guacaneme, 2015).*

The small wind mini-grid industry is still under development, and economies of scale will further reduce manufacturing costs. This, in turn, will make small wind mini-grids more cost-competitive with diesel generators in developing countries. At present, greenfield wind-based mini-grids require subsidy schemes because of the cost structures and the risks.

Technology. Wind-based mini-grids typically utilise small to medium-size wind turbines (up to 250 kW). The majority of small-scale wind turbines are built on freestanding poles or towers. Wind tower height is a crucial variable, as winds are generally stronger and more reliable at greater heights. A common tower height for small wind turbines is 25 meters (80 feet) or more. A rule of thumb employed in the small-wind industry is that the wind turbine hub for turbines under 20 kW must be at least 30 feet high (10 meters) (Woofenden and Butler, 2015).

Considering the extreme environment in which wind turbines are installed (high on a tower in the windiest environment possible) reliability is enhanced by having as few moving parts as possible. Direct drives that allow power production without a gearbox are best. Most small wind turbines (below 50 kW) use direct-drive generators, whereas many medium-size wind turbines (from 50 kW to 250 kW) rely on induction generators and gearboxes (ARE, 2012). These type of generators produce alternating current (AC), which must be converted to DC for battery charging. Wind turbines below 10 kW are connected to a DC bus for charging batteries (Corbus *et al.*, 2003).

Like solar electricity, wind power is intermittent. Mini-grids that utilise wind turbines must therefore also use fossil-fuel generators (generally diesel) or battery storage, or both (Bhattacharya, 2015). Larger turbines connect on the AC bus and must therefore run synchronously with any other AC sources present, such as fossil-fuel generators and inverters. In village-scale wind-diesel hybrid systems, diesel generators are often run 24 hours a day, and the wind power is employed to reduce diesel fuel consumption when the wind resource is available (Box 2.14). Adding solar to create solar-wind-diesel hybrid systems can provide further benefits, especially if solar and wind power alternate seasonally (solar in summer, wind in winter) or daily (strong, consistent winds at night), but will present additional technical challenge for mini-grid supervisory control. (Bhattacharya, 2015). In this way, parallel use of two intermittent renewable resources decreases the overall intermittency of renewable-energy generation.

Box 2.14 Brownfield integration of wind: The case of Phu Quy Island, Vietnam

Phu Quy is an isolated island in Vietnam's Binh Thuan province, about 120 km southeast of Phan Thiet city. Living on the island are about 27 000 people in 3,293 households. Their main economic activities are fishing and agriculture. Previously, power for the island was generated solely by the diesel plant. The total capacity of the generators was 3 MW — 6 diesel generator units with a capacity of 500 kW each operating 16 hours a day. The production cost of the energy was 24 USD cents/kWh. Because of frequent interruptions and outages and plentiful wind, wind power was integrated at the site.

The project was funded by the Petro Vietnam Power Corporation (PV Power ER). Construction began in 2010 and was finished in September 2012. Six MW of wind power were installed, an amount that covers 80% of energy demand. The total investment was USD 17 million (VND 335 billion). Currently, households are paying 1,863 VND/kWh (9 USD cents/kWh) for domestic use (for the first 50 kWh/month), and business users pay VND 2 329 – 3 105/kWh (11 – 15 USD cents/kWh).

Source: SNV, 2014.

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Low wind energy penetration (less than 50% instantaneous load) generally requires little or no modi-fication to diesel controls. Medium penetration (50% to 100%) requires measures to ensure voltage and frequency stability (including the ability to curtail wind power), dispatchable loads, and special electronic or electro-mechanical systems to enable low- or zero-load operation of the diesel. High penetration wind (100% to 400% of instantaneous load) allows diesels to be shut off completely at times, but requires the measures just mentioned, as well as an integrated network managed by advanced system controls, which may include a synchronous condenser (for voltage stability), load banks, dispatchable loads, power converters, and possibly storage in the form of batteries or flywheel systems (Baring-Gould and Dabo, 2009).

Operation and management. Battacharya (2015) identified that the main challenges for the small wind mini-grid sector in developing countries are competition with diesel and PV systems, cost reduction through economies of scale, creating customer awareness, and gathering a year's worth of wind-resource data. High maintenance and associated administrative capacity have proven problematic in some village mini-grids (Mario, 2009).

Challenges for long-term operation of wind-hybrid micro- and mini-grids are the availability of spare parts and qualified personnel for maintenance and repairs. Small and medium-sized wind turbines require regular light maintenance (once or twice a year) such as greasing; visual and audio inspection; verification of guy wires, bolts, and screws; as well as some heavy maintenance (every couple of years), including refurbishment of rotor blades and replacement of guy wires (ARE, 2012).

2.4 CONCLUSION

This chapter has shown that renewable energy–based mini-grids using an array of technologies are being deployed in different contexts and geographical locations to provide electricity services across all tiers of access. In most cases, they represent the least-cost option for expanding certain levels of electricity access in rural areas and offer the opportunity to reduce costs and environmental impact when integrated with existing fossil-fuel-based mini-grids. The business models accompanying these technology solutions and tariffs also vary.

Solar-powered DC mini-grids, which tend to be owned and operated by the private sector, deploy agile, scalable systems to provide initial-tier services. Larger solar mini-grids, and those powered by biomass, are providing round-the-clock electricity of sufficient quantity for productive use, while taking advantage of the scalability of solar electricity to grow as loads increase over time. Continuing cost reductions in battery storage will further catalyse the development of these mini-grids. Small-hydro mini-grids are bifurcated, with many built as community owned or managed projects, while others are developed with the involvement of private enterprises. Adding wind power to hybridise existing diesel–renewable energy mini-grids is increasingly common as a way to reduce fuel and storage costs and to scale up electricity service.

Each type of mini-grid system described above could play a specific role in a given country's rural electrification strategies for achieving the SE4All targets. Combined with individual stand-alone solutions, they could meet a substantial share of the additional generation needed to reach universal access to electricity in a timely and sustainable manner. This effort benefits from increasing involvement of the private sector, which requires, in turn, a policy and regulatory framework tailored to the local context.

The technologies and scales discussed in this chapter also raise various implementation issues that often must be anticipated in regulations. Micro-hydropower projects need to be built in ways that do not unduly affect other water users; they also require assurances that the supply of water will not be diverted for other purposes. Solar PV technology, which typically

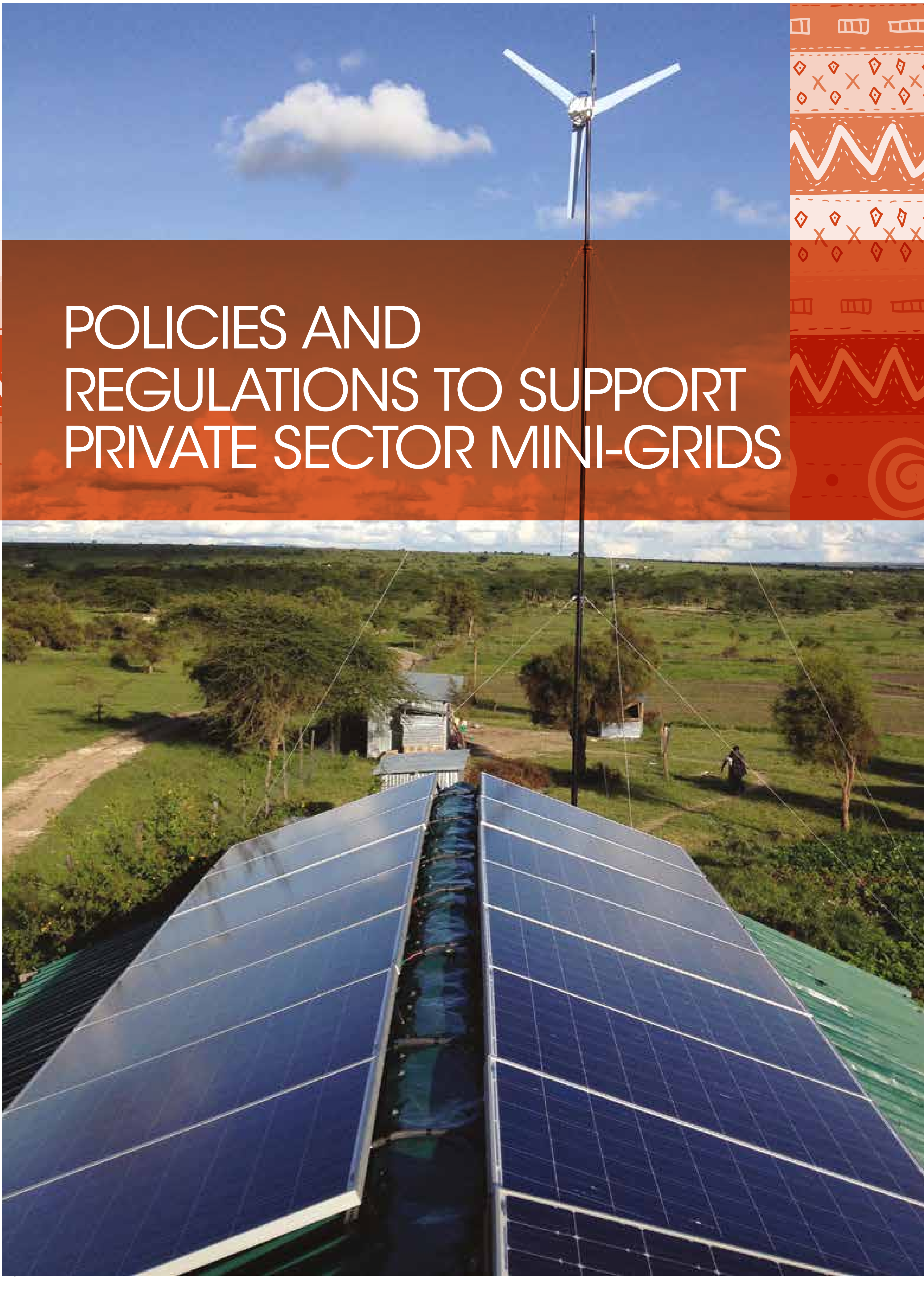
15. Instantaneous penetration of wind turbines in mini-grids is defined as the wind turbine power output (kW) divided by the primary electrical load (kW).

uses lead-acid batteries, requires adequate end-of-life management. Biomass projects raise particular concerns about the supply of fuel, and communities have the right to be protected from the environmental impact of the combustion of those fuels and disposal of the subsequent waste products.

Unlocking capital for mini-grids at different scales requires regulations that mitigate the risks of specific elements of the projects, including those associated with licensing provisions, cost recovery and tariff setting, and main-grid arrival.

Regulatory frameworks for mini-grids need to play a balancing role between protecting the investors' interest and those of consumers and their environment. What constitutes that enabling framework is discussed in the next chapter, while the final chapter outlines how some regulators are maintaining the necessary balance of interests.

POLICIES AND REGULATIONS TO SUPPORT PRIVATE SECTOR MINI-GRIDS



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Development of the mini-grid sector depends on the right policy and regulatory environment. If that environment is to support private sector involvement, it must fulfil certain general conditions as well as specific conditions related to various combinations of technology and access tier.

Mini-grids powered by renewable energy have been deployed on a project-by-project basis for decades. Since the mid-2000s, however, governments have shown increasing interest in accelerating their development; several have introduced dedicated measures to promote them.

With time, substantial experience with the policy and regulatory requirements for mini-grids has been accumulated. That experience has been translated into national, regional, and global analyses. Notable examples include the World Bank's *From the Bottom Up: How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa (2014)*, Africa-EU RECP's *Mini-Grid Policy Toolkit (2015)*, and the work on framework conditions for green mini-grids done by the Regional Electricity Regulators' Association within the Southern African Development Community (SADC RERA, 2014).

There is a growing consensus on key policy and regulatory conditions for supporting private sector involvement in the mini-grid sector (Box 3.1). The conditions fall into the categories of legal and licensing provisions (Section 3.1), cost recovery and tariff regulation (Section 3.2), the risks posed by arrival of the main grid (Section 3.3), and measures to facilitate access to finance (Section 3.4). But not all apply equally to all types of mini-grids, and policy making can benefit from a deeper understanding of the sensitivities of particular combinations of technologies and tiers of access. Section 3.5 of this report assesses the influence of policy and regulatory conditions on the various mini-grid approaches discussed in the previous chapter.

Box 3.1 Key policy and regulatory conditions for private sector participation

1. The generation, distribution, and sale of electricity by private firms must be legal. Licenses and permits should be obtainable within a reasonable time and at a reasonable cost.
2. Private mini-grid developers, operators, and investors must be allowed to recover costs for sustainable operation and within a reasonable time and at margins commensurate with risk.
3. Regulations must address the risk to mini-grids created by the arrival of the main grid.
4. Measures should be taken to facilitate access by mini-grids to affordable finance.

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3.1 LEGAL AND LICENSING PROVISIONS

If the private sector is to have a significant role in mini-grid development, it must have the legal right to develop projects, generate power, distribute and sell electricity to end-users. Broadly, this encompasses the requirements for forming a company; leasing or owning land; and acquiring building permits, water use rights, and licenses to generate, distribute, and sell electricity. Obtaining the required licenses and permits can be a lengthy, costly and risky process. In some cases, licensing costs can exceed 10% of a project's capital costs (ESMAP, 2016).

Processes and procedures related to mini-grid development typically receive low priority with public authorities, given the small size of projects and their seemingly low ratio of impact to effort (from the authority's perspective). Sluggish responsiveness, excessive bureaucracy, and undue complexity can cause delays and long lead times during project development. Where a dedicated legal framework for mini-grids exists, the procedures are often unclear and the institutional capacity to implement and administer policies and regulations is often lacking. National business and property laws often cause additional complexities when investment comes from abroad.

From the perspective of the developer of a mini-grid project, these issues increase costs, uncertainty, and risk. And although there is no single 'right way' to create an enabling legal and licensing environment, some general design principles can be adduced from recent policy developments and stakeholder consultations. Chief among these are clarity in processes and roles, streamlined regulatory requirements, and specific (or targeted) licensing arrangements.

3.1.1 CLARITY IN PROCESSES, PROCEDURES, AND INSTITUTIONAL ROLES

Clear processes and procedures for acquiring needed licenses and meeting regulatory requirements removes a key barrier to market entry. Such procedures often fall in a grey area of the regulatory framework—the grey area between grid operators, independent power producers (IPPs), and electricity suppliers—which complicates the task of public institutions (Practical Action, 2016). For that reason, dedicated guidelines and licensing procedures for mini-grids are welcome, along with efforts to publicize the information (Box 3.2).

The guide to mini-grid licensing in Kenya put out by GIZ, the German development agency, and the Ministry of Energy and Petroleum's (GIZ, 2015) is a good example of how such information can be made more accessible. Tanzania's mini-grids information portal (minigrids.go.tz) also provides comprehensive information for investors on licensing requirements, financing, and GIS maps. The site offers a library of laws and policies, reports, forms, tariff standards, and technical guidelines.

Box 3.2 Addressing market information barriers

Private firms interested in mini-grid opportunities often have difficulties finding information on (i) pertinent laws and regulations; (ii) licensing requirements, procedures, documentation, and fees; (iii) benchmark project-development costs in off-grid areas; and (iv) local socioeconomic indicators and the current state of energy access, including populations, income levels, the primary source of lighting, and so on.

Bridging this information gap will encourage more actors to enter the market. In this regard, public institutions such as rural electrification agencies, can play an important role by identifying suitable mini-grid sites in consultation with other actors, including those responsible for grid extension. Preliminary work of this kind would reduce the burden on private developers to conduct resource-intensive tasks, including site appraisals, demand assessment, and community engagement.

The institutions involved at each stage of the licensing process vary from country to country. In some countries, such as the Lao People's Democratic Republic, Thailand, and Tunisia, the public utility takes the lead in developing and implementing mini-grid programmes. Where national utilities are not actively engaged in mini-grid development, other institutions, notably rural electrification agencies

(REAs) have been created. The presence of an institution that exists for the express purpose of coordinating stakeholders, documenting processes and procedures, managing the project approval process, delivering capacity building, and facilitating the administration of financial and other incentive schemes is welcomed by mini-grid operators. REAs exist in several countries in Africa and other regions. Examples include Nepal's Alternate Energy Promotion Centre (AEPC) and the Rural Electrification Board in Bangladesh (Box 3.3).

Box 3.3 The role of institutions responsible for rural electrification

Dedicated rural electrification agencies (REAs) provide higher visibility for rural electrification as a policy goal and, hence, attract the attention of key public and private actors, including investors.

There are multiple viewpoints on what should be the mandate of REAs. Some would prefer to have them focus exclusively on the off-grid market segment, as grid-based solutions are often handled by traditional utilities. REAs can make targeted efforts to scale up the development of off-grid solutions and deploy rural electrification funds and other tools to create an ecosystem that will attract the participation of the private sector.

A contrary view is that REAs should be all-inclusive agencies responsible for on- and off-grid electrification alike, thus mainstreaming off-grid solutions, at least institutionally. The fact that Tanzania's REA embraces both electrification approaches has made possible a levy on all electricity sales and the use of some of the revenue (together with donor funds) to fund off-grid development.

A key concern raised in stakeholder consultations is that REAs sometimes deviate from their intended role as nodal agencies for the development of off-grid solutions and end-up focusing on grid-based solutions. This may be an institutional problem, or it may be related to the conditions and expectations of donors (*e.g.*, maximising the number of connections). It is important that nodal agencies dealing with rural electrification actually serve their mandate in accordance with a national electrification master plan or strategy that outlines the role of both grid-based and off-grid solutions.

In Africa, 30 rural electrification agencies and similar bodies have come together in the Association Africaine pour l'Electrification Rurale (African association for rural electrification), or Club-ER (http://www.club-er.org/en/) to accelerate the pace of increasing rural access to electricity.

In general, the fewer the institutions involved in the project-development phase, the more attractive the market becomes for the private sector. To give a sense of the challenge, the first greenfield 4 MW small-hydro project in Tanzania required approximately 27 permits, licenses, or agreements (Rift Valley Corporation, 2013). An increasingly common approach is establishing a single-window clearance facility hosted at an existing public agency such as an REA-like body. A single window can help reduce transaction costs and speed up licensing processes. In the Indian state of Uttar Pradesh, for example, the Mini-Grid Policy of 2016 establishes that the Uttar Pradesh New and Renewable Energy Development Agency (UPNEDA) will 'act as the nodal agency for single-window clearance for all mini-grid projects, which include[s] the task [of issuing and facilitating] desired Government orders, necessary sanctions/permissions, clearances, approvals, consent, etc., in a time-bound manner' (UPNEDA, 2016).

3.1.2 STREAMLINED REGULATORY REQUIREMENTS TO REDUCE COSTS

Regulatory requirements need to strike a balance between ensuring that only serious actors participate in the market and affordable compliance, particularly for new entrants. As a general guideline, fees and other development costs should not exceed 1–2% of

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the total costs of the project (SADC RERA, 2013). The cost of obtaining some permits outside the electricity sector permits (*e.g.*, environmental impact assessments, water-rights licenses) does not scale linearly with project size (Box 3.4).

Box 3.4 Non-electricity sector permits in Zimbabwe

Although the Zimbabwe Energy Regulatory Authority (ZERA) exempted projects under 100 kW from licenses and permits, other agencies such as the Environmental Management Agency (EMA) and the Zimbabwe National Water Authority (ZINWA) imposed charges that affected the viability of low-impact, small renewable energy projects (SADC RERA, 2013). EMA, for instance, charged 1.5% of the total project value to evaluate the environmental impact assessment and issue a certificate. This, added to independent consultant fees, pushed the total cost of compliance up to 6.5% of the project budget (SADC RERA, 2013). In an effort to improve the ease of doing business and reduce administrative costs, the EMA has reduced the environmental impact fees from 1.5% of project cost to a sliding scale, with the smallest projects paying a fee of USD 210, larger projects paying 0.8% of project cost, and high-impact projects paying 1.0 %. Projects of very high impact would pay 1–2 % of the total project cost (Black Crystal Consulting, 2016).

Mini-grids of varying sizes cannot be regulated in the same way. For that reason, a segmented approach to regulatory requirements for mini-grid projects is increasingly preferred. The segmented approach is based on the capacity of the project (in the case of licenses and permits) and its impact (in the case of environmental and resource permits). In Tanzania, for instance, mini-grids with a capacity of less than 1 MW need not apply for a generation license (GIZ, 2016).[16] The regulatory framework in Rwanda categorizes mini-grids as large, medium, small, and very small, imposing different licensing requirements in each case (RURA, 2015). Namibia uses 500 kW as the cut-off for applying for a license, while several countries, such as Zimbabwe, use 100 kW. In some countries the regulators use simplified registration for systems under a specific capacity. Registration, unlike licensing, is solely for information purposes (Tenenbaum *et al.*, 2014). The process is meant to give the private sector a degree of assurance from the government side, while helping create a central database of mini-grids. In cases when licences are required, the evolving practice is that isolated mini-grid developers should not have to apply for separate licenses for generation, distribution, and retailing (SADC RERA, 2013).

Alongside the advantages of segmented licensing are some disadvantages. A license provides a mini-grid developer the legal basis to generate and distribute electricity, thereby lowering or eliminating the risk of specific elements or stages of their projects. Larger mini-grids require more capital and involve more risk, thus increasing the value of licenses for 'derisking'. An appropriate approach to segmented licensing would keep project development costs low and mitigate some investment risks. A hybrid approach would impose basic licensing requirements along with voluntary measures that the developers could take if they wished. In Tanzania, for example, projects that are exempt from licensing requirements may still opt to obtain a license, and, in the process, gain the ability to reserve the project site during the development process.

Box 3.5 covers some specific measures that could reduce costs for private developers when integrated into mini-grid licensing procedures. To varying degrees, these have been applied to mini-grids in several countries, and more widely for other infrastructure projects; they are known to contribute positively to attracting private sector participation.

