Mini-grid Policy Toolkit

Policy and Business Frameworks for Successful Mini-grid Roll-outs

RECP
Africa-EU Renewable Energy Cooperation Programme

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Alliance for Rural Electrification
Shining a Light for Progress

REN21
Renewable Energy Policy Network for the 21st Century

The Toolkit is a product of the Africa-EU Renewable Energy Cooperation Programme (RECP). The RECP is an instrument of the Africa-EU Energy Partnership (AEEP) and aims at promoting renewable energy market development in Africa.

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Implementing Partners

The EUEI PDF is a flexible instrument of the EU Energy Initiative (EUEI) supporting the creation of an enabling environment for investments in sustainable energy markets across Africa, Southeast Asia, Latin America and the Pacific. Furthermore, the EUEI PDF supports the strategic energy dialogue of the Africa-EU Energy Partnership (AEEP) as a secretariat and the implementation of the Renewable Energy Cooperation Programme (RECP).

ARE is an international business association representing the decentralised energy sector working towards the integration of renewables into rural electrification markets in developing and emerging countries. ARE serves as a global platform for sharing knowledge and best practices to provide for swift implementation of available and advanced RE technologies and services.

REN21 is the global renewable energy policy multi-stakeholder network that connects a wide range of key actors. REN21's goal is to facilitate knowledge exchange, policy development and joint action towards a swift global transition to renewable energy. Bringing together a wide range of stakeholders, REN21 provides high quality information, catalyses discussion and debate and supports the development of thematic networks.

Main Chapters

How to use this document

The primary purpose of the Toolkit is to provide guidance on how to design an appropriate policy and regulatory framework for promoting investment in mini-grids.

The Toolkit's starting point is that successful implementation can only be achieved on the basis of a sound understanding of the benefits and characteristics of mini-grids, and in particular the applicable business or operator models.

We therefore advise newcomers to the mini-grid policy field to start from the beginning since the Toolkit provides essential background, and introduces mini-grid economics and operator models. However, the document is written in a modular form, and experts in the field can start at any section they are especially interested in.

Boxes are used to illustrate specific details, or to provide summaries for policy-makers. At the end of each chapter, suggested literature for further reading is provided.

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This document, its case studies and highlighted calculation tools are available for download at: *http://euei-pdf.org/downloads/flagship-publications*; or at *minigridpolicytoolkit.euei-pdf.org*.

Table of Content

Foreword

Africa is the continent of opportunities. African societies and economies are accelerating their rise and integration into the world economy. Building on a strong agricultural base and on vast natural resources, industrialization and the service sector - e.g. through innovations such as mobile banking - are generating jobs and welfare for the African people.

None of this would be possible without access to affordable and reliable energy. Energy is the pre-requisite for economic activity and for human development as well as for water supply, health care, education, and recreational activities.

Africa has progressed in great strides towards building up its energy infrastructure. And yet, vast areas of the continent remain literally in the dark. Rural electrification has reached hundreds of communities through the extension of national grids. However, geography and technology dictate that there are economic limits to further advancing the power networks also in view of the available alternatives. Recent technological innovations have made isolated networks, or mini-grids, one such viable alternative. And yet, so far very few mini-grids have been deployed successfully in Africa. There is thus only limited experience both in terms of technical skills and with regards to providing the required policy conditions. Accelerating mini-grid deployment can play an important role for meeting the evergrowing energy needs of the continent.

It will not be possible to provide all Africans with access to modern and sustainable energy services without increased private contributions. It is widely acknowledged that the energy sector urgently needs private capital and investment to complement the scarce public resources. The private sector, however, does not commit without minimum requirements being met in terms of a stable and attractive policy environment.

This Mini-Grid Policy Toolkit therefore provides much-needed orientation and guidance for policymakers and assists in shaping the policies needed to effectively promote mini-grid deployment. The Toolkit is a tangible result of the Africa-EU Energy Partnership (AEEP), which was funded under the Renewable Energy Cooperation Programme (RECP). The African Union Commission (AUC) has been providing political leadership in the AEEP. The RECP is thus proving an important complementary initiative to the African priority agenda, the Programme for Infrastructure Development in Africa (PIDA). While PIDA focuses on large-scale power generation, transmission and distribution infrastructure, the RECP provides highly appreciated and valuable support to the development of opportunities in the field of small- and medium-scale renewable energy. The AUC applauds these efforts, and remains committed to supporting and facilitating the formulation of conducive policy environments for the African energy markets.
We commend the authors and all the contributors from Africa and from abroad on their efforts. It is our expectation that this document will build a stepping stone for shaping up the policy and regulatory frameworks, and thus for attracting the highly needed investment into Africa's energy markets.

Mr. Aboubakari Baba MOUSSA
Director for Infrastructure and Energy,
African Union Commission

Executive Summary

Rural electrification improves people's quality of life and enables economic development in rural areas. To date, rural electrification in Africa has been based predominately on grid extension. However, progress has remained slow due to the high cost of grid extension to remote areas and limited utility/state budgets for electrification. It is thus advisable to extend the central grid only where it makes economic sense, to operate mini-grids in villages outside the reach of the central grid, and to apply stand-alone systems (like Solar Home Systems and pico-PV systems) in sparsely populated areas with weak demand potential. **The future electrification will rely on mini-grids to a large extent; the International Energy Agency (IEA) anticipates that more than 50% of the rural population currently without energy access are best supplied with electricity via mini-grids.**

Mini-grids involve small-scale electricity generation (10 kW to 10MW) which serves a limited number of consumers via a distribution grid that can operate in isolation from national electricity transmission networks. Putting in place the right policy for mini-grid deployment, and thus accelerating its uptake, requires considerable effort but can yield significant improvements in access to electricity, as examples from Senegal, Mali, Tanzania, Kenya and other countries show.

When using mini-grids as part of a rural electrification portfolio, policy-makers are advised to tailor policy and regulatory frameworks to one or more suitable operator models. **Mini-grids can be operated by utilities, dedicated private companies, community-based organisations or some combination of these.** In practice these four major options are called the utility, private, community and hybrid operator models. The preferred choice of model depends on national, social and political circumstances as well as on the size and structure of the mini-grids. Today, more and more governments are trying to attract private financiers and private mini-grid operators in view of constrained public budgets.

The major hurdles for mini-grid implementation and operation at present are related to socio-economic, policy, regulatory, economics and financing issues. Despite the occasional presence of poorly designed, implemented, operated and maintained systems, **mini-grid technologies themselves have a sufficient track record to merit the inclusion of mini-grids in rural electrification planning. Furthermore, renewable energy technologies used in mini-grids can provide electricity at a lower cost than fossil fuel-based power generation at many sites.** They also provide increased energy security and system adaptability under changing climatic conditions. Some renewable energy mini-grids installed in the early 1990s are still in operation today and provide reliable electricity services, proving their value in rural electrification.

In principle, mini-grid revenues need to cover the investment as well as operation, management and maintenance (O&M&M) costs. The investment costs accrue through purchasing the generation and distribution assets and via investment in project development, project implementation and project financing (incl. interest). These investment and O&M&M costs need to be covered by electricity revenues, and by subsidies where necessary and appropriate. Mini-grid revenues depend on electricity demand, the affordability of connections, as well as the tariffs for households, businesses and public institutions. Collecting sufficient revenue in rural areas is more challenging than in urban areas because electricity demand and the ability to pay

are lower in these areas. Policy-makers can mitigate the resulting economic risk through a suitable policy and regulatory framework. This includes defining appropriate tariff structures that reflect the mini-grid operators' cost structure, through adequate financial support, and a well-designed process for obtaining and holding permits, licences and concessions.

Given the low margins of return often associated with mini-grid systems, it is challenging not only to recover the investment but also to finance the initial investment in the first place. While private capital is required because of limited public funds, private investors still perceive mini-grids as a high-risk and low-return investment. Policy-makers can step in with instruments like a reliable and long-lasting tariff scheme, a dependable generation- and distribution licence policy and transparent main-grid extension planning or demand guarantees.

Understanding the level of interest and possible contribution of stakeholders is essential for policy-makers in order to design and implement a conducive mini-grid policy and regulatory framework. Indeed, engagement with stakeholders, such as customers, public utilities, private developers and operators, as well as financiers, is also critical for successful mini-grid implementation. Customers want affordable and quality electricity. However, getting electricity sooner rather than later is often more important for customers than getting it cheaply. Utilities can be mini-grid implementers and operators in larger mini-grid systems (e.g. mini-grid systems >1MW). Smaller systems need more decentralised management structures, which often do not fit with the management practices of large utilities. While utilities may be interested in operating larger mini-grid systems, it is mainly dedicated private companies and community-based organisations that have traditionally been involved in mini-grid development, implementation and operation (with some funding and support from donors or public actors). Experience from countries such as Cambodia, India, Mali, Nepal and Senegal shows that there is significant potential for dedicated private companies and local entrepreneurs to develop and operate mini-grids.

Financiers can provide equity and debt finance, but to do so they need adequate risk-return profiles for their investments, and must trust the policy and regulatory framework as well as the project developers they finance. This trust can be fostered by policy-makers by creating a suitable and reliable framework, by supporting the creation of a track record for project developers (e.g. through demonstration projects under real life conditions), and by leveraging existing instruments, contributions and expertise from relevant stakeholders.

In the short and medium term, **rural electrification investment in developing countries cannot only rely on revenues from clients, but needs subsidies** (as was also the case in OECD countries during their initial rural electrification roll-outs). Yet, subsidy schemes have to be well-designed as ill-designed subsidies can hinder rather than support mini-grid roll-outs. Finding the right way of subsidising mini-grids, managing public investment, attracting private co-financing for long-term and efficient operation of mini-grids are complex and demanding tasks.

This Mini-Grid Policy Toolkit provides guidance on how African policy-makers can develop a sustainable mini-grid policy. Such a policy should aim at fostering electricity access and economic activity with quality -

and ideally clean electricity over the long-term. Before mini-grid policies and regulations can be designed, some major political decisions have to be taken. Among these are whether to include mini-grids in rural electrification at all, which general approach to adopt (centralised vs. decentralised), how to finance it up front (government vs. private), and how to set tariffs (cross-subsidised vs. cost-covering tariffs). These decisions create the foundation for the policy and regulatory framework and determine which mini-grid operator models can be applied. The framework should be based on sound principles, i.e. be stable and long-lived, clear and comprehensive, accessible, cost-effective and efficient, light-handed and simplified, ensure reliable, affordable electricity as well as be transparent and predictable. Public institutions then need to be able to implement this policy and regulatory framework and take on specific roles and responsibilities to support mini-grids.

The most essential components of an effective mini-grid policy and regulatory framework can be organised into different categories:

- political decisions and energy policy,
- economic policy and regulations,
- customer and environmental policy and regulations,
- licensing and contract regulations,
- financial sector support, and
- other sector support schemes.

Schematic overview of the Links between policy instruments and mini-grid operator models

The table on the next page details the specific policy instruments discussed in this Mini-grid Policy Toolkit, and indicates their importance for specific mini-grid operator models. The operator models are indicated by the letters in the boxes, on the right hand side:

- U for utility operator model,
- H for hybrid operator model,
- P for private operator model, and
- C for community operator model.

For each model, the intensity of the colour of the box indicates the importance of the instrument:

- high priority is shown with a solid colour box,
- and supportive instruments with a lightly shaded colour box.

In this Toolkit, each instrument is defined, its relevance explained, and further literature, tools, guidebooks and examples are referenced.

The instruments presented are embedded in a broader process of designing and implementing mini-grid policy and the regulatory framework. This process can follow various possible paths, one of which is presented in the last chapter of this Mini-grid Policy Toolkit.

Table 1 Regulation, Financing, Technical Assistance instruments according to priority for each operator model

Level	Ref	Instrument	Operator model
Energy and Electricity Policy	A1.	National Electricity or Electrification Policy	**U** **H** **P** **C**
	A2.	Rural Electrification Strategy and Master Plan	**U** **H** **P** **C**
	A3.	Energy and Electricity Law (incl. Implementing Institutions)	**U** **H** **P** **C**
	A4.	Tariff Policy and Regulation (incl. Connection Fee)	**U** **H** **P** **C**
Economic Policy and Regulation	B1.	Fiscal Policy and Regulation (Taxation, Import Duty, etc.)	U **H** **P** **C**
Customer Protection and Environmental Policy and Regulation	C1.	Technical Regulation (incl. Grid Connection)	U **H** **P** **C**
	C2.	Quality of Service Regulation	U **H** **P** **C**
	C3.	Environmental Policy and Regulation	U H P C
Licences and Contract Regulation	D1.	Generation and Distribution Permits and Licences	U **H** **P** **C**
	D2.	Concession Contracts and Schemes	U H **P** **C**
	D3.	Power Purchase Agreements (PPA)	**H**
Financial Support Schemes	E1.	Grants and Subsidies (incl. CAPEX, OPEX and performance based)	U H P **C**
	E2.	Loan Support and Risk Mitigation Instruments	H P C
Technical Assistance	F1.	Technical Assistance (incl. Awareness Raising and Promotion, Vocational Training, Institutional Capacity Development, Network Development, Project Developer Guidelines, relevant Data (e.g. grid extension, socio-economic data, resource maps)	U H P **C**

Legend: U stands for utility, H for hybrid, P for private and C for community operator model.
U **H** **P** **C** symbols stand for high priority instruments,
U H P C symbols stand for supportive instruments.

1. Introduction

Policy-makers are in a difficult situation; there is vast demand for electricity in both urban and rural areas, yet providing access to quality electricity entails a high cost. At the same time, government and utility budgets are limited. Governments and utilities can therefore only afford to provide access to electricity to a limited number of people each year, and have to prioritise. Providing electricity in urban areas and in areas close to existing grid structures is cheaper. Yet most people in Africa are living in rural areas, often far away from the grid.

Often the most cost effective way to provide electricity is with mini-grids. This Mini-grid Policy Toolkit presents background information, guidance through pragmatic solutions, useful tools and valuable literature for the creation of supportive policy and regulatory frameworks for mini-grids.

The **Mini-grid Policy Toolkit is primarily written for African policy-makers with the objective of enabling scale-up of mini-grids beyond a few pilot projects.** However the core elements contained in this toolkit are also relevant to policy-makers on other continents, as well as development banks and donor agencies seeking to support and advocate for improved policies and regulations. The aim of this publication is to improve the understanding about mini-grids, the stakeholders of the mini-grid sector and the options for a supportive mini-grid policy and regulatory framework. Important policy and regulatory instruments to support the mini-grid sector are introduced and further ´tools´ - literature and sample documents - are referenced in order to facilitate a deeper understanding of each of the topics addressed.

The Toolkit provides essential information for understanding the mini-grid space. It first illustrates alternative electrification options - grid connection, mini-grids and stand-alone systems (e.g. Solar Home Systems, pico-PV systems). It then takes a closer look at the benefits of electrification in general, both for the abovementioned options and specifically for mini-grids before discussing international and African experience with mini-grids in *chapter 2*. Technical basics of mini-grids are addressed in the Annexes (technical regulatory issues are covered in the main text). It also briefly presents the four key mini-grid business or operator models (the private, utility, community and hybrid models) in *chapter 3*.

Mini-grid Definition

In this publication we define mini-grids[1] as involving small-scale electricity generation (from 10kW to 10MW), and the distribution of electricity to a limited number of customers via a distribution grid that can operate in isolation from national electricity transmission networks and supply relatively concentrated settlements with electricity at grid quality level.[2] "Micro-grids" are similar to mini-grids[3] but operate at a smaller size and generation capacity (1-10 kW).

1) A short discussion on mini-grid technology can be found in Annex I: Mini-grid Technologies.
2) Mini-grids can either be unconnected with the national grid or connected, in which case they have the option of operating in isolation at times when the national grid is not operational.
3) Throughout this document, "micro" and "mini" grids are used interchangeably.

As government and utility budgets are limited, financing mini-grids is challenging for the public sector. Thus, privately financed, owned and operated mini-grids are getting more and more attention. **Hence the Toolkit has some degree of focus on private operators and financiers** especially in its economics chapter *(chapter 4)* which discusses electricity demand, cost, revenues and financing of mini-grids.

Designing a policy and regulatory framework for mini-grids is a complicated task. Rural electrification is typically a complex issue because of different, and sometimes competing, interests of the key stakeholders: customers, utilities, private developers/operators and financiers. To shed some light on these issues, this Toolkit addresses the motivations, interests and contributions of stakeholder groups in *chapter 5*.

This provides the basis for designing policy and regulatory requirements, which are presented in *chapter 6*. **Policy and regulatory instruments promoting mini-grids need to reflect the characteristics of the different operator models.** Until now, no clear guidance is available about which measures or instruments are required for each operator model. **This Toolkit aims at filling this knowledge gap.** The discussion is structured into six modules, which cover energy policy, economic policy and regulation, customer and environmental policy and regulation, licences and contract regulation, financial support schemes and technical assistance respectively. **For each of the four different operator models the chapter illustrates both essential aspects, as well as more supportive policy instruments.** The toolkit ends with an example of how the design and implementation of the policy and regulatory process could look like in *chapter 7*.

In general, the focus of the toolkit is on enabling electrification, so it is written in a technology-neutral way. However, the long-term cost and energy security advantages of renewable energy generation technologies such as hydro power, photovoltaic (PV), and wind are demonstrated and discussed throughout the document. As this Toolkit attempts to be useful for both newcomers and experts it has a medium level of detail. It is also written in a modular way, so experts already highly familiar with the basics, operator models, mini-grid economics and the stakeholders can jump straight to the *chapters 6* and *7* where the policy and regulatory instruments are described. In addition, the Toolkit merges established understanding of mini-grid policy and regulation with recent developments as well as presenting new and partly unpublished insights from practitioners.

FURTHER READING

For readers who have only recently started to deal with mini-grids or who are looking for short, comprehensive summaries, the following publication is recommended:

1.0 **GVEP International (2011).**
The history of mini-grid development in developing countries. Policy briefing.

2. Basics of Mini-grids and Rural Electrification

Mini-grids have emerged as a game-changer for rapid, cost-effective, and high quality electrification in rural Africa. Under the right conditions, mini-grids can complement national grid electrification strategies for providing access to electricity. This in turn can modernise standards of living and enable small rural businesses.

Electricity Access in Africa

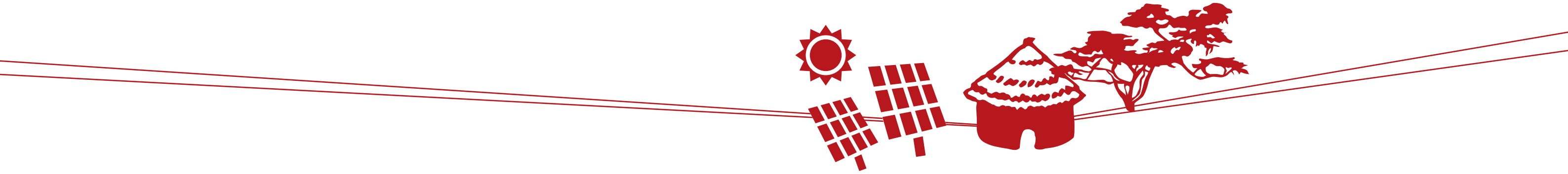
The challenge of electrification is best summarised by giving some widely cited numbers for Africa. The IEA (2013a) estimates that 599 million people in Sub-Saharan Africa had no access to electricity in 2011. In business as usual scenarios, this number is expected to increase to 645 million people by 2030 due to population growth. Investment in the power sector is so far insufficient to reverse the trend and achieve universal access to electricity by 2030. To reach this goal, the United Nations Sustainable Energy for All Initiative (UN SE4ALLl) estimates in their Global Tracking Framework (2013) that Sub-Saharan Africa would need an additional 19.1 bn USD of investment annually for high quality electricity access. It is further estimated that 86% of people living in rural areas in Sub-Saharan Africa have no access to electricity, compared to 37% in urban areas (SE4ALL, 2013).

2.1 Technical Solutions to Rural Electrification

The three alternatives for providing electricity access in rural areas are national grid extension, mini-grids and stand-alone systems. **Rural electrification experts usually recommend using grid extension only where the cost is reasonable, operating mini-grids in villages where the cost of grid extension is too high, and applying stand-alone systems (e.g. Solar Home Systems and pico-PV systems) in scarcely populated areas with weak demand potential.** IEA's Energy for All (2011) report estimates that only 30% of the world's rural populations currently without access to electricity are best served by extending the main grid. The remaining 70% are better suited either to mini-grids (in total 52.5%) or stand-alone systems (in total 17.5%). These figures demonstrate the enormous need for investment in rural electrification in general and mini-grids in particular.

The extension of the national electricity grid should only be done for densely populated areas with enough demand potential to justify the high investment cost of transmission lines, which may be more than 22,750 EUR[4] per kilometre, and of distribution lines, which cost around 12,000 EUR per kilometre (ARE, 2011) in most African countries. Grid-based retail electricity tariffs in African countries range from less than 0.04 EUR/kWh (subsidised tariffs) to over 0.23 EUR/kWh (non-subsidised tariffs) (IMF, 2008).

4) In the following, all price quotes from original sources are converted into Euros using the exchange rates from 24th of August 2014. The U.S. Dollar exchange rate was 1.00 Euro = 1.3187 U.S. Dollar.



Stand Alone Systems are mostly small diesel gensets and photovoltaic systems in the form of Solar Home Systems (SHS, up to 150Wp) or pico-PV systems (up to 10Wp). The systems are installed directly at the end-user's house without any distribution networks. Their advantages are affordability in terms of initial investment (compared to the two other approaches) and the immediate benefits (replacing kerosene, battery or other expensive energy sources). The main disadvantage is the limitation in terms of electrical power, which allows only low load applications to be connected. All over Africa, 4.4 million pico-lighting systems were sold between 2009 and 2012. While pico-PV systems typically cost less than 75 EUR, the prices for SHS vary widely - between 1.21 EUR/kWh and 1.52 EUR/kWh (on LCOE basis) in Africa (REN21, 2014).