16. *While exempted from generation license, mini-grids with a capacity of under 1 MW require different levels of environmental impact assessment. To determine whether a full assessment is necessary, the developer must approach the National Environment Management Council and/or district environmental offices for an opinion. The developer then registers the project and submits a project brief which, after a maximum of 45 days, elicits a response. Three alternative outcomes are possible: (i) the regulator deems the project brief sufficient, which is usually the case for very small projects (< 100 kW) unless they are situated in a nature conservancy; (ii) the regulator requests a preliminary EIA; or (iii) the regulator requires a full EIA (GIZ, 2016).*

Box 3.5 Improving licensing procedures for mini-grids

Standardising project documents. Everyone wins when transactions with regulatory bodies are transparent, standardised, and timely. Guidelines and templates for small projects can be standardised and, as far as possible, non-negotiable in order to remove administrative barriers and uncertainties. As the system size increases, standardised templates may still be available, but with negotiable terms and provisions (SADC RERA, 2013). Standard feasibility reports and detailed project reports[17] should be emphasised, especially where local resources strongly influence project viability (*e.g.*, small hydro). Standardisation enables regulators to evaluate projects quickly against established benchmarks, while the developer is aware of its obligations and kept well informed. Digital data management and automation may also be integrated into the process, with online applications for licenses and automatic evaluation of sites based on GIS databases.

Minimising/standardising response times. Maximum response times or, in certain cases, positive administrative silence (if a request is not answered within a certain time, it can be deemed approved) as well as the principle of subsidiarity (where possible, the authority closest to the issue with full access to data has the authority to decide on the issue) can be applied to simplify and streamline processes.

Enabling import regulations for off-grid systems. Fiscal measures, such as import tax exemptions, have been used to incentivise renewable energy deployment. When importing equipment, requests to reduce or waive taxes are usually made to the concerned ministry or authority. In practice, officials in those ministries often have limited understanding of the specifications of renewable energy equipment and may have trouble making expedient decisions on whether a particular waiver applies or not. Collaboration and coordination between the relevant agencies will help developers (and the import officials) save time and cost. This also applies to equipment being shipped within national boundaries, where widely different tax codes may apply to renewable energy components across state borders.

Striving for regional harmonisation. The private sector will always be looking to grow and expand its market. Regional harmony, comparable policy structures, and similarity in regulatory requirements and working documents all help the private sector execute projects more efficiently and with greater confidence, because regional harmony can greatly reduce the costs of market development. Regional bodies can play an important role in supporting regional harmonisation efforts. Examples include the ECOWAS Regional Centre for Renewable Energy and Energy Efficiency; the newly formed Centre for Renewable Energy and Energy Efficiency within the Southern African Development Community; and the East African Centre for Renewable Energy and Energy and the Regional Centre for Renewable Energy and Energy Efficiency (RCREEE).

Quality assurance and safety. While safety is paramount, appropriate standards should be balanced against the cost of compliance and verification. Examples of efforts in this direction include the Renewable Energy Test Station in Nepal, which assists the nation's Alternative Energy Promotion Centre in setting product quality standards and later tests products based on the standards set, and the Mini-grid Quality Assurance Framework developed by the U.S. Department of Energy, which provides a standardised protocol for assessing mini-grid power quality and reliability across a wide spectrum of mini-grid tier levels, comparing the results with advertised performance levels (USDOE, 2015).

17. *The detailed project report is prepared once the feasibility report is accepted. It covers details on capital cost, technical parameters, technology, existing resources, techno-economic and environmental studies, schedules, and so on.*

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3.1.3 MITIGATING PROJECT-DEVELOPMENT RISKS THROUGH PROVISIONAL LICENSES AND CONCESSIONS

In some countries, one observes competition for good mini-grid sites between private project developers. This situation creates the risk that two or more project developers will carry out costly assessments and stakeholder consultations on the same site, whereas only one project developer will get the license. Introducing provisional licenses would allow project developers to allocate their resources more efficiently and would enable mini-grid projects to be developed at more sites. Provisional licences provide exclusivity for a few years, allowing the licensee to conduct preparatory activities (such as assessment studies, financial structuring, land acquisition, construction, and so on) and facilitating the process of obtaining general business documents (incorporation, tax registration) and building permits (EUEI PDF, 2014).

The concession model is another possible solution to the problem of site risk and licensing. A concession is a contract between a public and private entity granting the latter an exclusive right to build, operate, and maintain assets for the generation, transmission, distribution, and sale of electricity to end-users for a given number of years in specified geographic service areas. It binds the private operator to deliver a specified quality of service and a certain number of connections.

Holding the concession for a specified area typically entails a guarantee that no other parties will be allowed to develop and operate mini-grids in the same area, along with preferential tariff arrangements and possibly financial incentives. Concessions are usually awarded for larger areas through tendering, allowing the holder to bundle or cluster mini-grid projects or to adopt another approach (such as grid extension) to provide the necessary services. While the provisional license model is more suitable for bottom-up mini-grid development, where the private sector approaches the public authority with a proposal to develop projects within a certain area, the concession model is top-down: the public body puts out tenders for private developers to service selected areas under predefined conditions (discussion in detail in 3.3.2).

3.2 COST-RECOVERY AND TARIFF REGULATION

Tariff regulation has a strong influence on the viability and sustainability of mini-grids, as well as on the attractiveness of the mini-grid sector for private operators. From a private sector perspective, recovering costs and earning margins appropriate for the degree of risk assumed are essential for roll out beyond a few pilot projects.

The topic of tariffs is also a highly politically sensitive, especially when—as it is often the case—mini-grid models are built on charging tariffs higher than the national grid tariff. Often this issue is viewed through the lens of equality and fairness between mini-grid and main-grid customers. The fact that the rural population pays more than its urban counterpart is perceived as unfair.

However, there is a growing recognition of two countervailing facts: First, the generation and distribution cost of providing electricity in rural areas not reached by the main grid is simply higher than it is in urban or peri-urban grid-connected areas. And second, although cost-recovery tariffs for renewable energy–based mini-grids may be higher than main-grid tariffs, they are lower than alternatives, such as kerosene lighting, dry cell batteries and diesel generation, and provide better and cleaner services.

In recent years, a growing number of countries have adjusted their tariff regulations to attract greater private sector interest in the mini-grid sector. Recent policy developments suggest a trend towards tailored regulatory requirements for different scales of mini-grids (Figure 3.1).

Increasingly, small-scale systems[18] (several kWs to around 100 kW) are being exempted from tariff approvals, allowing operators to decide tariffs (as well as structures) in consultation with the communities they serve. As systems become larger, operators prefer some form of official tariff approval to mitigate the risks of future tariff disputes that could put capital investment at risk. Approaches to tariff regulation include allowing operators to charge either the national uniform tariff (where applicable), coupled with some form of 'viability gap' funding (such as recurrent tariff subsidies, capital subsidies, or both); or a pre-approved tariff combined (if the tariff does not cover costs) with capital subsidies. This section analyses these approaches and puts forth some general recommendations for tariff regulation.

3.2.1 SMALL MINI-GRIDS: EXEMPTION FROM REGULATORY TARIFF APPROVAL

Exemption from regulatory approval for tariffs charged by mini-grids operating below a certain capacity threshold (*e.g.*, 100 kW) means that the task of balancing cost-recovery and consumer affordability rests mainly with the private developer or operator. Under these circumstances, project developers can test business models (such as cross-subsidisation)[19] and technologies in a light-handed regulatory space in which they can design cost-recovery tariffs at low regulatory costs and lower revenue risk. At the same time, regulatory agencies save money and time, as they need not approve tariffs for a large number of projects each servicing a small number of customers. This is a boon because, if mini-grids were deployed at the scale needed to make advancements in rural electrification, a case-by-case approach to tariff regulation would consume substantial regulatory time (unless approval processes were largely standardised), while introducing time delays and tariff risks for projects.

Several countries have adopted regulations that exempt small mini-grids from tariff regulation. In Tanzania, no prior regulatory review or approval of proposed retail tariffs is needed for mini-grids below 100 kW. The Electric Power Sector Reform Act in Nigeria also exempts systems below 100 kW of distributed power from retail tariff approval. Peru, which offers concessions to private mini-grid operators, exempts municipally-owned small power producers from tariff regulation. The Uttar Pradesh Electricity Regulatory Commission recently announced regulations for mini-

18. *The threshold between small and large mini-grids varies greatly between countries as well as by technology, as will be evident from the country examples presented later.*
19. *Cross-subsidisation is the practice of charging higher prices to one group of consumers to subsidise lower prices for another group. It is usually done by charging higher prices to anchor loads or local businesses. Whereas closing the viability gap entails outflows of public funds, cross-subsidies place less additional burden on the government.*

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grids generating electricity from renewable sources, stating that mini-grids being developed without public subsidy can set tariffs as mutually agreed with their consumers (UPERC, 2016).

But as proven models are scaled up, some form of tariff regulation may be needed to protect investors from the disputes that could arise once the developer's engagement is irreversible. In Tanzania, the regulator EWURA considered and partly resolved this issue in rules applicable to small power producers. The rules state that the regulator may review the retail tariffs of very small power projects upon receipt of a petition signed by 15% of the households in the area served by the producer (GIZ, 2016).

In Rwanda, the regulation does not set tariffs, stating instead that 'The Authority shall have the right to review the tariff calculations undertaken by Isolated Grid … Licensees' to ensure that tariffs generate required revenues[20] (RURA, 2015). In this context, standardisation of the methodology of tariff calculation simplifies the process of approving tariffs before implementation while also protecting the interests of both operator and customers. From a mini-grid investor's perspective, the more concrete and well-defined the tariff calculation process is, the greater the protection and the lower the risk. Therefore, in cases where tariffs are not determined bilaterally between the community and operator, regulators are advised to define the mini-grid tariff calculation methodology as accurately as possible (see Box 3.6).

Providing operators the freedom to set tariffs does not necessarily guarantee cost-recovery. From an operator's perspective, tariffs are a major source of revenue to meet operating costs and, in some cases, the costs of capital investments, risk, and contingency funds for unscheduled maintenance and repairs. But local socioeconomic conditions may constrain, at least initially, how much the operator is able to recover through tariffs. Moreover, initial consumption from a mini-grid may be low, especially if the village is starting from a situation in which households own few electrical appliances. To bridge the so-called viability gap, financial support may be required. In Nepal, for example, even though isolated mini-grids are already exempted from tariff regulation, they benefit from capital subsidies in recognition of the viability gap. The country's policy of subsidizing renewable energy supplies the basis for subsidising isolated mini-grid projects (*e.g.*, micro-hydro from 1 kW to 1 MW, solar up to 1 MW, and wind/solar-wind hybrid up to 100 kW) (AEPC, 2016).

3.2.2 LARGE MINI-GRIDS: NATIONAL UNIFORM TARIFFS WITH VIABILITY GAP FUNDING

National uniform tariffs (or their pursuit) are common in developing countries. In most cases, they are too low to allow cost-recovery and thus too low to allow sustainable operation and attract private investment in mini-grids. In such cases, the uniform tariffs must be coupled with viability gap funding. An approach is to utilise large and diverse customer base by pursuing cross-subsidisation. In this case, the rural communities would pay the national uniform tariff, and the utility would charge all of its customers a levy. Although cross-subsidisation may be a solution for a small number of mini-grid projects, it has limited potential for scale-up.

In Kenya, the generation assets of at least 19 mini-grids, predominantly diesel-based, financed through the country's Rural Energy Authority are owned by the Ministry of Energy and Petroleum. Kenya Power (KPLC), a national utility, operates and maintains the generation systems, as well as the distribution assets. Because the electricity tariff is uniform for both on- and off-grid power, the more-expensive electricity from diesel-based mini-grids must be cross-subsidised by the government through a rural energy levy on all electricity bills. An approach where the ratepayers and the government must cover the cost of all electrification rollouts would require tremendous financial resources (EUEI PDF, 2014).[21]

20. Under the regulation, revenues from tariffs should cover reasonable costs of operating the grid, including depreciation charges and fuel costs, if any, plus a reasonable return on the net fixed value of the generation and distribution assets, plus a reasonable margin to cover the costs of supply activities, less subsidies or grants received specifically for the purpose of lowering tariff levels.

21. The energy regulatory commission has allowed one private company, Powerhive, to charge a tariff higher than the national uniform tariff. This could signal a shift in Kenya's tariff policy for mini-grids.

Even as several countries are now introducing regulatory changes to accommodate more flexible (yet standardised) approaches for tariff setting, others remain committed to national uniform tariffs. In those cases, cost recovery depends heavily on financial support. Many private mini-grid operators find that it is 'unrealistic to expect that governments and donors will be able to offer a credible commitment to cover any ongoing shortfall in revenues' (Tenenbaum *et al.*, 2014). On an operational level, it is risky for a private project operator to place its trust in ongoing public financial support (*e.g.* more than 10 years) given often unforeseeable changes in policy and underfunded budgets. For these reasons, subsidisation of capital expenditures is often preferred over operating subsidies by the private sector.

Even with capital subsidies, the business case for renewable energy–based mini-grids remains relatively weak under a uniform tariff scenario. Considering the economics of the various mini-grid technologies, the technology that might work with capital subsidies alone is small hydro (because it has the lowest generation costs). The others in many cases cannot be operated profitably at uniform tariff levels without ongoing subsidisation. In some cases, both forms of subsidy may be needed for sustainability. A study done in Ghana showed that, to achieve cost recovery for a 140 kW solar photovoltaic (PV) mini-grid with a 100 kVA diesel backup, subsidies of more than 50% of the capital costs would be needed to ensure that electricity could be supplied at tariffs that the community would pay. In order for the mini-grid to provide electricity at the national uniform tariff, ongoing operating subsidies would be needed in addition to a 100% capital cost subsidy (ESMAP, 2016).

In a national uniform tariff, creating an ecosystem for private sector participation and large-scale deployment of mini-grids would be challenging, without a major outlay of financial support. A possible solution in such circumstances is a hybrid approach allowing private operators to charge higher tariffs that, while still regulated to protect consumers, would ensure greater cost recovery for operators and reduce the level of public support needed.

3.2.3 LARGE MINI-GRIDS: COST-COVERING TARIFFS AND VIABILITY GAP FUNDING

Regulated cost-covering tariffs for mini-grids may be broadly classified into break-even tariffs and profitable tariffs. The former are often associated with community-owned and -operated mini-grids. Profitable tariffs, designed to generate sufficient return on investment to appeal to private investors, typically cover all investment, operating, and financing costs, as well as those of scaling up to reach more customers. Generally, a margin taken by a private company increases tariffs. However, well-run companies can make up for this margin through efficiency, thus keeping tariffs at reasonable levels.

Larger mini-grids (generally those with a distributed power capacity of greater than 100 kW) are more likely to be subject to tariff regulation, given their wider customer base and the need to protect investments from local tariff disputes. Regulators may take a variety of approaches to cost-recovery tariffs, while still protecting customers from tariffs that yield higher-than-expected returns to operators. Tariff caps are one such approach. Another is standardised tariff calculation methodologies. Both are discussed below.

Tariff caps limit mini-grid tariffs to a certain maximum linked to generation technology, village type, and system size. The operator is free to apply any tariff up to the maximum. Where tariff caps are applied without taking into consideration the differential costs of technologies, some technologies with relatively higher generation costs may not be sustained in the regulated sector. This may be the case, for example, with solar PV-battery systems. Therefore, in countries with tariff caps, PV-battery systems are usually found in the unregulated sector below a certain power size (*e.g.*, solar DC mini-grids). In some cases, tariff caps are not applied by the regulator or through the energy laws, but by a financing institution in the form of a quasi-tariff cap. One example is IDCOL in Bangladesh, which limits mini-grid tariffs to around

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35 Taka/kWh (USD 0.43/kWh in June 2016), while providing capital subsidies and attractive debt financing conditions to the mini-grid operator.[21]

IDCOL's mini-grid program is well received among mini-grid developers, even though its tariff cap is relatively low. It is important to note, however, that tariff caps do not protect the mini-grid operators from local political interference, because they do not set the tariff but only indicate its upper limit.

Transparent and standardised tariff calculation methodologies based on pragmatic assumptions for cost and revenues, as well as available financing, are crucial to ensure that the market has the right incentives to develop mini-grids. One of the most common approaches is the cost-plus method (Box 3.6).

Box 3.6 Tariff calculation using the cost-plus approach

The most common tariff calculation methodology is the cost-plus method. The first step in the method is determination of the regulatory asset base: an assessment of the value of the assets currently in use for the regulated service. This assessment is typically conducted periodically (*e.g.*, every second or third year) to account for new expansion and depreciation. Considering inflation, the assets are commonly valued at what it would cost to replace them today. Valuation includes depreciation in the value of the asset through wear and tear. Typically, assets funded by grants are excluded from the regulatory asset base because it would not be appropriate for the private sector to earn a return on the donor's capital. Annual revenue requirements are calculated based on operational expenses (comprising fuel costs plus operations and maintenance, management, and development costs), the cost of financing the business, and the allowable depreciation of assets. The cost of financing the business is typically measured as the weighted average cost of capital. The average regulated cost-plus tariff is calculated as the revenue requirements divided by the number of kWh sold each year.

When a project is first commissioned, the cost-plus method uses assumed costs. These are replaced by real costs as soon as they are known. Although the method is well-defined, several negotiable parameters affect the tariff, such as the details of asset evaluation and allowable depreciation rates. Negotiating these parameters individually for each mini-grid is a drain on the authority's human resources. Recognising this, governments in Senegal or in Nigeria are in the process of establishing more standardised procedures to speed up the process.

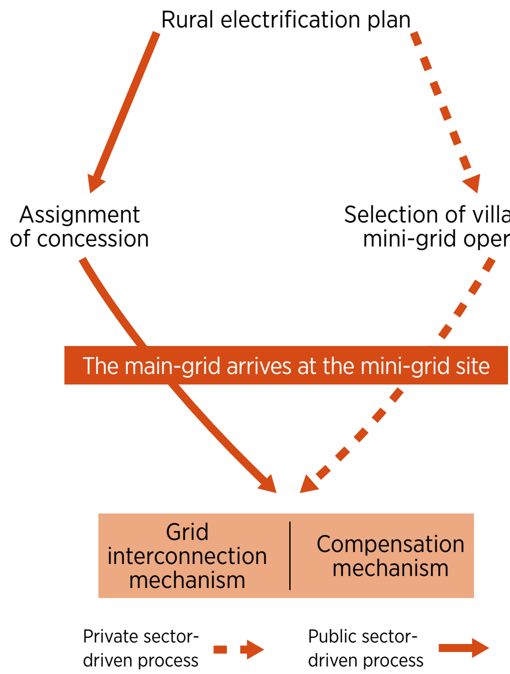
In Senegal, the regulator (Commission de Régulation du Secteur de l'Electricité, CRSE) reevaluated the effort required for cost-plus tariff setting in mini-grids after having approved the very first such tariff in 2013. CRSE concluded that the number of kWh sold under the tariff set is much too small to justify the effort. Therefore, CRSE stopped using the conventional cost plus method and began developing a new approach. To set tariff caps for solar-battery mini-grids, CRSE applied the cost-plus method to several existing mini-grid businesses and compared the outcomes. From this exercise, it derived tariff caps for different subsidy levels of solar-battery hybrid systems. Operators of systems with a 50% capital subsidy may charge a higher tariff than operators of systems with a 90% capital subsidy. The fixed cap encourages electricity supply companies to secure the largest villages available, since economies of scale reduce the costs and increase margins.

The Nigerian regulatory commission NERC is making efforts to simplify the calculation methodology by developing a cost-plus software tool for mini-grids. In other words, it is using information technology to reduce the effort required to define tariffs.

21. *IDCOL channels grants and concessionary financing up to 50% and 30% of the project costs, respectively. The remaining 20% of the project costs are met by the project sponsor. The concessionary loan has a maximum tenure of 10 years, with a two-year grace period. The applicable interest rate is 6% per annum (IDCOL, 2015).*

Tariff calculation methods are increasingly being standardised to allow for more systematic assessment and approval by regulators. Greater standardisation in tariff calculation means that mini-grid operators approach the regulatory authority with a nearly ready model that then serves as the basis for brief negotiations between all parties involved. While encouraging progress has been made, in many markets the legal framework for cost-covering tariffs for mini-grids still does not exist or, if it exists, is not implemented. Even where tariff differentiation is permitted, the methodology for tariff approval may not be clearly established; where it has been established, it may not permit cost recovery because of incorrect or overly rigid input assumptions or because insufficient experience with the method still raises uncertainties and costs. Policy makers are encouraged to take measures to identify the most suitable tariff determination approach in consultation with local stakeholders, and to formalise adoption, thereby helping to lower the risk of a key component of the mini-grid business model.

Figure 3.1 Regulatory approaches to protect mini-grid operators from losses in case of main-grid arrival



3.3 MITIGATING THE RISK POSED BY THE ARRIVAL OF THE MAIN GRID

One of the main risks faced by mini-grid operators is the unexpected arrival, within their service area, of the national grid, particularly if their assets have not yet been amortised. Although the risk of untimely arrival of the main grid has been a major hurdle for mini-grid development, the risk can be effectively mitigated by reliable rural electrification master plans that reveal the exact location and time for grid extension (and other mini-grid projects) over the short, medium, and long term. This information helps mini-grid developers select sites based on the grid-extension plan and their own preferred amortisation timeframe (Figure 3.1). Alternatively, concession arrangements assigning exclusive areas to specific mini-grid operators can provide security from main-grid connection until the end of the concession period (typically 10 to 20 years). Finally, in case of main grid connection, compensation arrangements and grid interconnection mechanisms can be established to provide security to mini-grid operators.

3.3.1 RURAL ELECTRIFICATION MASTER PLANS

The selection of any mini-grid site is based on information about when the main grid will reach the site. Such information, when it is available, is usually contained in a rural electrification master plan (or strategy) in the form of maps defining existing and planned extension of the national grid. Mini-grid developers (in a bottom-up, market-driven approach) and public authorities (in a top-down concession scheme) will use the information to select villages with a long lead time for main-grid connection. Rural electrification master plans may also provide information on population density, average household income, likely income growth, and potential semi-industrial and industrial customers (telecommunication towers, mines, forestry, etc.), as well as on whether other mini-grid project developers are already active, possess licenses, or have registered for specific sites. Generally, rural electrification master plans are meant to be well-integrated into the national development agenda (Box 3.7).

Owing to changes in the political landscape and the budget, rural electrification master plans are often out of date and unreliable. In some countries, they do not exist or are not published for fear of provoking a backlash from communities that are dissatisfied with the timeframe for grid connection. Another key challenge faced by governments is that electrification initiatives are often tied to availability of public financing from both domestic and international sources, which is often difficult to predict. Problems of coordination between federal and state actors and with distribution companies are also common, making it difficult for any single entity to produce a long-term plan. Under such circumstances, complementary policy and regulatory measures are needed to tackle the risk of main-grid arrival. These include concessions, compensation, and interconnection. All are discussed in turn below.

Box 3.7 Rural electrification master plans and the national development agenda

Access to electricity has substantial forward linkages for rural communities and their socioeconomic well-being. Generally, these linkages are marked by considerable improvements in productivity, income, and livelihoods, all of which produce spill-over effects for water, health, and food. In fact, off-grid renewable energy solutions have the potential to advance at least 12 of the Sustainable Development Goals defined by the United Nations. It is for that reason that access to electricity should be considered a core part of the national development agenda.

A country's rural electrification strategy should closely assess the role of grid-based and off-grid solutions to expand electricity access in a cost-effective, time-bound, and sustainable manner. Integrating off-grid solutions, including mini-grids, into the rural electrification plan sends a strong political signal to sector participants and helps overcome institutional inertia. Designing a plan is an important first step.[22] But backing the plan with concrete measures in a way that mobilizes action at the institutional level is often considerably more challenging. If accomplished, its effect on private sector participation can be very positive.

Not all forms of electrification are the same. Its forward linkages are greatly influenced by the quantity and quality of supply, and by the ability of rural households and enterprises to afford it. Rural electrification strategies must therefore identify the supply-side options (*e.g.*, grid extension and off-grid solutions) and take into account the present and future energy landscape of rural communities. This includes anticipating how energy consumption might evolve over time, considering appliances (lighting, radio, television), telecommunications (base stations, mobiles), agriculture (agro-processing, irrigation), health (vaccine cooling, lighting), water (pumping, treatment), community infrastructure (street lighting, schools, community centres), and rural enterprise loads (*e.g.* sewing machines). Given these interlinkages, policy makers are encouraged to examine closely the opportunities that mini-grid solutions offer for both electrification and sustainable development goals.

3.3.2 CONCESSION ARRANGEMENTS

Concession contracts grant operators exclusive rights to service a given area for a period of time (typically 15–25 years) that is long enough for the operator to amortise all assets under tariffs that do not exceed customers' willingness to pay. The regions and villages selected for concessions (typically based on a rural electrification master plan) are generally in places where the main grid is unlikely to arrive in the short term and the mini-grid represents a bridge solution with a clearly defined timeframe.

22. *Among the energy access planning tools available to policy makers is the Asian Development Bank's Sustainable Energy Access Planning framework (http://energyaccess.org/wp-content/uploads/2015/06/Sustainable-Energy-Access-Planning.compressed.pdf).*

The concession system can take a top-down or bottom-up approach, as seen from the country examples in Box 3.8. The bottom-up approach has seen much greater interest among the private sector, given the higher transaction costs associated with participating in tenders. The two approaches may be adopted simultaneously.

There are drawbacks to concession arrangements. Should the main grid arrive earlier than expected, the community served by the concessionnaire risks being locked into mini-grid service. In such cases, compensation or interconnection becomes important, as discussed in the next section.

Box 3.8 Concession models in Mali, Senegal, and Madagascar

Mali has aggressively pursued private concessions for the development of mini-grids, adopting a dual approach: top-down and bottom-up. In the first case, the Malian Agency for Household Energy and Rural Electrification (AMADER) solicits bids for the electrification of designated 'priority electrification zones'. Projects are selected on the basis of the lowest proposed tariff. If bidders prove reluctant, the rural electrification fund may finance feasibility studies. In the second case, projects are selected based on promoters' ability to develop and operate a viable project with a fixed investment subsidy (limited to an average 75% of the capital investment cost).

More than 60 local private or community-based operators are now active in about 190 mini-grids, spread nearly evenly between the top-down and bottom-up approaches. Minimum technical specifications and quality-of-service standards are set in the concession contract documents. Concessions are usually granted for 12 or 15 years depending on the installed capacity. Ownership of the fixed assets remains with the state; the operator is compensated at the end of the contract for the nondepreciated portion of its contribution to the assets. The tariffs charged by mini-grids operated by private actors are often much higher than those of the national utility—at approximately USD 0.50/kWh rather than the utility's USD 0.20/kWh. Most of the concessions operate diesel mini-grids, but the government has started supporting hybridisation, using funding from bilateral and multilateral donors and development banks (ESMAP, 2016).

Senegal's bottom-up approach, which runs alongside its top-down approach, provides opportunities for private micro-utilities to develop projects to supply power to remote communities. Under the ERIL programme, operators apply for a renewable contract under which a 15-year concession is issued by the Ministry of Energy and the Development of Renewable Energies. To date, approximately 30 systems are operating in the country, owned and managed by numerous different private operators, with several hundred more in the pipeline. A key factor in the success of the ERIL programme has been the ability for operators to set their own tariffs under the authority of the national regulator, CRSE (Commission de Régulation du Secteur de l'Electricité), and a clearly defined tariff calculation model (ESMAP, 2016).

In **Madagascar**, low electrification rates are being tackled through a build-operate-transfer mini-grid model based on concessions awarded through tenders. After technical acceptance by the Agence de Développement de l'Électrification Rurale (ADER), the tariff is negotiated between the contractor and the local community and submitted to the regulator for approval (ECREEE, 2012). Under the policy, the government will award concessions to eligible projects for a duration of 15–25 years. The first tender for four solar-PV mini-grids was launched in mid-2015. Further auctions for solar PV mini-grid capacities are expected throughout 2016. To date, ADER has launched two calls and has planned more for 2016 and 2017 to achieve its rural electrification objectives. PV, wind, and hybrid power are expected to play a crucial role in the future (Federal Ministry for Economic Affairs and Energy, 2016).

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3.3.3 INTERCONNECTION AND COMPENSATION

When main grids reach mini-grid sites before concessions have expired or assets have been amortised, the mini-grid must be integrated within the main grid and/or the operator compensated. The mechanisms for both must be put in place ahead of time to minimise risk and allow proper planning (financial and otherwise) of mini-grid development.

There are three possibilities for connecting a mini-grid to the newly arrived grid, a process referred to as interconnection.

First, if the mini-grid operator continues to generate electricity and sell it in bulk to the grid, it becomes a 'small power producer' (Box 3.9). This approach has been implemented in Tanzania, among other places. Such migrations require (i) a feed-in tariff with a prespecified pricing formula and (ii) a standardised power purchase agreement with guaranteed purchase of power. Because mini-grids have lower capacities and higher transaction and operating costs than the main grid, the traditional feed-in tariff may be insufficient to recover investments in accordance with the original timeframe. For this reason, a special tariff framework has to be set up for mini-grid projects. The policy should clearly outline who will bear the cost of interconnection and why.

Second, if mini-grids continue to serve retail customers with electricity bought from the national grid, they become 'small power distributers'. In such cases, additional legal provisions and the applicable tariff regulation need to be considered. In Cambodia, 250 small power distributors are licensed by the Electricity Authority of Cambodia. These formerly isolated mini-grids gave up operating diesel generators in favour of purchasing cheaper 24-hour electricity from the national grid.

Third, a mini-grid with the capacity to generate power can potentially improve the quality of electricity supply to consumers through tail-end/local voltage support, running its mini-grid in 'island' mode. Its power generation can also serve as a backup whenever the main grid fails. Such models are increasingly being discussed in markets where large areas connected to the grid are underserved.[23]

To ensure that the interconnection mechanism truly mitigates risk for mini-grid operators, full information about the applicable feed-in tariffs and other requirements must be available before the investments in mini-grid assets are made.

Box 3.9 Connecting micro-hydro to the grid in Nepal and Tanzania

Based on a policy approved in July 2014, the Nepal Electricity Authority signed a power purchase agreement with two community-owned micro-hydro projects that were installed in 2007 with technical guidance and subsidies from the Alternative Energy Promotion Centre. Leguwa Khola (23 kW) in the Dhankuta district and Syaure Bhumi (40kW) in the Nuwakot district will now be connected to the utility grid. The agreement calls for a purchase price of 8 U.S. cents/kWh during the dry season and 4.57 U.S. cents/kWh in the wet season. With more than 2 000 pico, micro, and mini projects existing in the country and more than 100 private companies involved in the supply of equipment for these projects, this step from the authority is very encouraging for private sectors.

In Tanzania, a 4 MW small-hydro plant is the first greenfield project under the SPAA scheme, which brings electricity to 14 villages (3 000 households, 25 000 people) while also selling electricity to TANESCO, the national utility. The project includes the construction of 120 km of power lines and the operation of an innovative cellular phone–based, prepaid electricity vending system to sell electricity directly to customers (Rift Valley Corporation, 2013).

23. In India, current regulations require the mini-grid generator to shut down if the main-grid fails, thus depriving the mini-grid of the opportunity to supply its customers. From a mini-grid standpoint, these regulations will have to be followed unless proper controls can be installed to ensure islanding (isolation) that meets distribution company's technical requirements (MNRE, 2016).

The other way of addressing the risk of main-grid arrival is to compensate operators for the residual value of the mini-grid assets rendered uncompetitive by the main grid. With a compensation mechanism, the regulatory authority can, when setting the tariff, assign a depreciation scenario for fixed assets such as the distribution system. Moveable assets, such as generators and solar panels, would not be included, because the operator is free to move these to another site. In a fair compensation scheme, depreciation times are set according to the main-grid connection risk that the operator bears and the limits shown in the profit and loss statement of the applicable financial model. To incentivize mini-grid operators to find sites that are far enough from the main grid, the depreciation time for all intangible assets, such as project development costs, may be low (*e.g.*, five years).

Countries have introduced a variety of compensation mechanisms for mini-grids (Box 3.10), though in most cases the mechanism is not specified in enough detail in the legislation or regulations to allow the operator to build a business model around it. In other cases, the modalities of payment of the compensation remain to be defined. Rural electrification authorities may be prevented from making direct payments; often they are required to tender their spending above a minimum threshold. Addressing such restrictions may require additional rules for compensation funds or specific provisions within rural electrification funds. Rules regulating existing compensation funds (*e.g.* for resettlement, way leaves) could be adjusted to allow compensation for assets not yet realised as well as those already depreciated.

Box 3.10 Interconnection options for mini-grids in Uttar Pradesh (India), Tanzania, and Rwanda

In **Uttar Pradesh (India)**, the government has adopted provisions for exit procedures to take effect upon arrival of the main grid. Operators may continue to supply electricity to consumers at a mutually agreed tariff (or at an imposed tariff in cases where the project benefits from state government subsidy). They may also sell excess or surplus electricity to the distribution licensee at the interconnection point at the applicable feed-in tariff. Or they may elect to supply all of their electricity to the said distribution licensee. Operators also have the option of transferring ownership of their distribution network to the distribution licensee upon mutual agreement on the depreciated value of assets (UPERC, 2016).

In 2009, **Tanzania's** government incentivised independent power production by establishing standardised power purchase agreements. Although the rules do not provide full protection from stranded investment in the event of main-grid connection of isolated mini-grids, they do foresee three different scenarios: (i) the operator sells its distribution grid to TANESCO and dismantles its generation assets; (ii) the operator buys electricity from TANESCO and distributes and sells it to its customers; and (iii) the operator generates electricity, sells it to its customers, and feeds excess electricity back to TANESCO (EUEI-PDF, 2015).

Rwanda. Regulations put in place in September 2015 cover the case in which mini-grids are eventually connected to the main grid. When this happens, the mini-grid operator has a range of options. It may become a small power producer and/or distributor, selling some of its assets to the utility, or, if feasible, it may relocate its assets. (In fact, it is not prevented from doing both.) If an agreement on the purchasing price or compensation for relocation cannot be reached, the regulator will provide binding conflict resolution.

The decision on whether to interconnect or to seek compensation should ideally depend on how the mini-grid's levellised cost of generation (LCOE) compares to the tariff and the LCOE of the main grid. Figure 3.2 illustrates the options that are most relevant for mini-grids under various conditions. Policy makers may

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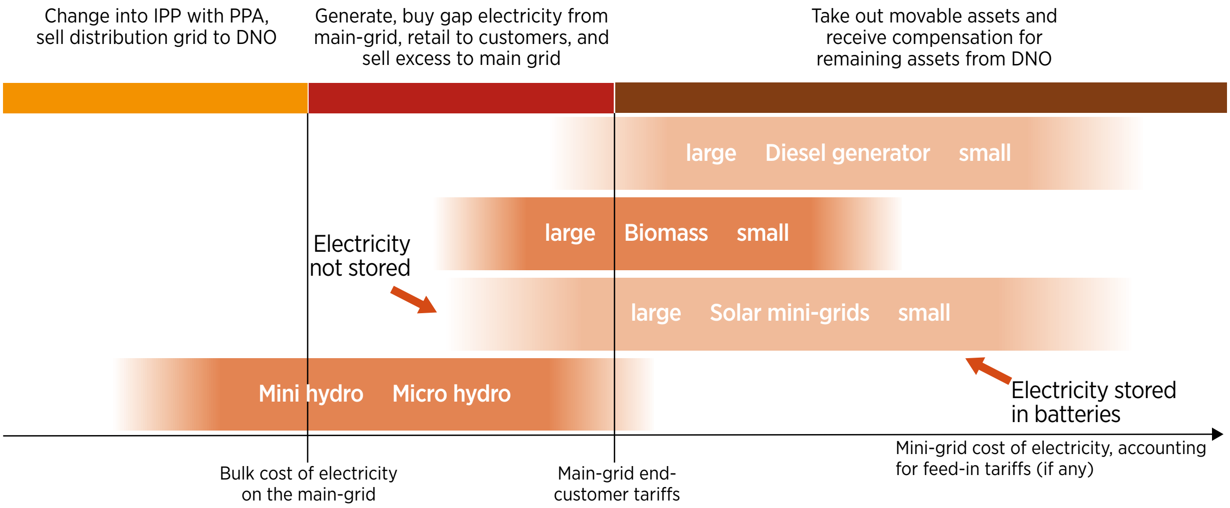
Figure 3.2 Regulation options for main-grid connection to the mini-grid (depending on generation costs)



Note: IPP = independent power producer; PPA = power purchase agreement; DNO = distribution network operator.

adjust the main-grid's LCOE limit beyond the main-grid tariff through feed-in tariffs or by developing standardised PPAs that oblige distribution network operators on the main grid to purchase electricity from distributed generation (Box 3.11), with the caveat that this requirement will not apply where the utility offers an attractive feed-in tariff for grid-connected small-scale renewables.

Box 3.11 Interconnecting mini-grids: Supplying reliable electricity to underserved main-grid networks

Private mini-grid operators can do more than just electrify rural communities. In some rural areas served by the national grid, the distribution network operator (DNO) cannot earn profits owing to missing generation or transmission capacity, or because of low demand and the high cost of collection. Under such circumstances, DNOs try to minimise their losses by reducing the hours of electricity supply and cutting maintenance. In Nigeria and India, for example, thousands of kilometres of distribution lines are not operated at all or are underutilised, supplying low-quality power for just a few hours a day.

Private mini-grid operators are often well positioned to take over these parts of the grid and run them as interconnected mini-grids with their own generation assets (to power the grid whenever the main grid is not available) and local management. In contrast to DNOs, mini-grid operators tend to have decentralised management structures in each village they serve. As a result, demand usually increases over time and conflicts are quickly settled. Reliable electricity is the basis for customer satisfaction.

The mini-grid operator may pay a small rent to the DNO for the right to use the distribution grid, thereby turning loss-making assets into profit-making ones. The connected community of customers must agree to pay higher tariffs in return for reliable electricity. The income-generating opportunities opened up by reliable electricity supply, together with energy efficiency measures, typically outweigh the disadvantages of the higher tariffs. Interconnected mini-grids require the consent of the DNO and the regulator. Dedicated regulation can facilitate and streamline private sector activities in this regard.

3.4 POLICY MEASURES TO FACILITATE ACCESS TO FINANCE

Scaling-up mini-grid deployment requires efforts to attract capital into the sector. The role of governments in making this happen can be three-fold:

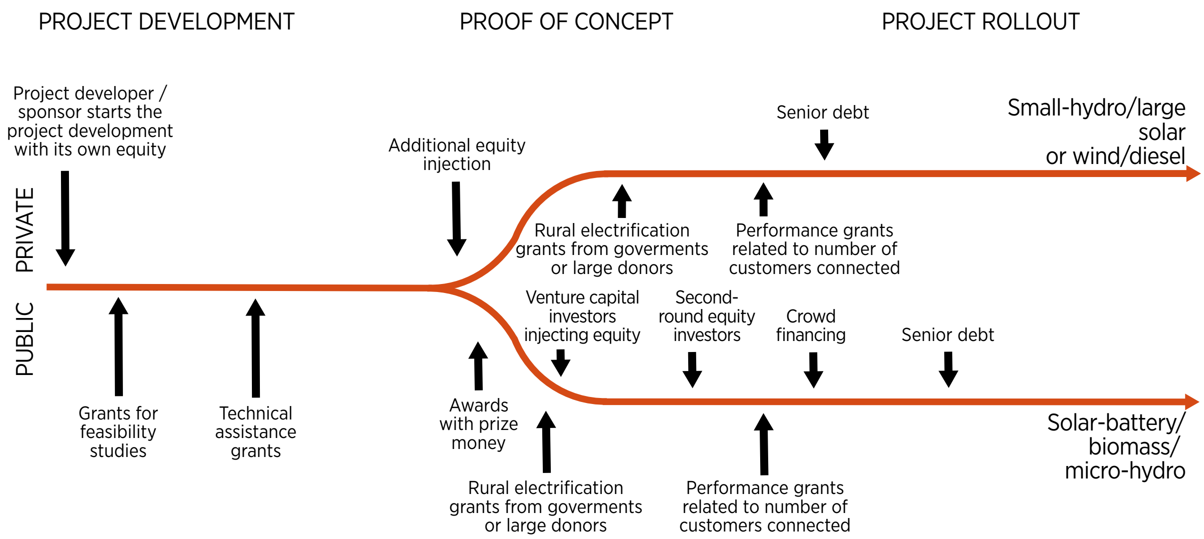
- First, to introduce dedicated measures to facilitate access to finance for mini-grid projects at different phases of development. This includes efforts to put in place an enabling policy and regulatory environment (as discussed elsewhere in this chapter) to help create a pipeline of bankable mini-grid projects, as well as measures to address specific gaps in financing.[24]
- Second, to take steps to mitigate specific risks of the mini-grid business model that negatively affect its ability to raise financing.
- Third, to design public financial support and the delivery mechanism in a manner that leverages private capital into the sector and ensures sustainability of projects over their lifetime.

3.4.1 MINI-GRID DEVELOPMENT PHASES AND FINANCING NEEDS

Private mini-grids pass through different phases with varying financing needs until they are finally installed and commissioned. These phases can be broadly classified into project development, proof of concept, and project rollout. Figure 3.4 illustrates typical financing requirements at each phase for large (in the range of hundreds of kWs to MWs) and small mini-grid projects; these phased requirements will be discussed in detail in this section. The two project scales not only have different capital requirements, especially in the proof-of-concept and project rollout phases, but also use different financing structures.

In the case of larger mini-grids (*e.g.*, small-hydro and large brownfield projects, referred to below as 'first string'), each mini-grid is generally structured using a project finance scheme. The smaller mini-grids (*e.g.*, solar, biomass-based, and micro-hydro—referred as 'second string') can be rolled out one after the other, deploying new financing approaches that have

Figure 3.3 Examples of financing needs along the project-development chain



24. *Governments also influence the wider environment in ways that affect access to finance. Examples include the country's attractiveness for investors (as determined by the ease of starting a business, land registration, investor protection, ability to enforce contracts, transparency, and so on) as well as local financial and fiscal regulations (such as currency inconvertibility and nontransferability, repatriation, taxation, import duties, and local content requirements) (IRENA, 2016).*

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elements of both project and corporate finance. These approaches are currently being shaped and defined with more clarity as developers gain operational experience and as their market and risk profiles come to be better understood.

Project-development phase. During the project-development phase, sites are selected, communities are contacted, demand is projected, mini-grid systems are designed, legal frameworks are analysed, and business models are developed. Finally, financial models are prepared, administrative approvals acquired, and company structures established. This phase is typically financed by the equity of sponsors and project developers. In some cases, grants for feasibility studies may be available, as in Mali (World Bank, 2012). In a later stage of project development, technical assistance grants help the developers perform tasks that involve third-party consultancy such as GIS analyses, detailed demand assessments, or environmental and social impact assessments (ESIAs). In some cases, technical system design, administrative procedures and financial modelling can be done using the financial resources made available for technical assistance. The grants typically come directly from development banks or development funds, such as the African Development Bank's Sustainable Energy Fund for Africa (SEFA) (Box 3.12) and the Overseas Private Investment Corporation's U.S.-Africa Clean Energy Finance Initiative (ACEF). Alternatively, they may be channelled through concerned government bodies (*e.g.*, rural energy agencies).

Box 3.12 The Sustainable Energy Fund for Africa (SEFA)

SEFA is a USD 95 million facility funded by the governments of Denmark, Italy, the United Kingdom, and the United States. It is hosted by the African Development Bank. In 2015, SEFA awarded the Republic of Rwanda a grant of USD 840 000 to support the scale-up of mini-grids through a targeted intervention to strengthen the enabling environment. The intervention will lay the foundation for co-financing private sector development of mini-grids, focused largely on micro-hydro sites. The project includes detailed feasibility studies of 20 selected hydro sites sized between 5kW and 100kW, as well as rollout and implementation plans that include tariff and business models for mini-grids.

SEFA has approved additional programs aimed at developing mini-grid policy in Mozambique and Niger, with an additional four-country program in the pipeline.