SUMMARY FOR POLICY-MAKERS

According to IEA estimates, the number of people in Sub-Sahara Africa without access to electricity is expected to rise from 599 to 649 million in 2030, unless investment can be substantially accelerated.

The three alternatives for providing electricity access in rural areas are national grid extension, mini-grids and stand-alone systems. The regional deployment of these systems should be based on local economic, geographic and social factors.

Mini-grids thus have their "space" where they are the most appropriate option for rural electrification, i.e. where it is too expensive to provide grid electricity, and where settlements are sufficiently concentrated and clustered. In addition to the overall benefits of rural electrification, mini-grids have specific benefits, including speed of deployment, additional private sector growth, and flexibility of technical and operational models as well as - especially when supplied by domestic renewable sources - energy security.

Today's main barriers for mini-grid deployment are not related to technology, but to economic, financial, regulatory aspects as well as institutional and human capacity. Past experiences have revealed challenges with the sustainable operation of mini-grids. However, examples from both Africa as well as from other regions have shown that these problems can be overcome, in particular through business driven approaches.

Sound rural electrification planning is required and must address future integration of mini-grids into the national grid. This rural electrification planning should identify areas for electrification through national grid extension, mini-grid electrification, or stand-alone systems. State of the art for rural electrification planning are GIS based spatial least cost planning tools for rural electrification.

The Role of Renewable Energy in Mini-grids and the Hybridisation Potential in Africa

Many mini-grids worldwide still solely depend on diesel for electricity generation. However, using renewable energy (hydro, solar, biomass, or wind energy) in mini-grids reduces cost, increases energy security and reduces environmental pollution. A diesel generator may supply electricity in times when the renewable energy supply is not sufficient and thereby help to guarantee reliable electricity supply at lower cost.

Hybridisation, the addition of wind, PV or biomass power to an existing diesel mini-grid, is widely discussed among experts in the mini-grid field because of these benefits. Hybridisation of existing diesel generators, of which thousands exist world wide, "represent[s] an excellent cost competitive option for many rural areas and a real opportunity for renewables" (ARE, 2011).[5]

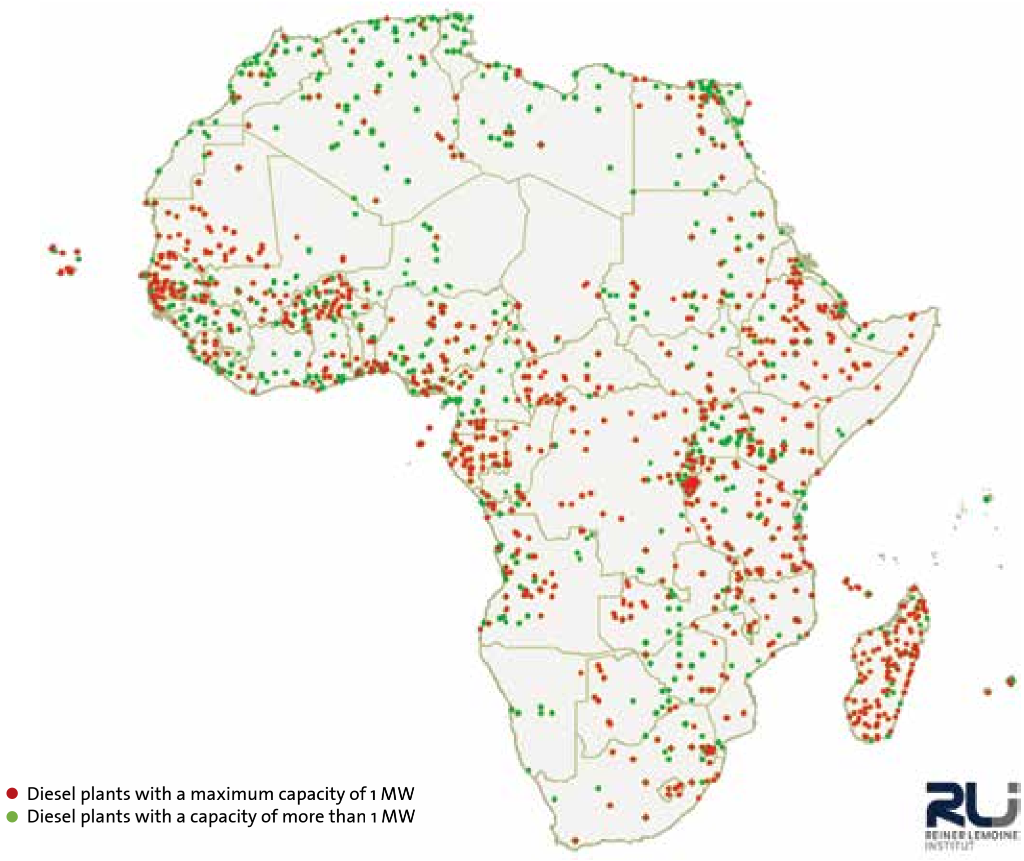
The map on the next page shows a total of 1,101 known diesel generators in Africa that are not connected to national grids, thereby illustrating the opportunities for hybridisation. To create this map, RLI used power plant data from the UDI World Electric Power Plant Database and excluded areas covered by existing transmission grids (including a 50km buffer zone) from digitalised maps.[6] With the methodology used, a lot of small mini-grids have not been captured. For example in Mali, there are 200 existing diesel mini-grids.

Mini-grids are typically used in remote locations and usually have a capacity below 10 MW. Micro-grids are similar to mini-grids, but operate at a smaller size and generation capacity (1-10 kW). Both grid types connect a limited number of consumers to a power generation system through a distribution network that can operate in isolation from the national grid. These decentralised grids can meet the needs of people living and working in close proximity (clustered houses, businesses and institutions). Renewable energies such as hydro, solar, and biomass mini-grids, sometimes including a small diesel generator (hybrid systems) are often the most cost effective options for electricity generation. Typical mini-grid retail tariffs in Africa may encompass a wide range from 0.10 EUR/kWh to 1.20 EUR/kWh, depending on the technology, the operator model, the regulatory framework, financial support and financing sources. For details on mini-grid technologies please refer to *Annex II*.

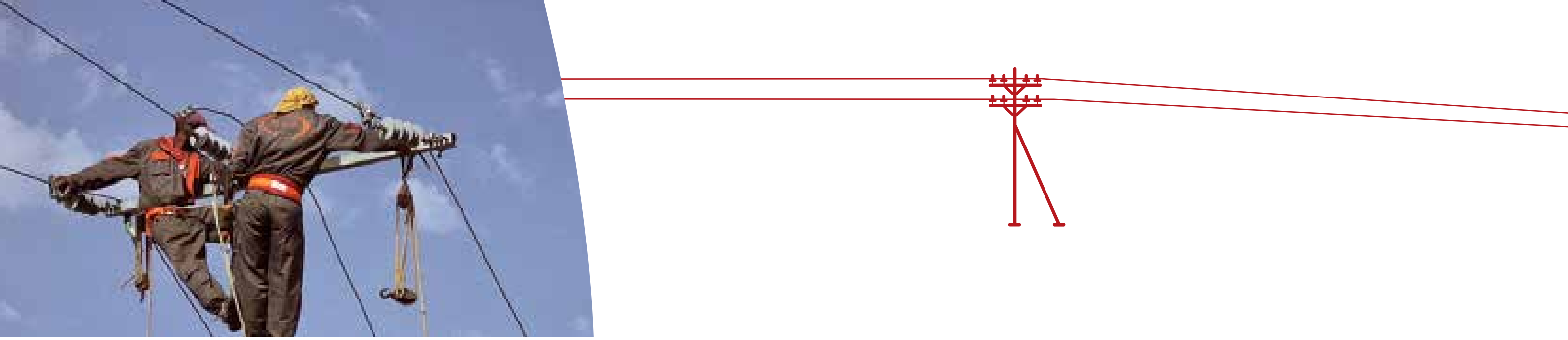
5) The design, technology and implementation of PV-diesel hybrid mini-grid systems are discussed in Léna, IED, IEA PVPS, Club-ER (2013). *Rural Electrification with PV Hybrid Systems; Overview and Recommendations for Further Deployment*.

6) More detailed information on the methodology can be found in Bertheau, RLI (2012). *Geographic, technological and economic analysis of isolated diesel grids; Assessment of the upgrading potential with renewable energies for the examples of Peru, the Philippines and Tanzania.*

Figure 1 Existing diesel generators in Africa



Source: Cader (2014) "Diesel generators in Africa", Reiner Lemoine Institute gGmbH non-profit, using data sources of GADM (2014) ww.gadm.org, Platts UDI World Electric Power Plants Database (2011/2013)

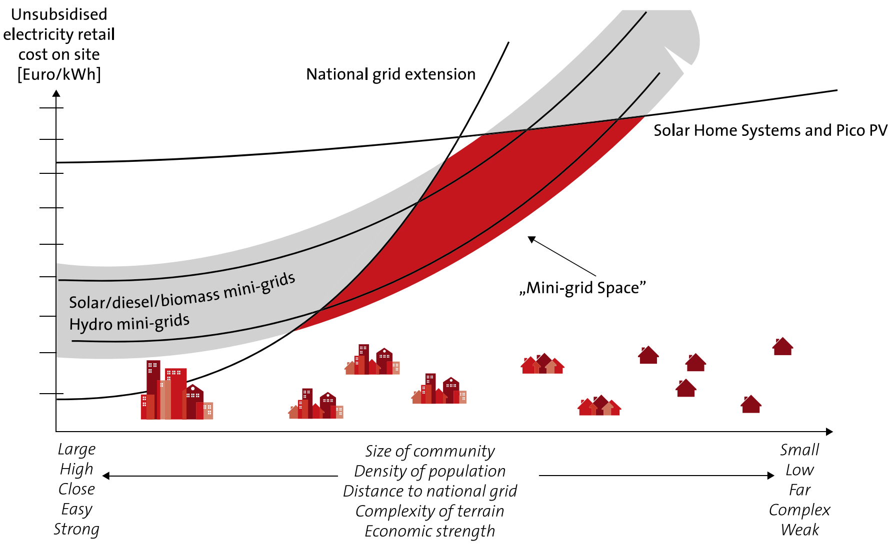


2.2 Mini-grids versus other Rural Electrification Approaches

The graph below *(Figure 2)* is an illustration of the window in which mini-grids are the most suitable rural electrification solution. **This "Mini-grid Space" is found where mini-grids have the lowest cost (unsubsidised electricity retail cost on site in EUR/kWh) compared to grid extension and stand-alone systems.** The cost of the technologies is influenced to different degrees by various local conditions: the size of the community, the density of the population, the distance to the existing national grid, the topography and general socio-economic factors such as energy demand and economic growth potential.

Mini-grids are mostly used where grid extension is not economically attractive but where communities live in a core village with houses in close proximity. The different suitable spaces for mini-grids, grid extension, and solar home systems make **rural electrification planning** a complex and dynamic task, but one that is highly recommended to conduct.

Figure 2 Illustrating the "mini-grid space" (qualitative)

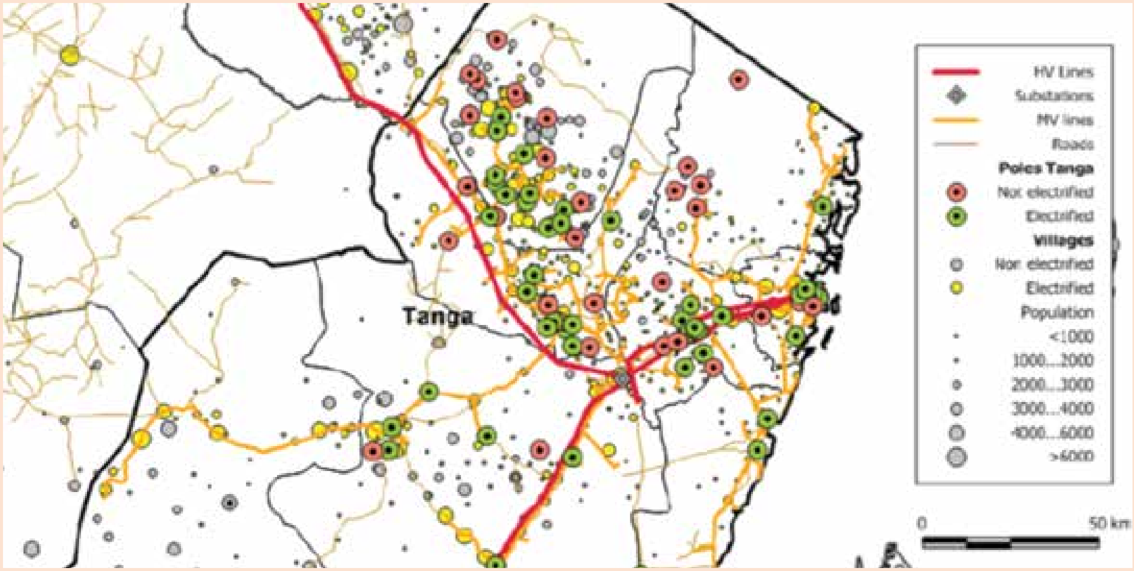


Source: Inensus

Rural Electrification Planning

In general, **rural electrification planning has the aim of maximising access to electricity in a given territory, within a certain time horizon.** In general, this planning should be technology neutral and use present costs in optimising electricity supply options. It can either follow a techno-economic approach, which only aims at optimising economic criterion, or a multisector approach which additionally includes a qualitative assessment of the energy distributed (Watchueng, Jacob & Frandji, Club-ER, 2010). One result can be the identification of priority areas for electrification measures, including areas where off-grid technologies (incl. mini-grids) are to be used. The graph below shows a GIS based rural electrification snapshot for the Tanga region in Tanzania, to illustrate the possibilities of rural electrification planning.

Figure 3 Example for rural electrification planning from Tanzania, adapted from Club-ER (2010)



Source: IED (2013)

Mini-grids may eventually find themselves in competition with the expanding national grid. What happens when the national grid arrives at a location already powered by a private or community-run mini-grid? The issues that arise "when the big grid connects to the small grid" are discussed in the next box.

Mini-grids and the Arrival of the National Grid

Connecting mini-grids to the main utility grid is a desired end for the customers. As a rule, central grid tariffs are lower than mini-grid tariffs because of economies of scale (in generation, transmission, and distribution of power) and because of regulatory interventions and cross-subsidisation (subsidising rural consumers by charging higher tariffs from urban and industrial consumers).

The risk of an uncompensated 'takeover' by an expanding grid is a significant deterrent to investors. However, in a positive policy environment, grid connection can instead provide the opportunity for the mini-grid operator to retain the business and earn income by selling the electricity produced to the grid. The best approach is to govern these risks up front, with a regulatory framework that protects investors, guarantees fair compensation, and - ideally - offers transparent information about grid extension plans (created through rural electrification planning) so that the timing and location thereof can be adequately incorporated into mini-grid technical and financial design.

For a mini-grid to qualify for grid connection, the technical requirements of the main utility need to be met. These include overall network safety needs, frequency and voltage regulation, the integration of the distribution system into the utility system, whether the mini-grid system is able to "island" in the event of grid failure, and whether it is used as a "dispatchable" asset of the grid.

Additionally, financial issues need to be resolved before the utility enters the area. If the mini-grid operator has been charging a higher tariff than the utility (and the utility is "taking over" the concession) the new tariff has to be agreed and any obligations due to the mini-grid operator to enable it to "close out" its operations have to be met. If the mini-grid operator will continue to operate the site, then new tariff, generation and distribution agreements and Feed in Tariffs may have to be negotiated or regulated. An example for regulatory guidance on these issues can be found in the "second generation" SPP and mini-grid rules recently issued by EWURA (the Tanzanian regulator).[7]

As described by Greacen, Engel & Quetchenbach (2013), the following should be clarified to facilitate successful connection of a mini-grid to the national utility:

1) A clear application process that caters for technical, governance and tariff issues,

2) Responsibility for analysis and approval of interconnections,

3) Responsibility for payment and construction,

4) Responsibility for safety and protection requirements,

5) A testing and commissioning procedure, and

6) Communications and data exchange between the mini-grid, the utility, and the regulator.

If adequate compensation and technical arrangements can be made, there is no reason why the mini-grid cannot be connected to the main grid. There are different ways of structuring this new operating model to optimise power supply, and costs to investors, consumers and the utility. *See the MGPT Rwanda case study* for one example of a mini-grid connected to the national grid.

7) EWURA website (2014): http://www.ewura.go.tz

2.3 Benefits of Mini-grids

The evidence from surveys and research is that rural electrification improves quality of life, increases economic activity and is necessary for rural economic development. Rural electrification in general acts as:

- An **enabler of socio-economic development** (through provision of basic electricity services for households)

  Impact evaluations[8] have shown that electric lights alone bring benefits such as extended hours for small businesses, benefits for education and health, as well as greater security. Some say that the "primary story to tell about the impact of electricity is not lighting, but communication: television, mobile phones and the internet" (IOB, 2013). After all, around half of electrified households in rural areas have a television or a radio, and around 253 million people had a mobile phone in Sub-Saharan Africa in June 2013. The use of television, radio, and mobile phones results in improved access to news, business information, and distance education. People in rural areas often already use these services but at exorbitant fees *(see Figure 6)*, so they clearly appreciate the benefits of these services and are willing to pay for them.[9]

- A **facilitator for the delivery of public services** (through the electrification of social institutions)

  Rural electrification can also improve education through better lighting in schools and at home and can improve better health care through better lights and more reliable use of medical appliances (e.g. vaccine refrigerators).

- An **enabler of rural industrial development** (through enabling productive use of electricity for SMEs)

  Another important part of the rural electrification story is that it can drive economic development and improve household incomes by enabling households to establish micro home enterprises[10] and by providing existing SMEs the possibility to switch to a cheaper, cleaner more convenient form of energy for their motors. However, this depends on higher voltage services and thus on grid or mini-grid access (IOB, 2013).

Mini-grids have **multiple specific benefits** in comparison to other electrification options. These include the possible **speed of deployment**, additional **private sector growth**, and **flexibility of technical and operational models**. The benefits of different electricity generation technologies are clearly illustrated with the tier system of energy access of the UN SE4ALL initiative *(see next box)*.

8) Impact Evaluations assess intended and unintended changes that can be traced back to particular intervention (for example providing reliable electricity access).
9) The sources for this paragraph are IEG (2008), IOB (2013), GSMA (2013), and Edenhofer et al./IPCC (2013)
10) The adoption of productive uses of electricity in the form of micro home enterprises typically reaches approximately 10% of households. Studies further show that small enterprises can be supported by specific programmes promoting productive uses of electricity, which in turn has a positive impact on household income. (IOB, 2013)

The UN SE4ALL – Tier system for measuring energy access

The UN SE4ALL tier system is a measurement and evaluation system for electricity access that can be used for global comparisons. The electrification solution, whether grid, mini-grid or a stand-alone system (home systems, rechargeable batteries, pico-PV/solar lanterns), plays a core role in the evaluation; each of these is evaluated according to the services provided (lighting, television, fan, etc.) and other metrics (peak capacity, duration of electricity, evening supply, affordability, formality and quality).

Households are categorised into one of five different tiers. The access rate is evaluated by looking at the individual connections and the services potentially available as well as other attributes of electricity supply. Only mini-grids and grid connection can provide full electricity services (the two highest tier levels). Thus, according to the tier system, mini-grids can be among the highest quality electricity supply systems available. However, currently far more mini-grids are in tiers two and three than in tiers four and five.

Table 2 UN SE4ALL - Global Tracking Framework[11]

Energy Access according to Global Tracking for SE4ALL	**No**	**Basic**	**Advanced**			
Attributes	Tier-0	Tier-1	Tier-2	Tier-3	Tier-4	Tier-5
Services		Task light AND phone charging	General lighting AND television AND fan	Tier-2 AND any low-power appliances	Tier-3 AND any medium power appliances	Tier-4 AND any higher power appliances
Peak Available Capacity[12] (Watts)	-	> 1 W	> 20W/50W	> 200W/500W	> 2,000W	> 2,000W
Duration (hours)	-	> 4 hrs	> 4 hrs	> 8 hrs	> 16 hrs	> 22 hrs
Evening Supply (hours)	-	> 2 hrs	> 2 hrs	> 2 hrs	> 4 hrs	> 4 hrs
Affordability	-		√	√	√	√
Formality (Legality)	-			√	√	√
Quality (Voltage)	-			√	√	√
Indicated Minimum Technology		**Nano-grids/ Micro-grids,** Pico-PV/Solar lantern	**Micro-grids/ Mini-grids,** Rechargeable batteries, Solar Home systems	**Micro-grids, Mini-grids,** Home systems	**Mini-grids** AND grid	**Mini-grids** AND grid

Tiers based on regular use of appliances and attributes of electricity supply (Bhatia, World Bank, 2013),[i] as described by Tenenbaum et al. (The World Bank, 2014)

11) This is not a static framework so it is designed to evolve and to be refined over time as more information becomes available.
12) The two sources, Bhatia (2013) and Tenenbaum et al. (2014), differ in their descriptions on the peak available capacity.

2.4 International Experiences with Mini-grids

The development of mini-grids is driven by different national priorities and takes various forms around the world. Mini-grid operating models are constantly improving as lessons are shared and governments are gradually opening up to alternatives to extension of the national grid.