Source: AfDB, 2016.

The most innovative mini-grid operational models are often deployed by small, young companies that have very limited budgets. Typically, such companies do not even have enough capital to provide their equity contribution to a publicly supported project or to be able to afford the administrative cost of the above-mentioned support instruments. In such contexts, support instruments such as African Development Bank's Market Intelligence and Business Development Support (part of the bank's Green Mini-Grid Market Development Program) can help close the knowledge and financial gap by making expert advice available at no charge and reducing the costs associated with project preparation and feasibility analysis.

The project-development phase is a crucial step that strongly influences the development of a project pipeline for sustainable mini-grids that are well-positioned and equipped to raise financing during the remaining phases. Policy makers can take several measures, summarised in Table 3.1, to help developers in this phase in gaining access to financing, including equity, grants for technical assistance and feasibility studies.

Table 3.1 Measures to facilitate access to finance during project development

Phase	Financing type	Measures
PROJECT DEVELOPMENT	Equity	• Fulfil the other three conditions to attract private developers' interest in mini-grid development. • Provide market information on early-stage financing sources and data needed to perform initial market assessments and feasibility studies (*e.g.*, number of unelectrified villages, potential anchor customers, income distribution). • Undertake regular consultations with private sector mini-grid developers to identify policy and regulatory risks to business models.
	Grants for feasibility studies Technical assistance grants	• Prioritise mini-grids as a key pillar of the electrification strategy to attract international development funds for projects (either directly or channelled through public agencies). • Cooperate closely with regional and global funding facilities to attract early-stage grants using dedicated frameworks, such as rural electrification funds, to pool together international and local financing, and to channel funds to projects. • Set up dedicated help desks or extend support through incubation centres, providing advice to mini-grid developers during project development.

Project rollout phase. Following the project-development phase, the financing flow splits into two specific strings:

In the first string (large mini-grids), projects typically have a short proof-of-concept phase that is generally theoretical in nature and integrated into the due-diligence process. This is possible because the individual components of the project, as well as the demand for electricity, are already well understood. This applies especially to small-hydro projects and large brownfield projects in which large diesel mini-grids are integrated with renewables. Many of the brownfield projects tend to have anchor clients, such as a state utility or industrial off-taker, which provides some degree of certainty about demand and future cash flows. Since the demand for and the generation characteristics of solar PV/wind are well known, the proof-of-concept phase is generally replaced by an extended theoretical due-diligence process covering various risks (discussed in detail further on) and mitigation approaches. In this first string, the due-diligence process can be very resource-intensive. For that reason, additional equity is often needed. Some development banks and development funds award technical assistance grants to support the due-diligence process.

In the second string, mini-grids are faced with an extensive proof-of-concept phase. They have to prove their ability to generate adequate revenues against predicted costs. Therefore, the proof-of-concept phase is a major part of the due-diligence process required to qualify for further equity and debt finance. In the proof-of-concept phase, the mini-grid developer implements a first system and operates it under stringent cost and revenue monitoring. Typically, the phase is implemented using the developer's or sponsors' own equity. Alternatively, prize money from business plan competitions may be used.[25] Husk Power Systems for instance, won the CISCO and Draper Fisher Jurvetson global business plan competition in 2009, raising USD 250,000 and financing their proof of concept. Some international development organisations award grants to co-finance pilot projects. The related funds may either be assigned to a specific country (as with certain projects funded by the European Union or the United Kingdom's Department for International Development) or to a wider geographic region, but in the latter case they may be limited by constraints relating to company size and financing structure (*e.g.*, the develoPPP program).

Table 3.2 provides an overview of the measures that governments can take to facilitate access to finance, both equity and grants, during the proof-of-concept phase for both large and small mini-grids.

25. *Examples of such competitions are the Lighting Rural Tanzania Competition of the Rural Energy Agency and the Renewable Energy Business Plan Competition managed by ECREEE and Climate Technology Initiative.*

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Table 3.2 Measures to facilitate access to finance during the proof-of-concept phase

Phase	Financing type	Measures
Proof of concept (String 1)	Equity	• Easy repatriation of money and low withholding tax to attract international investors. • Indexation of tariffs to diesel price, foreign exchange rate, and inflation.
	Technical assistance grants for due diligence	• Close cooperation with national, regional, and global funding facilities to attract technical assistance grants to be disbursed to projects through dedicated frameworks, such as rural electrification funds. • Creation of a framework for private sector mini-grids to raise direct technical assistance grants from international development funds.
Proof of concept (String 2)	Equity	• Easy repatriation of money and low withholding tax to attract international investors. • Indexation of tariffs to diesel price, foreign exchange rate, and inflation.
	Grants for first system(s)	• Close cooperation with national, regional and global funding facilities to attract grants suitable for proof of concept of small mini-grids. • National business plan competitions.

Proof-of-concept/pilot phase. After a successful proof of concept, the company must attract grants and equity—or a mix of grant, equity, and debt—to enter the project rollout phase.

Mini-grid developers in the first string—that is, with comparatively large generation assets and distribution networks—often use processes that resemble those used for grid-connected renewable energy projects. Equity investors and debt financiers tend to be attracted to mini-grid projects that are able, technically and legally, to sell excess power to the utility under a power purchase agreement when and if the national grid arrives. Preferably such sales are in hard currency, with clauses pertaining to minimum availability of the grid, combined with government guarantees. In some cases, as in Tanzania, projects also use balance-sheet financing from parent companies active in other core industries (*e.g.*, tea, coffee, sugar). In addition, they make use of grant funding for capital investments in equipment and/or performance grants (per connection) from the national rural electrification agency.[26] These funds are usually administered by dedicated funding agencies that channel both local and international development finance.

Mini-grid developers in the second string, having succeeded in developing a scalable mini-grid business model and proven their concept, can begin to attract venture capital in the form of equity (Box 3.13). Equity investors generally look for businesses with quick cash return, which is reputed to be an indicator of low risk and good scalability of the model. Thus, product sales businesses (*e.g.*, solar home system companies) are preferred over infrastructure operations and electricity sales businesses (*e.g.*, mini-grids). The largest equity success so far among second string mini-grid companies was scored by Powerhive in Kenya, which acquired USD 20 million in early 2016. The financing was led by Prelude Ventures, with participation from Caterpillar Ventures, Total Energy Ventures, Tao Capital Partners, and Pi Investments. The round came soon after a USD 11 million equity investment by Enel Green Power to build and operate a 1 MW portfolio of mini-grids in 100 villages serving approximately 90,000 people in western Kenya (ESI, 2015).

26. An example of a performance grant is REA Tanzania's Performance Grant. Under REA's TEDAP program, grants covered up to USD 500 per connection and up to 80% of distribution and metering costs in rural areas.

Box 3.13 Venture capital in the mini-grid sector

The sources of venture capital in the mini-grid sector can be divided into four groups:

- Investors with a utility background, such as Enel Green Power or Engie, aiming to be at the forefront as frontier markets move towards a new breakthrough in electricity supply.
- Investors coming from an energy product market, such as Caterpillar, that see an opportunity to sell additional products.
- Renewable energy project developers, such as RP Global or First Solar, that want to develop new business models for electricity sales.
- Impact investors with a financial background, such as Acumen or Bamboo Finance, and impact-driven foundations, such as Shell, Doen, or Rockefeller.

Usually, utilities and energy-product investors are willing to enter at an earlier stage than investors with a finance background. Foundations may be willing to take higher risks if convinced of the socioeconomic impact of certain business models. Generally, there is limited competition between venture capitalists in the market, putting them in a strong position to impose conditions. Such conditions may include reevaluation of demand, additional documentation of design steps or of quality management, government approvals, and revenue verifications, all of which are designed to reduce investment risk.

Some equity investors link their engagement to a successful acquisition of debt. However, as the availability of equity is typically itself a condition for debt acquisition, equity investors and debt financiers sometimes aim to close simultaneously. The equity acquisition process can take up to 12 months or more, and debt acquisition and simultaneous closings usually take even longer, as debt financiers require even more proof of concept and more security than do most equity investors. Under such circumstances, project developers typically contact potential venture capitalists and lenders early in the project-development cycle, armed with immature business and financial models, which may be counterproductive since it causes investors to view the sector as a whole as unattractive.

Recently, crowdfunding has emerge as a complementary solution to traditional methods of raising financing for smaller mini-grids (Box 3.14). Although the amounts raised through crowdfunding are still relatively small and the legal and regulatory regimes governing the sector are still being worked out, the appeal is growing. Funds raised over crowdfunding platforms are typically less expensive and impose fewer demands and expectations on fund-seekers than conventional private, public, or charitable sources, and financing rounds can be closed more quickly. Successful adoption of this concept has already been demonstrated by organisations such as SunFunder (Tanzania and Uganda) and Mera Gao Power (India) (IIED, 2015).

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Box 3.14 Crowdfunding complementing traditional finance: The case of Mlinda and Mobile Solarkraftwerke Afrika

Mlinda, a not-for-profit organisation, installs 150W–225W micro grids for households in Sunderbans and remote tribal areas of West Bengal such as Purulia. The projects are owned by Mlinda, and their capital expenses are raised in form of both equity and debt. Although the organisation does benefit from traditional lenders such as NABARD (a rural bank), United Bank of India, India, the Climate Group and CSR funds. It has also been raising funds from crowdfunding platforms such as Milaap.

The organisation raises debt finance at interest rates of 4%–5%. Grants are obtained to fund smart meters, capacity building, local repair and maintenance, and Mlinda's overhead. Thus far, Mlinda has raised between USD 74 000 and USD 82 000 through crowdfunding. To the extent that the debt is paid off on an annual basis by village-level joint liability groups, some portion of the collateral amount is freed up to be channelled back into the project for scale-up (CLEAN, 2015).

Mobile Solarkraftwerke Afrika GmbH & Co. KG was able to obtain funding through Bettervest, a crowdfunding platform. The funding goal of EUR 107 700 was met within four days by 174 investors. Investors could start investing as little as EUR 100, with an expected annual return of 9% over seven years. The project now provides electricity to an isolated rural village Mourdiah with no connection to the power grid (Akerboom, 2015).

As highlighted earlier, the ability of projects to raise both international and domestic equity and debt depends greatly on how well risks are managed and how public financial support is designed and delivered. The remainder of this section tackles these two aspects and highlights additional measures that governments can take to facilitate access to finance for mini-grids. Table 3.3 provides an overview of the measures that governments can take to help large and small mini-grids access financing, including equity, grants and debt, during project rollout.

Table 3.3 Measures to facilitate access to finance during project rollout

Phase	Financing type	Measures
Project rollout (string 1)	Performance grants/ subsidy per connected customer or operational/ public private partnership	• Set up a rural electrification fund replenished from national budgets and levies, and by international donors. Ensure good governance of the fund. • Cooperate with international donors to attract grants directly for projects.
	Equity	• Ensure easy repatriation of funds and low withholding tax to attract international investors. • Permit tariffs to be indexed to diesel price, foreign exchange rate, and inflation.
	International debt	• Ensure easy repatriation of funds. • Address identified policy and regulatory risks and protect against retroactive changes to support measures. • Consider providing partial default guarantees to mini-grid projects to leverage debt financing.
	Domestic debt	• Enable low interest rates for local currency loans with long tenures using dedicated funds—*e.g.*, funds channelled through the central bank to local commercial banks. • Build capacity in local commercial banks on mini-grid financing. • Consider using partial default guarantees to enable project financing structures other than corporate financing.
Project rollout (string 2)	Performance grants/subsidy per connected customer or public private partnership	As above
	Equity	As above
	Crowdfunding	• Easy repatriation of funds. • Review existing regulations on crowdfunding from local and international lenders.
	International debt	As above
	Domestic debt	As above

3.4.2 RISK MITIGATION FOR LARGE AND SMALL MINI-GRIDS

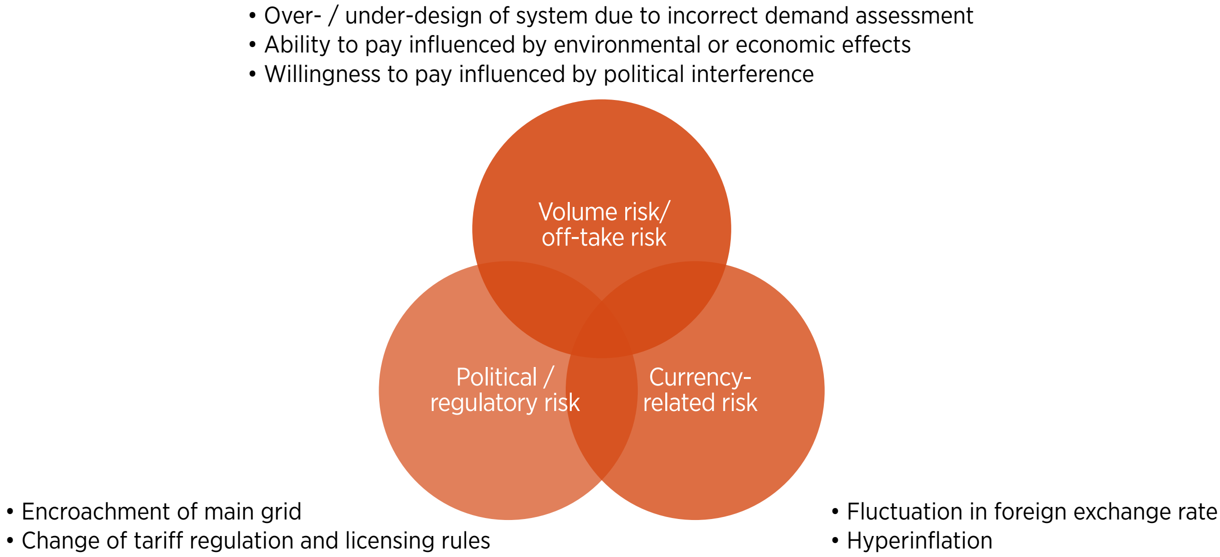
A wide range of investment risks accompany the phases of mini-grid development and operation. The three major risks faced by mini-grids (Figure 3.5) are:

- Volume/off-take risk
- Policy and regulatory risk
- Currency-related risk.

All key actors involved in mini-grid development—including financing institutions, public agencies, and project sponsors and developers—can take measures to mitigate some of these risks.

The discussion here will focus on measures that governments can take to derisk elements of the mini-grid business model that could facilitate access to financing for projects.

Figure 3.4 Key risks for mini-grids



For isolated mini-grid projects in the first string, where renewable energy capacity is added to existing diesel generation, a track record of energy demand, revenues, and costs exists, thus mitigating volume/off-take risk to a certain extent. Additionally, it is not uncommon for large mini-grids to operate under concession agreements, which goes a long way towards mitigating the risks of untimely arrival of the main grid. The only operational risks that cannot be mitigated are those related to unanticipated regulatory changes (*e.g.*, affecting the tariffs that mini-grids can charge to consumers) and currency-related risks. Local-currency debt financing and hedging instruments can be combined to address the latter.

For mini-grids connected to the main grid, government-backed power purchase agreements in hard currency[27] will mitigate, to a certain extent, two of the three main risks in renewable energy–based mini-grid operations—namely currency and volume/off-take risk. The reduction in risk is only 'to a certain extent' because tariffs for bulk sales to the national utility are generally considerably lower than retail tariffs. Thus, while it is true that the main grid represents a 24/7 off-taker, tariffs may still not be high enough for revenues to cover debt service. Project developers planning to sell to the national utility may want to investigate the off-taker risk associated with the national utility buyer. Many national utilities have a history of late payments to small power producers.

27. The issue of exchange-rate risk is a critical one. Most mini-grids denominate their capital expenditures in hard currency, while revenues from electricity sales arrive in local currency, making it extremely difficult to service hard currency loans and remunerate equity investors. As many currencies are volatile, projecting revenues becomes challenging.

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The remaining operational risk is political risk, which can partly be mitigated by political risk insurance through the Multilateral Investment Guarantee Agency, the Overseas Private Investment Corporation, export credit agencies, or private insurers (ARE, 2015), together with contractual arrangements under the power purchase agreement. These conditions help developers secure debt capital from international development banks. With all their assets in one place, first-string projects have relatively easy access to project finance without the need for additional collateral.

In the second string of smaller, isolated mini-grids, the above-mentioned payment guarantees and power purchase agreements are typically not available; neither are hard currency cash flows. This means that the three main risks in mini-grid operation need to be mitigated using other measures.

The volume risk can be mitigated to a certain extent by accurate demand assessments and conservative dimensioning of renewable energy investments (solar, wind, etc.), while providing for sufficient generation capacity (*e.g.*, diesel generators) in hybrid systems. This way, a risky oversizing of the renewable generation capacity can be avoided. Engineering decisions should allow for scaling of the renewable energy portion as load materializes. This includes choosing equipment that can be 'stacked' or operated in parallel as new renewable energy generation and storage are added.

The currency risk can be mitigated either by using loans in local currency or by combining hard-currency loans with hedging instruments such as the one offered by The Currency Exchange Fund (TCX). Up to now, both strategies have resulted in extremely high interest rates and, consequently, a high LCOE, which often cannot be matched with electricity tariffs acceptable to customers and regulatory authorities, rendering projects financially unviable. As the capital market cannot presently offer any adequate mitigation for foreign-exchange risk on second-string projects, governments and central banks may fill the gap with low-interest debt in local currency channelled through commercial banks to mini-grid projects (Box 3.15).

The political/regulatory risk, as discussed earlier, can be partly mitigated by political risk insurance, but also by a robust policy and regulatory framework for mini-grids backed by demonstrated political commitment.

Box 3.15 Channelling low-interest, local-currency debt for mini-grid projects

The predominantly small companies active in the second string market segment cannot provide the security and do not have the balance sheets required for substantial corporate finance, especially in scenarios where their business model has not been proven. Because assets are widely distributed, banks are reluctant to accept them as collateral. Dedicated low-interest loans in local currency, offered by central banks through local commercial banks, can be a boon to local developers of small mini-grids. International developers set up mini-grid companies as special purpose vehicles that must cover their entire overhead, which requires a certain scale of business activity. By contrast, local companies can usually blend the mini-grid's overhead costs into their existing business. Because they require less debt, such local projects often fall below the threshold of international development banks, which typically begins in the range of USD 5–10 million in debt capital, leaving local developers with local commercial banks. Being accustomed to handling small amounts of debt finance, these local commercial banks could close the financing gap if adequate subordinated debt tranches from government funds were available.

In this context, cooperation between banks and international development partners to provide blended financing packages consisting of grants and debt would facilitate mini-grid development. The packaging of grants and debt has been successfully tested in some cases. In Bangladesh, IDCOL provides a grant equivalent to 50% of the mini-grid's capital expenditure, coupled with a 10-year, local-currency loan for 30% of the capital at an interest rate of 6%. In India, Mlinda Foundation is packaging grants with a loan facility from NABARD, a rural bank.

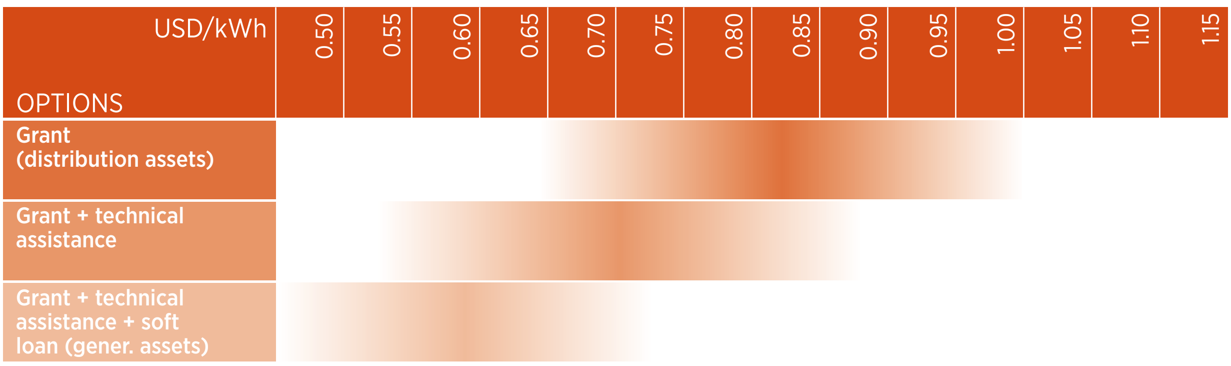
The remainder of this section sums up the recommendations for mitigating risk in mini-grid projects.

- In the case of local-currency loans, central banks can set up subordinated debt facilities at low interest rates and with long tenures. These can be managed by local commercial banks well-trained in handling mini-grid debt financing. One example of such a structure is the Micro, Small and Medium Size Enterprise Development Fund (MSMEDF) of the Central Bank of Nigeria, which is also accessible for mini-grid projects. In Nepal, examples are provided by Himalayan Bank Limited and Clean Energy Development Bank Ltd.
- Government guarantees can be provided as partial default guarantees covering 50–80% of any loss that a lender might incur in case a borrower defaults. The lender could cover its remaining exposure through project-related collateral, such as the assets of the mini-grid systems. Such a combination may even apply to small distributed mini-grids. Instead of setting up default guarantees by themselves, governments may choose to liaise with international development agencies that already offer this type of guarantee. One of the first actors in this segment is the U.S. Agency for International Development, which extends U.S. government guarantees under the Power Africa Initiative. In some cases, mini-grid developers may need to back up government guarantees with additional guarantees from the Multilateral Investment Guarantee Agency or a similar institution to make government guarantees bankable.
- Where a government is willing to issue a 100% guarantee, extremely low-cost debt capital can be attracted (*e.g.*, from the IRENA–Abu Dhabi Fund for Development Project Facility). Relieving the mini-grid operator of all debt-related risk may not be advisable, however, as it is important that private developers have some 'skin in the game'. In such cases, the government may seek some collateral from the developer.
- Most mini-grid developers would prefer local currency channelled through a local bank finance under concessional conditions over international bank finance in hard currency combined with foreign-exchange hedging.