2.4.1 African Experience

In the past, most national governments in Sub-Saharan Africa have prioritised the grid extension approach for rural electrification. However, progress often remained very slow due to the remoteness of many areas and the costly investment required for grid extension and large-scale central power plant development. In some cases, the rate of electrification was even lower than population growth (Bhattacharyya, 2013). Mini-grids are therefore seeing a surge in interest as governments and private developers take stock of the socio-economic implications of large unelectrified rural populations, national grid extension costs and the potential for innovative public-private partnerships to deliver commercially sustainable, effective, reliable, 'green' power to improve rural livelihoods.

The following examples highlight the progress that has been made in the recent past in several countries that have introduced national rural electrification policies and recognise mini-grids as an important pillar of electrification.

Kenya has traditionally set up diesel-powered mini-grids in off-grid areas of commercial or strategic importance. These are managed by the national utility. Political pressure to continue expanding electricity access to the entire population has led to a revised policy framework under which the national Rural Electrification Authority now handles development of mini-grid sites throughout the country. These activities are carried out by the Kenya Power company, a for-profit corporation majority-owned by the government, which implements this public sector model. Meanwhile, the high cost of diesel is driving the development of hybrid renewable-diesel mini-grids in a number of remote areas. Currently 7 hybrid mini-grids exist, and 12 of the existing diesel-based mini-grids are planned to be hybridised. In 2013, 27 new PV and wind Green Mini-grids were planned (IED, DFID, 2013). More details are given in the *MGPT Kenya Case Study*.

Mali has had probably more success than any other country in Africa when it comes to promoting isolated mini-grids. More than 200 mostly small diesel mini-grids are in operation in the country, around 60 of those are privately run and a significant number are in the process of hybridisation. Most of these mini-grids received initial capital cost subsidies (of about 570 EUR per new connection) from AMADER, Mali's REA, to connect new customers. AMADER, makes all major decisions concerning mini-grids which is a key success factor of Mali´s mini-grid roll-out. The current electricity tariff in mini-grids for households is about 0.44 EUR/kWh. This is considered high compared to the tariff for grid-connected customers, which is 0.11 EUR/kWh (Eberhard et al., 2011) and has caused "tariff envy", leading to the rapid extension of the national grid to seven mini-grids sites located close to the national utility's

concession area (Tenenbaum et al., 2014). This example shows that mini-grids can act as a valuable intermediate step towards grid electrification for communities, and that it is important to select mini-grid locations far from the main grid for mini-grid operators (who do not want to connect to the main grid).

Namibia has a well-defined grid and off-grid electrification master plan (the REDMP and OGEMP). In these plans, areas that are off-grid are clearly identified, and are to be supplied by the government with standalone solutions and mini-grids. Up to now only a small number of pilot mini-grid projects are in operation. These pilot-projects have shown that mini-grid systems are viable in Namibia, especially solar, biomass and solar/diesel hybrids. Tsumkwe village is a good example of a large and economic mini-grid as all customers connected to the solar/diesel hybrid system pay cost covering tariffs for stable electricity (24h). (RECP/EUEI PDF, 2014).

Senegal has a well-regulated, two-pronged concession approach for private sector involvement. On the one hand, concessions for large areas are granted to private utility-type companies receiving up to 80% upfront investment subsidies for a mix of grid extension and off-grid electrification. On the other hand, "mini-concessions" for so called ERIL projects (Electrification Rurale d'Initiative Locale – Locally Initiated Rural Electrification) are issued to private micro-utilities for the implementation and operation of stand-alone mini-grids for individual remote communities. Political and regulatory responsibilities are shared between three authorities which in the past created a certain level of complexity regarding the implementation of the framework. ERIL operators are accompanied by the Senegalese Rural Electrification Agency ASER (Agence Sénégalaise d'Electrification Rurale) to apply for a renewable contract with a 15-year licence for electricity sales and a 25-year concession for electricity distribution which is issued by the Senegalese Ministry of Energy and the Development of Renewable Energies. Based on a well-defined tariff scheme, the national regulator CRSE (Commission de Régulation du Secteur de l'Electricité) sets the maximum tariffs for each project individually (which leads to different tariffs in different projects), allowing an IRR of 12% on the private investment. As in all stand-alone power supply systems, the off-grid tariffs applied in Senegal are significantly higher than the national utility tariffs. Numerous private operators are active in Senegal with approx. 30 systems currently in operation and a portfolio of several hundred mini-grids in the pipeline. Up to now, only one project has been issued with an ERIL licence/concession: the wind-solar-diesel mini-grid implemented and operated by the company ENERSA S.A. in the village Sine Moussa Abdou. Different approaches with different financial models and tariff schemes are applied in Senegal by different operators, which has proven a crucial success factor in Senegal. More information can be found in the *MGPT Senegal Case Study*.

Tanzania's policy allows small power producers to supply electricity from both grid-connected and off-grid power supply systems. The Tanzanian Rural Energy Agency created TEDAP (Tanzania Energy Development and Access Project), which is funded by the World Bank and channels funds into subsidies, special collateral financing, preferential interest rates and technical assistance for grid-tied and off-grid projects. Small Power Producers (SPPs) with generation capacity of less than 1 MW are exempted from obtaining a licence but required to register with the national regulatory author-

ity EWURA and they may be subject to ex post review of their tariffs upon complaint from 15% of their customers. The Rural Energy Fund was set up to provide grants to support initial project preparation (in the form of a matching grant), as well as connection subsidies of up to 380 EUR per connection or up to 80% of the transmission and distribution costs. By 2010, 17 MW of off-grid projects based on small hydro and biomass were in various stages of development. More information is provided in the *MGPT Tanzania case study*.

Zimbabwe's policy and legal framework at present has no specific provision for mini-grid development. This lack of regulation does not preclude mini-grid development and operation through a number of models. So far, donor funded projects have been the most prevalent. According to the Zimbabwe Case Study of RERA (RECP/ EUEI PDF, 2013f), the country had 7 MW of mini-hydro, about 350 kW of micro-hydro, 32kWp of solar mini-grids for irrigation (installed by NGOs) and 372 0.9 kWp solar mini-grids for schools and clinics (installed by the Rural Electrification Agency) (RECP/ EUEI PDF, 2013f).

Further African experiences with mini-grids can be found in the case studies presented in the Mini-grid Policy Toolkit, including Cape Verde, Rwanda, and Uganda.

2.4.2 International Experience

Most developing countries have some experience with mini-grids. A short introduction to the mini-grid programmes of five different non-African countries - Brazil, China, India, Nepal and the Philippines - is given below.

The **Brazilian** electricity regulatory agency, ANEEL, recognised that around 250,000 households (mainly in the Amazon region) cannot be connected to the grid economically or technically. Thus, the Ministry of Mines and Energy issued a Special Project Manual to support mini-grids (including an 85% capital subsidy, especially for RE). In 2010, this programme already operated 15 small hydro power plants and one solar PV plant in remote Amazon regions. (Deshmukh, Carvallo & Gambhir, 2013). In addition, utilities are mandated to develop mini-grid systems in their service territories where the grid is not going to reach remote areas, like in many regions in the Amazon basin. Furthermore, private actors have been contracted to implement mini-grids under a Build-Own-Operate (BOO) arrangement.

In **China** the central government started its Township Electrification Program in 2002. In total around 1,065 villages were electrified in 3 years. 377 villages used small hydropower (with a combined capacity of 264 MW) and 688 villages used PV and PV/wind hybrid mini-grids (with a combined capacity of 20MWp). All systems are intended to eventually be connected with the central grid. (Deshmukh, Carvallo & Gambhir, 2013).[13] This programme benefited from close integration with other rural electrification programmes and strong government commitment (Bhattacharyya, 2013).

India has pursued several programmes and policies for the development of rural mini-grids. For example, in the state of Chhattisgarh, a state agency has electrified around 35,000 households across 1,000 villages and hamlets with mini-grids (Palit, 2013). In another

13) The paper by Zhang and Kumar (2011) analyses the challenges of the rural electrification programme in Western China and suggests potential solutions.

programme, the Jawaharlal Nehru National Solar Mission announced that it would promote the installation of 2,000 MW of off-grid PV systems (including solar lan-terns, Solar Home Systems and pico/mini-grids) with capital subsidies. Additionally, many different private developers have started to develop mini- and micro-grids (Deshmukh, Carvallo & Gambhir, 2013). Well-known examples include companies like Husk Power, Mera Gaon Power and Desi Power.

In **Nepal** the national government, together with external donor agencies, catalysed the installation of 317 micro-hydro mini-grids with a cumulative capacity of 5,814 kW under its Rural Energy Development Program (REDP), which included the creation of a Rural Energy Fund (REF). The REDP focuses on involving local communities and building institutional capacities and local skills, and the REF provides subsidies for mini-grid electrification and solar energy (Deshmukh, Carvallo & Gambhir, 2013). Drivers of success have been a relatively well functioning subsidy scheme and a mini-hydro revolving debt fund.

The **Philippines** consist of 7,107 islands. Around half of those are populated and can best be supplied with electricity using mini-grids. There are around 108 isolated diesel grids, from 46 operators, in operation. Most of these operators are cooperatives. To provide electricity access to smaller settlements that are not electrified yet, regulations have been adjusted to attract and foster private sector and community initiatives.

Why are Mini-grids not Used more in Africa?

"The major hurdles in the success of mini-grids are not technology-related. There are no significant technology barriers that hinder mini-grids whether they are powered by diesel generators, renewable energy or a combination of both (hybrid systems). Rather, since supply to remote villages with low income is not economically viable, financial sustainability is the key challenging factor. Compounding the problem is the fact that there is no "one-size-fits-all" solution."
(SE4ALL Energy Access Committee, OFID 2014)

In recent decades, a number of pilot projects have been tested in different African countries. Many of these have focused on technological and socio-economic aspects, leaving business-related aspects unconsidered. Some of these projects were unsuccessful, causing discouragement especially among policy-makers. The most common **reasons for project failure** are given below:

- Scarce and inaccurate data, in particular over- or underestimated electricity demand
- Non-inclusion of transaction, management, and risk mitigation costs into tariff calculation
- No flexibility in tariff structures for cost coverage
- Supply-chain failure to provide spare parts
- Mismanagement, including a lack of provision for operations and maintenance
- Donor-based projects with a 4-year cycle – what happens afterwards?
- Long registration/permitting/licensing processes
- Inadequate human capacities (managers, operators, technicians)
- Insufficient policy and regulatory framework - pilot projects fall through the regulatory cracks – upscaling however requires a sound legal basis

These failures have created scepticism about the scalability of mini-grids. However, other **projects – in particular those with more business driven approaches – have addressed these problems adequately and are potential sources for inspiration.** Different business and operator models have been developed and successfully implemented *(see the case studies)*.

In most African countries these prerequisites for investment in mini-grids are not present. However, there are positive examples where countries, such as Kenya, Mali, Senegal and Uganda, are setting the conditions right and are preparing for a mini-grid roll-out.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FURTHER READING

For readers who have only recently started to deal with mini-grids or who are looking for short, comprehensive summaries, the following publication is recommended:

2.0 Electricity Access

EUEI PDF (2014). *Status Report - African-EU Energy Partnership - Progress, achievements, future perspectives.*

2.1 Rural Electrification Planning

Watchueng, Jacob & Frandji, Club-ER (2010). *Planning tools and methodologies for rural electrification.* ARE (2011). *Rural Electrification with Renewable Energy - Technologies, quality standards and business models.*

Grid Interconnection

Greacen, Engel & Quetchenbach (2013). *A Guidebook on Grid Interconnection and Islanded Operation of Mini-Grid Power Systems up to 200kW.*

2.2 Benefits of Mini-grids

IEG (2008). *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits*

IOB (2013). *Renewable Energy: Access and Impact; A systematic literature review of the impact on livelihoods of interventions providing access to renewable energy in developing countries.*

2.3 International Experiences with Mini-grids

Deshmukh, Carvallo & Gambhir, 2013. *Sustainable Development of Renewable Energy Mini-grids for Energy Access: A Framework for Policy Design.*

IED, DFID (2013). *Low Carbon Mini-Grids; "Identifying the gaps and building the evidence base on low carbon mini-grids"*

RECP/EUEI PDF (2013f). *Zimbabwe Case Study - Gap analysis and National Action Plan.*

RECP/EUEI PDF (2014). *Namibia Case Study Gap analysis and National Action Plan.*

EUEI PDF (2014). *Mini Grid Policy Toolkit Case Studies. (minigridpolicytoolkit.euei-pdf.org/casestudies)*

3. Mini-grid Operator Models

Mini-grid operator models describe the organisational structure of mini-grid implementation and operation. **The four main mini-grid operator models[14] are the utility, private sector, community and hybrid models.** These models differ based on who owns the power generation and distribution assets, and who operates and maintains the system, and they are further defined according to relationships with customers. In general, **there is no 'best practice' or ´one-size-fits-all´ operator[15] model for mini-grids.** Successful deployment of each model depends on its unique context: the natural environment (e.g. geography, energy resources and climate/weather conditions), the local socio-economic context, and the policy and regulatory environment. Therefore, **policy decisions about which models to support through a suitable policy and regulatory framework determine which mini-grid operator models can flourish in a country** *(see chapter 6)*.

Mini-grids can have two operational entities, a small power producer (SPP) and a small power distributor (SPD)[16]. Mini-grid operators can fulfil both roles (the generation and distribution) and must thus be allowed to produce and sell power either to public power distributors or directly to end-users via mini-grids. The size of the mini-grids and the available energy sources also shape the organisational structure.

The operator models are described below, and special implementation approaches are briefly explained. In all of these mini-grid operator models, management and operations[17] can also be contracted to a third party[18].

3.1 Utility Operator Models

In the **utility operator model** the utility is responsible for all mini-grid operations. The funding is usually secured from the national treasury or government. The utility operates the mini-grids in much the same way that it operates the national electricity network. Power is generated by the utility, fed into the distribution grid and supplied to the consumers, usually at the same

14) More information on operator models can be found in the publication: Rolland, Glania, ARE/USAID (2011). *Hybrid Mini-Grids for Rural Electrification: Lessons Learned.*

15) An 'operator' has two main functions: to ensure that electricity generation and distribution equipment functions (and are repaired and replaced if necessary), and to collect payments from the customers. Sustainable long-term mini-grid operation requires that the operator costs are covered, and that some profit can be made.

16) More information on SPDs and especially on SPPs can be found in Tenenbaum et al. (2014)

17) Operation is understood here as the day to day supervision and control of the processes involved in generating and selling electricity in a mini-grid. Management is the function that coordinates people's efforts to plan, organise, lead, and control mini-grid planning, implementation, and operation. It encompasses the deployment and steering of human resources, financial resources, technological resources and natural resources.

18) Possible contract options include: an authorisation arrangement, a contracted operation, a leasing contract, or full ownership transfer to the operator or the community after completing construction. Further details can be found in *China Village Power Project Development Guidebook; Getting Power to the People Who Need it Most; A Practical Guidebook for the Development of Renewable Energy Systems for Village Power Projects*, Doe et al., SET/UNDP/GEF (2005), chapter 5.2

rates paid by the utility's customers connected to its main grid. Thus, utilities usually cross-subsidise electricity tariffs for mini-grids.

Utilities, given adequate financial and human capacities to manage mini-grids, could rapidly install a large number of mini-grids in rural areas. However, utilities usually do not invest voluntarily in mini-grids because they often consider mini-grids as a non-core business. Therefore, when utilities manage mini-grids, most of the time they are directed to do so by the government. For more information on the utility operator model *see MGPT Kenya case study*.

3.2 Private Operator Models

In **private operator models**, a private entity plans, builds, manages and operates the mini-grid system. The funding depends on private equity and commercial loans as well as some form of government support, e.g. grants, subsidies, results-based financing, or public sector loan guarantees. Pure private sector operator models in which all the investment comes from private sources are rare but do exist, e.g Mesh Power and Powerhive. The private sector is often better suited (than utilities) to manage smaller mini-grids *see MGPT Senegal case study*.

SUMMARY FOR POLICY-MAKERS

Four main mini-grid operator models exist that are capable of delivering energy access through mini-grid deployment. They differ in terms of who owns the power generation and distribution assets, who operates and maintains the system, and by the relationships between operator and customers.

Utility operator models can be scaled-up quickly, but only if public funding is available. While tariffs can be cross-subsidised with ease, this model is prone to political interference and procurement problems.

Private operator models have a high potential for scale-up, for attracting private investments and for mobilising the know-how of the private sector. However, they require a supportive enabling environment.

Community-based models are well suited to ensure local ownership and sustainability, but are exposed to management risks and usually require high grant components.

Hybrid operator models combine different aspects of these three models, and may present a good compromise and initial starting point for mini-grid scale-up.

Scalable private sector models include the franchise approach, the ABC (Anchor-Business-Community) approach, the clustering approach and the local entrepreneur approach. All of these approaches are designed to meet the challenge of having little revenue from end-users at each site while facing inevitable management and operational costs. Some of these approaches can overlap and a mini-grid operator may implement them at the same time. The **franchise approach** bundles management costs at the franchiser level and minimises this burden for the franchisee. With a large number of franchisees, economies of scale in theory outweigh the additional management costs of the franchising structure. In the **ABC model**, the operator strives to select sites where **(A) anchor customers** such as telecom tower companies, factories or lodges can provide a reliable cash flow, **(B)** the mini-grid can be extended to high potential **local businesses**, **(C)** direct power supply to **customers** is only seen as a top-up to the revenues from the first two customer groups. In the **clustering approach**, a number of villages situated close to each other are electrified by non-interconnected mini-grids that are bundled under one operational management structure to save on overheads, labour, travel and transport costs. The **local entrepreneur approach** takes advantage of the fact that a local entrepreneur is constantly on site. The local entrepreneur operates the system and owns parts of the generation and distribution assets. He typically has a well-established social network, reducing costs for security, CRM, money collection, etc.

In places without energy infrastructure or regulatory framework, private companies are free to negotiate profitable cost-reflective tariffs with communities, though this may mean high user tariffs in the absence of subsidies *(See Somalia case study)*. Also Cambodia has had success with effective deregulation, with now close to 200 private operators of isolated mini-grids.

3.3 Community Based Models

In **community-based models**, the local community owns, operates and manages the system and provides all services for the benefit of its members. The financing is typically highly grant-based with some community contributions (financial or in-kind). The planning, procurement of equipment, installation and commissioning is often done by third parties, as local communities rarely have the technical and economic expertise to develop and implement mini-grids. To allow long-term operation of the system, it is essential that community operated mini-grids at least charge tariffs that cover reinvestment/depreciation, operations and maintenance costs. Small community models require working social and decision-making structures in the village to prevent conflicts. Larger community-driven cooperative models running generation in the multi MW scale are more formalised and depend less on local structures. Communities most often use the **cooperative approach** for mini-grid ownership and management.

3.4 Hybrid Operator Models

Hybrid operator models combine different aspects of the three models presented above. Investment, ownership and operation of a mini-grid might not be carried out by the same entity. Joint venture or specific contrac-

tual arrangements between different actors are applied. Generation and distribution of electricity may be split and carried out separately by government utilities, private companies or communities in the form of small power producers (SPP) and small power distributers (SPD). Alternatively, the duties and responsibilities can be split according to who builds, owns, operates and maintains the system. It is essential to clearly define roles and responsibilities prior to commissioning. No matter which form of hybrid model is used, it depends on a regulatory framework that accommodates 'mixed' ownership and management, as well as the political will of the utility to allow or pursue it. *See MGPT Namibia case study.*

Contractual Options for Hybrid Operator Models

Usually, different forms of contractual arrangements are applied in hybrid operator models. Such arrangements could include public private partnerships (PPP), or power purchase agreements (PPA).

- The **public private partnership approach** can be seen as any form of private sector involvement with a contract between a public and a private party. A public partner can for example finance, own and manage the mini-grid while contracting a private partner to operate and maintain the power generation system.
- This can take the form of a **Renewable Energy Service Company (RESCO)** approach, where RESCO companies work similarly to utilities at a smaller scale. The equipment is purchased and owned by the government while the RESCOs operate and maintain the systems and collect fees from the users.
- Another PPP approach is the **concession model** where the holder of a concession, which is usually a private company, enjoys beneficial terms for providing electricity services to rural communities (in countries like South Africa, Senegal, Mali). Their beneficial terms can be an electricity supply monopoly, preferential market access for a certain period of time (typically from 15 to 25 years, in a defined geographical area) or specifically designed tariff for the area. *See MGPT Senegal case study.*
- In the **Power Purchase Agreement (PPA)** approach the distribution assets and the generation assets are not in the hands of one entity. In these cases, a contract (the PPA) for delivery of electricity has to be signed by the parties.

Table 3 Summary of operator models

	Utility Model 1	Hybrid Model 2	Private Model 3a (Unregulated)	Private Model 3b (Regulated)	Community Model 4
Owners of power generation and distribution assets	Utility	Private/Utility/Community	Private	Private	Community
Brief description	Government or parastatal utility manages all aspects of mini-grid	Private actors generates and utility distributes the electricity, or the reverse; or private entity to commercialise electricity generated by and distributed through public assets	Private company manages all aspects, in the absence of Government regulation	Private company manages all aspects, in a regulated environment	Community members organise to manage generation and distribution in a regulated environment, with support and/or coordination from an NGO or private company
Pros	▸ Can absorb funds easily; ▸ Less regulation needed; ▸ Connection of mini-grid to main-grid can be easier; ▸ Cross-subsidisation of tariffs, thus affordability easier ensured; ▸ Aim to fulfil national electrification aims	▸ Different actors contribute their strengths, technical and management know-how; ▸ Scalable, profitable; ▸ Less conflict potential with customers in case of distribution by utility with cross-subsidised tariffs.	▸ Commercial sustainability creates incentives for long-term operation; ▸ Ability to act fast without government interference; ▸ Profitability ideally allows for scaling up of operations	▸ Scalability through private capital; ▸ Technical know-how, high reliability; ▸ Profitability ideally allows for scaling up operations; ▸ Legal security of regulated market attracts private finance	▸ Self-managed public infrastructure; ▸ Less conflict potential with customers and officials; ▸ Creating assets and local ownership; ▸ Enabling self-determination and economic development

	Utility Model 1	Hybrid Model 2	Private Model 3a (Unregulated)	Private Model 3b (Regulated)	Community Model 4
Cons	▸ Not the core business; ▸ Unsuited company structure for smaller projects; ▸ Strain on limited budget; ▸ Political interference; ▸ Possibly corruption in procurement;	▸ Complex management, feasibility of models depend on regional/ local context/ structures; ▸ Non-fulfilment of contracts due to conflicts between business partners; ▸ Insolvency of one partner (either SPD or SPP) puts full operator model at risk	▸ No financial support from public obtainable; ▸ Grid interconnection challenging/ impossible; ▸ Changes in regulation and fixed tariffs can reduce profitability; ▸ Conflicts with customers due to monopoly; ▸ Insufficient quality and safety risks of service can occur if it is not supervised, which can contribute to a bad image of mini-grids	▸ Reliable regulation needed, dependency on lengthy approval procedures; ▸ Debt financing needed for scaling up; ▸ Vulnerable to changes in regulation, fixed tariffs, conflict with customers; ▸ High transaction costs; ▸ Potential risk: grid interconnections	▸ Insufficient local human (technical and management) capacity; ▸ Often unclear ownership structure; ▸ Usually high grants needed; ▸ Tariffs not covering operation and maintenance (O&M) and reinvestment costs; ▸ Corruption risk due to overlapping of management and social and family connections

FURTHER READING

3.0 Mini-grid Operator Models

ARE/USAID (2011). *Hybrid Mini-grids for Rural Electrification: Lessons Learned.*

Private/Hybrid Model: SBI (2013). *Scaling up Successful Micro-Utilities for Rural Electrification; Private Sector Perspectives on Operational Approaches, Financing Instruments and Stakeholder Interaction.*

Community Model – Cooperative Approach: NRECA, (2009) “Guides for Electric Cooperative Development and Rural Electrification”

4. Mini-grid Economics

Mini-grid operators need to cover their costs and a risk-equivalent return through revenues in order to be attracted to the mini-grid business in the first place and to guarantee long term operation of the mini-grid. The costs of mini-grids accrue through project development and investment (and reinvestment), the cost of generation and distribution assets, and running cost from operation, maintenance and management. Revenues originate from connection fees, electricity sales and grants or subsidies. Connection fees, electricity sales and sometimes also subsidies depend on the number of customers, their electricity demand and their willingness to pay for electricity.

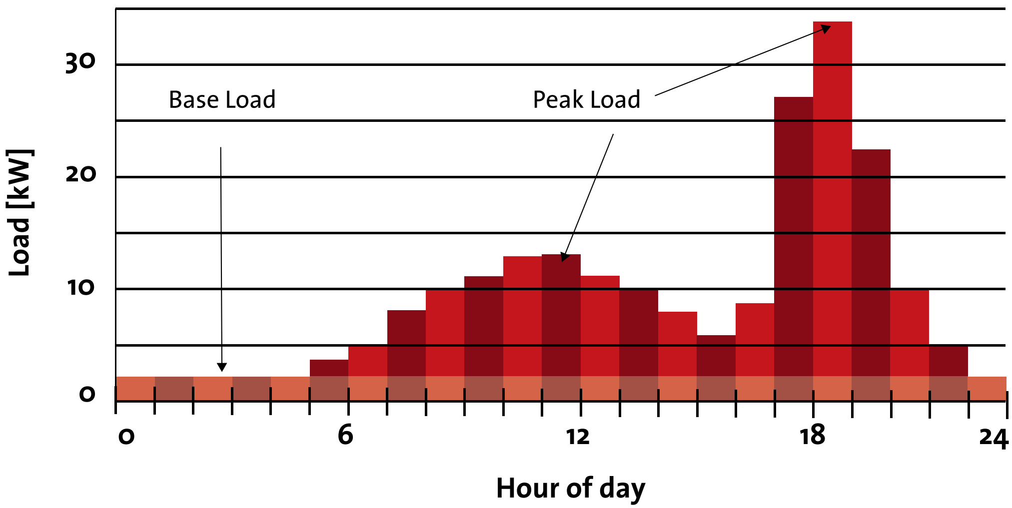
4.1 Demand Characteristics

The demand for electricity does not only need to be properly assessed but also sufficiently matched during mini-grid operation in order for mini-grids to be economically sustainable.

4.1.1 Assessing the Demand

Mini-grids need accurate predictions of electricity demand. The challenges with this demand prediction are to assess the power demand for the near future in rural areas where people do not have personal experience with electricity, and then to accurately estimate demand growth over time.

Figure 4 Typical load curve of a large mini-grid



The daily and seasonal demand for electricity in a mini-grid depends on various factors, including:

- Income patterns of villagers and therefore available cash for consumer applications of electricity *(see textbox on Local Willingness to Pay)*;
- Seasons and their influence on lighting, cooling loads and other loads;
- The operation of small industries, businesses, farms, etc.;
- Crop cycles for farming-related productive loads (e.g. irrigation, milling);
- The efficiency of appliances and machines, and
- Occasional events like festivals and weddings causing ad hoc increases in demand. The mini-grid must be sufficiently flexible (technically and in its operator model or tariff model).

SUMMARY FOR POLICY-MAKERS

Mini-grid operations, like any other business, must be economically attractive. In addition to covering cost, a risk-equivalent return is needed in order to attract investment.

Fixed cost of mini-grids include generation and distribution hardware. Variable costs arise from operations, maintenance and management costs. Renewable energy and hybrid solutions can play an important role in mini-grid economics, as they often have a lower Levelised Cost of Electricity (LCOE) than diesel generators.

Revenues originate from connection fees, electricity sales and grants or subsidies. Stable revenues require both accurate predictions of electricity demand, as well as matching customers' electricity demand with the electricity supply.

Connection fees must form a balance between ensuring commitment of electricity customers and covering connection cost, while still being affordable for customers.

Subsidies influence the average tariff, the affordability and the scalability of mini-grids. They should be as high as necessary, yet as low as possible. Different tariff systems can be deployed, ranging from flat rate tariffs to pure energy prices, from energy based, or power based to service based tariffs, as well as from progressive tariffs to regressive tariffs.

Financing of mini-grids can come from public or private sources. In terms of private financing, project finance is so far difficult to acquire. In the meantime, corporate finance can be raised to develop and demonstrate business models. Different sources of equity and debt capital are available in principle, but access remains challenging. With emerging track records and improving enabling environments, private investment and project financing will become available, in particular as "bundling" of projects into larger transactions becomes possible. Development finance institutions and some of their instruments are currently partly bridging the gap.

Local Willingness to Pay

Willingness to pay is **"the maximum amount that an individual indicates that he or she is willing to pay for a good or service" (**NRECA, 2009). The WTP can either be asked directly, e.g. by asking potential customers which services they want and what they are willing to pay for it, which results in the ´expressed´ WTP (which often leads to overestimations of more than 50% as customers answer strategically). Or it can be assessed through asking questions on the current energy consumption and expenditure of comparable services, which will result in the ´revealed´ WTP (which often results in an underestimation of electricity demand as electricity allows the usage of more services than traditional fuel sources). An overestimated demand assessment will lead to instant cash flow problems. If the demand is underestimated, conflicts with the customers and the community may arise.

One method to get accurate feedback on willingness to pay is based on unbinding take-or-pay contracts. Once customers are requested to sign this take-or-pay contract for a specific amount of electricity at a specific price they often rethink their initially stated demand and available budget. Thus, if they sign it, it usually shows that they can afford it.

On average people in rural areas in developing countries spend between 5 and 10% of their household budget on energy (Banerjee et al., 2008). In Africa, end-users and small businesses pay in total around 17 billion USD per year on kerosene for lamps and candles alone (Muzenda, 2009). Expenditure on lighting using traditional sources of energy can be reduced by grid, mini-grid or stand-alone electricity supply. Consumer surveys in some African countries have indicated that consumers are willing to pay higher tariffs for better service, as long as the higher tariffs are below the costs of self-generation of electricity. In 2010, the willingness to pay in Sub-Saharan Africa was estimated to be around 0.38 EUR/kWh, and would therefore be higher than the prevailing grid-tariffs (IMF, 2013). **Willingness to pay is however not a fixed value but strongly depends on the quality of service provided and the available alternatives.** In any case, it is important to obtain specific local data to assess the actual willingness to pay (World Bank, 2008).

4.1.2 Matching Demand and Supply

Matching customers' electricity demand with the electricity supply is another critical element in mini-grids from both a technical and an economic perspective.

From a **technical perspective**, like in all electricity grids, mini-grid electricity supply has to meet electricity demand at all times. Yet, as mini-grids have fewer customers and less varied consumer types than national grids, the concurrency of demand is higher and load profiles are more volatile. A typical mini-grid load curve with mainly residential customers can be seen in the graph in figure 4, with some productive use during the day, a peak from lighting and TV during the evening hours, and little demand at night.

The technical solutions for meeting demand at all times have costs. Other solutions to manage demand through demand side management also increase cost, but allow for a better utilisation of the available power station capacity (Harper, 2013).

Moreover, a very basic economic perspective is that the more electricity produced in a system can be sold, the lower the tariffs for the customers can be. Thus, mini-grid economics mainly depend on the electricity demand, the electricity supply and cost, and the potential revenues. The crux is that the electricity demand, electricity tariffs plus connection fees, and electricity supply are interdependent. For example, the lower the electricity tariff the higher the overall electricity demand but the lower the margin on the cost of electricity supply.

Design Process

Designing a system that properly matches electricity demand, electricity tariffs and connection fees with the mini-grid generation and distribution system and its cost is a process with multiple steps, e.g. as follows:

- After selecting and assessing the potential site, the preliminary cost (incl. potential subsidies and the risk equivalent margin) of the mini-grid system have to be calculated.
- Based on this cost and some assumptions, an indicative tariff and connection fee can be derived.
- This tariff and connection fee can be used in the demand assessment in the village.
- The outcome of this demand assessment in turn allows the developer to design the mini-grid system accurately and to calculate the financial model based on local conditions.
- This then allows the evaluation of feasibility of the project site.

4.2 Supply – Cost Structures in Mini-grid Operations

Investment and running costs in mini-grids, as in any other business, can be split into fixed and variable costs. Fixed costs in this context are defined to be independent of variations in the number of kWh produced, show marginal or no short-term dependency on the number of customers connected, and depend only marginally on the number of sites serviced. Variable costs, on the other hand, increase with electricity generated.

4.2.1 Fixed Costs

Typical fixed cost are generation and distribution infrastructure costs. These include the depreciation of assets (which is the investment cost distributed over the useful life of the assets), interest on debt and fixed taxes and fees (e.g. on infrastructure and land). **Further, fixed costs include overhead and transaction costs, local management, and local operations** such as local power plant operation, money collection, maintenance, guards, customer relationship management, fixed technical losses (self-consumption of inverters, batteries, iron losses of transformers, etc.) and cleaning of equipment and buildings.

Three fixed cost positions are regularly underestimated – overheads, transaction costs, and customer relationship management. Company overheads and transaction costs accrue through administration, coordination, social and technical problem solving, bookkeeping, reporting (to donors, lenders and authorities), and hospitability to high-ranking guests. Customer relationship management is essential to guarantee customer satisfaction and thus long term operation of the mini-grid. Tasks include conflict resolution to overcome what is usually insufficiently institutionalised decision making and consensus seeking procedures in villages, as well as training on safe and efficient use of electricity. These tasks have to be undertaken continuously and independently of the number of kWh sold.

4.2.2 Variable Costs

Variable costs increase with demand in mini-grids. They are for example fuel costs, lubrication oil, maintenance costs that depend on runtime/energy throughput, load-dependent technical losses (conversion losses of inverters, copper losses of transformers, battery storage losses), battery depreciation and revenue- or energy-related taxes.

Annualised fixed and variable costs in mini-grids are summarised in table 4 with some indication, based on the authors' experience, about the share of each cost item in systems of sizes using solar-diesel-battery generation. In biomass systems, the variable fuel and maintenance costs are increased. In hydro power stations, fixed asset depreciation is higher.

Renewable Energy Sources and Mini-grid Costs

Although electricity generation from renewable energy usually entails high fixed costs and related risks, renewables can play an important role in mini-grids as prices have decreased considerably within the last few years. Nowadays, for most sites in Africa, **renewable energy and hybrid solutions have a lower Levelised Cost of Electricity (LCOE) than diesel** generators[19].

Biogas generators with gas from gasification or digesters can provide power flexibly. Also, hydro power stations are flexible as long as their capacity and the water flow are adequate. Other technologies like solar PV modules and wind turbines only produce electricity when the sun shines or the wind blows. Up to a certain percentage of solar and wind energy can be introduced into the mini-grid without providing for costly storage systems.

Whenever a system combines different sources, it is recommended to evaluate its performance using computer simulation tools like HOMER.[20] The financial performance of the system can either be reviewed using the same tool or by introducing the technical output data into a financial model.[21]

19) For current LCOE cost data of renewable energy see REN21 (2014) (page 64). Calculating LCOE of diesel: To get a first quick value of the LCOE from diesel generation without considering financing costs, the following formula can be used: Pel= Pfuel/Cons + Inv/(pavg*Life) + Maint/Prod; Pel = Indicative price of electricity generated by the diesel generator [EUR/kWhel]; Pfuel = Price of diesel fuel on site [EUR/L]; Cons = Fuel consumption of the diesel generator in litres of diesel fuel per kWh of electricity produced. Depending on the type and size of the diesel generator as well as the load curve, consumption values are between 0.27 and 0.35 L/kWhel; Inv = Engineering, procurement, installation and commissioning costs for the diesel generator [EUR]; Pavg = Average power output of the diesel generator [kW]; Life = Total lifetime of the diesel generator in hours of runtime, ranging from under 5,000 hours for small generator below 10kW to 15,000 hours for larger generators; Maint = Cost of annual maintenance [EUR], e.g. in a maintenance contract; Prod = Annual electricity production of the diesel generator [kWhel]

20) It should be noted that this requires the availability of primary information/data like the local aggregated electricity demand, local resource availability and resource cost, country specific data for investment and O&M&M costs.

21) A financial model like the one available at the MGPT homepage under *minigridpolicytoolkit.euei-pdf.org/tools*.

Table 4 Indicative fixed and variable costs for **PV-hybrid systems**[22]

	Annualised cost items	Electricity Generation	Electricity Distribution	Electricity Sales		
		3 systems of 70 kWp PV, 30 kVA diesel, 250 kwh C10 battery, 242 kWh/d production, 79% renewable fraction each				
	Project Development and Infrastructure Investment	annualised investment cost[23]			147,607 €	65%
Fixed Costs	Depreciation of project development cost	2,333 €	2,333 €	2,333 €		
	Asset depreciation	31,362 €	7,050 €			
	Average debt interest over tenor	23,409 €				
	Operations, Maintenance and Management	annual cost				
	Headmanagement-, travel- and transaction-cost	11,644 €	5,822 €	29,110 €		
	Local management and money collection			1,183 €		
	Local power plant operations	1.183 €				
	Guards an cleaning	5,678 €				
	Maintenance incl. travel cost (fixed)	379 €	189 €			
	Customer relationship management			11,644 €		
	Technical losses (fixed)		5,655 €			
	Insurance	2,880 €	960 €	960 €		
	Taxes and fees (fixed) and misc	500 €	500 €	500 €		
Variable Costs	Non-payment and theft			11.310 €	79,982 €	35%
	Fuel	24,794 €				
	Lubrication oil	1.514 €				
	Maintenance (variable)	1,136 €	568 €			
	Technical losses (load dependent)		5,655 €			
	Battery and inverter deprec. with lifetime	19,278 €				
	Taxes (variable)			15.727 €		
		126,091 €	28,732 €	72,767 €		
		55 %	13%	32%		

3 systems of 700 kWp PV, 300 kVA diesel, 2.5 MWh C10 battery;
2420 kWh/d production, 79% renewable fraction each

Electricity Generation	Electricity Distribution	Electricity Sales		
annualised investment cost			822,629 €	53%
4,778 €	4,778 €	4,778 €		
270,870 €	57,000 €			
205,106 €				
annual cost				
34,606 €	17,303 €	86,514 €		
		14,196 €		
14,196 €				
5,678 €				
1,136 €	568 €			
		34,606 €		
	41,019 €			
12,600 €	4,200 €	4,200 €		
1,500 €	1,500 €	1,500 €		
		82,037 €	743,833 €	47%
247,943 €				
4,543 €				
3,407 €	1,703 €			
	41,019 €			
192,780 €				
		170,401 €		
999,142 €	169,089 €	398,231 €		
64%	11%	25%		

22) For calculation methodology and assumptions see MGPT financial model on the homepage: *minigridpolicy-toolkit.euei-pdf.org/tools*

23) The calculation is based on 33% grant, 20% equity and 47% debt portion. It further assumes a 15 year project duration, and a 10 year tenure for debt financing (with 8% interest rate and 2 years grace period)

4.3 Revenues and Tariffs

Revenues can be acquired through connection fees, subsidies and tariffs. In general, monthly electricity bills of more than 7.60 EUR are not affordable for a large share of the rural population. Thus, spreading connection fees, obtaining subsidies, and offering different tariff or service levels for customer groups usually improve affordability for customers. (Banerjee et al., 2008; World Bank, 2008)[24]

Tariff Structure in Mini-grids

Most tariffs can be divided into energy-based, power-based or fee-for service tariffs.

- **Energy-based tariffs** depend on the actual electricity consumed and are thus based on measured kWh. For example, one PV diesel hybrid mini-grid in Bangladesh has a connection fee of c. 47 EUR and an operational tariff of c. 0.28 EUR/kWh (Philipp, 2014).
- **Power-based tariffs** are based on the expected power consumption, which in turn determines the maximum power available for the consumers. These tariffs are calculated on a Watt basis. A basic tariff would limit consumer consumption to e.g. 60W and charge each consumer 5.54 EUR each month (ESMAP, 2000). It might also be linked to the number of light bulbs and appliances that the consumer proposes to use.
- **Fee-for service tariffs** charge for services provided and not per unit of energy. The tariff is based on kg, hour, litres or other units of service, e.g. TV service: 0.68 EUR per hour per person (Philipp, MicroEnergy international, 2014). The price of services is often determined around the avoided cost of kerosene/diesel.

These tariffs can be either **pre-paid or post-paid. Pre-payment tariffs** give both mini-grid operators and consumers more planning security. In Africa, these prepayment systems are also viewed positively because of the good experience with a similar payment scheme for mobile phones.

Tariffs can further be distinguished between break-even tariffs or profitable tariffs (free-of-charge tariffs are not discussed here).

- **Break-even tariffs** are designed to ensure cost-coverage (often used in community mini-grids)
- **Profitable tariffs**, which are usually higher, are designed to generate sufficient return on investment to appeal to private sector investors, typically cover all system costs, and are flexible and can be revised.

Other tariffs which can be energy-based, power-based or on a fee-for service basis, as well as either break-even or profitable, include:

- **Customer class tariff regime:** sets diverse tariffs according to consumer group, e.g. residents, institutions and businesses. It is mostly used to cross-subsidise residents.
- **Stepped tariff regime:** includes different tariffs depending on consumption level of the consumers.
  - With **progressive tariffs**, consumers pay low tariffs for the first kilowatt-hours (or Watts) and higher tariffs for further consumption **(cross-subsidisation)**. It may also include a **lifeline tariff**, which basically is a subsidised tariff providing basic electricity needs.
  - With **regressive tariffs**, larger consumers pay a lower unit price.
- **Flat-rate tariffs:** fixed tariffs that do not depend on electricity consumption, and only need a load limiter as a metering technology.
- **Time-based tariffs:** variable tariffs based on the time of day. They are mostly applied for commercial and industrial consumers and are also used for load scheduling (Demand Side Management).
- **Flexible tariff structure:** includes tariffs that change according to electricity demand or power demand, providing incentives for electricity usage when surplus energy is available. Here advanced metering systems are needed.

4.3.1 Connection Fees

Connection fees are **an important measure to guarantee commitment of electricity customers and cover connection cost but must be affordable**. Many customers are unable to pay one-time connection charges of around 60-250 EUR (which is usually the cost of connection and in-house installation). Thus, reducing the one-time connection charge, for example by spreading 50% of the connection fees over a certain time period (e.g. using end-user finance programmes, or including them in the tariff charge) is an effective way to gain more customers.

24) These statements were made for grid connection but also hold true for mini-grids in most cases.

4.3.2 Grants and Subsidies

In general, the amount of **subsidy influences the average tariff, the affordability and the scalability of mini-grids.** The higher the subsidies the lower the tariffs can be, the more people can afford these tariffs at the mini-grid site, but the less mini-grid systems can be supported by public institutions; and vice-versa.

Tariffs and Subsidies in Mini-grids

Policy-makers face the challenge of supporting demonstration projects while maintaining real life conditions and not over-supporting the projects. This especially relates to subsidy schemes that can hinder rather than support mini-grid roll-outs if they are exaggerated. Giveaway programmes and unrealistic promises are also not helpful for the mini-grid market and should be avoided (IFC, 2012). This also relates to the fact that mini-grid customers, in particular, need to be aware of the importance of energy saving.