3.4.3. PUBLIC FINANCIAL SUPPORT AND DELIVERY MECHANISMS

The foregoing discussion introduced several options for public financial support of mini-grid development and implementation. Most of that support involves some form of government intervention using the government's own funds or grants from donor organisations. In the early stages of mini-grid market development and when political pressure may be exerted to set tariffs below cost-recovery levels, financial support is often needed to buy down tariffs. Figure 3.6 provides an example of the effect of different types of support on a solar-hybrid mini-grid tariff.

Figure 3.5 Illustration of effect of financial support on tariffs for a 300 kW solar-battery-diesel mini-grid



Source: Adapted from NESP, 2016.

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Grants for mini-grid development. Grants have been an important mechanism in the development of mini-grids. They have been used to lower the end-customer tariff. In practice, the business models for mini-grid electrification have some natural limitations in terms of how much grant they can absorb:

One of those limits is reached when grants compromise the company's commitment to deliver quality results. Full grant coverage of project-development costs (including the company's own cost) would be likely to result in such a compromise, just as 100% risk coverage through government guarantees would probably erode the company's performance. With 100% guarantees, a private company has too little financial incentive to manage risks and please customers.

A second limit can be found in the level of subsidy provided to reduce the company's capital expenditure. If the private operator is to be able to meet the growing electricity demand of connected customers without the need for additional subsidies, no grants should be used for generation assets. If this rule is not followed, tariffs will jump as soon as equity and debt are obtained to extend the system. One way to mitigate this risk is to use grants only to fund non-generating assets such as distribution networks, metering, and buildings.

A third limit is related to the costs of operations and maintenance and administration, which should be covered by tariffs to avoid ongoing cross-subsidisation, which may inhibit large-scale mini-grid development (Section 3.2 and Box 3.16). Subsidies on consumption represent a major burden for the government with substantial revenue risk for the private sector.

These limitations mean that grants should not be viewed as an alternative to tariffs that are higher than those of the main grid.

Box 3.16 General design principles for subsidies

No subsidy on consumption (per kWh). While capital costs may be subsidised, recurrent tariff subsidies should be avoided, particularly in markets where projects must struggle to prove bankability. One-off subsidies may be provided to ensure cost-recovery at depressed tariff levels. But spreading subsidies per unit generated over all or part of the system's lifetime increases risk for investments into the project (Tenenbaum *et al.*, 2014).

Competition between mini-grid developers. Inducing competition for financial support between potential developers can improve effectiveness and efficiency. In countries where competitive tenders are being launched for mini-grid development, bids are received on a wide range of parameters. These parameters are often based on the technology used, tariffs for services, and the level of public support necessary to deliver services at specified tariffs, among others. In Senegal, for example, a hybrid mini-grids bidding program with a fixed capital subsidy had a minimum tender requirement of 8 500 connections, but the winning bidder pledged to connect 21 800. For a small project or for new entrants, tenders may not be the most suitable approach.

Catalysing additional financing. Subsidies to catalyse complementary financing (*i.e.*, subsidies from concessional and public sources) should leverage capital from beneficiary or promoter. It is bad practice for subsidies to cover the entire cost of the system. Where project financing through commercial sources is sought, it may be necessary for the public body to provide derisking tools, as discussed elsewhere in this chapter.

Source: Based on SADC RERA, 2013.

The efficient delivery of public support through grants should be based on a transparent selection procedure. The support may be awarded on a step-by-step basis (wherein it is applied for at the end of each development phase) or be integrated into a consolidated competitive process (wherein the support linked to the next development phase is automatically unlocked upon achievement of the preceding phase). Such an approach can ensure that a project is well developed and can be fully implemented without waiting for the next phase or instrument of public support to be put in place. Additionally, under the consolidated approach, the mini-grid developer will strive to deliver on agreed targets so as to access the next grant stage. On the other hand, no early-stage grant is lost just because the beneficiary does not have access to the next grant level. Finally, with a linked approach the administrative procedure of selecting winners can be streamlined and administrative effort minimised, since repeated selection processes with different procedures are avoided. One example of such an approach is the Guided Idea Competition developed and implemented by the Nigerian Energy Support Programme (NESP) (Box 3.17).

Box 3.17 The Guided Idea Competition: A new approach to awarding grants in mini-grids

The Nigerian Energy Support Programme has developed a new approach to support mini-grid projects. The Guided Idea Competition is a three-stage process:

- **Step 1.** General training on mini-grid project development is offered to private sector companies. The training is followed by a call for expressions of interest in the form of a three-page application covering the applicant's experience in the sector, financial stability of the company, project idea, and willingness to inject equity into the project.
- **Step 2.** A number of applicants are selected from the expressions of interest. These receive in-depth training in system simulation and financial modelling of mini-grids. Applicants that complete the training are invited to submit a full business plan under a call for proposals to obtain a grant.
- **Step 3.** The winners of the call for proposals receive individual technical assistance in assessing demand for electricity in the selected communities; designing the mini-grids, power stations, and business strategy (operations and maintenance, collection, metering, theft protection, community management, and so on); licensing; financial modelling; and presentation to investors and banks. The grant is used to finance the distribution network according to the mini-grid operator's requirements. Ownership of the distribution assets lies with the government, with the mini-grid operator holding the right to use the network.

The first projects are moving towards financial close.

Other financial instruments. To unlock debt, dedicated instruments can be deployed, including:

- *Subordinated debt (also known as junior debt)* is debt that is paid after higher-ranking (senior) debts, when a company falls into liquidation. The use of public funds as subordinated debt can reduce risk for commercial banks and other providers of senior debt. Subordinated debt, or debt that is converted into equity under certain conditions, can make up for missing equity in very small operations and thereby unlock senior debt. The disadvantage is that the senior debt amount may be reduced to the point that lending requirements cannot be met in one step.
- *Nonperforming debt buyouts.* As with a guarantee program, a development partner or government commits itself to buying nonperforming debt from commercial banks in order to reduce the credit risk of their lending to mini-grids.
- *Third-party collateralisation.* This form of collateralisation marshals a development partner's collateral (*e.g.*, national utility assets) to enable a mini-grid developer to qualify for corporate finance from a local bank.

- *Syndicated loans.* Considering the high capital expense of large-scale mini-grids, syndicated loans may offer an important pathway wherein several financial institutions jointly finance the system. In such cases, risk-sharing and the combined resources and competencies of financing institutions may facilitate project implementation (European Microfinance Platform, 2014).

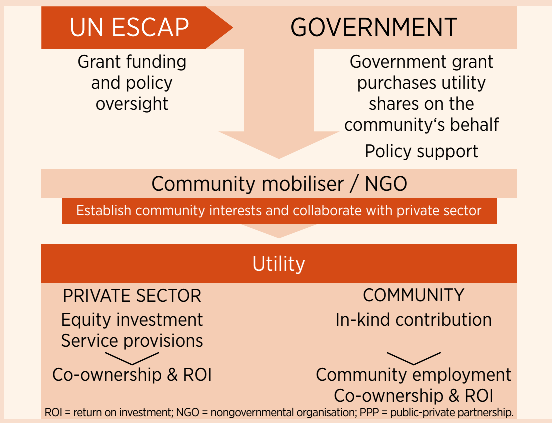
To attract debt and equity investors, traditional infrastructure development models, such as public-private partnerships (PPP) and concessions, can also be applied to mini-grid development. The goal is to reduce risks, improve project bankability and improve the delivery of financial support.

Public-private partnership (PPP) models in which ownership of publicly financed assets remains with the government can be used to reduce the capital investments demanded of private operators.[28] The Nigerian Energy Support Programme (NESP) is trying this approach in the mini-grid sector in cooperation with five different state governments, with support from the federal government. While NESP is injecting international grants to finance distribution networks that will be transferred to state government, some state governments are already preparing to extend the program using their own funds. Another form of PPP approach for mini-grids is described in Box 3.18. PPPs could represent a stepping stone between a purely government-driven mini-grid approach and one led by IPPs. By sharing risk within a PPP, private operators for whom the IPP route would still be too risky can engage in mini-grid development.

Box 3.18 ESCAP's pro-poor public-private partnership approach

Various models of public-private partnership may be appropriate depending on the circumstances in which mini-grid infrastructure is to be developed. The pro-poor PPP model is being tested in Nepal and the Lao People's Democratic Republic. In the model, a special purpose vehicle for maintenance and operation is established with a 60% private sector stake and 40% community stake. Unlike a conventional PPP model, the public sector does not own any assets and the SPV has complete ownership. Tariffs are set to cover private and community investment, operations and maintenance costs, and other community activities. Revenues are used by the cooperative for community development and to subsidise tariff rates.

Figure 3.6 Illustration of UNESCAP's PPP approach



Demonstration projects, involving solar PV and micro-hydro plants of 16–23 kW capacity, have been developed in Nepal (Makwanpur and Tanahun districts) and Lao PDR (Xayabouly province). The model's financing has fixed components, specifically the tariff rate, and an 80% grant component to meet required return on investment and cash flows. Economies of scale and village clusters are necessary to ensure financial viability and to reduce the grant share. The major issue is not the availability of capital, but the lack of mechanisms to access funds. To address this, alternative financing approaches are being analysed—among them impact investment networks, fund, clean energy credit guarantees, micro-finance, green bonds, and policy tools (feed-in tariffs, transparent PPA/IPP policy frameworks).

Source: UNESCAP.

28. *Financial institutions may be concerned that government ownership of distribution grids may make maintenance and repair more complicated. This concern can be overcome if the right-of-usage contract between the government and the operator specifies that maintenance and repair of the distribution assets are the operator's responsibility.*

Argentina and Colombia are among the Latin American countries that have extensive experience with the concessional model in roads and telecommunications, experience that they are now applying to rural electrification. With support from the Inter-American Development Bank, Colombia has recently developed an innovative way to scale up mini-grid implementation with enhanced private sector participation (Box 3.19).

Box 3.19 Scaling up investments in isolated renewable energy–based mini-grid systems in Colombia

About 60 percent of Colombia's territory is not connected to the electricity grid, and roughly 1.8 million of its people rely on limited and scattered power services. Recently, the Inter-American Development Bank has announced the approval of a loan of USD 9.3 million to promote private investment in the generation of renewable energy in isolated/unconnected areas of Colombia. The project is receiving funding from international donors and is part of IDB's efforts to support Bancoldex, a commercial bank that operates as Colombia's entrepreneurial development and export-import bank. Bancoldex will act as the implementing agency for the programme.

The aim of the investment strategy is to use concessional financing to mobilize investment from the private sector to mainstream renewable energy–based mini-grid projects and engage local financial institutions. The IDB loan aims to support private companies that supply and administer public electricity services, as well as providers of renewable energy technology that have a history with mini-grids. The final objective is to develop a model that can be replicated and scaled up across the region. The program is one of the innovative mechanisms for public-private financing that the IDB has been promoting to increase private investment in renewable energy. The operation, which will draw on Climate Investment Funds, has a payout period of five years, with a 10.5-year grace period and an interest rate fixed at 0.75 percent.

Source: IDB, 2016.

In deciding where to set the level of public support and how to design associated delivery mechanisms, policy makers may wish to keep in mind the following considerations, offered as a summary of this section.

- Any grant related to second-string rollouts should take the private mini-grid operator beyond the break-even point. The grant should fund enough customer connections to permit the mini-grid operator to generate sufficient revenue to cover all of its costs, including overhead. As a rule of thumb, that level is typically in the range of 5 000 rural households.
- If the mini-grid is to meet increasing demand through extension of generation assets, while keeping retail tariffs constant, grants cannot be used for generation assets. Instead, connection-related assets such as distribution networks, household connections, and meters can be 100% grant financed, as these typically do not need to be extended as the demand of each household increases.
- With respect to performance-related grants, a fixed grant amount per customer connected leads mini-grid developers to focus first on areas with high population density. If local authorities want to attract mini-grid developers to less densely populated areas, the grant should be linked to the cost of the distribution network and to a tendering procedure. Alternatively, the distribution network could be installed directly by the grantor.
- Grants should not be seen as an alternative to tariffs that are higher than those charged by the main grid. This is important for ensuring the viability of private mini-grid projects and avoiding

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unsustainable public subsidisation that ultimately inhibits large-scale deployment of mini-grids.

- Subsidies from concessional and public sources should leverage capital from the project promoter or beneficiary, as well as from commercial financial institutions. With respect to the latter, derisking tools and dedicated debt funds will be needed to bridge the financing gap.
- PPPs can be a stepping stone between a purely government-driven mini-grid approach and one led by IPPs.

3.5 POLICY DESIGN FOR DIFFERENT COMBINATIONS OF TECHNOLOGY AND SERVICE TIER

By designing mini-grid policy and regulation that precisely meets the requirements of certain delivery models, policy makers can direct private investment streams to certain combinations of technology and tier. In this way, policy makers can not only influence the pace of rural electrification, but also the level of access, the extent of public spending, and, to some extent, customer satisfaction.

All these aspects are related, and improvements in one may come at the expense of another. For instance, a policy focus on solar DC mini-grids will result in extremely fast electrification with a low requirement for government spending but will reach only Tier 2 or 3 of service. In fact, once installed, these systems cannot easily be upgraded to a higher tier without changes in supply, distribution, and consumption.

In contrast, a policy focus on small-hydro mini-grids would probably yield a much lower pace of electrification and require public funds for technical assistance, tangible assets, and guarantees of long-term debt financing. The service tier achieved would likely be higher than in the case of solar DC mini-grids and would provide greater customer satisfaction, since the installed capacity and available energy can be increased at lower costs. All other AC technology options have their own specificities but generally can be located between the two just described.

A well-balanced policy definition can optimize sector development under the given constraints. In this effort, an understanding of how policy and regulations affect different technology-tier combinations is paramount.

This section sets out to improve that understanding by using the four key conditions discussed in the previous sections—namely legal and licensing provisions, cost recovery and tariff regulation, the risks associated with arrival of the main grid, and measures to facilitate access to finance. In each case, key points are highlighted.

3.5.1 SOLAR DC (TIERS 1–3)

Solar DC mini-grid businesses rely on their ability to serve unserved or underserved markets at the lowest possible cost. Modular technology and a less capital intensive model allows rapid scale-up and economies of scale. The following policy and regulatory conditions are known to affect solar DC mini-grids substantially.

Legal and licensing provisions. The viability of solar DC mini-grid projects is highly sensitive to project development costs, as these are distributed over fewer kWhs generated. To keep costs low, many solar DC mini-grids operate in an environment where regulatory interaction is minimal—that is, where mini-grids of very small scale (usually under 3 kW) are exempted from licensing requirements. The exemption must be explicit, enshrined in legislation, and offered to projects that fall below a predefined, technology-specific threshold. DC mini-grids should further be exempted from the national grid codes, which makes sense because they are not technically compatible with the grid.

Project-specific regulatory requirements, such as ESIAs, also introduce costs. Conducting an ESIA requires hiring a certified consultant. Additionally, the environmental agency may charge a fee for its services, which may include the visit by public officials to the site during the approval process as well as annual inspections. Such requirements, if any, should be tailored to project size, thus reducing burdens on smaller projects.

In Tanzania, for instance, the National Environment Management Council (NEMC) decides on a case-by-case basis if a full ESIA, a simplified ESIA, or no ESIA is needed. Since the environmental and social footprint of solar DC mini-grids can be largely similar across a province or a country, development costs can be reduced by conducting a one-time benchmark ESIA to assess impacts. Depending on the results obtained, this may be followed by waiving ESIA requirements entirely or minimising and standardising them for similar projects in the pipeline. Additionally or alternatively, developers may be asked to agree to comply with environmental regulations, the violation of which would incur a penalty.

- Solar DC mini-grids below a specified capacity should be exempted from regulatory requirements (*e.g.*, tariff approval).
- Based on assessments conducted for benchmarked projects, ESIA requirements may either be waived entirely or minimised and standardised for other projects in the pipeline.

Cost recovery and tariff regulation. Tariff structures for solar DC mini-grids are generally designed to be in line with a household's existing spending on energy for lighting, mobile phone charging, and so on. Imposing standardised tariff regulations, such as uniform national tariffs, would inhibit operators' ability to tailor payment structures, possibly reducing the affordability of services and viability of the project. Even if they are initially exempted from tariff regulation, operators remain concerned that it could be imposed retroactively.

In the early years of operation, solar DC mini-grid projects are particularly vulnerable to external factors that can affect cost recovery. These include uncertainty about grid extension (discussed further on) and competition with stand-alone solutions such as solar home systems. In Bangladesh, for example, solar DC mini-grids have to compete with solar home systems that benefit from different forms of financial support. Under such circumstances, solar home systems can push small mini-grids out of local markets with high population density where, under natural market conditions, mini-grid solutions might be more suitable. In general, a level playing field for various technologies is needed, ideally based on a comprehensive rural electrification strategy, to allow the solutions that are most appropriate from the perspective of cost and service delivery to be deployed.

The goals of recovering costs and earning risk-equivalent margins also benefit from policy measures that reduce project development and installation costs. Campaigns to raise awareness and inform customers about the capabilities of solar energy in unelectrified rural areas are major costs for solar DC mini-grid projects. Campaigns supported by local governing bodies can play an important role in overcoming initial barriers to uptake.

With small-scale mini-grids, tax exemptions for system components and accessories (such as energy-efficient DC appliances) can have a marked impact on costs. Access to DC appliances can keep capacity demand low and make it possible to supply higher electricity services (such as lighting, television, fans).[29] DC appliances have yet to become off-the-shelf products. Framing a clear policy towards DC mini-grids would create incentives for the private sector and create a downstream market for appliances. Targeted efforts to reduce appliance costs, such as centralising procurement at the village or provincial level, could also be considered.

On the operational side, operators are also looking at technology options to reduce costs. An example is the use of 'mobile money' for tariff collection, which represents a cost-effective mechanism for collecting and handling payments. In countries like Kenya and

29. *In the case of SolarIC in Bangladesh, generation and storage units operate at the 48V DC level, whereas distribution to households is at 220V. This allows most common AC appliances to be used, as they can run on DC power as long as the voltage matches their required input voltage (Groh et al., 2014)..*

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Uganda, customers of one telecommunication operator are able to send money across operators. But, in Tanzania, regulations permit only transactions between customers of the same operator. There, developers had to set up and maintain business relationships with various telecommunication operators, increasing overhead costs.

- Tariff regulations should allow flexibility in tariff design for different end-users to ensure viability and allow scalability.
- DC appliances should be considered for tax reduction.
- The public should be informed of the benefits of solar mini-grids.
- National regulations should permit interoperability of mobile money collection platforms.

Mitigating the risk posed by the arrival of the main grid. Untimely arrival of the main grid could render the solar DC mini-grid redundant. It is important to note, however, that solar DC mini-grids are relatively less exposed to this risk than are larger mini-grids. Major down-scaling of solar DC technology has meant that, in some cases, operators can move their systems to another site. Although this avoids stranded assets, it does imply a cost in terms of developing the new market and re-installing the system. Greater clarity on grid-extension plans in the short-, medium-, and long-term, as well as demarcation of sites for stand-alone and mini-grid development, would reduce developers' uncertainty.

- Clarity on grid-extension plans and demarcation of sites for mini-grid development will reduce uncertainty for developers.

Policy measures to facilitate access to finance. The solar DC mini-grid venture is most efficient under a continuous and ongoing rollout strategy. To finance expansion, operators need short-term capital (typically 3 to 5 years) without balance-sheet finance or corporate guarantees. Equity acquisition is relatively manageable if the operator's business model is scalable and has a track record. In order to scale faster, debt is important, as it costs less than equity capital. Local commercial banks in most developing countries have yet to fully realise the investment opportunity offered by solar DC mini-grids, often requiring collateral if they agree to lend at all, and solar DC mini-grid components are usually not accepted as collateral.

Mini-grid operators could attract debt capital from abroad in hard currency, but hedging against the dollar exchange risk remains a key concern. Government intervention can be important, particularly at the early stages of mini-grid enterprise development (before the operator's track record has been established) and for low-cost debt during scale-up. This could be achieved through dedicated debt funds managed by public agencies responsible for rural electrification or by local commercial banks (through on-lending). Public financing can also be used as guarantees to leverage commercial debt on favourable terms. This could further be supportedsupported by measures that would give renewable energy priority in commercial banks' lending.

- Dedicated debt funds for mini-grid projects can bridge the financing gap during scale-up.
- Derisking and on-lending instruments would encourage commercial banks to be flexible with respect to collateral, track record, rates, and tenors.

3.5.2 SOLAR AND SOLAR-HYBRID AC (TIERS 1–5), BIOMASS (TIERS 1–5), AND WIND AND WIND-HYBRID MINI-GRIDS (TIERS 2–5)

Solar, biomass, and wind/hybrid mini-grids are widespread solutions for rural electrification. Together, they cover all tiers of electricity service and offer unique advantages for mini-grid development. Modularity, cost, and ease of development favour solar-based solutions; biomass-based options cover more tiers of service at lower costs but are subject to feedstock availability. Wind and wind-hybrid solutions are increasingly preferred for hybridisation, especially in larger mini-grids in rural and island contexts. Because the policy and regulatory conditions for these mini-grids are largely similar, they are analysed together here. Depending on the current state of technology and market penetration, specific measures may still be necessary.

Legal and licensing provisions. Segmented licensing allows regulators to calibrate the extent of oversight needed, while keeping administrative effort on the part of the regulator and developer to a minimum (as explained in 3.1). Thresholds for exemptions vary but are usually around 100 kW. The class of mini-grids under discussion here (solar/solar-hybrid, wind/wind-hybrid, and biomass) spans both sides of that threshold, with biomass and solar/wind-hybrid systems likely to reach MW scale. Small-scale greenfield rural electrification projects based on, say, solar/solar-hybrid and biomass technology and falling below a specific threshold should be considered for exemption from licenses. A key differentiating factor is the ESIA requirement. Solar and wind-based solutions, in both greenfield and brownfield contexts, are known to have similar impacts and, therefore, a certain level of standardisation is appropriate. Often, small simplifications are possible within the existing framework. In Tanzania, for example, JUMEME was allowed to carry out ESIAs on a cluster basis, rather than by individual project. But biomass-based projects can have wider environmental and social impacts associated both with the collection of the feedstock and with the by-products of combustion (ash, liquid wastewater). Regulators and environmental agencies will want to consider what scale and which activities warrant an approval process to balance public protection with the benefits of biomass-based power generation.