Grants and subsidies have to be high enough to allow affordability for customers (increasing electricity access), and hence increasing electricity demand and improving the economics of the electricity system, which in turn can attract private investors. **At the same time, grants and subsidies should be as low as possible to allow scaling up beyond a few pilot projects and upgrading of existing mini-grids.**

For mini-grids, these **grants or subsidies can be provided during the project planning/pre-investment phase** (for feasibility studies, business plan development, technical planning, capacity building and transaction costs), **during implementation/construction** (e.g. as capital subsidies, connection subsidies), or **during operation** (operational subsides, tariff top-ups, cross-subsidies). Subsidies can also be made available to the mini-grid operator **upon reaching certain milestones** (results-based subsidies).

Subsidies for Generation Assets in Privately Financed PV Hybrid Mini-Grids (and other systems with high investment cost portions)

Electricity tariffs in privately run mini-grids are usually calculated to generate an adequate IRR on the private investment portion. In PV mini-grid systems, electricity output increases almost proportionally to investment in generation assets due to the modularity of the generation systems. In other words, if you double the investment in generation assets you double the output of your power station. Since PV power stations operating costs are marginal, it is possible to calculate an indicative cost of generation based on the investment cost of generation assets and energy output over their lifetime.

In the case of subsidised generation assets, electricity tariffs can be reduced in comparison with a purely privately financed electricity generation system. However, demand increases over time require

4.3.3 Tariff Setting

Tariffs are either **pure flat rate/basic prices** (which are fixed regardless of electricity consumption), **pure energy prices** (which are tariffs based solely on the consumed amount of energy) or a **combination of both**. Electricity customers usually prefer higher energy tariff components over higher fixed basic tariff components since this provides them with more financial flexibility. As customers usually oppose high basic prices that reflect the fixed costs, the calculated margin can only be realised by selling a certain amount of electricity (kWh) per year. Any kWh sold beyond the planned electricity sales volume will generate an extra margin.

From a mini-grid point of view, the risk would be lowest if the tariff would have a combination of both prices, where revenues from the fixed basic tariff exactly covered the fixed costs and energy prices are slightly higher than variable costs. Unfortunately, high fixed

additional investment in the extension of generation assets. For example, a power station may initially cost 100,000 EUR and receive an 80,000 EUR (80%) subsidy. The operator calculates the tariffs based on the 20,000 EUR of private finance (plus IRR expectations). If electricity demand doubles after five years, this requires the power station capacity to double. Up to now, since it is very difficult for existing projects to acquire subsidies for the extension of generation assets as grant or subsidies are usually only available for newly established mini-grids, additional generation assets are normally only financed by private sources. In the example, the total invested private capital increases to 120,000 EUR after the extension, which is six times higher than the initial private investment. To amortise the new total generation investment with just twice the energy output, the tariffs have to be increased by a factor of three. That means tariffs are three times as high after power station extension as the original tariffs. This example is an extreme case, but the relationship between tariffs and generation subsidies also holds true for smaller generation extensions, e.g. increasing the power station capacity by 50% or 20% - tariffs increase instantly in steps. These high instantaneous increases in electricity tariffs have significant negative impacts, especially on local micro businesses.

For mini-grid systems with high investment cost like PV, hydro or wind systems), there are two options to address this problem:

- Only distribution assets are subsidised;
- Reliable access to subsidies for power generation extension. This however implies higher risks as explained above for the mini-grid operators and their customers.

tariff components do not incentivise customers to use electricity efficiently. This **efficient use of energy is, however, necessary in a mini-grid system with limited power generation and distribution capacity.** Flatrate tariffs are nonetheless used in nano-grids and mini-grids – although their appropriateness is contested[25]. A tariff consisting of the energy tariff component only, like in a pay-as-you-go scenario, results in the highest possible risk for the mini-grid operator.

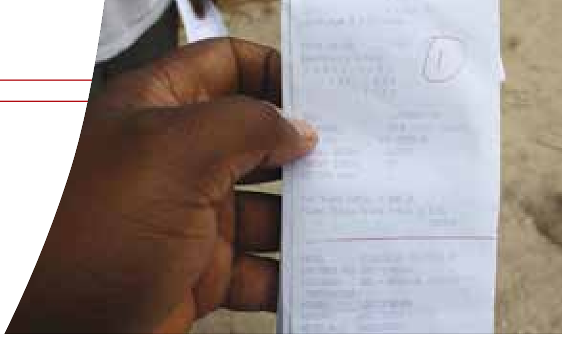
Pay-As-You-Go and Mini-grids

Pay-as-you-go is currently receiving a lot of attention. Pay-as-you-go means that electricity customers pre-pay and consume electricity based on the availability of cash. This means that electricity consumption can vary considerably with time. This is not well suited to off-grid electricity systems with high fixed costs such as PV- and battery-based mini-grids.

In such systems, the operator must try to sell all the electricity produced before it gets lost, which occurs when the battery is full. The lower the amount of available/produced electricity that is sold the lower are the revenues and the higher is the tariff per kWh. Thus, a daily electricity demand that uses all the electricity produced would be favourable for the system's economics and the affordability of electricity for all mini-grid customers.

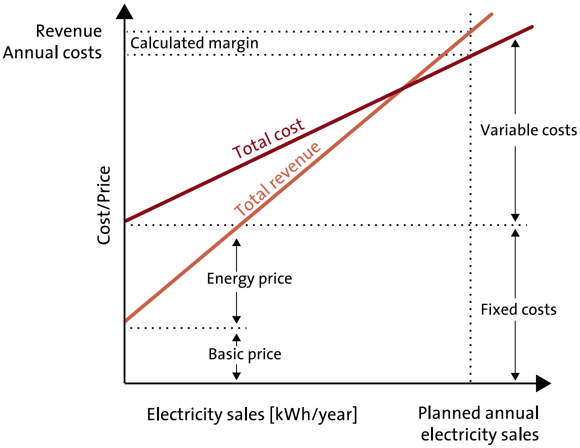
To provide the flexibility required for pay-as-you-go payment and related varying load curves, a more flexible power source is required. This power source should have a low investment cost and can have higher operational costs. A diesel generator would be such a power source. For PV-based mini-grids, flat-rate or take-or-pay contracts are thus more suitable than pay-as-you-go.

25) There are examples in Senegal and Mali where flatrate tariffs for electricity result in excessive use of electricity. In some cases customers do not even switch off the electric lights during the daytime. This causes considerable strain on the power system, which eventually suffers from financial losses.



The schematic diagram in *Figure 5* shows how electricity prices can be derived from electricity generation, distribution and sales costs.

Figure 5 Schematic mini-grid electricity costs, prices and profit margin (Müller, 2001)[26]



Private mini-grid operators in Africa expect a project Internal Rate of Return (IRR) (which is depicted as the calculated margin in *Figure 5*) of at least 12 percent and an equity IRR above 16 percent. (These IRRs are considered to be adequate by social entrepreneurs but not for purely profit oriented companies and investors.)

The tariff-setting process can be used by project developers as well as by regulators. Usually, there is a national regulatory authority that has to approve tariffs with the objective of guaranteeing fair tariffs for customers. In the approval process, regulatory agencies use their own calculating methodologies for defining the 'appropriate tariffs'. Unfortunately, often, they do not include all cost positions; in particular transaction and management costs are often neglected.

The following table shows simulation results of a PV-diesel-battery mini-grid system based on data adapted from a real life example in Bangladesh, including the technical design, capital structure, cost summaries, financial indicators and tariff design.

26) The Y axis shows the cost/price, and the X axis shows the amount of electricity sold per year. The blue curve indicates the total cost, which is based on fixed costs (which accrue independent of electricity sales) and variable costs (which increase with increased sales). The yellow curve represents the total revenues also based on a fixed part - the basic price - and a variable part - the energy price. The point at which the yellow and blue curves meet is the break-even point. Upwards from this point, the mini-grid can not only cover its cost but also generate profit. With this break-even point in mind, and with projected electricity sales indicated by the demand assessment, the final tariff levels can be calculated.

Table 5 Exemplary financial model results of Bangladesh

Technical System Design	
Solar PV	100 kWp
Diesel generator size	100 kVA
Battery size	560 kWh C10
Battery inverter size	60 kW
System type	Mixed AC/DC coupled
Mini-grid length	Approx. 3.5 km
Mini-grid efficiency	96%
Capital	
Equity	20%
Debt	30%
Grant	50%
Total investment	520,000 €
Renewable Fraction	
Renewable fraction	47%
O&M&M Cost Summary I	
Diesel price on site	0.70 €/L
Overheads	15,000 €/year

Financial Indicators	
Project IRR	10%
Equity IRR	15%
Project lifetime (in simul.)	20 years
Debt Terms	
Tenure	10 years
Grace period	2 years
Interest rate	6%
Type	Constant principal amount
Tariff	
Electricity sales price	0.43 €/kWh
Purely energy based	This is a deviation of the simulation from the actual setup
No fixed basic tariff comp.	
Electricity Sales	
Avg. electricity sales	420 kWh/day
O&M&M Cost Summary II	
O&M on site	10,000 €/year
Battery/inverter replacement	After 7 years/5 years

4.4 Financing of Mini-grids

It is important to understand not only mini-grid economics, but also the available financing options and sources for mini-grid investment.

4.5 Public Finance

The nascent state of the mini-grid sector, as well as political pressure to limit tariffs to levels lower than what is fully cost-reflective, are the main reasons to justify the **need for grant funding** (Tenenbaum et al., 2014).

Capital subsidies are a common method of reducing project costs. They can offset the high costs of grid infrastructure and user connections and be disbursed in intervals to ensure performance. Capital subsidies may be calculated based on the number of connections, total capital costs, or project IRR. **Grants** typically support projects to achieve equity IRRs of 15-20%[27], which do not adjust to the increased risks encountered in developing country projects. Besides capital costs, grant funding may be used to provide technical assistance (TA) for feasibility work to make projects investible, or to offset development risk by providing grants to match equity commitments.[28] While the structure and volume of subsidies are important, attracting private capital requires an efficient disbursement process. Subsidy programmes that are not responsive and generate high transaction costs, and are delivered by inefficient government agencies, will fail to deliver the sector stimulus they aim to achieve.

4.6 Private Finance

4.6.1 Project versus Corporate Finance

The capital required to start a business or to build an infrastructure project is usually obtained by raising **corporate or project finance**. Mini-grid distribution and generation assets can be financed using both approaches. A private company that builds these assets could raise funds at the corporate level, or could establish a Special Purpose Vehicle (SPV) for which it could arrange project financing. A utility could do either one or the other, but a community would likely not have a balance sheet/track record to raise corporate finance. Typically, community mini-grids would be developed and implemented by

27) This IRR is typical for projects realised in industrialised countries, which comprise lower risks than projects in developing countries.

28) Grants are available from national and international sources. In Tanzania, various grants support mini-grid development. The World Bank TEDAP program provides a subsidy of $500 per connection (described as a performance grant) and a concessionary debt facility administered by the Tanzania Investment Bank. Also, some governments in West Africa, e.g. Burkina Faso, are using government funds, obtained mainly from concessional loans, to finance mini-grid deployments, and even regional organisations like the ECOWAS Renewable Energy Facility (EREF) provide grant co-funding for small and medium sized renewable energy projects and businesses. Energy SMEs, another World Bank program, provides development funding for energy sector TA provider GVEP International to provide development support to several mini-grid developers in Tanzania and Rwanda. Also donor agencies such as the European Commission Energy Facility, KfW, and Energising Development (EnDev) provide grant capital to mini-grids through various funding windows.

a third-party project developer that would structure a project entity, into which financing would be raised, and in which the community would have some ownership based on their contribution in terms of land, labour, materials, etc.

There are several reasons why **project finance is - or rather will be - appropriate for mini-grids**. Similar to other power generation assets, mini-grids are highly capital intensive, though systems are small. Mini-grids may be owned by SPVs, as financing is naturally cash flow-based. However, project finance is a challenging solution in the near term. Even bundled mini-grid projects are relatively small, and project finance is difficult to justify below 20 million EUR. Project finance equity investors accept lower internal rates of return (IRR) due to predictability of cash flows, which mini-grids do not necessarily provide.

Since project finance for mini-grids is hard to come by, most mini-grid development companies are raising corporate finance from equity investors in order to build demonstration projects and develop their business models. Through corporate finance, a developer may be financed in multiple transactions as it deploys systems, in contrast to an infrastructure project that requires a large financial commitment at “financial close” prior to the start of construction.

4.6.2 Providers of Equity Capital

It is necessary to understand the profile and requirements of equity investors that may finance mini-grids. Very early stage (seed) equity may be sourced from **angel investors**, slightly later-stage funding may be provided by **venture capital funds**, and expansion capital by **private equity funds**, family offices, and public capital markets. Decisions to invest are based on the operator model, the market opportunity, the management team track record, and the perceived scalability of the company. An increasing number of Africa-focused investors identify themselves as **impact investors** with a mandate to achieve social and environmental impact in addition to financial returns and which are measured by the job creations, by the new/improved energy access, or by the carbon avoidance. While some accept lower than risk-adjusted returns, many investors target relatively high returns (e.g. 20%+ equity IRRs). The numerous challenges associated with mini-grids provide insufficient risk-adjusted returns for investors seeking high-growth and scalable ventures, with higher potential returns.

In addition to private investors, multilateral development banks and **development finance institutions** (collectively “DFIs”) design, finance, and operate facilities that provide equity. These actors typically prioritise development impact as well as financial viability, and provide growth equity to established companies or capital for larger projects.[29] While mini-grids present a number of challenges to these financiers, there is an increasing interest in pursuing mini-grids as viable opportunities. Successful pilot projects and larger-scale rollouts will help these natural investors participate, who are bringing their experience in energy project development.

29) Private equity funds such as the AfDB-sponsored African Renewable Energy Fund, IFU-sponsored Frontier Investments and Gaz de France (GDF), as well as DFIs including FMO, OPIC, and multilaterals such as AfDB and OFID all provide equity to large energy projects.

4.6.3 Providers of Debt and Mezzanine Capital

The risk/return profile mismatch limits the number of potential equity investors, thus **access to appropriate debt finance** is highly challenging for mini-grid developers (cKinetics, 2013). Debt is theoretically available from local and international banks, DFIs, funds and crowdfunding platforms. However, as mini-grids are largely an unproven model, commercial lenders are hesitant to lend. Projects will struggle to raise commercial debt until some of the technical, regulatory, and operational challenges are addressed and risks mitigated.

Local financial institutions are a natural debt provider due to their ability to understand market dynamics and perform due diligence. However these institutions have limited experience in cash flow analysis, and rely on collateral for corporate lending. Local banks typically offer short tenor, high cost loans that are not viable for mini-grids. Interest rates may range from 16-24%, while the few precedents for project finance have resulted in interest rates around 10%.

Mezzanine finance is closer to equity than debt on the risk/return spectrum, insofar as mezzanine investors have a lower degree of preference than lenders and they are paid after lenders in the event of bankruptcy/liquidation. Therefore mezzanine instruments typically command a higher return to compensate for this additional risk relative to debt. However, mezzanine finance is typically a senior, or a paid before equity, and thus it does not command as much financial return (interest rate) as straight equity.

DFIs attempt to fill the gap left by local banks, however the limited scale of mini-grids leads to prohibitively high transaction costs. In some cases, developers bundle mini-grids into sufficiently large transactions, a trend likely to accelerate as developers establish track records.[30] DFIs may also provide credit lines or guarantees to encourage lending.[31]

Impact funds and crowd funding platforms also provide debt, although the limited amount of capital available is unlikely to finance at scale. However, they may lend to pilot projects to demonstrate project viability and carry lower interest rates and higher risk tolerance than many banks.

30) OPIC, an American DFI, provides debt for renewables projects at interest rates of 4-8%. While most of the projects OPIC has financed in Africa are grid-connected, the organisation is interested in mini-grids and is likely to become a more active lender as operator models are successfully demonstrated. Further, the European Investment Bank and the “Kreditanstalt für Wiederaufbau” (KfW) also provide debt through local banks.

31) The Regional Technical Assistance Programme funded by AFD, the French DFI, provides a credit line to CfC Stanbic and Coop Bank to lend in Kenya, Tanzania and Uganda. More recently, a 26.6 million EUR USAID and Sida-sponsored facility is being established in Kenya and Tanzania to provide a 50% shared loss guarantee for loans to energy borrowers, including mini-grids.

Table 6 Profile of capital providers in Africa, by Peter George (adapted from cKinetics (2013)), the scale in depth of market, engagement in mini-grid sector and risk appetite is illustrated on a scale from 1 – low to 4 high.

	Grants		Equity		Debt	
	Subsidies / TA	Seed / Start-up	Growth / Expansion	Infrastructure	SME / Corporate	Project Finance
Sources	▸ Governments ▸ Foundations ▸ Donors / DFIs	▸ Friends & Family ▸ Angel investors ▸ Impact funds ▸ Foundations	▸ Impact funds ▸ Venture cap funds ▸ PE funds	▸ PE funds, most DFI-sponsored	▸ Local banks ▸ Int'l banks w/ local presence	▸ Commercial banks ▸ EXIM banks ▸ DFIs
Depth of market	+++	+	+++	++	+++	+
Engagement in mini-grid sector	++	++	+	+	+	+
Risk appetite	++++	+++	++	++	+	+
Basis for funding decision	Business model, management / developer track record					
	▸ Dev impact ▸ Status of sector / need for subsidy	▸ Dev impact ▸ Market potential	▸ Profitability ▸ Balance sheet	▸ Stage of dev. ▸ PPA / permits ▸ Other contractual agreements	▸ Balance sheet ▸ Collateral	▸ Debt service coverage ratios ▸ Guarantees, other risk mitigants
Amount	$30k – 10m	$100k – 1m	$1 – 5m	$10m+	$20k – 10m	$15m+ (selected smaller transactions)
Expected tenure	N/A	3 – 7 years	3 – 5 years	5 – 10 years	6 months – 5 years	7 – 15 years

→ *Table continues on page 57*

	Grants		Equity		Debt	
	Subsidies / TA	Seed / Start-up	Growth / Expansion	Infrastructure	SME / Corporate	Project Finance
Typical return expectations	None (in some cases return of capital)	Impact: 5 – 35% Commercial: 30%+	Impact: 5 – 20%+ Commercial: 20%+	15 – 25%	16 – 24% (local currency)	6 – 12% (hard currency)
Examples	▸ AECF REACT ▸ EEP S&EA ▸ TEDAP / ESME ▸ USAID DCA ▸ USAID DIV	▸ Beyond Capital ▸ Eleos Foundation ▸ ERM Foundation ▸ Invested Dev'mnt ▸ NovaStar	▸ Acumen ▸ Bamboo ▸ Khosla Impact ▸ LGT VP ▸ Persistent	▸ Berkeley / AREF ▸ Frontier ▸ IFC InfraVentures ▸ InfraCo ▸ ResponsAbility	▸ Barclays ▸ CfC Stanbic ▸ EcoBank ▸ Equity Bank ▸ StanChart	▸ AfDB ▸ CfC Stanbic ▸ FMO ▸ Norfund ▸ OPIC

FURTHER READING

4.1 **Mini-grid Economics**
4.2 NRECA, (2009) "Guides for Electric Cooperative
4.3 Development and Rural Electrification"
TOOL: MGPT Financial Model for Mini-grids
(minigridpolicytoolkit.euei-pdf.org/tools)

4.4 **Mini-grid Financing**
Lindlein, Mostert, KfW (2005). *Financing Renewable Energy; Instruments, Strategies, Practice Approaches.*
Justice, UNEP (2009). *Private Financing of Renewable Energy - A Guide for Policymakers.*

SBI (2013). *Scaling up Successful Micro-Utilities for Rural Electrification; Private Sector Perspectives on Operational Approaches, Financing Instruments and Stakeholder Interaction.*

5. Stakeholders' Interests and Contributions

Understanding the key stakeholders and their interests, possible contributions and conflicts enables governments to design policy and regulation that facilitate concerted actions and thus accelerate mini-grid roll-out. This chapter explains the stakeholders' views on mini-grids together with their expectations and aims as well as their motivation to contribute to the development of the sector. In view of the widely quoted need to mobilise private investment, the section on private developers and operators is more detailed than the others.

5.1 Customers

5.1.1 Household Customers

Rural people aspire to gain access to affordable modern energy services (with applications like mobile phone charging, televisions and fans) in their homes and increase their standard of living. Low-income rural households without access to grid electricity usually pay 2.30 - 11.40 EUR per month for traditional sources of energy (candles, kerosene, disposable batteries, and battery charging) (World Bank, 2008). The shocking truth is that **un-electrified electricity customers in Africa can pay 20 – 80 EUR/kWh for cell phone charging, and 40 – 80**

Community Involvement

Customers want to be actively involved in decision making regarding their energy supply, especially in small villages which traditionally debate community issues. This community involvement is not only requested by the communities themselves but also makes economic sense. **Involving local communities from the start can help to improve mini-grid design, ensure local support, mobilise contributions in cash or in kind, and increase local ownership, which in turn contributes to operational sustainability** (Bhattacharya, 2013).

Furthermore, local participation helps to reduce theft and distribution losses, improves billing and revenue collection efficiency, ensures stable delivery of electricity, and prevents many potential conflicts. Community involvement may leave some decision-making power to the community through discussions (sometimes also negotiations) on eyelevel between the mini-grid operator and community representatives.

An electricity supplier who wants to be accepted in the village may want to avoid establishing a monopolistic system. A split of generation and distribution ownership and responsibility is advisable. For example, communities can take ownership of the distribution grid or be endowed with tariff determination, penalty definition, and monitoring and verification activities.

EUR/kWh for electricity from disposable dry cell batteries. Richer un-electrified households, which consume electricity from small, inefficient petrol or diesel gensets with an extremely short lifetime and low efficiency, pay 1.50 – 3.00 EUR/kWh[32]. The graph on the next page gives an overview of prices of typical household uses of electricity with different power supply options for Haiti.

32) Mobile phone charging assumptions: 0.10 - 0.40 EUR per mobile phone charged, 5 Wh per battery charged; Disposable dry cell batteries (baby cell) average cost of 0.70 EUR per battery with a battery capacity of 11.7 Wh; further assumptions are a simple petrol generators with efficiency of 15% (1.5kWhel/litre diesel) and a price of 1 EUR per litre of petrol imply running cost of around 0.60 EUR/kWh, and a 1 kW generator with investment costs of 200 EUR and runs for 300 hours at 500 W resulting in an investment cost in kWh of 1.3 EUR, totalling 1.9 EUR/kWh.

SUMMARY FOR POLICY-MAKERS

Electricity customers expect electricity at a reasonable quality and a reasonable price. There are different types of customers with specific needs and implications for the operations of mini-grids, including households, social institutions, as well as productive users.

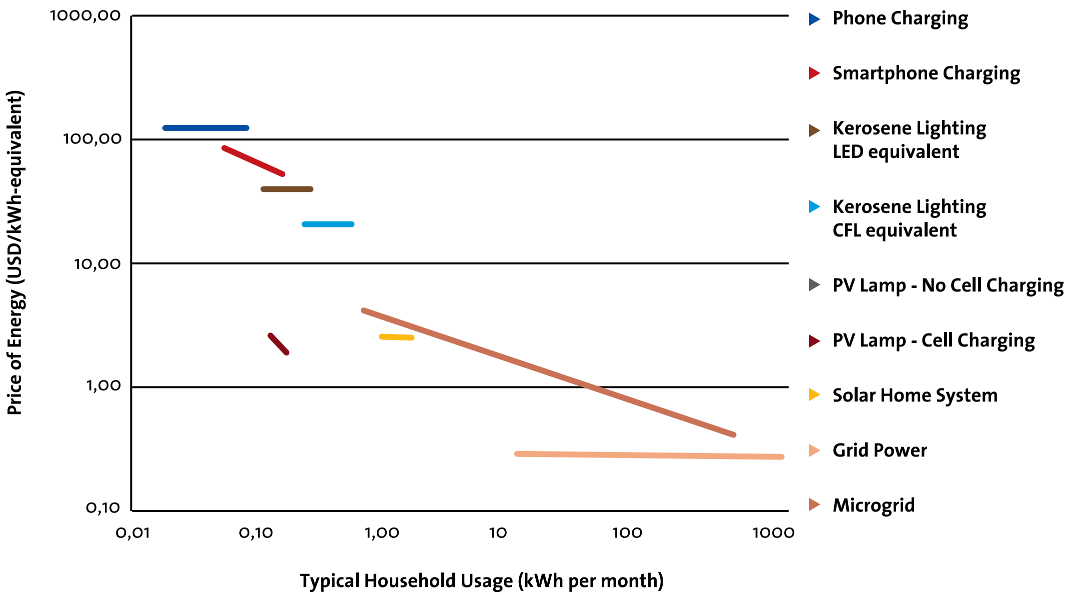
Customers are often prepared to pay electricity tariffs in excess of national grid tariffs in order to gain electricity access before the arrival of the national grid. Customers are willing to pay these higher tariffs as long as their electricity expenditures are below the current energy expenditure for similar services.

The organisational structure, capacity and experience of utilities make them suitable for operating large and complex electricity supply systems; this also holds true for mini-grids. The smaller the mini-grid is, the more decentralised the required management structures can be.

Private sector can only engage in developing and operating mini-grid projects in countries that allow legal electricity generation, distribution and sales, profitable tariffs, and have dedicated mini-grid sites with a business case that is protected in the case of the arrival of the main grid.

Mini-grid financiers expect adequate returns given the perceived level of macro and project risks. Due to the limited experience and limited positive track record in the mini-grid sector, many risks are not tangible for private financiers. As a result, they expect high returns. These high return expectations can be lowered with suitable and accessible risk mitigation measures which in turn can be addressed through an adequate policy framework.

Figure 6 Price of energy vs. typical household usage for different power supply devices and connections in Haiti (Archambault, 2012)



5.1.2 Social Institutions as Customers

For many countries, electrifying community or public social institutions is a priority as it enables the facilitation of public services, which has a major development impact. This may include schools, medical centres, other public buildings, streetlights, community drinking water pumps, drinking water purification, or sanitation infrastructure.

If this infrastructure exists in a village and the community can afford electricity services, **social institutions should be priority customers** as they often have predictable and stable electricity demand which occurs at different times to household customers. Community customers should also have the obligation to pay cost-reflective tariffs. In some countries this is not a problem, as public infrastructure has a dedicated budget for electricity that is not being used, but in other countries finding the necessary budget is challenging.

5.1.3 Productive Use Customers

Businesses and industry, so-called productive use customers, use the electricity for different purposes – depending on their business' activity - which can be categorised as follows:

- Agricultural Loads (e.g. irrigation pumps)
- Productive Loads (e.g. milling, rice de-husking, oil pressing, wood/metal workshops)
- Commercial Loads (e.g. shops, bars, ice-makers, battery charging and renting, lantern renting)
- Anchor loads (e.g. telecom towers, mines, greenhouses, hotels, loggias)

Each productive user group has distinctive loads/appliances, with specific load profiles that depend on national and local circumstances and available machines. Often, these productive users already use diesel engines to power their machines and appliances. Exchanging existing diesel-run machines with electric machines can be economical if the electricity cost is less than the cost of locally available diesel. If productive users do not yet use diesel-run machines, adopting electric machines can improve productivity, but promoting their adoption becomes more challenging. In general, when planning electrification with mini-grids, initiating or enhancing productive uses of electricity should be considered to both support the economic development of rural areas as well as significantly increase the sustainability and profitability of mini-grid projects.

Productive users need a **stable electricity tariff regime** because a spike in electricity tariffs (e.g. an increase of 50% of the tariff) can drive micro businesses into bankruptcy. Thus, step-changes in tariffs should be avoided. This also means that financing additional generation capacity should be done by connecting additional customers or productive loads and not by increasing tariffs.

5.2 Public Utilities

Utilities plan their electrification activities primarily in areas already covered by or close to the existing grid. Yet, in some cases they are explicitly involved in building and operating mini-grids. In other cases they play the role of facilitator or regulator while letting private developers and the communities be in charge of mini-grid systems (Deshmukh, Carvallo & Gambhir, 2013).

In general, **public utilities are structured for the operation of the main grid and centralised power stations.** Successful mini-grids, however, require local operation and depend on the availability of technical expertise for maintenance of small generation units. Thus, utilities that operate mini-grids need additional personnel for local operations and maintenance, and may need to set up a dedicated department to deal with a large number of smaller mini-grids.

Building and operating mini-grids in remote rural areas is rarely of interest to utilities because of low demand, low load factors, high investment

and O&M costs as well as financial constraints faced by the utilities themselves (Sanoh et al. 2012). Public utilities are well aware that the smaller the community, the higher the electrification challenges in terms of:

1) Technical system stability due to higher concurrency of loads
2) Revenue stabilisation due to less diverse income sources of customers
3) Increased operating and transaction costs per kWh, requiring new management approaches
4) Prevention of conflicts due to opaque community decision-making-structures

Thus, **when public utilities build and operate mini-grids, they do so directed by national governments.**[33] Governments often require public utilities to run isolated diesel-based mini-grids as an intermediate solution before the main grid arrives. Utilities have limited interest in operating mini-grids in remote small and medium sized settlements and are content to let these be run privately or by local communities.[34]

The graph on the next page indicates when the private sector or national and large/medium size utilities would be best suited to be in charge of mini-grids.

Utilities may also opt for a hybrid operator model in which the utility owns and operates the mini-grid distribution assets and a Small Power Producer (SPP) own and operate the generation assets and agree a standard power purchase agreement (PPA). This would make the process of interconnection when the main grid arrives easier as the distribution grid already belongs to the utility and the generation equipment can be moved to another village.

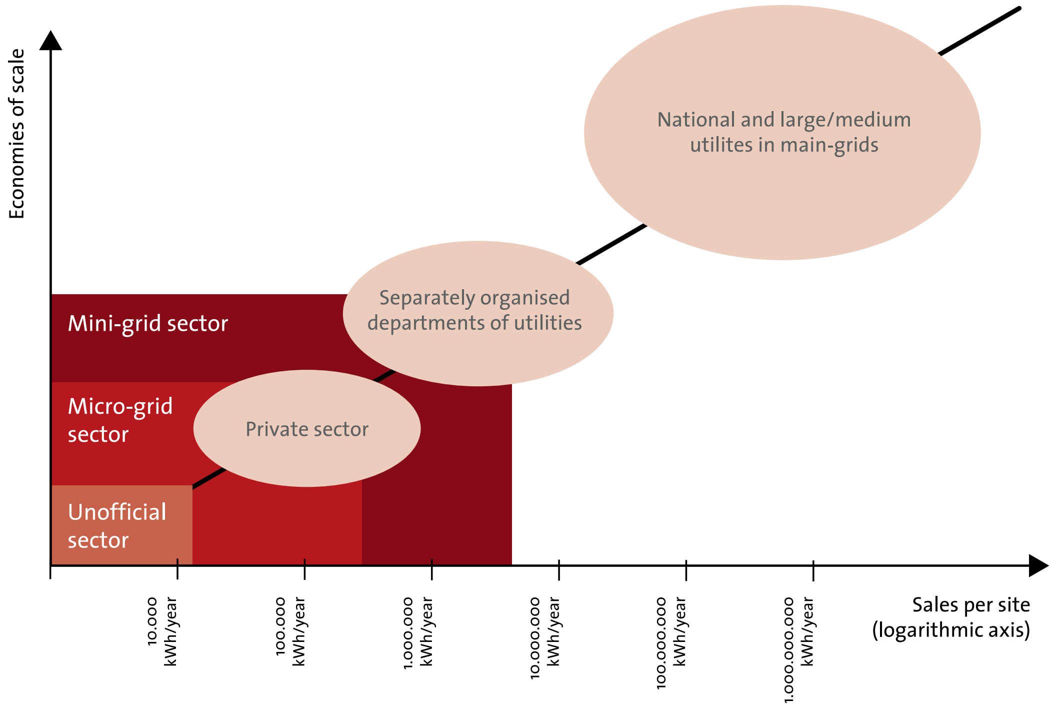
In order to successfully develop and operate mini-grids, utilities need low cost upfront financing and cost-reflective tariffs. Capital costs need to be subsidised through grants and low-interest loans. In terms of cost-reflective tariffs, opinions appear to differ: some utility representatives say that cost-reflective tariffs are necessary, others state that uniform tariffs are the best policy. If cost-reflective tariffs are deployed, long-term stability of the tariff regime is essential, in particular with a view to the possibility of changing political preferences.

5.3 Private Developers and Operators

Private developers and operators of mini-grids are rare, as it is still difficult to generate adequate margins with mini-grids. The few mini-grid operators who have been active for years usually have a development or social focus. Thus, these companies usually use either a **cooperative structure** and are close to the NGO sector, they are often **social entrepreneurs** and they are typically Small and Medium sized Enterprises (SMEs). Larger, commercially minded companies are experimenting with operator models in pilot projects but have not yet entered the sector with larger investments. Until now, profit-oriented companies can only be found as providers of Engineering, Procurement (of the power system), Installation and Commissioning services (EPC) and as consultancy firms.

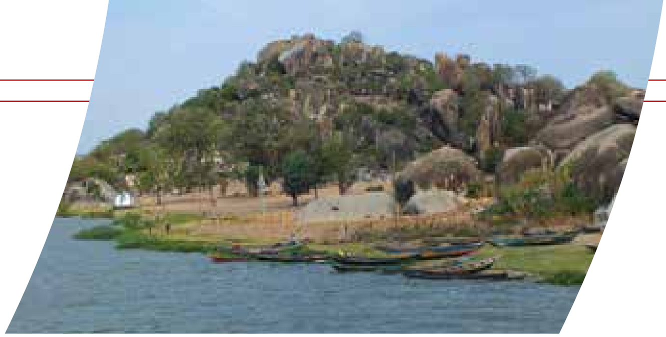
33) An example of this is in Kenya, where KPLC was instructed to establish mini-grids in some communities; 15 of these mini-grids were in operation and 13 under construction in mid-2014.
34) In Mali, for example, the public utility (EDM) runs mini-grids above 300 kW, and the regulatory agency (AMADER) oversees smaller, privately run systems.

Figure 7 Indicated suitability of utility and private sector for different sizes of mini-grids



Mobilising the **private sector** to operate mini-grids - with its capacity to lead project development, to manage complex businesses "on the ground", and to access private sector finance - is key to a larger mini-grid roll-out, especially in smaller villages. This requires a conducive enabling environment. After all, private companies and cooperatives only want to participate in the mini-grid sector in countries where risks are equivalent to the margins that can be earned.

From a private project developer's point of view, a country becomes suitable for mini-grid roll-outs as soon as it fulfils the following three prerequisites:



- It must be **legal to operate a mini- or micro-utility**, and licences should be obtained easily.
- Micro-utilities must be allowed to charge **tariffs** that allow **“risk equivalent” margins**.
- Ministries/authorities must **disclose attractive villages/towns listed for mini-grid electrification** which will not be connected to the main grid within a guaranteed period of time and also implement a clear, reliable and long-term scheme for when the national grid does arrive.

As of today, these requirements are largely not met in most African countries. Many countries still apply a purely **centralised approach**, have a national utility monopoly and do not allow any other electricity suppliers. As a consequence, mini-grid operators are pushed into the informal sector, which prevents mini-grid operators from acquiring finance and imposes a serious legal risk on mini-grid companies. Thus, countries which do not allow private mini-grid operation legally only see a limited number of mini-grids being established. Other countries are following a **decentralised approach** and have unbundled their electricity sector, allowing competition in electricity generation and/or distribution, subject to strict control by the regulatory authority. These schemes are in principle appropriate for private mini-grid operation; However, other practical issues may hinder a mini-grid roll-out, as for example complex and time consuming licensing and tariff setting processes, or prohibitively high fees for the various licences, permits and approvals.

A Private Developer’s Perspective on Tariffs

From a private developer’s perspective, tariffs must be cost-reflective. Otherwise, mini-grids cannot be run profitably, which prevents potential customers in rural areas from receiving high quality electricity at all.

Operational subsidies or cross-subsidised tariffs on a kWh basis are not favoured by small private sector players, as they do not want to be dependent on transfers from large utilities or government authorities, which may be delayed, driving small private sector organisations into insolvency.

In general, private sector mini-grid operators prefer cost-reflective tariffs, enabling them to manage their own revenue risk through payment schemes, micro-payments and Customer Relationship Management approaches.

Furthermore, mini-grid operators like linear or close to linear tariff schemes (in which each kWh delivered is the same price) as these reduce the revenue risk related to demographic changes in the village. Lifeline tariffs for poor customers, which are especially common in Eastern and Southern Africa, or lower per kWh tariffs for richer and productive-use customers, like in the Senegalese ERIL programme, add considerable uncertainty to the mini-grid operator’s income stream and are therefore not desired.

Private developers and operators will consider entering the mini-grid business in countries where this activity can be **profitable, or at least cost covering** in the case of social businesses, NGOs and cooperatives. As indicated before, the costs of generation and distribution of electricity in mini-grids are higher than on the national grid. An additional cost factor that is regularly underestimated is the interaction with governments – and also development organisations - and the related transaction costs incurred by small organisations *(chapter 3.5)*. These transaction costs reduce profitability and cash-flow in the critical stage of project development. Thus, **in order to attract private investment, electricity tariffs must be higher than the national grid tariff. In the absence of cheaper alternatives, electricity customers are often ready to pay for these high tariffs.**

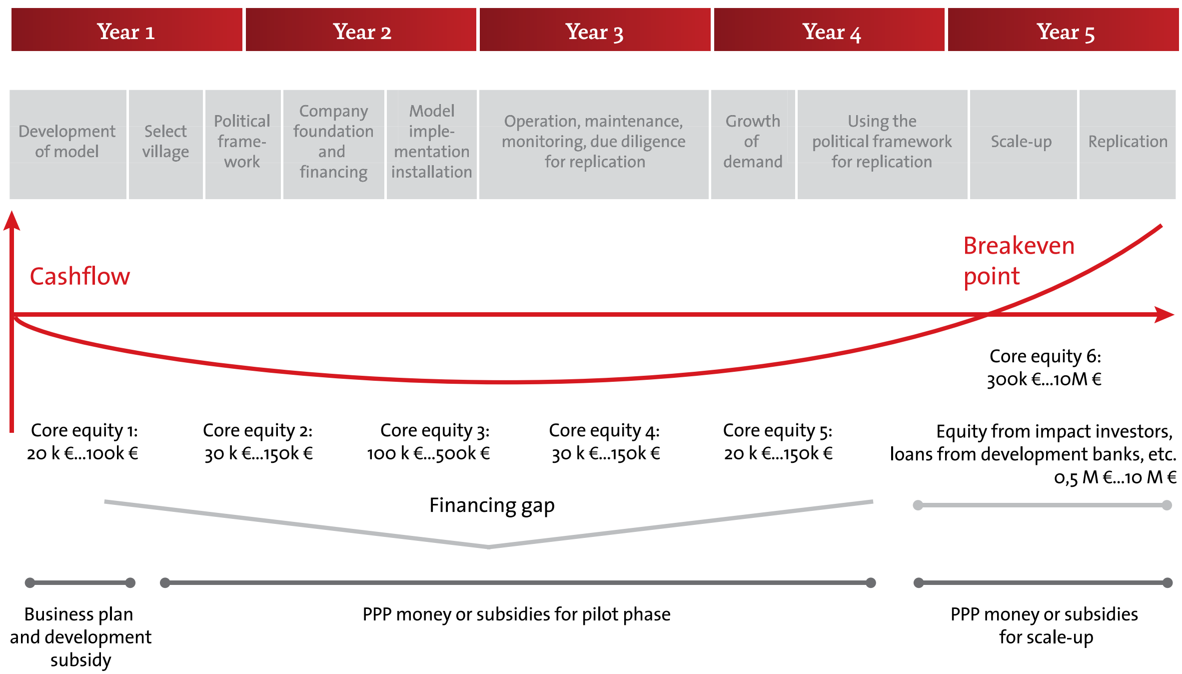
One of the main risks that mini-grid operators are confronted with is the **connection of their mini-grid site to the national transmission grid.** As indicated in chapter 3.1, a national electrification plan should clearly identify areas assigned for mini-grid electrification that the main grid will not reach within a well-defined period of time. In the best case, a period of 10 to 15 years should be guaranteed. This could be in the form of a mini-grid concession, guarantee or contract. **If the national grid arrives before its time, the mini-grid operator needs to be compensated for the stranded investment.**

Once a private mini-grid developer has identified a suitable country and appropriate sites that meet all three requirements above, he needs to design and to implement his operational and payment collection strategies and arrange the finance for project development and implementation. The smaller the community to be electrified, the more locally involved the mini-grid operator needs to be. Financing for project development steps like feasibility studies, business plan development, adjustment of operator models to local conditions, etc. is especially difficult to obtain for small developers.

Although subsidies are available, equity for co-financing is lacking. As explained in the mini-grid economics chapter, the considerable fixed costs in mini-grid operations mean that scaling up electricity sales to break-even as early as possible must be the main aim for all newly established private mini-grid operators. However, the project development phase commonly takes longer than expected because proof of concept often takes a considerable amount of time. This means that reaching break-even can take up to 4 years as indicated in the example below [SBI, 2013].

Generally, **different types of financing are applicable at different times during the project cycle.** Small private project developers in particular can accelerate their electrification activities if the policy framework includes explicit guidance on the government support available, whether it is debt, equity, grants, subsidies or tariffs. Clear information about access to finance and a straight forward licensing procedure shorten project preparation time and reduce risks for mini-grid developers considerably. Implementing these basic elements of a conducive framework in turn attracts more private sector players to enter the mini-grid sector.

Figure 8 Typical mini-grid cashflow, financing and break-even



Source: Inensus

5.4 Private Financiers

Private financiers approach investment in mini-grids in the same way as other investments in developing countries. The basis is always the **risk-return profile of mini-grids in the specific country context and the track record and business plan of the mini-grid developer and operator**. Having described the revenues of mini-grids and the sources of capital above, this chapter highlights risk considerations of financiers, as these are important to consider for attracting private finance.

In general, financial institutions expect returns that are proportional to the risk they undertake –more risk means that a greater return will be expected (UNEP, 2009). Financiers see the African mini-grid sector as being at an early stage of development, with few demonstrated projects. This lack of track record serves as a barrier to financing, as investors and lenders are not yet fully able to capture and mitigate risks associated with potential investments. It will take time and successful pilots for bankable projects to attract capital, and for commercial financing costs to come down. In general today, most of the existing debt and equity financing instruments do not fit the demand of the mini-grid sector.

Profit oriented investors willing to explore new and innovative markets may contribute substantially to the private financing the scale-up of mini-grid roll-outs. Financiers distinguish between brownfield and greenfield mini-grid projects. **Brownfield projects** involve adding renewable energy to existing mini-grids that use diesel generators, and have electricity demand and a revenue stream that are proven. **Greenfield projects** are newly established mini-grids without a track record in terms of electricity demand or revenue stream. Brownfield projects are attracting some attention from profit oriented private investors while greenfield projects are as of yet out of reach for these investors, mainly due to the risk of unpredictable revenues. **Governments may provide instruments mitigating these risks** including demand/revenue guarantees, advance payments, or security deposits. Prepaid metering, in-depth market studies, and anchor off-taker (e.g. mobile tower) PPAs also mitigate revenue risk, and governments should support and facilitate these where possible. Policy instruments reducing this revenue risk are being discussed. Experts are developing government guarantees that provide minimum mitigation of revenue-related and other risks.