Mini-grids can be rolled out in clusters of villages, meaning that a large number of systems can be installed at several sites within a short time frame. The acquisition of land titles for all these sites can represent a considerable cost and prove extremely time consuming. Where assignment of land titles is administered on a regional or national level, the processes can be streamlined and fast-tracked. Challenges emerge in countries where local authorities are responsible for the administrative process. Because they are typically not involved in rural electrification planning, local authorities may lack an interest in accelerating the process, further complicating attempts to streamline land acquisition.

Demand and load management are essential instruments in the economic operation of mini-grids. Especially in systems with high solar or wind penetration, they enable proper use of generated and stored electricity, thereby lowering the LCOE and increasing system lifetime. Effective demand and load management also allow productive users to be supplied during times of high wind or solar availability at tariffs competitive with those of the main grid. Demand and load management functions are typically performed with smart metering technology specifically developed for use in mini-grid settings. Because these technologies are constantly improving and changing, setting standards or requiring specific certifications would stifle innovation. At the same time, governments and donor agencies must establish minimum specifications for service levels and safety. This trade-off should be carefully considered. While exemptions of mini-grid meters from the metering code is one approach, the adoption of international certification and testing standards is another. Larger renewable energy markets (such as those of the Philippines and Nigeria) may have country-specific certification and testing procedures, while smaller markets would be well advised to accept international certificates. In the medium-term, harmonisation of meter certification and testing would benefit the sector considerably.

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More generally, adopting technology-specific international quality standards and certifications can support market development. For instance, international standards, such as IEC 61400-2 (small wind turbines), IEC 61400-12-1 (performance), and IEC 61400-11 (acoustics), and certification programs such as the Small Wind Certification Council and Microgeneration Certification Scheme can fast track the implementation of wind-hybrid mini-grid systems (WWEA, 2014).

- Small-scale greenfield rural electrification projects based on solar/wind and biomass technology, under a specific threshold, could be exempt from licensing requirements.
- Environmental impact assessments and land acquisition processes can be simplified and standardised by bundling projects. In projects that have the same structure and impact and limited variations from site to site, assessments can be replaced with mandatory environmental guidelines.
- Certification requirements for mini-grid meters should allow innovation and ensure quality service for consumers.

Cost recovery and tariff regulation. To ensure cost recovery, a special emphasis on tariffs and off-take is needed. Operators should not be bound by national uniform tariffs but be permitted to charge tariffs in accordance with local willingness to pay and cost recovery, as discussed in Section 3.2. In addition to direct financial support, there are different ways through which governments can buy down consumer tariffs, including fiscal measures (*e.g.*, exemptions from import and value-added taxes, and tax breaks or caps). Senegal, for instance, has implemented a policy under which any mini-grid project within the ERIL programme can be exempted from import tax.

Off-take, specifically in the form of productive loads, plays an important role in securing long-term cash flows, especially in the case of highly capital-intensive solar, wind, and biomass hybrid mini-grids. PPAs with industrial and commercial off-takers, including telecommunication towers, are known to provide a strong basis for developing private mini-grids that can sustainably cater to rural loads. Another key avenue for growth, specifically for solar and wind-hybrid systems, are brownfield sites where renewables offer a major opportunity to reduce diesel consumption provided a reliable off-taker is in place to limit the risk generally associated with the project-development stage of greenfield projects.

Solar, wind, and biomass-based mini-grid solutions are differently positioned in the mini-grid market. With recent decreases in costs and greater modularity, solar PV is increasingly the preferred technology option where resources permit it. Wind-based solutions are gaining a niche in hybridisation and in the large-scale island mini-grid market. Biomass, which is reliant on feedstocks, is growing both for rural electrification application and for captive use (*e.g.*, bagasse). Depending on their positioning, some additional policy incentives may be needed to accelerate market development (Box 3.20).

Box 3.20 Incentives for decentralised wind development

Wind technology offers important opportunities for powering mini-grids in rural areas as well as in island networks where space is a constraint and larger systems with better economies of scale can be deployed. Targeted incentives that facilitate resource assessments and foster research, development, demonstration, and commercialisation would give the market a better understanding of the opportunity at hand and diversify the technology solutions available to power mini-grids. Policy instruments, such as feed-in-tariffs and standardised PPAs, could also be supportive for brownfield investments targeting publicly owned diesel mini-grids that can be hybridised with wind or solar.

The quality of information on resource availability is a major cost and risk factor, especially in the case of wind, which can be very site-specific and requires very detailed resource assessments. By facilitating the financing of feasibility studies and wind assessments, governments can reduce the time, cost, and risk of project development for wind-hybrid mini-grids. REAs or other public agencies could spearhead a campaign to gather the necessary information and make wind resource data available in a central database. Nepal's Alternative Energy Promotion Centre has supported solar-wind hybrid development by installing 30-meter wind-measurement stations and monitoring wind data at various sites, among other measures. Publicly available and online tools, such as IRENA Global Atlas, could also be important in undertaking preliminary resource assessments for mini-grid development (Box 3.21).

Another cost factor for developers is building human capital to ensure operability of systems over the long term. In cooperation with national training institutes, measures can be taken to develop a workforce of skilled technicians who have the training and knowledge needed to install, operate, and maintain mini-grid systems.

Box 3.21 Online resource assessment tools for prefeasibility analysis: IRENA's Global Atlas

IRENA's Global Atlas for Renewable Energy (http://irena.masdar.ac.ae/) features data from a consortium of 67 countries and 50 data providers, making it world's largest collection of the most recent and accurate public maps of renewable energy resources. The Global Atlas supports public and private entities in performing map-based prefeasibility analyses. Maps are particularly valuable because they provide a common language for dialog with local communities, thereby enhancing citizens' understanding of projects and their potential impact. They also help companies and investors to complete high-level evaluations of projects.

- Tariff design should allow economic viability and sustainability of projects.
- To complement direct financial support, fiscal measures can be deployed to reduce consumer tariffs.
- Targeted incentives that facilitate resource assessments and foster research, development, demonstration, and commercialisation would diversify the technology solutions available to power mini-grids.
- Policy instruments, such as standardised PPAs, could also be supportive for brownfield investments targeting publicly owned diesel mini-grids that can be hybridised with wind or solar.

Mitigating the risk posed by the arrival of the main grid. On arrival of the main grid, mechanisms must be in place to connect mini-grids to the main grid or to compensate mini-grid operators. Such mechanisms were discussed in detail in Section 3.3. The discussion here highlights specific issues related to solar, wind, and biomass mini-grids.

PPAs for mini-grids feeding into the main grid. Tariff setting for PPAs governing the sale of power from mini-grids to the main grid must reflect the differing economics. For example, the generation cost of new solar power plants decreases over time as technology costs reduce. This means that old mini-grids are likely to offer electricity to DNOs at a price that is higher than that of new mini-grids, making it less palatable for DNOs to interconnect mini-grids once the main grid arrives. RURA's regulation for Rwanda, for example, states that 'The Small Power Producer Licensee shall have the right, if eligible, to sell electricity under the Renewable Feed-in-tariff programme in force at the time of conversion.' To mitigate the risk of stranded investments, the DNOs would need to accept a higher feed-in tariff for old mini-grids. Therefore, a license alone does not protect the operator from stranded investment in case of main-grid connection.

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Compensation mechanisms and spilt of assets in PPPs. Except in small-hydro mini-grids, the separation of movable and fixed assets is fairly well defined, which opens up additional options for main-grid interconnection. Generally, the generation part of mini-grids includes many assets that can be moved, such as batteries, solar PV panels, smaller generators, small wind turbines, gasification stations, distribution boards, and so on. Such assets carry a comparatively low investment risk, as they can be easily redeployed. In contrast, fixed infrastructure (distribution networks and buildings) are subject to high risk because they cannot be moved and reused elsewhere. An approach often taken to overcome this risk is to have the PPP provide for a split of assets: The public sector invests in, and perhaps owns, high-risk fixed assets, whereas the private mini-grid operator finances the lower-risk movable assets. This way, in the event of main-grid connection, the fixed assets may be handed over to the main-grid distribution network operator free of charge or in return for compensation paid to the government.

In any main-grid interconnection scenario, the business value that the mini-grid operator generated should be considered. For instance, mini-grid customers are typically already willing and able to pay for electricity, are accustomed to using electrical appliances, and present higher demand than newly electrified customers. In RURA's regulation of Rwanda's mini-grids, this business value is taken care of by adding 'the present value of expected net profits over the remainder of the Isolated Grid License and based on a discount rate provided by the Authority' to the value of current assets. In Nigeria a similar approach is being discussed.

- The feed-in tariffs that will apply in the event of main-grid connection should clear at early stage of project development.
- To reduce investment risks, PPPs should consider the approach of split of assets.
- The business value of a mini-grid, as well as the current value of assets, should be reflected in compensation mechanisms.

Policy measures to facilitate access to finance. In order to achieve economies of scale, financing is structured around clusters of mini-grids developed in parallel and rolled out under the same project within a short time frame. (Except in the case of small-hydro mini-grids, few technical adjustments are required by specific sites.) Clustering poses challenges related to the acquisition of long-term project-based debt finance. As the assets are spread across a large geographic area and so cannot be liquidated easily, financiers struggle to accept the assets as collateral. While the movable generation assets of solar, solar hybrid, small wind, and biogasification systems may have some value to the financiers, the ability to liquidate fixed assets, notably distribution networks, is typically considered very limited. Therefore, distribution networks have limited value as collateral in the financing structure.

The PPP approach with a split of assets, as explained above, is one way to overcome this problem. To repeat, the private investor invests in movable generation assets, while the government (or community) covers the cost of the riskier distribution assets. The approach is being tested in Nigeria and seems to be accepted by local commercial banks, which are handling subordinated debt funds (combined with partial default guarantees from international donors) and collateral provided by the mini-grid operator.

Solar and biomass mini-grids provide the mini-grid sector a good point of access to local banks, as the resources and technology are well understood and systems can be rolled out easily. Sector-specific knowledge gained by the bank in one project can be recycled in the next. To expand and reinforce that knowledge, training for local bankers provided by public institutions and development agencies can be very effective. In Tanzania, this approach has been tried with the TEDAP Credit Line but so far has not led to interest rates and tenors acceptable to mini-grid operators. To reach that stage, additional measures, such as low-interest subordinated debt funds combined with partial default guarantees may need to be applied.

For the same reason of replicability, solar as well as biomass mini-grids are of high interest to international venture capitalists, who typically have a medium-term investment strategy with a clear exit target. As local equity investors are usually more oriented toward the short term, international equity investors are often the only viable option for mini-grid companies. Governments wishing to attract international equity investors, who often bring along international development banks, should review and simplify their rules for repatriation of capital rules and withholding of tax.

Most expertise and experience in solar, wind, and biomass mini-grids lies with small companies that have taken the time to experiment with different business models. These small companies have limited resources available for project development, especially when it comes to rolling out larger projects that require intensive resource assessments (as in the case of wind). Technical assistance grants can help to meet this challenge. Tanzania is one of the forerunners in this area with its TEDAP Matching Grants.

A harmonised approach to mini-grid subsidisation will ensure fair market conditions for all players (public, private, NGOs, development agencies). To provide a clear signal to the private sector, the subsidisation approach should be set up in such a way as to be visibly sustainable over the long run (with a gradual phaseout, if necessary). Only with a clear long-term perspective can the investors needed for large-scale rollouts be attracted.

- Innovative PPP models should be explored, focusing on risk-sharing between the public instead of government sector. One promising model is to split ownership of assets, with the private investor investing in movable generation assets, while the government (or community) covers the cost of the riskier distribution assets.
- Local banks should be given training and guidance in developing financing instruments for mini-grids.
- Where necessary, a combination of partial default guarantees and low-interest subordinated debt may be offered by the central bank or development banks.
- Subsidies may be used to establish a level playing field for all actors in the market, while providing a long-term development vision for the private sector.

3.5.3 HYDRO (RUN-OF-RIVER) (TIERS 1–5)

Global experience has shown that micro- and mini-hydro has developed in markets with and without direct policy support, although with major differences in the scale and quality of services provided. Nepal and Myanmar present interesting cases, as discussed in Chapter 2. The following policy and regulatory aspects are known to affect small-hydro mini-grid development.

Legal and licensing provisions. The legal framework strongly influences when and how the private sector will enter the project development cycle. The micro- and mini-hydro policy of the Indian state of Uttarakhand, announced in 2015, sets as one of its objectives the creation of a favourable environment for community ownership and private sector participation in micro/mini hydropower, pointing to a PPP structure (Government of Uttarakhand, 2015). The Small Power Producers programme in Tanzania, on the other hand, envisages a greater role for the private sector in the development, operation, and management of the plant. There is no single answer to the question of which development model works best—various approaches are successfully operating in many different contexts. A key lesson that has been learned, however, is the importance of distinguishing between the participating actors and making explicit their respective responsibilities. To avoid situations in which power management becomes economically and administratively unsustainable, it should be clear who the owner of the plant is, who will monitor service quality, who will manage local power service, and who accepts obligations to pay the established tariff (Practical Action, 2005). Government must attend to all of these aspects in order to reduce the risk of stranding assets and to create an environment in which private actors will readily assume the various roles that they are well suited to play.

The unique environmental and social impacts of small-hydro mini-grids compared with solar or wind-based mini-grids make them particularly susceptible to complex ESIA procedures, especially for larger projects. These procedures should be streamlined, simplified, made transparent, and, wherever possible, standardised. Very small micro-hydro plants may lie outside the scope of regulation regime. In fact, in

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Malaysia, Myanmar, and Indonesia, hundreds of micro-hydro plants (most in the range of tens of kW) have thrived, with private entities, such as community-based organisations and NGOs, developing locally customised solutions. The absence of a regulatory regime has kept development costs low, but an issue of standardisation has emerged. Different development entities are adopting different standards for project development, and some standards of safety, quality of power supply, and technical competency of developers are needed to ensure sustainable operations and growth in the sector.

- Governments should ensure the roles of the actors actors participating in mini-grid projects are clearly defined; their respective responsibilities of ownership, operation, management, and monitoring must be explicit to reduce the risk of stranding assets and to create an environment in which private actors will readily assume various roles.
- ESIA processes should be streamlined, simplified, transparent, and, wherever possible, standardised.
- Even where very small projects are not subject to regulation, minimum standards of safety, quality of supply, and competency of operators should be in place to ensure sustainable operations.

Cost recovery and tariff regulation. The private sector will not invest in mini-hydro projects unless it knows that it will be permitted to recover costs. Policy and regulation can provide the necessary assurance by providing certainty about cash flows, ensuring that tariff-setting processes are standardised and predictable (while also being sensitive to the context in which plants are deployed)[30], and by introducing fiscal incentives to address the capital cost challenge and allow technology transfer.

For grid-connected mini-hydro plants, measures to provide certainty on cash flows could involve PPAs for mini-hydro projects being developed under configurations of 100% feed-in tariffs and under mixed configurations. Leasing models are also emerging to improve management and operation of new and existing micro-hydro projects (Box 3.22). For isolated mini-grids, a suitable model of public-community-private partnership could be devised, with the public sector taking over some revenue risks from the private partner, thus increasing the likelihood of attracting private capital. Additional measures to increase capacity factors, such as promotion of local productive uses and identification of anchor loads, are also recommended.

Fiscal incentives to lower developers' capital costs and facilitate technology transfer may include import licenses and tax exemptions for generation, control, and metering technology. Control and metering technology, in particular, remain critical technologies that are yet to be localised even in mature markets. Therefore, proactive policies focusing on critical technology transfer could reduce costs, make the technology more accessible to local players, and increase the sustainability of projects.

Box 3.22 Twenty-two micro-hydro power plants leased to private developers in Rwanda

The Rwandan government has leased 22 micro-power projects to private developers for 25 years. The micro-hydro plants will be developed or upgraded and managed by private investors over the period, before reverting to government control. 15 of the projects are new, while seven are in need of upgrades to boost capacity and efficiency. The leasing approach is meant to promote private-public partnerships in the energy sector to attract private investors. The plants, located in Northern and Western provinces, include Agatobwe, Nyamyotsi I and II, Kimbili Rukarara V, Rugezi, Mutobo, Base I and II, and Ngororero. They are expected to add about 24.6 MW to the national grid.

Source: Tumwebaze, 2015; Ministry of Infrastructure, 2015a.

30. *Because substantial investment is required to connect micro-hydro plants to the national grid, applicable PPA tariffs must be designed on a cost-plus-return basis if projects are to be attractive to developers.*

- Targeted policy measures can address revenue risks for the private sector, including well-defined tariffs and PPAs for grid-connected small-hydro projects and innovative public-private-community models for isolated projects.
- Measures to increase capacity utilisation in isolated small-hydro projects, such as promotion of local productive uses and identification of anchor loads, are recommended.
- Tariff-approval processes should take into consideration the settings settings in which plants may be deployed.
- Fiscal incentives may be necessary to reduce developers' capital cost and consumer tariffs and to facilitate critical technology transfer.

Mitigating the risk posed by the arrival of the main grid. Isolated small-hydro projects—like solar, wind, biomass-based mini-grids—remain at risk of encroachment by the national grid. Transparency in grid-extension planning and greater institutional coordination can address this risk. In Nepal, the government provides financial support for expansion of the national grid extension and for micro-hydro plant development, but through different independent entities (NEA and AEPC). The same is true of India and Nigeria, where institutions at the federal and state level pursue electrification in parallel. Under such circumstances, electrification programmes need to be harmonised and coordinated so that financing is optimally deployed and the risk of stranded assets reduced.

When the grid arrives, policy and regulatory measures need to be in place to either compensate the operator (different approaches are discussed in Section 3.3) or connect the plants to the grid (Box 3.23). For the latter to occur, some technical and economic challenges need to be overcome.

On the technical front, synchronisation of frequency and voltage is not always straightforward. Also, transitioning a small-hydro power station from a grid-forming device to a grid-following one may be challenging, especially in areas where grid stability and the generation capacity of the small-hydro station are low. To solve this problem, Nepal has tried aggregation. In 2011, AEPC successfully piloted interconnection of six nearby micro-hydro plants to form a local grid with a total capacity of 106 kW. The interconnected Baglung mini-grid, with its enhanced generation capacity, is now being connected to the main grid. Another project, the Taplejung mini-grid, interconnects eight micro-hydro plants (26–95 kW) and two mini-hydro plants.

Current financing structures for micro-hydro plants, which are primarily based on grants, make it difficult to access the additional financing required to upgrade the plant to make it compatible with the main grid. Therefore these costs must be factored into the original system design and costing or PPA tariffs must be set to justify the additional investment.

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Box 3.23 The benefits of integrating an isolated small-hydro project upon arrival of the main grid

Many isolated micro- and mini-hydro plants operate at low capacity factors (*e.g.*, around 20% in Nepal). When such plants are connected to the main grid, this capacity factor increases to close to 100%. In cases where the levellised cost of energy of the micro/mini-hydro project (after taking transmission and distribution losses into account) is below the lowest consumer tariff on the main grid, main-grid interconnection can boost profitability for both the mini-grid operator and the operator of the main grid's distribution network. Standardised PPAs for power sales, which make the mini-grid operator a small power producer, and bulk power purchases (in case the mini-grid operator also becomes a small power distributer for the main grid) can create enabling conditions for mini-grid operators, as they do under the SPP2 rules in Tanzania. Interconnection would improve the economic viability of these projects, while reducing transmission and distribution losses for the utilities. Projects are underway in several countries. In Nepal, for instance, the Syaurebhumi micro-hydro (23kW) and Leguwa Khola micro-hydro (40kW) have their PPAs finalised at NPR 4.80 per kWh for the wet season and NPR 8.6 per kWh for the dry season (Kathmandu Post, January 6, 2016).

- Transparency in planning extensions of the national grid and greater institutional coordination on electrification programmes can minimise the risk associated with untimely arrival of the main grid.
- Policy and regulatory measures need to be in place to either compensate mini-grid operators upon arrival of the main grid or to connect the operator's plant to the grid.
- Current financing structures for micro-hydro plants make it difficult to access the additional financing needed to make the plants compatible with the main grid. These costs need to be factored into the original system design and costing, or PPA tariffs must be set to justify the additional investment.

Policy measures to facilitate access to finance. Project development costs for hydro-power sites can be quite high compared with those of solar and biomass systems. In addition to the costs associated with electrical, mechanical, and civil engineering, there are those of transporting equipment to remote areas (often involving week-long treks or delivery by helicopter). Often overlooked are the prefinancing costs of technical and community-engagement visits, system design, preparation of loan requests, and drawing up legal documents. Technical assistance and project development grants can ease the prefinancing burden on private project developers.

Concessional loans with tenors of at least 10 years can provide projects with sufficient funds to service debt and pay for operations and maintenance. Grants for capital expenses are effective in bringing down the investment needed to build the plant, as well as its generation cost. But grants have to be designed in such a way as to allow for sustainable operations and eventual scaling up. Setting grants based on predefined household loads constrains the ability of the system to cope with increases in community demand (World Bank, 2015).

In general, a sustainable and market-driven approach is needed to increase the effectiveness of public financing. One approach could be to establish revolving funds pooling international development finance with local public finance to fund projects directly or to provide risk guarantees that enable local financing institutions, in particular commercial banks, to lend. Box 3.24 presents an overview of one such arrangement in Nepal. Innovative approaches such as partial default guarantees or subordinated debt financing from donors or development banks may also be solutions to the financing challenge.

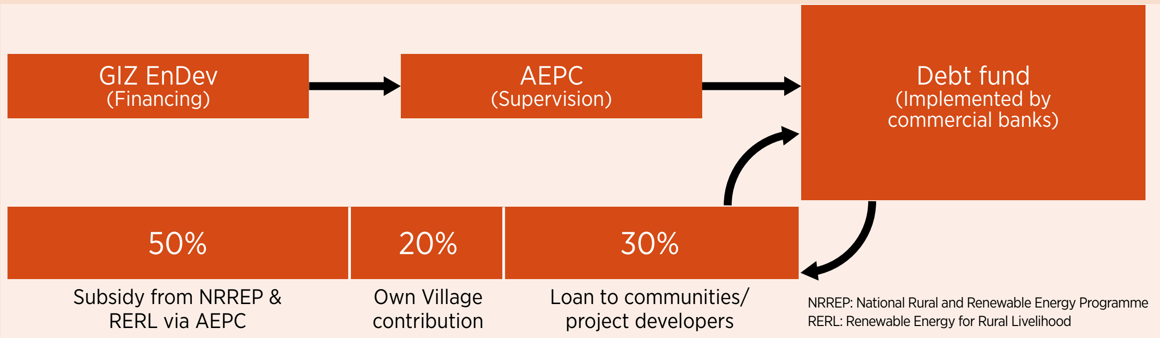
Box 3.24 A debt fund for micro-hydro projects: EnDev Nepal

Government financial support for micro-hydro development in Nepal covers up to half of the total investment, leaving the remaining financing gap to be filled by the local community or private developer. Commercial banks could fill this gap, but their limited experience with renewable energy projects and with lending in rural areas raises their perceived risk—and their interest rates and collateral requirements.

To address this, the Micro Hydropower Debt Fund has been set up under the supervision of Nepal's Alternate Energy Promotion Centre (AEPC) and placed at two commercial banks for administration. Besides providing financial support to local communities, the banks are expected to gain experience in financing micro-hydro project development. Multilateral financial institutions involved as partners administer the loan in the field on behalf of the selected partner bank. Once the loans have been repaid by the communities the funds will be used to finance additional micro-hydro schemes.

The developers of 27 micro-hydro plants have so far benefited from financial support through the debt fund. Twelve of these plants were in operation by the end of 2015, following the severe earthquake of April 2015, and four others were set to reopen.

Figure 3.7 Illustration of financing scheme in Nepal



Source: GIZ, n.d.

Larger mini-hydro systems are better placed than smaller ones to secure long-term project financing, especially in cases where they are (or could be) grid-connected and benefit from PPAs at suitable tariffs. Generally, larger systems with suitable PPAs can guarantee a sufficient return on investment to attract private financing, as has been the case with other technologies.

The longevity of the power plants (well in excess of 25 years) requires special consideration from governments as well as IPPs with a possibility of refinancing or leasing (as seen earlier) or even PPP models (*e.g.*, build-operate-transfer). The financing needs of local equipment manufacturers also deserve attention, since, in many markets, turbines are locally manufactured and represent a substantial part of projects' capital expenditure.

- Technical assistance and project development grants can be useful during the prefinancing phase for private project developers.
- Access to low-cost, long tenor loans increase the effectiveness of public financing.
- Access to debt financing can be expanded through dedicated debt funds, financial risk guarantee instruments, enhanced capacity and experience within local commercial banks, and derisking measures such as long-term PPAs for grid-connected installations.
- Financing for local manufacturers play an important role in the value chain and should be facilitated.

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3.6 CONCLUSION

This chapter discussed policy and regulatory requirements of various combinations of mini-grid technology and tiers of service. Table 3.4 summarises the analysis, categorising the different policy recommendations into primary, secondary, and tertiary measures. The next chapter will explore this categorisation in greater detail and discuss how countries translate the identified recommendations into laws, regulations, and other legal frameworks.

Table 3.4 Policy requirements for different combinations of mini-grid technology and tier of electricity service

<table>
<tr><th></th><th></th><th>Solar DC (tiers 1–3)</th><th>Hydro (run-of-river) (tiers 1–5)</th></tr>
<tr><td rowspan="4">Legal and licensing provisions</td><td rowspan="2">Primary</td><td colspan="2">Generating, distributing and selling of electricity is legal</td></tr>
<tr><td>• Exemption from licensing
• Exclusion from grid code</td><td>• Simplified and standardised licensing processes
• Innovative metering allowed without certification</td></tr>
<tr><td rowspan="2">Secondary</td><td colspan="2">Administrative effort to acquire other permits is reduced and streamlined</td></tr>
<tr><td></td><td>• Land rights simplified for small projects of e.g. <1MW
• Simplified procedures for ESIAs

Water rights laws simplified for small projects of e.g. <1MW</td></tr>
<tr><td rowspan="3">Cost recovery and tariff regulation</td><td>Primary</td><td>• Solar DC mini-grids exempted from tariff regulation</td><td>• Streamlined and standardised tariff approval procedure</td></tr>
<tr><td rowspan="2">Secondary</td><td colspan="2">• Import license and tax exemption for generation, control, and metering technology
• Electricity sales revenue in mini-grids (<100 kW) exempted from VAT; other mini-grids benefit from reduced VAT + tax break or cap</td></tr>
<tr><td>• Efficient DC appliances exempted from import tax and VAT</td><td></td></tr>
<tr><td rowspan="3">Mitigating the risk posed by the arrival of the main grid</td><td rowspan="2">Primary</td><td colspan="2">Reliable information on national grid planning is publicly available</td></tr>
<tr><td>• Provisions for village exclusivity established in policy and law</td><td>• Interconnection rules, FiTs, standardised PPAs established</td></tr>
<tr><td>Secondary</td><td>n/a</td><td></td></tr>
<tr><td rowspan="2">Policy measures to facilitate access to finance</td><td>Primary</td><td>• Long-term grant program
• Revolving debt/equity fund or debt guarantee fund</td><td>• Revolving debt fund with tenors of >15 years partial default guarantee or convertible grant funding</td></tr>
<tr><td>Secondary</td><td>• Low-collateral loans facilitated by national banks prioritising lending to solar DC mini-grids</td><td>• Foreign investments enabled by simple repatriation rules and low withholding tax. Manage foreign exchange rate risk or facilitate local currency loans</td></tr>
<tr><td colspan="2">Tertiary measures</td><td>• A level playing field in terms of public support for different technologies
• Interoperability of mobile money platforms
• Information on benefits of solar is disseminated</td><td>• Hydro resource data is publicly available
• GIS data on settlement location, number of inhabitants, and settlement density is available
• Corruption is prevented through transparent administrative processes</td></tr>
</table>

<table>
<tr><th>Solar and solar-hybrid AC (tiers 1–5)</th><th>Wind and wind-hybrid (tiers 1–5)</th><th>Biomass (tiers 1–5)</th></tr>
<tr><td colspan="3">Generating, distributing and selling of electricity is legal</td></tr>
<tr><td colspan="2">• Mini grids (<100 kW) exempted from licensing
• Mini grids (>100 kW) follow simplified and standardised licensing processes
• Innovative metering allowed without certification</td><td></td></tr>
<tr><td></td><td>• International standards and certificates recognised</td><td></td></tr>
<tr><td colspan="3">Administrative effort to acquire other permits is reduced and streamlined</td></tr>
<tr><td colspan="2">• Land rights simplified for small projects of e.g. <1MW
• Simplified procedures for ESIAs
Water rights laws simplified for small projects of e.g. <1MW</td><td></td></tr>
<tr><td colspan="2">• Mini-grids (<100 kW) exempted from tariff regulation
• Mini-grids (>100 kW) have streamlined and standardized tariff approval procedure</td><td></td></tr>
<tr><td colspan="3">• Import license and tax exemption for generation, control, and metering technology
• Electricity sales revenue in mini-grids (<100 kW) exempted from VAT; other mini-grids benefit from reduced VAT + tax break or cap</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Reliable information on national grid planning is publicly available</td></tr>
<tr><td colspan="3">• Interconnection rules, FiTs, standardised PPAs established for greenfield and brownfield projects
• Main-grid connection risk mitigated through compensation mechanism or predefined PPA tariff together with obligation of distribution company to contract
• Communities allowed to sign exclusivity contracts with mini-grid operators; contracts binding on distribution network operators</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">• Technical assistance and project development grants available
• CAPEX grants covering distribution/public assets preferably delivered as performance grants or through long term PPP facilities</td></tr>
<tr><td>• A revolving debt fund with tenures of >8 years; partial default guarantee or convertible grant funding</td><td>• A revolving debt fund with tenures of >8 years; partial default guarantee or convertible grant funding</td><td>• A revolving debt fund with tenures of >5 years; partial default guarantee or convertible grant funding</td></tr>
<tr><td colspan="2">• Foreign investments enabled by simple repatriation rules and low withholding tax. Manage foreign exchange rate risk or facilitate local currency loans</td><td></td></tr>
<tr><td>• GIS data on settlement location, number of inhabitants, and settlement density is available
• Corruption is prevented through transparent administrative processes
• Interoperability of mobile money platforms is regulated
• Match making platforms and events for small industrial off-grid power consumers and mini-grid operators</td><td>• Feasibility studies and wind assessments are facilitated or financed
Wind resource data is publicly available
• GIS data on settlement location, number of inhabitants, settlement density is available
• Corruption is prevented through transparent administrative processes
• Interoperability of mobile money platforms is regulated
• Matching making platforms and events for small industrial off-grid power consumers and mini-grid operators</td><td>• Biomass resource data is publicly available
GIS data on settlement location, number of inhabitants, settlement density is available
• Corruption is prevented through transparent administrative processes
• Interoperability of mobile money platforms is regulated
• Matching making platforms and events for small industrial off-grid power consumers and mini-grid operators
• Skilled labour and academics trained for operation</td></tr>
</table>

TRANSLATING RECOMMENDATIONS INTO POLICIES AND REGULATIONS

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Developing the policy and regulatory framework needed to scale up mini-grid deployment would require introducing new, or adapting existing, policies, regulations and other legal structures that govern the functioning of the electricity sector. Additional measures that transcend ministerial mandates, such as policies and regulations governing the financial sector, data and statistics, and rural development, would also be needed. This chapter focuses on the measures needed to create an enabling environment for mini-grid development. It begins by classifying measures as primary, secondary, or tertiary (Section 4.1). Then, it provides examples of national implementation of each type of measure to promote private mini-grid deployment (Section 4.2 to Section 4.4).

4.1 CLASSIFYING POLICY AND REGULATORY MEASURES

Developing the policy and regulatory environment outlined in Chapter 3 involves measures that can be broadly classified as primary, secondary, or tertiary.

- *Primary measures* are intrinsically related to the national energy framework and remain under the purview of public institutions mandated with energy matters, such as ministries of energy. These include policies and regulations related to the electricity sector, rural electrification plans, and direct financial support provided for mini-grid projects.
- *Secondary measures* are not specific to the energy sector but greatly affect the viability of mini-grid development. These are typically put in place by non-energy ministries and associated public agencies. They include policies related to taxation, land rights, environmental protection, and banking.
- *Tertiary measures* contribute to the broader enabling environment for mini-grids. These enable the efficient implementation of primary and secondary measures, while supporting the sector indirectly (although their effects cannot be easily measured and attributed directly). Examples of such measures include statistics, data collection and fossil fuel pricing.

Table 4.1 summarises the various primary, secondary, and tertiary measures and their relevance to the mini-grid sector. Because legal frameworks and processes vary from country to country, the aspects included in the table are only indicative. The remainder of this chapter will discuss how primary, secondary, and tertiary measures are being implemented.

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Table 4.1 Primary, secondary and tertiary measures to promote mini-grid deployment

	Measures	Relevance to the mini-grid sector
Primary	National policy on energy, renewable energy, and mini-grids	Sets country objectives, identifies priority areas, and outlines the vision for electricity sector development and the role of renewable energy, including off-grid solutions. Dedicated mini-grid policies bring further definition and refinement, including capacity definitions, descriptions of different actors and their roles, and specification of implementation-level interventions, service requirements, and financial incentives.
	Rural electrification strategy; master plan	Defines the timeline, mode, and implementation strategy for rural electrification, covering aspects such as: • The definition of electricity access • Districts/villages identified as being unconnected and areas where specific solutions (*e.g.*, mini-grids) are particularly suited • Financing and grant support strategies.
	Energy legislation	Provides the legal basis for licenses, permits, and concession contracts and schemes for private generation, distribution, and sale of electricity. Establishes the legal and institutional framework for the design, implementation, and enforcement of regulations. Establishes dedicated institutions and defines roles and responsibilities within the sector.
	Mini-grid regulations	Implements the strategies and sets the rules of the game for all mini-grid stakeholders: • Defines tariff guidelines for mini-grid operators. • Provides grid interconnection regulations and procedures. • Ensures safe and reliable operation. • Establishes quality-of-service regulations. • Defines regulations governing feed-in tariffs and power purchase agreements. • Sets conditions for safety, power quality and service level.
	Financial support for mini-grids	Outlines the dedicated financial support available for mini-grid projects: • Defines the types of financial support and their combinations (*e.g.*, grants, concessional loans, guarantees, etc.). • Outlines the purpose of financing (*e.g.*, for project development, fixed assets, capacity building, operational subsidies, leveraging working capital, etc.). • Puts forth the conditions and processes for securing financing (*e.g.*, track record, cofinancing requirements, repayment options, equipment or service standards, etc.). • Provides the source of financing (*e.g.*, revolving debt funds, rural electrification funds, electricity levy or duty, etc.).
Secondary	Environmental and health protection	Defines environmental and health-related obligations of mini-grid developers and operators (*e.g.*, environmental impact assessments, evaluation of use of hydro and biomass resources, etc.).
	Taxation and other fiscal measures	Relates to taxation of rural electricity supply and imported equipment: • Defines taxation (*e.g.*, value-added tax) on mini-grid tariffs. If VAT applies, the amount paid per kWh by a mini-grid customer could be capped at the absolute amount of VAT paid by main-grid customer. • Establishes tax treaties between countries to avoid double taxation for foreign private sector developers and operators. • Outlines tax breaks, tax holidays, and incentives based on tax credits. • Defines exemptions from VAT for locally procured equipment, exemptions from service tax, etc. • Determines reductions in import taxes and duties for imported equipment. • Defines incentive for accelerated depreciation of generation assets.
	Land rights and use	Provides the basis for land acquisition or operators' use of land for generation and distribution (*e.g.*, land ownership and leasing rules for local and foreign companies).
	Incorporation, company formation	Determines rules and procedures for establishing a company, including resources needed to establish special purpose vehicles and the right to transfer profits overseas.
	Building and construction	Defines processes during construction and installation, including permits and approvals for movable structures (*e.g.*, containers), small buildings (*e.g.*, power houses), etc.
	Banking	Affects the willingness and ability of: • Domestic financing institutions to lend to mini-grid projects (*e.g.*, priority sector lending provisions). • International financing institutions to finance local projects/enterprises. • Insurance providers to cater to mini-grid project requirements. • Shapes the extent to which nontraditional financing can be used (*e.g.*, mobile payment, international crowdfunding, etc.)
Tertiary	Technical assistance and capacity building	Establishes the knowledge base on mini-grid systems and business models and increases capacity for the implementation and administration of projects at the individual, organisational, and enabling-environment levels.
	Statistics and data collection	Gathers and makes available data to facilitate site selection, specifically on inhabitants per town/village, average income and existing semi-industrial loads, GPS locations and renewable resources. Identifies institutions responsible for storing and processing data useful for planning.
	Synergies with other sectors	Expands the scope of electricity access discussions to other sectors—including health, education, micro-industries, telecommunications, agriculture, and water—to identify synergies (*e.g.*, as anchor loads) and maximise development impact.

4.2 IMPLEMENTATION OF POLICY RECOMMENDATIONS THROUGH PRIMARY MEASURES

In this section, primary policy measures are briefly illustrated. Key recommendations for specific mini-grid technologies are given where applicable.

National policy on energy, renewable energy, and mini-grids. Integrating mini-grids into national energy policy is essential for creating a conducive environment for private mini-grid development. In a growing number of countries, national energy policy addresses mini-grids and other off-grid solutions for electrification, with explicit mention of private sector participation:

- 'Policies and a supportive regulatory framework shall also be enacted to expand investment and private sector engagement in off-grid electricity service provision, including through partnerships and innovative business models.' —Rwanda's energy policy (2015)
- 'Promote private sector participation in the development and supply of modern energy services' —Tanzania's National Energy Policy (2015)

Dedicated policies for mini-grid development are also being announced. These provide greater clarity and detail on different aspects, including definitions, performance and technical standards, site identification and development, options on main-grid arrival, financial assistance and other incentives, and institutional roles and processes. Such policies may be general (that is, technology-neutral) or apply to specific technologies, as in the case of India.

- India announced its draft National Policy on Renewable Energy-Based Mini/Micro Grids in June 2016 (MNRE, 2016). The draft policy is expected to serve as a guide for dedicated policies at the state level. The state of Uttar Pradesh launched its own mini-grid policy (Uttar Pradesh Mini-Grid Policy, 2016), which defines the development process, business model, financial support available and exit options when the main grid arrives (UPNEDA, 2016). The Uttar Pradesh Electricity Regulatory Commission followed that policy with its Mini-Grid Renewable Energy Generation and Supply Regulations, 2016 (UPERC, 2016).
- In 2015, the Indian state of Uttrakhand unveiled a policy entitled Development of Micro and Mini Hydro Power Projects up to 2 MW (2015) to create conditions conducive to private sector and community participation (Government of Uttrakhand, 2015).

Energy policies in several countries provide dedicated targets for rural electrification or off-grid generation (*e.g.*, in Rwanda and Kenya). To reach the targets, the policies set guiding principles, including the development and implementation of a rural electrification strategy, or master plan.

Rural electrification strategy; master plan. Rural electrification strategies (or master plans) are increasingly popular ways to provide clarity to sector stakeholders—public agencies, private firms, and development organisations—on how the government intends to progress towards universal electricity access. There is no common structure for such plans and no common methodology for developing one; the level and scope of the information presented varies substantially. In some cases the plans for grid-based and off-grid solutions are kept separate. In Namibia, the Off-Grid Energisation Plan (OGEMP) is complementary to the Regional Electricity Distribution Master Plan (REDMP). The underlying objective of the first is to provide access to appropriate energy technologies to everyone living or working in off-grid, pre-grid, and 'grey' areas[31] (UNDP, 2007). As one of its outcomes, Kenya's National Energy and Petroleum Policy (2015), provides the basis for the development of a comprehensive electrification strategy for universal access to electricity by 2020. The strategy is expected to call for an electrification fund, set technical standards, determine the number and location of households and the extent of electricity supply, prioritise areas to be electrified, propose off-grid systems where appropriate, and define the role

31. Off-grid areas are those that, according to the REDMP, will not have access to electricity within 20 years. Pre-grid areas, as defined in the REDMP, are those that will not have access to electricity within 5 years. However, the OGEMP focuses on providing access to pre-grid areas that will not have access to electricity within 10 years in the updated REDMP GIS database. Grey areas are those where it is not clear in the REDMP how or if access to electricity will be provided of county governments in the national electrification strategy (Ministry of Energy and Petroleum, 2015).

In general, rural electrification master plans should include clear budget references and output indicators. It should explicitly identify grid-extension areas and off-grid areas suitable for mini-grids. A single public organisation should be responsible for collecting all relevant information and preparing updated maps on an annual basis. The information to be collected and presented includes: current and planned grid extensions, reliable numbers of inhabitants per town and village and their average income, and existing and potential semi-industrial operations. Sources include the national census, GPS data on villages, and renewable resource data.

Energy legislation. Energy laws or acts codify and consolidate policy decisions on electrification and renewable energy. They form the legal basis and institutional framework for legal private electricity generation, distribution, and sales. The codification of energy policy might include formulations similar to those sampled in Table 4.2.

Table 4.2 Examples of policy decisions appearing in legislation

Policy decision	Legislative formulation or description	Jurisdiction and date
Exemptions from licensing and tariff approval	'Very Small Isolated Grids that, at the time of commissioning or subsequently following expansion, have total net generation capacity of less than 50 kW (< 50 kW) shall be exempted from licenses issued under this Regulation. The Developer of a Very Small (<50kW) Isolated Grid shall however notify the Authority on such activity prior to its commencement.'	Rwanda (2015)
Simplified processes for obtaining licenses for mini-grids	'The developers intending to carry out the following activities shall apply for a Simplified Electricity License: a. Medium-size Isolated Grids that, at the time of commissioning or subsequently following expansion, have total net generation capacity that is connected to the Isolated Grid of between 100 kW and 1 MW(100 kW- 1MW); b. Small Isolated Grids that, at the time of commissioning or subsequently following expansion, have total net generation capacity that is connected to the Isolated Grid of between 50 kW and 100 kW (50-100kW).'	Rwanda (2015)
Standarised licensing or concession processes for mini-grids	Standardised templates for registration and licensing/concession request will be available at the homepage of the regulator. These templates have reduced information and non-sector permits requirements, and inform about regulatory decision making processes transparently	Tanzania (2016)
Principle of subsidiarity	'Single Window Clearance: UPNEDA will act as the Nodal Agency for Single window clearance for all Mini Grid Projects which include the task related to issuance and facilitation of desired Government orders, necessary sanctions/ permissions, clearances, approvals, consent, etc. in a time bound manner.'	India, Uttar Pradesh (2016)
Cost-covering tariffs	'Any SPP or SPD that sells electricity to retail Customers, shall charge a tariff that, at a maximum, shall be limited to the sum of operating costs, depreciation on capital, whether supplied by the SPP or SPD or others, debt payments, reserves to deal with emergency repairs and replacements, taxes, plus a reasonable return on capital provided by the SPP or SPD that reflects the risks faced by the SPP or SPD.'	Tanzania (2015)
Exemption from regulatory approval for micro-grid tariffs	'An operator of a VSPP [<100kW] who intends to sell power to a retail Customer shall not be obliged to apply to the Authority for approval of its Retail Tariffs, but the Authority may review the VSPP's Retail Tariff upon receipt of a petition on the Retail Tariff charged signed by 15% of the households in the area served by the VSPP.'	Tanzania (2015)
	'The Authority shall not accept comparisons between tariffs charged by the Licensees under this Regulation and tariffs charged by Large Distribution Network Licensees as a valid reason for customer complaints.'	Rwanda (2015)

Table 4.2 (continued) Examples of policy decisions appearing in legislation

Policy decision	Legislative formulation or description	Jurisdiction and date
Tariff caps	Electricity Tariff: Developer will charge Rs. 60/- per month for load of 50 Watt, Rs. 120/- per month for load up to 100 Watt for 8 hours of daily electricity supply and for the load more than 100 Watt tariff will be on mutual consent between consumers and developer	India, Uttar Pradesh (2016)
Concession with exclusivity	A concession is required to generate, transmit and sell electricity. The concession is granted for at least 15 years. The main-grid operator shall not connect the mini-grid to the main-grid within these 15 years.	Mali (no date; unofficial translations of concession documents by World Bank)
Feed-in tariffs and standardised power purchase agreements for renewables	'24. (3) In the event a SPP Developer who has been operating an SPP that has been previously operated on a Mini-Grid requests the Authority to operate as an SPP selling bulk electricity to a DNO connected to the Main-Grid under Rule 24 (1) (a): (...) (c) the applicable tariff paid to the SPP shall be the Mini-Grid tariff until: (i) the interconnection with the Main-Grid; or (ii) the date specified in the notice described under Rule 24 (1), whichever comes later; and (d) thereafter, the applicable tariff shall be: (i) for SPPAs executed before coming into force of the Rules, the Main-Grid Standardised SPP Tariff calculated on the basis of avoided cost principles shall apply; (ii) for SPPAs executed after coming into force of these Rules, the Main-Grid Standardised SPP Tariff calculated on the basis of technology cost principles shall apply'	Tanzania (2015)
Compensation mechanism	'The price for the purchase of assets and rights of the Isolated Grid (...) shall be negotiated based on the following: a. The net book value of fixed assets indexed with the consumer price index and based on generally accepted accounting principles, plus b. The value of current assets less current liabilities; plus c. The present value of expected net profits over the remainder of the Isolated Grid License and based on a discount rate provided by the Authority. '	Rwanda (2015)
Interconnected mini-grids	'24. (1) An SPP Developer who has built a distribution system to standards that allow interconnection with the Main-Grid shall, in the event of an SPP that has been operating on an isolated Mini-Grid and eventually becomes connected to the Main-Grid, apply to the Authority for the right to operate as: (a) an SPP selling to a DNO that is connected to and operating on the Main-Grid; (b) an SPD that purchases electricity in bulk from a DNO connected to the Main-Grid and then resells that electricity to the SPD's retail Customers; or (c) a combination of a Small Power Producer and an SPD.'	Tanzania (2015)
Debt support	A concessional debt support fund for renewable energy mini-grids shall be established and administered by two competitively selected local banks.	Nepal (2016)

Sources: RURA, 2015; EWURA, 2016; Government of Uttar Pradesh, 2016; Tanzania, 2015; EnDev, 2016.