Impact investors fill the gap left by first market investors with concessional finance. Impact investors are prepared to take the risk of unknown revenue streams in greenfield projects. They try to use existing financing instruments to tackle new challenges. They may already be familiar with corporate finance for businesses selling products like solar home systems or solar lanterns to rural customers, and large project finance for multi megawatt grid connected energy infrastructure projects.

Mini-grid Risks – Macro Level

Mini-grid projects in developing countries face multiple risks. These risks should be managed by the party best able to manage the specific risk, which in turn depends on the parties' ability to influence, anticipate, respond, and absorb the risk and the related transaction costs (WB, 2007). Below is a list of macro level risks where policy-makers and regulators can have a strong influence in mitigating these risks (excluding project risks that need to be mainly managed by project developers):

Table 7 Macro-level risks for mini-grid investment[35]

Political Risks		
Country Risks	Risk of regime/government instability	Expropriation through nationalisation, war, insurrection, famine, new government
	Risk of policy changes	Changes of policy (subsidies, power pricing and grid extension plans, etc.), e.g. through referendum
	Risk of international policy changes	Sanctions, changes in policy of IMF or World Bank, changing access to carbon markets
	Risk of industrial action	Strikes, lockouts, work bans, work-to-rules, blockade, go-slow action, etc. that increase cost or downtime
Fiscal Risks	Risk of taxation or import duty changes	Risk that tax rates, tax credits, or import duties change
	Risk of changes to applicable allowances	Changing rules for amortisation, depreciation, export credit guarantees, national grants, etc.

35) Adapted from, Justice (2009), IEA (2011), UNEP (2012), IED-DFID (2013), Tenenbaum et al. (2014)

Political Risks		
Legal Risks	Recourse risk	Questionable legal access, non-independent justice or arbitration
	Remedy risk	Uncertain enforcement of court awards e.g. damages
Regulatory Risks	Risk of obtaining permits and approval	Risk of non-transparent or changing permitting processes for generation licences, water-use rights, land use permits, environmental permits, building permits, etc.
	Risk due to multiple permitting authorities	Risk associated with multiple permitting authorities with over-lapping competencies (e.g. national, regional, local, land use planning, energy ministry, etc.)
	Energy regulation risk	Changes in regulations for grid connection, tariff regulations, volume requirements, etc.
	Health & safety risk	Risk of costly safety reports, authorisations
Social Risks		
Environment Risks	Risk to fauna/flora	Risk that project related activity damage/harm or pollute fauna, flora, groundwater, air (possibly also leading to loss of reputation)
	Risk of pollution	Effluents, thermal, air, water biocides, chemicals, dust
	Risk of waste	E.g. construction/operation waste, decommissioning waste/recycling
Public Risks	Risk of criminality	Vandalism, sabotage, terrorism, insurgency, corruption
	Risk of non-acceptance	By local communities, Non-Governmental Organisations (NGOs)

→ *Table continues on page 70*

Economic Risks		
Financial Risks	Risk of lack of fi-nance availability	Risk that domestic and international long-term debt and/ or equity finance is not available on a non-recourse basis
	Interest rate risk	Changes of interest rates
	Credit risk	Risk that the project is deemed to be not creditworthy, that the cost of capital is too high, and re-financing is not secured
	Currency risk	Risk that exchange rate and/or inflation develops adversely
Additional risks relevant for financiers and insurers		
Financing Risks	Insurance risk	Risks that can be insured (mechanical breakdown, collision, third party liability, theft, property loss, business interrup-tion) cannot be evaluated properly for new technology or in a new context (country, climate)
	Option price	Undeveloped financial markets, leading to unavailability of derivatives, hedges, or swaps in most developing countries
	Security risk	Risk that the lender cannot take possession of a plant in case of default on the loan or is not allowed to operate in case of repossession
	Transaction cost risk	Risk for a small project that transaction and administration cost increase beyond feasibility
	Exit risk	Uncertainty over available monetisation options

FURTHER READING

The following publications are for readers who want to know more about productive use, mini-grid project development and project risk management for renewable energy projects.

5.1 Productive Use
EUEI PDF, GIZ (2011). *Productive Use of Energy - PRODUSE; A Manual for Electrification Practitioners.*

ESMAP (2008). *Maximising the Productive Uses of Electricity to Increase the Impact of Rural Electrification Programs.*

5.2 Project Development
5.3 Doe et al., SET/UNDP/GEF (2005). *China Village Power Project Development Guidebook; Getting Power to the People Who Need it Most; A Practical Guidebook for the Development of Renewable Energy Systems for Village Power Projects.*

SBI (2013). *Scaling up Successful Micro-Utilities for Rural Electrification; Private Sector Perspectives on Operational Approaches, Financing Instruments and Stakeholder Interaction.*

5.3 Project Risk Management
IEA (2011). *Risk Quantification and Risk management in Renewable Energy Projects.*

UNEP (2004). *Financial Risk Management Instruments for Renewable Energy Projects; Summary document.*

Justice, UNEP (2009). *Private Financing of Renewable Energy - A Guide for Policymakers.*

6. Policy and Regulation for Mini-grids

Policy and regulation are means to an end. What ultimately matters are outcomes. The benefits of policy and regulation must exceed their costs.[36]

The **Mini-grid policy and regulatory framework comprises the binding rules, strategies, institutions and associated processes that govern the mini-grid sector.** It is developed and adopted by public bodies, including parliament and government agencies, and it determines whether and how mini-grid development takes places as well as whether and through which models mini-grids are developed, implemented and operated.

Main mini-grid policy decisions[37] should be based on sound data and information, and address the following:

- **Whether or not to integrate mini-grids as an option rural electrification?**
- **Which strategic approach (centralised or decentralised) to take?**
- **How to finance mini-grids?**
- **How to subsidise mini-grids?**
- **Which electricity tariffs to apply?**

The principles of mini-grid policy and regulation should, in the best case, be stable and long-lived, clear and comprehensive, accessible, cost-effective and efficient, light-handed and simplified as well as transparent and predictable.

6.1 Strategic Decisions for Mini-grid Policy-making

Before mini-grid policy and regulation can be designed, the basic political decision whether to include mini-grids in the rural electrification strategy has to be made. The basis for this decision, including mini-grid alternatives, benefits, operator models, and economics, is discussed in previous chapters of this toolkit. Further strategic decisions have to be taken before going into the detailed planning of regulation and its implementation. These decisions relate to the general approach to be adopted (centralised vs. decentralised), upfront financing (government vs. private), and tariffs (cross-subsidised vs. cost-covering tariffs), each of which is discussed below. These decisions determine which mini-grid operator models can be applied in a country (it may also be beneficial to support more than one operator model). In other words, they are crucial starting points, since they are streamlined subsequently throughout the policy and regulatory framework.

The decision path to this choice of operator models is illustrated in the graph in *figure 9*.

6.1.1 Centralised versus Decentralised Rural Electrification Approach

Most governments in Africa have developed national electrification strategies following either the central-

36) Adapted after Reiche et al, 2006.

37) The book Power-Sector Reform and Regulation in Africa; Lessons from Kenya, Tanzania, Uganda, Zambia, Namibia and Ghana by Kapika and Eberhard (2013) presents description of the current state of electricity regulation in Sub-Saharan Africa. The focus of the book is on electricity sector regulation as a whole.

ised or the decentralised approach. In a **centralised approach**, national government entities such as a public utility, rural electrification agencies or ministries undertake electrification alone or together and national grid extension is usually the primary means to electrification, with mini-grids playing a minor role. With the **decentralised approach**, private and community players take over the electrification of areas far from the national grid, but are often still supported by public institutions in the planning, implementation and operation of mini-grids (Tenenbaum et al., 2014).[38]

38) The book "*From the Bottom Up; How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa*" (Tenenbaum et al., The World Bank 2014) is one of the best guides to policy and regulatory decisions and other issues concerning the decentralised track.

SUMMARY FOR POLICY-MAKERS

A sound policy and regulatory framework is a prerequisite for mini-grids deployment, and thus for leveraging their potential to contribute to rural electrification and energy access. It comprises the binding rules, strategies, institutions and associated processes that govern the mini-grid sector.

Policy defines which strategic approach for rural electrification is taken (a centralised or decentralised approach), how mini-grids are financed, how they are financially supported, and which electricity tariffs can be applied. Together, these strategic decisions determine the mini-grid operator models that can be deployed. Each model has more or less specific requirements. The enabling environment is thus the foundation for mobilising public or private investment in mini-grids.

The framework should be stable and long-lived, clear and comprehensive, accessible, cost-effective and efficient, light-handed and simplified as well as transparent and predictable to guide the decision-making process of stakeholders and project developers. It should balance the needs and expectations of the different stakeholder groups, in particular in terms of allowing reasonable revenues for public or private investors, while addressing customer needs in terms of safety and affordability.

The policy and regulatory framework includes policies, laws, institutions, and regulations, and the arising processes and procedures. It includes elements at distinctive levels, ranging from the general policy and strategy level, to economic regulations, customer and environmental regulations, licences and contract regulations to financial and other applicable support schemes. Some policy instruments are essential for specific operator models, while others are only supportive. These instruments in many cases depend on each other and must thus be designed and implemented in a concerted way. In general, policy-makers have a wide range of measures at their disposal to enable electricity access in rural areas through mini-grids.

Principles of Policy and Regulation

Regulation is always based on principles – either intended or unintended ones. This section gives a short overview of recommended principles to follow for the design and implementation of mini-grid regulation.

Stable and Long-lived
A stable policy and regulatory environment is the basis for attracting investment into mini-grids. Mini-grid investors require reassurance that both macro-scale and specific regulatory support mechanisms will remain stable and predictable for the life of the project. There is nothing that makes investors - both existing and prospective - more nervous than the feeling that the regulatory environment may “shift beneath them” once they have already committed to their project.

Clear and Comprehensive
An incomplete or unclear mini-grid policy and regulatory framework will hinder rather than foster mini-grid roll-outs. There should be full clarity on permitted tariffs, licence and permit requirements, import duties, VAT, company taxes, and other possible incentives and subsidies, as well as the other policy and regulatory issues discussed in the next sections. The process by which regulatory decisions on these issues are reached should be clear and standardised for all transactions.

Accessible
Policy and regulatory frameworks should seek to ensure that the points of contact for permitting, technical and financing support are easily accessible and available. Stakeholders should be able to contact the agencies (and/or individuals) that are key to implementing their project.[39]

Cost-effective and Efficient
Regulations, procedures, and potentially resulting delays create transaction costs for the project developer, which are particularly critical for smaller developers. After all, mini-grids run on the “razor’s edge” of commercial viability (Reiche, Tenenbaum & Torres de Mästle, 2006). It is thus of paramount importance to design a mini-grid policy and regulatory framework that is cost-effective (for all players) and efficient, i.e. that minimises bureaucratic delays for granting licences and permits, responding to inquiries, or providing other support.

Light-handed and Simplified
In general, less regulation is often better than more regulation, especially with small mini-grids (e.g. with a capacity below 0.5 MW). Very small mini-grids can be exempted from all regulation, as is the case in Tanzania and Cameroon for mini-grids below 100kW.

Transparent and Predictable
Regulatory decisions must be transparent, fair, independent of power suppliers, and prevent government interference in day-to-day operations. Furthermore, regulatory decisions on similar issues should be consistent with previous decisions to give greater credibility to the regulatory process. (Eberhard and Kapika, 2013)

Technology Neutral
Incentives for mini-grids should allow a level playing field between rural electrification technologies, and between alternative energy sources. All potential cost effective mini-grid technologies should be considered in a mini-grid policy and regulatory framework.

Mini-grids can be an integral part of both approaches. In the centralised approach, either a public utility is given the mandate to install and operate mini-grids, or the state can own and/or operate generation and/or distribution mini-grid assets. In the decentralised approach, private companies or communities are allowed to own and operate generation, distribution or both types of assets.[40] **Following both models in parallel is possible, but requires more effort and capacity**, including very specific policy instruments and regulations to clearly define the roles and responsibilities of all actors. Governments have to decide which approach to follow, or whether to pursue both tracks at the same time.

Mini-grid deployment can be accelerated if regulatory processes are streamlined and actors are given the necessary tools and guidance for developing and implementing mini-grids. Levels of government involvement and types of operators models are interdependent and determine the pace and eventual success of implementation of mini-grids. *(see a qualitative indication in the figure 10)*. Support instruments like subsidies, tax breaks, etc. can accelerate roll-out.

39) For example, in Rwanda, clear rules have been created for off-grid electrification and for IPPs, and a one-stop-energy shop exists where all regulatory requirements can be arranged. In Tanzania all relevant regulatory documents are publicly available on the EWURA website: EWURA (2013,2014) http://www.ewura.go.tz/newsite/index.php/sppmenu

40) Côte d'Ivoire, Ghana, Kenya and South Africa have had success with a centralised approach and grid extension. Burkina Faso used the centralised approach and strongly promoted mini-grids with it. On the contrary, Guinea, Mali, Mozambique and Senegal have achieved good progress with a decentralised rural electrification approach (Eberhard et al., 2011 and Mostert, 2008).

Figure 9 Strategic decision paths for mini-grids

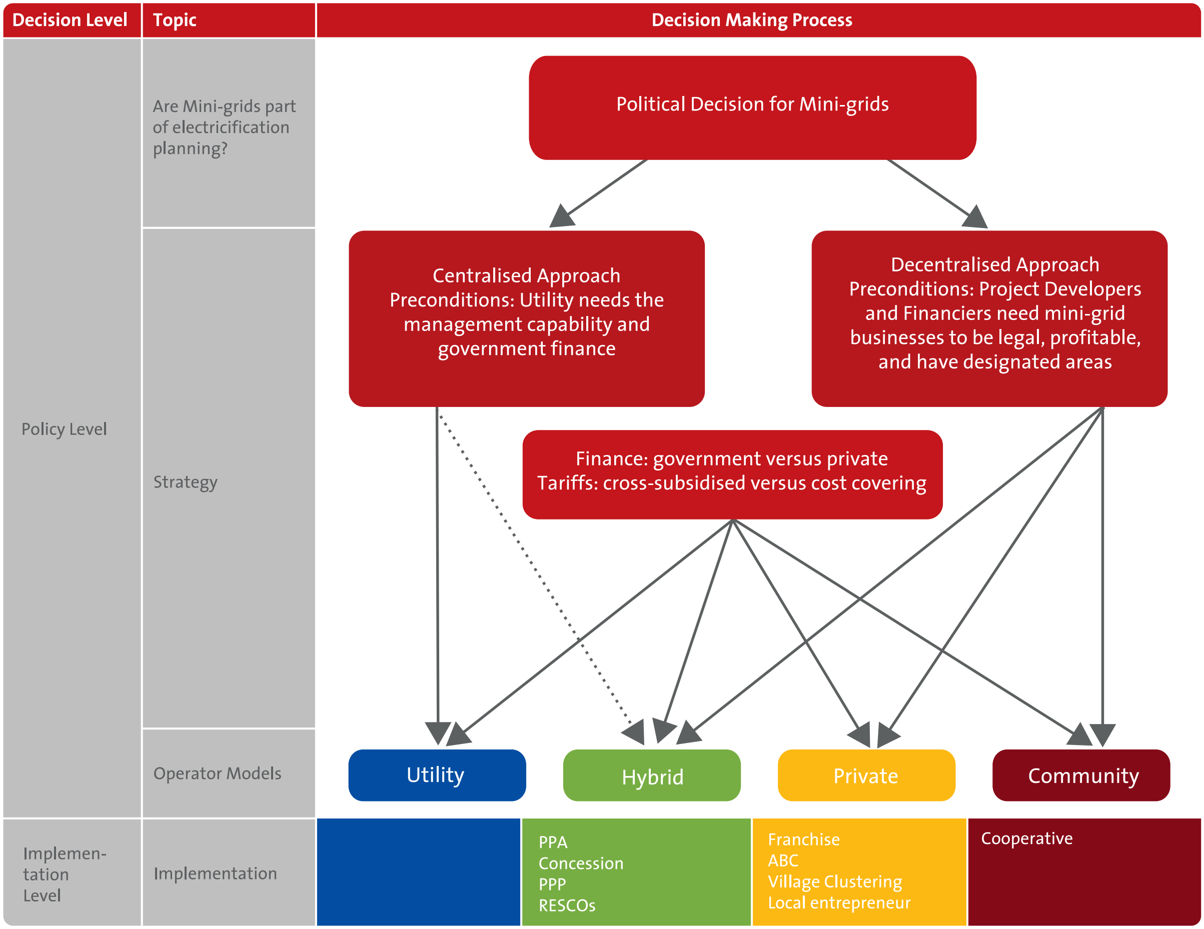
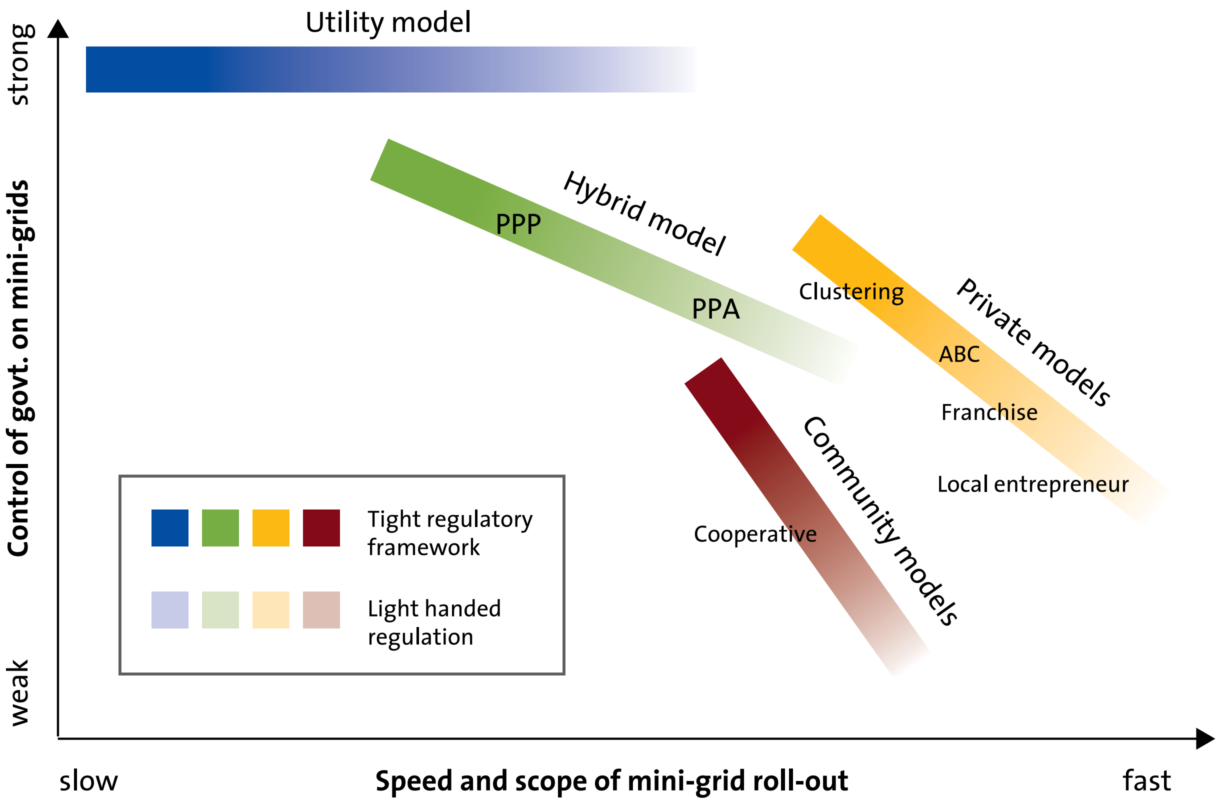


Figure 10 Illustrative link between operator models and desired government control and speed of mini-grid roll-out



6.1.2 Upfront Financing - Public versus Private Financing

Upfront financing of mini-grids can be provided by the public sector, the private sector, communities, or foreign donors (both public and private). **Public financing is the primary approach for the centralised track** using utilities and their national grids to improve electricity access. The **decentralised track usually involves other financial actors.** This is mostly done out of necessity; public budgets are limited and the investment cost of providing electricity access is high. **It is widely acknowledged that for providing universal electricity access, private investment is needed in most developing countries.** Private investment is more easily attracted by private operators. Community contributions (financial or in-kind) are also important as they improve a project's financial sustainability.

6.1.3 Uniform Tariffs versus Cost-Reflective Tariffs

Generally, policy-makers must define mini-grid tariff structures that strike a **balance between commercial viability and consumers' ability and willingness to pay.** However, since electricity generation costs for mini-grids are higher than grid tariffs *(see chapter 4)*, a political equality issue arises regarding whether and how to subsidise electricity. Below are a few options how these issues can be tackled:

1) a **uniform national electricity tariff**, with equal tariffs for mini-grid and national grid consumers throughout the country, which usually implies cross-subsidisation for rural electricity customers,

2) **cost-reflective tariffs** for mini-grids on a national level, which need a national consensus to accept different electricity tariffs for mini-grid customers,

3) an **incremental introduction of cost-reflective tariffs**, starting on a local level in order to determine whether it is politically sustainable (however, this is a high risk option for project developers).

According to Tenenbaum et al. (2014), "*Very few of the newer national electricity laws in Africa mandate a uniform national tariff. Instead, African electricity laws usually require that the regulator set cost-reflective tariffs. (...) But this does not happen in practice.*"

With **cost-reflective tariffs**, only the people consuming electricity provide the revenues for recovering mini-grid investment and O&M costs. The equity issue comes into play here: why should the rural poor pay a higher price for electricity (and the fundamental services it provides), when the urban middle and upper class enjoy electricity that is subsidised by the country as a whole? On the other hand, rural communities are generally willing to pay a fair price for consistent electric power - after all "consumers need electricity much more than they need low tariffs" (RECP/EUEI PDF, 2013e). Yet, purely cost-reflective tariffs are relatively high for mini-grids, even though they may be the most cost-effective solution for scaling up electricity access in many regions. The Tanzanian regulators recently issued the "second generation" mini-grid rules, which implicitly allows mini-grid operators to charge tariffs that are higher than the national utility's tariffs if this is required for commercial sustainability.