Mini-grid regulations. Regulators may consider exempting smaller mini-grid systems from regulation or reducing technical standards, environmental regulation, and quality-of-service requirements, while retaining necessary safety standards. Recognition of international standards and certification programs (ARE, 2011b) can facilitate the implementation of renewable energy mini-grids in general.

On the question of tariff regulation, it should ensure financial sustainability and viability for private developers or operators. It is important to establish clear methodologies for computing tariffs or caps, and to consult with relevant stakeholders during the decision-making process. It is also advisable to coordinate tariff methodology decisions with regulatory decisions outside the sector (*e.g.*, on land titles, tax registration,

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environmental approvals, etc.), and to bundle regulatory approval for a given company's mini-grid sites in order to streamline administrative processes. Where tariff regulation is exempted (*e.g.*, for mini-grids under a specific capacity), community-approved tariffs are arrived typically through a participatory approach. In either case, appropriate financial support may be needed to ensure sustainable operation and viability.

Financial support. The provision of financial support from government sources is often outlined in a policy document. An example is Nepal's Renewable Energy Subsidy Policy (2016), which discloses the subsidy amount for various renewable energy technologies and the regions where they are being deployed. A key determinant of the application of subsidies in the country is that the subsidy generally covers 40% of the total costs. The remainder is presumed to come in the form of credit (30%) and private sector investment. Often, communities or households may make cash or in-kind contributions (AEPC, 2016). In India, central financial assistance for off-grid and decentralised solar applications, including mini-grids, is set for each financial year in an official notice (MNRE, 2014). A great number of financing programmes involve partnerships between governments and donors or development agencies. In these cases, donors provide a dedicated funding line, often implemented through a public agency of the recipient government. Such partnerships are dynamic, and policy documents may explicitly declare the intention of the government to engage with the wider donor/development community to establish funding facilities.

4.3 IMPLEMENTATION OF POLICY RECOMMENDATIONS THROUGH SECONDARY MEASURES

Governments usually require mini-grid operators to obtain approvals and permits from within the energy sector and from outside it before starting their operations. Examples from outside the energy sector include environmental, health, and safety approvals; tax registration; import licenses; land and natural resource rights; and permission from local authorities to conduct business and to construct power generators and distribution lines. This section briefly discusses secondary measures, with specifics on mini-grid technologies when applicable.

Environmental and health protection. Instead of running through a dedicated environmental impact assessment (EIA), mini-grid projects could be categorised. Each project category has its specific set of environmental risks—of pollution, noise, and so on (Box 4.1). Experience suggests that solar mini-grid EIAs, for instance, are largely the same. Mini-grid operators should therefore be bound by rules established for each category of project. That way, costly on-site visits and regulatory requirements can be reduced to the minimum. Hydro and biomass projects, which cannot be assessed with the method above, should run through a well-structured and light-handed EIA procedure. A useful exercise would be to raise awareness amongst environmental regulators about the characteristics of renewable energy–based mini-grid projects to ensure that they are appropriately categorised.

Box 4.1 Environmental, health and safety regulations for small power producers in Thailand

The Thai Ministry of Natural Resources and Environment (MNRE) sets the environmental review requirements for industrial facilities including small power producers (10–90 MW) and very small power producers (VSPPs, <10 MW). From the origin of the VSPP program in 2002 until 2012, no environmental review was required for projects under 10 MW, but an environmental impact assessment (EIA) was required for projects above that capacity.

The arrangement was not ideal; a significant number of VSPPs were approved or built that were just below the 10 MW limit, skirting the MNRE rule and engendering a public backlash against local air pollution and the traffic and safety impact of trucks hauling biomass on local roads. By December 2012, of 42 VSPP projects that were online, 20 were between 9 and 9.9 MW. Moreover, out of 174 VSPP projects that were under development with signed power purchase agreements, 96 were 9.9 MW and another 36 were between 9.0 MW and 9.8 MW.

A so-called Code of Practice report is required for projects over 1 MW under the 'Notification of Energy Regulatory Commission (Code of Practice)' dated September 2014. The regulation requires that for a project to be approved by the Electricity Regulatory Commission, the owner must submit with the generation-license application an environmental checklist addressing issues throughout the project lifecycle. In addition, for projects above 5 MW but below 10 MW, an environmental and safety assessment is also required. The requirements of the assessment include establishing environmental baseline conditions and identifying and mitigating adverse impacts to the environment and natural resources.

Source: SLP Environmental, 2015.

Taxation and other fiscal measures. This category includes the taxation of rural electricity sales as well as taxes on imported equipment and appliances required for mini-grid installation or for subsequent electricity use (*e.g.*, DC appliances). With a proportional value-added tax, the amount of tax paid per kWh would be much higher for a mini-grid customer than for a main-grid customer, especially in mini-grids with cost-recovering tariffs. Thus, VAT tax exemptions, or caps for VATs on mini-grid tariffs, may be applied. To attract foreign companies as mini-grid investors and operators, tax-withholding regulations may be reviewed and bilateral tax treaties established to avoid double taxation of salaries, repatriated profits, and so on (Box 4.2).

Box 4.2 Creation of a favourable investment climate in Tanzania

Tanzania has supported the creation of an environment conducive for foreign investments through several measures:

- The One Stop Investment Centre brings all relevant governmental agencies together in one location to streamline the delivery of services to investors.
- Investors are guaranteed free import and convertibility of foreign exchange.
- Investors are guaranteed the unconditional transferability of funds through authorised dealers.
- Investments in Tanzania are guaranteed against nationalisation and expropriation.
- Tanzania has become a member of the Multilateral Investment Guarantee Agency and the International Centre for Settlement of Investment Disputes.

Source: Power Africa, 2015.

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Income tax reductions; tax holidays, exemptions, and reductions; and accelerated depreciation incentivise mini-grid investment and increase the economic feasibility of mini-grids at lower end-user tariffs. *Taxes and Incentives for Renewable Energy—2015*, produced by KPMG Global Taxes (KPMG, 2015), provides information on renewable energy taxation in 31 countries around the world. More information on specific tax incentives for renewable energy in various countries can be gained from a database maintained by the International Energy Agency and IRENA: Global Renewable Energy Joint Policies and Measures Database (www.iea.org/policiesandmeasures/renewableenergy/). Table 4.3 provides examples of taxation and fiscal measures employed to support renewable energy and mini-grid development.

Table 4.3 Examples of taxation laws and regulations that support mini-grid development

Measure	Country	Law/act formulation / description	Reference
Income tax holiday	Sri Lanka	A 5-year income tax holiday applies to 'power generation using renewable resources'.	Sri Lanka Board of Investment (BOI) (2013)
Reduced corporate income tax	Sri Lanka	Upon expiration of the tax holiday, income tax is limited to 12%.	Sri Lanka Board of Investment (BOI) (2013)
	Madagascar	In the Tax Code of 2015 investments in renewable energy can benefit from a reduction in corporate income tax equivalent to 50% of the investment undertaken.	Repoblikan'i Madagasikara (2015)
Reduced VAT	Madagascar	Equipment for the production of renewable energy is exempted from value-added tax. The list of products exempt from VAT includes wind power generators, hydropower generators, solar water heaters, and solar PV panels.	Repoblikan'i Madagasikara (2015)
Import tax reduction	Brazil	Companies producing electrical energy from wind, solar, and sea power enjoy reduced import taxes.	Tanzania (2015)
Exemptions from import duty and VAT	Kenya	Supplies imported or bought for the construction of power-generating plants, as well as certain equipment and machinery, are eligible for VAT and import duty exclusions under the VAT Act 2013 and VAT (Amendment) Act 2014: • Hydro turbines and water wheels are free from import duty but pay 16% VAT. • PV semi-conductor devices including PV cells and light-emitting diodes, together with wind-powered generating sets (preassembled), are subject to a 5% import duty and 16% VAT. • Solar cells and modules that are not equipped with elements such as diodes, batteries, or similar equipment are free from import duty and exempt from VAT. • Wind engines (wind mills) are free from import duty and exempt from VAT.	Various documents from IEA/IRENA Policies and Measures Database
Accelerated depreciation	Madagascar	Investment in equipment (except for buildings) can be depreciated at an accelerated rate of 30% of net value.	Syndicat des Industries de Madagascar (2015)

Table 4.3 (continued) Examples of taxation laws and regulations that support mini-grid development

Measure	Country	Law/act formulation / description	Reference
Exemption from goods and services tax	Seychelles	'Goods imported to be used in the process of conservation, generation or production of renewable or environment friendly energy sources, as endorsed by the Seychelles Energy Commission are exempt from Goods and Services Tax'. A similar exemption for renewable energy technologies is offered in the 2010 'Promotion of Environment Friendly Energy Regulations' under the Trades Tax Act.	Amendment 3 to the 2010 regulations of the Goods and Services Tax Act of 2001 (Regulation 163F)
VAT refund	Nepal	An arrangement has been made to refund VAT to small-hydro projects developed and operated by community-based consumers committees that do not elect to take the zero rate on import tax.	Nepal financial budget for the fiscal year 2015–16 (Crowe Horwath, 2015)

Land rights and use. Private mini-grid companies must acquire land for their generation assets and distribution grid, bringing them into contact with legislation governing the purchase, registration, and use of land. Automatic rights of way along public streets for distribution and transmission grids, templates for contracts between mini-grid operators and private landowners, and clearance for foreign ownership of land (if foreign investment is targeted) can speed project development and reduce its cost.

Incorporation and company formation. The legislation and regulations governing company formation are an essential concern of private mini-grid companies. Unfortunately, in many developing countries, establishing a business takes months and many separate steps, including the acquisition of various licenses and permits. For mini-grid business models that hinge on the creation of multiple special purpose vehicles, these lengthy procedures can have a detrimental effect on tariffs. The right to repatriate profits must be granted if foreign investment is targeted.

The World Bank's Doing Business project publishes an annual report that sets out the procedures for establishing a private company in 189 economies and selected cities, including the cost and typical approval time for required permits and approvals. Doing Business publications are available at: www.doingbusiness.org/.

Building and construction. Mini-grid operators must obtain permits to build a power plant and grids for transmission and distribution. The more complicated the process (and the more the process depends on obtaining still other regulatory permits and approvals), the more detrimental their effect on tariffs. Permitting processes should be simplified and streamlined. Exemption for building and construction permits should not encourage one type of solution over another (*e.g.*, locally built power house vs preassembled container).

Banking. Properly conceived banking regulations have the power to incentivise national financial institutions to lend to mini-grid projects. Advance preparation of risk assessments and campaigns to provide background knowledge about the sector can help. Including renewable energy projects among the sectors and projects that count towards the minimum portfolio obligations of financial institutions (or priority sector lending), as in Nepal and India, would make more credit available to mini-grid operators and end users of electricity.

4.4 IMPLEMENTATION OF POLICY RECOMMENDATIONS THROUGH TERTIARY MEASURES

Tertiary measures cannot be clearly attributed to either energy ministries or any single other ministry. Some of these measures are discussed below, where possible with country examples.

Capacity building through technical assistance. International or development organisations can finance independent capacity needs assessments at all levels and provide necessary capacity building through

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technical assistance grants or concessional loans. Capacity development can have a huge impact by increasing the ability of mini-grid developers to design and implement projects, undertake pilot projects, develop viable business models, and safely and efficiently operate and maintain mini-grids. It can help bankers understand mini-grids and how to conduct due diligence of mini-grid projects. It can help electricity ministry officials implement policies that enable mini-grids to contribute to rural electrification. And it can help regulators understand mini-grids better and adopt streamlined, light-handed regulation where appropriate. Broader information campaigns can improve the public's understanding of the opportunities and limitations of mini-grids. Table 4.4 provides some examples of capacity building initiatives in Uganda and Sri Lanka.

Table 4.4 Selected examples of capacity building initiatives

Measure	Country	Law/act formulation / description	Reference
Pre-investment barriers	Uganda	Besides providing a variety of financing assistance, the Uganda Energy Credit Capitalisation Company (UECCC) offers various forms of technical assistance to developers and financial institutions to address pre-investment barriers.	UECCC (n.d.)
Mini-grid development; productive end-use	Sri Lanka	Sri Lanka Lights Up: Renewable Energy for Rural Economic Development (RERED) assists communities and authorities with studies of micro-hydropower feasibility, income generation and the productive use of electricity, improved delivery of social services based on access to electricity, energy efficiency and load management, development of carbon-trading mechanisms, integration of renewables into government policy, provincial council development strategies, and sector reform initiatives.	World Bank (2012)

Statistics and data collection. Collecting, aggregating, analysing, and publicising reliable data pertinent to site selection can greatly facilitate project development for all types of mini-grids. Especially important are reliable numbers on inhabitants per town/village and their average income, locally available renewable energy resources and existing and potential productive uses. Sources include the national census, GPS data on villages, and renewable resource data. In addition to gathering the data, appropriate institutions should be responsible for storing the data, processing it (including into GIS maps and carrying out the modelling analysis), and then using them for planning. These functions may be spread across several entities. In Nigeria, data collection is handled by the National Bureau of Statistics, data management by GIS centres, and planning by the ministry and agencies responsible for electrification.

National policy makers and regulators can also facilitate the financing of feasibility studies and assessments of the availability of biomass, hydro, and wind resources, thereby reducing the time, cost, and risk of project development for mini-grids. In Tanzania's REA, GIS data on village locations and populations is superimposed on layers detailing the existing electricity network. The resulting dataset is then made available to mini-grid developers to determine mini-grid priority areas.

Efforts to develop and update centralised data sources can be complemented by bottom-up approaches involving diverse stakeholders at the local-level who are facilitated rather than directed.

Synergies with other sectors. Identifying synergies with other sectors can help mini-grid projects achieve greater end-user impact by creating a virtuous cycle powered by rising living standards, rising electricity demand, and gradually falling tariffs. The sectors with the highest potential synergies include agriculture, health, drinking water, sanitation, education, economic development, and telecommunications. One way of facilitating the collaboration of actors in these synergistic sectors is to organise regular matchmaking platforms—a recommendation that applies to all mini-grid technologies. For example, Sri Lanka's RERED program helps villages to develop productive uses of mini-grid electricity, notably by using electricity during off-peak daytime hours for income-producing productive uses such as agricultural processing, small-scale manufacturing, and handicraft production. Nepal provides a subsidy amounting to 30% of the total investment cost of energy conversion and processing equipment (up to USD 1 000) for enterprises using renewable energy in previously unelectrified areas.

4.5 CONCLUSION

Renewable energy-based mini-grid solutions are well positioned to deliver a large proportion of genera-tion needed to reach universal access to electricity. Faced with high levels of electricity demand growth, they also represent an opportunity for many developing countries to expand the power system from the bottom-up and, in the process, stimulate rural economies. This leap-frogging opportunity resonates strongly with the ongoing global energy sector transformation driven by accelerated growth of cost-effective, decentralised renewable energy solutions. Well-designed mini-grid policies and regulations can support, and even accelerate, this transformation with tremendous socio-economic benefits on offer (Box 4.4).

The policy and regulatory landscape for mini-grids is a dynamic one as governments introduce dedicated measures, gain experience and incorporate learning towards a more effective framework for mini-grid development. This policy development cycle is essential for successful adaptation to local conditions and to address barriers to deployment that arise during different stages of market development. As national policy and regulatory frameworks evolve, lessons learnt and best practices should be captured such that other countries looking to develop similar frameworks can draw on them.

This report analysed country experiences pertaining to one element of an enabling environment for mini-grids: Policy and regulations. There are others, such as business models, financing and capacity building, which were beyond the purview of this report, but contribute immensely to the scale-up of mini-grids. Equally, the report focused on catalysing private sector participation in the sector given re-cent interest and developments. Traditional actors, including community groups, NGOs and develop-ment agencies, have driven sector development for decades and can provide immense insights into de-veloping a sustainable model for mini-grid expansion. Tapping into the wealth of experience of each of the stakeholders, along with political commitment to put in place enabling conditions, policy makers have an immense opportunity at hand to reach electrification and development goals.

Box 4.3 Harnessing the cross-sector development opportunity

The forward linkages of electricity access for rural development are marked by considerable im-provements in productivity, income, and livelihoods, all of which produce further spill-over effects. As noted earlier in this report, renewable energy solutions have the potential to advance at least 12 of the Sustainable Development Goals. The development impact of electricity access depends on how effectively rural communities are able to harness the opportunities enabled through modern energy. An integrated approach that focuses on supply options as well as consumption would enable delivery of tailored technology, financing and capacity building solutions that maximise socio-economic im-pacts. Key sectors, such as agriculture, health and education, all benefit from access to modern ener-gy services, and the modularity of renewable energy technologies enables customisation for different applications . All tend to gain from an integrated approach – improved livelihoods for communities, reduced risks for energy service providers, and rural economy development for governments.

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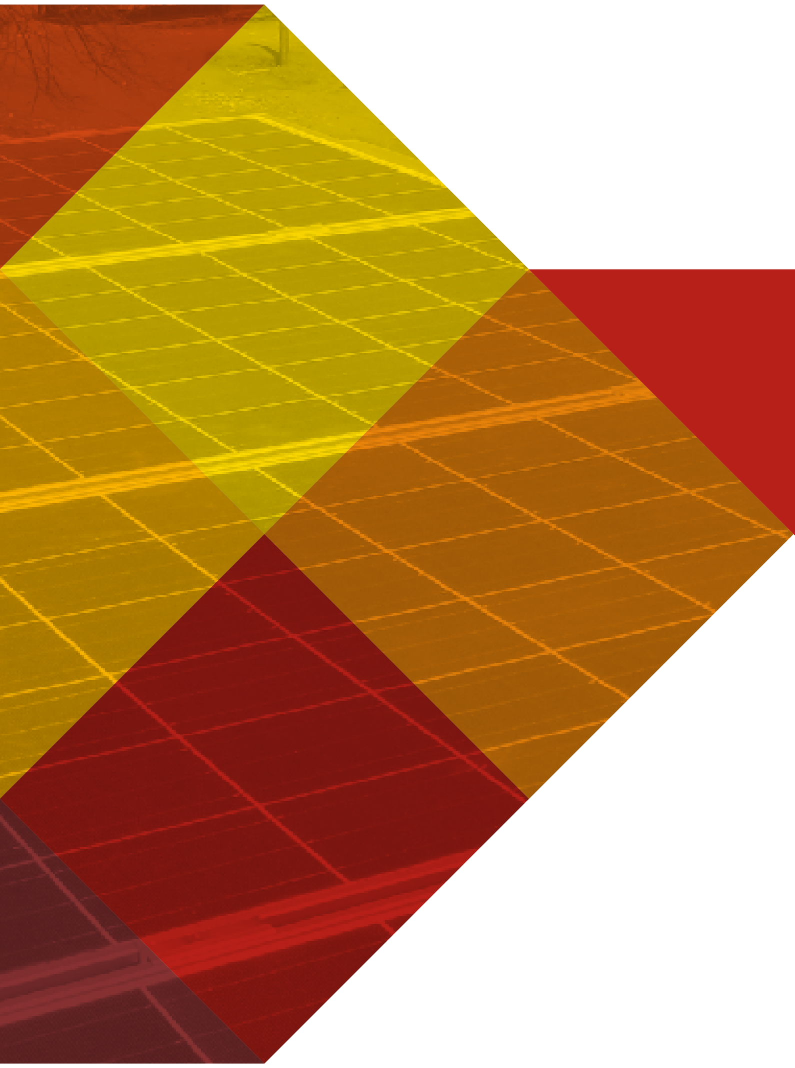

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