With a **uniform national tariff** the main question is: Who is subsidising mini-grid tariffs? Is it the whole pop-

ulation, through extra subsidies financed by government budgets, or existing customers through higher electricity tariffs (cross-subsidisation)? Indeed, electrification in most countries was and is financially supported by governments, and subsidising mini-grids can be the best option to provide quality electricity wherever mini-grids are more appropriate than the available alternatives Finding a combination of both – the golden mean – is probably the most pragmatic solution for scaling up electrification. For example, this approach could combine subsidies with ´cost-reflective tariffs´, allowing only a limited project IRR of 12 – 18% to be achieved through tariff collection and reducing the risk of the investor through publicly financed means. However, in order to make this or similar approaches work, it requires a national consensus on different national tariff levels, or the decision for an incremental introduction of cost-reflective tariffs, or an expanded definition of energy access and possibilities for costing of electricity services.

National Consensus on Cost-Reflective Tariffs

The fastest way to provide electricity at an acceptable cost to end-customers in many cases might be to allow for cost-reflective tariffs. However, policy-makers have to consider voter satisfaction with cost-reflective tariffs. How will mini-grid customers react to higher tariffs than the ones for the consumers of the national grid? The challenge for policy-makers is to find a national consensus on different tariff levels if they want rapid electrification without huge public investment.

This national consensus must be based on socio-economic and political realities and will have to be developed for each country individually. Even so, it is possible to learn from the experience of other countries. Senegal has reached consensus on cost-reflective tariffs. Tanzania is on its way. Namibia has a process of prioritising villages according to costs of electrification and expected development impact, which could, in theory, be extended to include cost-reflective tariffs.

6.2 Institutional Framework

Public actors (government ministries, rural electrification agencies, energy regulators, etc.) must reconcile institutional, political and financial realities with rural development aspirations and the aim of achieving the highest possible rate of electricity access. **As mini-grids can provide high quality electricity access in rural areas, a growing number of African governments aim to include mini-grids in their electrification strategies.** Governments are thus assigning roles and responsibilities to specific public bodies to support mini-grids, and are sometimes creating new public agencies to assume previously assigned responsibilities. Some of the operator models require more sophisticated regulation which poses higher demands for functionality on the institutional setup. Whichever model is chosen, effective and efficient institutions are essential for success.

In general, **mini-grid institutional stakeholders should have specific responsibilities that are clearly allocated to a single actor** to allow higher cost-effectiveness and

accessibility. When responsibility is split between different public actors, regular coordination and consultation meetings are advised in order to harmonise actions.

Typical roles and responsibilities of public actors regarding mini-grid policy and regulations (as seen in many countries) are summarised in the *Table below*.

Harmonising Regulatory Procedures

Contradictory regulatory procedures should be avoided. For example, there are countries where the regulatory authority simplifies licensing procedures to attract more project developers while at the same time the environmental authority treats each mini-grid project similar to a big power station. This requires the project developer into a time consuming environmental impact assessment process. For relatively small mini-grid projects, this is likely going to be prohibitive.

Table 8 Public institutional stakeholders and their roles in mini-grids

Stakeholder	Functions
Ministry of Energy/Infrastructure	▸ Design rural electrification targets, strategy/vision and mission ▸ Design and administer national energy policy and planning ▸ Define rural electrification strategy (incl. the selection of operator models) ▸ Administer public resource allocation ▸ Initiate mini-grid regulatory and institutional framework
Treasury/Finance Ministry	▸ Provide rural electrification budget ▸ Avail and coordinate grants and concessionary loans for rural electrification ▸ Provide input on national electricity tariffs and subsidies ▸ Determine stability of investment policy ▸ Design and implement fiscal incentives
Energy regulator	▸ Facilitate the implementation rural electrification targets, vision and mission ▸ Formulate and implement technical regulation (technical & service quality standards, main-grid interconnection requirements) ▸ Formulate and implement economic regulation (tariffs, PPA, etc.) ▸ Issue and monitor legal regulation (licensing, permit requirements) ▸ Mediate disputes ▸ Provide an advisory function to other entities

→ *Table continues on page 81*

Stakeholder	Functions
National environment agency	▸ Ensure mini-grid meets national environment standards ▸ Issue licences as required ▸ Monitor compliance with environmental regulations
Rural electrification agency	▸ Drive implementation of selected national operator models ▸ In some cases, perform specific regulatory tasks delegated to the REA ▸ Manage mini-grid project cycles, channel loans and grants for mini-grid projects (e.g. through a rural electrification fund) ▸ Monitor and evaluate mini-grid projects ▸ Development of electrification plans
Regional/local authority/administration	▸ Support the identification of target areas ▸ Authorise land use ▸ Award building permits ▸ Award resource utilisation permits, e.g. water rights ▸ Promote mini-grid programmes ▸ Facilitate contact with electricity users ▸ Train and perform capacity building

Source: RECP/EUEI PDF (2013 c)

6.3 Policy and Regulatory Instruments

In this section, priority policy and regulatory instruments for mini-grids and each operator model are identified and important supportive instruments are discussed. Many instruments are linked and their effectiveness and efficiency depend on the other instruments. How these instruments are linked with each other as well as how the processes to define/control/implement these instruments can work is illustrated in *chapter 7*.

- **Priority policy and regulatory instruments** are all the foundation elements that have to be in place to allow the development and operation of mini-grids by specific a specific operator model in the first place. These are critical conditions that have to be enshrined in law and implemented in practice.

- **Supportive policy and regulations** help scale roll-outs further and faster. Without these, key actors might be reluctant to participate and invest, or might wait for other players to pave the way before they start investing.

Table 9 identifies individual instruments that correspond to six levels of regulation, and shows the importance of each instrument for each operator model in the last column. The priority settings are indicated by colour:

- priority instruments are shown with a dark colour box,
- supportive instruments with a light colour box.

The operator models are indicated by the letters in the boxes:

- U for utility operator model,
- H for hybrid operator model,
- P for private operator model, and
- C for community operator model.

At the same time, the table provides the outline for this section. The five levels of regulation are treated in turn, and each of the instruments in the table is presented through a brief definition and an explanation of its relevance. The way these instruments can be designed and implemented is described in the references, examples, documents and tools (where available) illustrated in boxes at the end of each level.

6.3.1 Level A – Energy Policy

A1. National Electricity or Electrification Policy

U H P C

National energy policy defines objectives, identifies priorities, and outlines the broad guidelines for sector development. This might encompass the energy sector as a whole, or focus on specific sub-sectors, such as electricity and electrification.

A key element, and a pillar of public support of a national rural electrification policy in general and mini-grids in particular, is **the political aim for universal national electricity access.** Setting **targets**[41] and backing them up politically (by providing the necessary framework and resources) leads to focused action by the involved stakeholders.

Another essential aspect is **the explicit decision to integrate mini-grids into the rural electrification approach.** Subsequently, **the policy should identify appropriate operator models in the respective country context**, as each of the four basic operator models (utility, private, community and hybrid models) for mini-grids requires specific policy support. One possible path to decide which operator model to enable is described in *chapter 7.*

The energy or electrification policy thus lays the groundwork for the entire enabling environment, which is further operationalised at the subsequent levels.

41) Mini-grids themselves are not necessarily directly mentioned in energy access or renewable energy targets. Yet, whenever least-cost, environmentally sustainable, and quality or reliability factors are mentioned in the context of rural electrification, mini-grids (with either renewable or hybrid generation) should be included in any further analysis, planning and support. For example, the Regional Energy Access Strategy and Action Plan of the South African Development Community (SADC) specifies the following strategic goal: to "*harness regional energy resources to ensure, through national and regional action, that all people of the SADC Region have access to adequate, reliable, least-cost, environmentally sustainable energy services*'. (SADC/EUEI PDF, 2010) Some renewable energy policies, even regional ones, also mention specific targets for mini-grid development, e.g. the ECOWAS regional renewable energy policy, which states the aim to increase the share of rural population served by decentralised renewable electricity services (e.g. mini-grids and stand-alone systems) to 22% by 2020 and 25% by 2030. This would mean that approximately 128,000 mini-grids are installed by 2030 (Bugatti, 2014). The national aim for rural electrification is often embedded in international and regional aims. For example, the United Nations SE4ALL Initiative specifies an aim to provide universal access to modern energy services by 2030 (SE4ALL, 2013).

Table 9 Regulation, Financing, Technical Assistance instruments according to priority for each operator model

Level	Ref	Instrument	Operator model
Energy and Electricity Policy	A1.	National Electricity or Electrification Policy	**U** **H** **P** **C**
	A2.	Rural Electrification Strategy and Master Plan	**U** **H** **P** **C**
	A3.	Energy and Electricity Law (incl. Implementing Institutions)	**U** **H** **P** **C**
	A4.	Tariff Policy and Regulation (incl. Connection Fee)	**U** **H** **P** **C**
Economic Policy and Regulation	B1.	Fiscal Policy and Regulation (Taxation, Import Duty, etc.)	U **H** **P** **C**
Customer Protection and Environmental Policy and Regulation	C1.	Technical Regulation (incl. Grid Connection)	U **H** **P** **C**
	C2.	Quality of Service Regulation	U **H** **P** **C**
	C3.	Environmental Policy and Regulation	U H P C
Licences and Contract Regulation	D1.	Generation and Distribution Permits and Licences	U **H** **P** **C**
	D2.	Concession Contracts and Schemes	U H **P** **C**
	D3.	Power Purchase Agreements (PPA)	**H**
Financial Support Schemes	E1.	Grants and Subsidies (incl. CAPEX, OPEX and performance based)	U H P **C**
	E2.	Loan Support and Risk Mitigation Instruments	H P C
Technical Assistance	F1.	Technical Assistance (incl. Awareness Raising and Promotion, Vocational Training, Institutional Capacity Development, Network Development, Project Developer Guidelines, relevant Data (e.g. grid extension, socio-economic data, resource maps)	U H P **C**

Legend: **U** stands for utility, **H** for hybrid, **P** for private and **C** for community operator model.

U **H** **P** **C** symbols stand for high priority instruments,

U H P C symbols stand for supportive instruments.

A2. Rural Electrification Strategy and Master Plan

U H P C

If national electricity access targets are to be achieved, stakeholders need a plan to get there. For rural areas this plan should at least indicate grid and off-grid areas, on the basis of state of the art tools (including GIS-based spatial planning software).

The planned development of the main grid is required information for any mini-grid project developer in order to select suitable project locations. Thus, it is beneficial for mini-grid developers if the Ministry of Energy, assisted by its national electrification agency, develops a **rural electrification master plan** *(see chapter 2.1)*. This electrification strategy and master plan should ideally be based on data about the existing or potential income generation capacity of the beneficiaries of electrification, the distance from the main grid, population density, equity between geographic areas (RECP/EUEI PDF, 2013a) and the local energy resource potential[42] and cost. It is advisable to base the strategy and plan on a planning horizon that is adequate to achieve universal electricity access, as defined in the national electricity access targets.

The master plan needs to be **reviewed periodically** to adapt to changing circumstances. For example, the rapid decline in photovoltaic module costs would change master plan outcomes in favour of the deployment of mini-grids in some regions. If the necessary technical and administrative capacities and skills to design and adapt the strategy and master plan are not available in the responsible agency, these must be fostered, e.g. through specifying capacity building in the ToRs for the first master plan.

Countries like Namibia, Tanzania and Zambia have rural electrification master plans, however these are not focused on universal access targets (RECP/EUEI PDF, 2013c). The frameworks in Kenya and Senegal specify where and how mini-grids should be pursued under the national rural electrification programme. They identify the geographic regions to be targeted and provide for tariffs that are acceptable to the customer and to the operator.[43]

A3. Energy and Electricity Laws (incl. implementing institutions)

U H P C

Energy, electricity or renewable energy laws or acts establish the legal and institutional framework for public planning and the implementation and enforcement of regulations for rural electrification in general and mini-grids in particular, usually through an **act of parliament.**

They lay down the responsibilities of important actors and provide the basis for any specific regulations or promotion instruments. All the instruments presented in the next sections need this legal foundation, as well as public institutions to implement the energy and electricity laws, and design and enforce energy regulation.

42) The energy resource potential data for the rural electrification planning does not need to be based on a detailed resource assessment but must provide a general and yet accurate regional overview of energy resource potentials.

43) The majority of the 24 countries analysed in the African Infrastructure Country Diagnostic have explicit planning criteria, e.g. population density, least cost, or financial/economic returns (Eberhard et al., The World Bank, 2011).

A4. Tariff Policy and Regulation (incl. Connection Fee)

U H P C

A tariff is any charge, fee, price or rate that has to be paid for electricity purchases (Tenenbaum et al., 2014). The **regulation of tariffs is central to the viability of any mini-grid business**, and most tariff aspects have been discussed in previous chapters. The top-down national decision on cost-reflective or uniform tariffs was highlighted in *chapter 6.2*. The bottom-up necessity of revenues - tariffs, connection fees and subsidies – to cover all mini-grid costs was discussed in *chapter 4*. It was shown that the design of tariffs highly depends on regulation and on available financial support – subsidies (discussed in the next sub-chapter), debt service *(discussed in chapter 5.4)*, as well as on expectations for return on equity (for utilities and private operators). Factors such as population density and electricity demand also influence the economics of mini-grids and need to be considered while setting the tariffs. Generally, tariffs and connection fees, together with subsidies, must strike a balance between commercial viability of the mini-grid projects and consumers' ability and willingness to pay.

Utilities usually charge uniform national tariffs for their operational mini-grids. Private operators have to charge cost-reflective tariffs that also generate a profit. Community owned mini-grids (and particularly those whose capital costs have been fully subsidised) have to charge tariffs to cover the O&M costs at a minimum and to build up reserves for reinvestment to ensure the long-term operation of the mini-grid. Connection fees should be as low as possible for potential mini-grid customers, as the lower the connection fees, the higher the connection rates. If connection fees cannot be reduced, customer-financing options should be actively sought (e.g. like Stima Loan in Kenya). In Senegal, operators are obliged by law to pre-finance and install household installations, like basic wiring, sockets, switches and light points. The end-user pays them back within the first year of operation, which results in an immediate revenue stream for the operator and reduces waiting time before everybody can start using electricity in their homes.

Monitoring and verification of tariffs is necessary when they are regulated or when mini-grid projects are somehow subsidised (Deshmukh, Carvallo & Gambhir, 2013).

Mini-grid Tariff Level

Mini-grid tariffs and connection fees must be accepted by all parties before being put into place. If connection fees and tariffs are solely defined from the top down by the national regulatory authority, without calculating tariffs for each individual case, this might not allow cost-reflective operation of the mini-grid or might not be accepted by the villagers. Regulation can enable different methods of arriving at acceptable tariffs to all parties:

- **Uniform national tariffs:** Sometimes, national tariffs are offered to rural consumers and the utility or operator is provided with cross-subsidies to cover the mini-grid's higher costs. However, some countries also have specific policies for deviation from the uniform tariff, for example South Africa.

- **Cost-reflective tariffs** can be derived through:

  - **Negotiated tariffs and connection fees:** When governments (or government-selected concessions) manage mini-grids, prices are determined through negotiations between providers, electricity regulatory commissions, rural energy agencies and consumers.

  - **Approved tariffs and connection fees:** In cases where the loads are small and there is little chance of connection to the national grid, prices may be negotiated directly between consumers and providers. They are simply approved by regulators (this is often done with micro-grids) or they do not even require approval if the capacity is very small (e.g. below 100 kW like in Tanzania or Cameroon).

  - **Calculated tariffs and connection fees (a subform of approved tariffs):** In other cases, tariffs are calculated using standard formulae that input basic parameters, like fuel costs, operation costs, investment costs, depreciation, etc., and use these inputs to arrive at a fair power price. Calculation Tools for tariffs from RECP are included in the Literature and Toolbox at the end of this chapter.

FURTHER READING

Below are a few selected primary and secondary sources for further information on the topics: National Electrification Aims, Rural Electrification Policy, Energy and Electricity Law, and Tariff Policy and Regulation.

A.1 National Electricity or Electrification Policy

Bhatia, World Bank (2013). *Defining and Measuring Access to Energy; SREP Pilot Country Meeting*.
SADC, EUEI PDF, EUEI (2010). *ADC Regional Energy Access Strategy and Action Plan*.

Mini-grid Operator model

MGPT itself
Rolland, Glania, ARE/USAID (2011). *Hybrid Mini-Grids for Rural Electrification: Lessons Learned*.
IFC (2012). From Gap to Opportunity: *Business Models for Scaling Up Energy Access*.

A.2 Rural Electrification Strategy and Master Plan

RECP/EUEI PDF, (2013a), "*Guidelines on Market Needs and Demand*"
Watchueng, Jacob & Frandji, Club-ER (2010). Planning tools and methodologies for rural electrification. Master Plan: IED, IREP Tanzania (2005-2014). *http://www.irep.rea.go.tz/Resources/eLibrary.aspx*

A.3 Energy and Electricity Law

Eberhard and Kapika, (2013). *Power-Sector Reform and Regulation in Africa; Lessons from Kenya, Tanzania, Uganda, Zambia, Namibia and Ghana*.
Reiche, Tenenbaum & Torres de Mästle, Energy and Mining Sector Board, The World Bank Group (2006). *Electrification and Regulation: Principles and a Model Law*.
UNEP (2007). *UNEP Handbook for Drafting Laws on Energy Efficiency and Renewable Energy Resources*.
Climate Parliament, "*Parliamentarians Toolkit for Building Political Support for Energy Access Through Mini Grids*"
IMF (2013). *Energy Subsidy Reform in Sub-Saharan Africa; Experiences and Lessons*
Tanzania (2008). *The Electricity Act*. *www.tic.co.tz/media/Electricity%20Act%202008.pdf*

Tanzania (2014). *The Electricity Act (Cap 131); The Electricity (Development Of Small Power Projects) Rules, 2014; (Made under section 45); Arrangement of Rules*. *www.ewura.go.tz/newsite/attachments/article/165/The%20Electricity-Development%20of%20Small%20Power%20Projects%20-%20Rules%20-%202013.pdf*

A.4 Tariff Policy and Regulation (incl. Connection Fee)

Tenenbaum et al., *The World Bank (2014). From the Bottom Up; How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa*.
World Bank (2008). Issues Note of the REToolkit; REToolkit: A Resource for Renewable Energy Development. RECP/EUEI PDF (2013b): "*Ownership, Financing, Economic Regulation*" Chapter 7 Standardized tariff methodology
Tanzania (2014). *The Electricity Act (Cap 131); The Electricity (Development Of Small Power Projects) Rules, 2014; (Made under section 45); Arrangement of Rules*.

TOOLS

RECP RERA – FiT, Power Purchase and Retail Tariff Tools: *http://euei-pdf.org/regional-studies/supportive-framework-conditions-for-green-mini-grids*

6.3.2 Level B – Economic Policy and Regulation

B1. Fiscal Policy and Regulation (Taxation, Import Duty, etc.)

U H P C

Fiscal policy (and regulations) can support mini-grid implementation through low taxes and import duties, accelerated depreciation, or subsidies. Taxes on income, company profits, sales, property, value added or other taxes should be at least on the level of conventional grid supply and can be reduced further to stimulate the mini-grid market (e.g. through investment and production tax credits (Sawin, 2004). The same holds true for **import duties, taxes and fees**, which can be reduced or exonerated for mini-grid equipment or components in order to support the mini-grid market. In general, the lower these taxes and import costs, the lower mini-grid electricity tariffs can be. Accelerated depreciation allows a lower tax burden in the early years of a project. This depreciation should also be allowed for assets that are provided through grants, as these have to be replaced at the end of their lifetime (Tenenbaum et al., 2014). These fiscal rules should be clear and reliable to improve investor trust.

FURTHER READING

Below are a few selected primary and secondary sources for further information on the topic: Fiscal Policy and Regulation.

B.1 Fiscal Policy and Regulation

Sawin, Worldwatch Institute, Internationale Konferenz für Erneuerbare Energien (2004). *National Policy Instruments; Policy Lessons for the Advancement & Diffusion of Renewable Energy Technologies Around the World.*

Import tariff database: SE4ALL (2014). *http://www.energyaccess.org/resources/tariffs-database*

IED, DFID (2013). Low Carbon Mini-Grids; "*Identifying the gaps and building the evidence base on low carbon mini-grids*".

6.3.3 Level C – Customer Protection and Environmental Policy and Regulation

One purpose of regulation is to guarantee that products or services supplied to the public are safe and do not pose any danger in the short or long term. Technical, quality of service and environmental regulations serve this purpose. These regulations protect the customers, so they should be applied to all mini-grids regardless of the operator model. However, such regulation should be as lean as reasonable in order to minimise transaction costs for stakeholders (IFC, 2012). Recommended procedures for small power producers (and thus also mini-grids) can be found in Tenenbaum et al. (2014).

C1. Technical Regulation (products and services)

U H P C

Technical regulation is required for all operator models to ensure safe and reliable operations for the protection of customers without being obstructive for mini-grid developers and operators. Technical regulation for mini-grids should be designed, published and controlled by one responsible regulator and should have the following specific aspects:

- Minimum technical standards for mini-grid generation and distribution networks (including minimum safety requirements, allowable voltage and frequency variation as well as harmonic distortion),
- Operating and maintenance requirements,
- Safe and robust interconnections between the utility and the mini-grid in line with grid standards.

These technical standards should be specifically designed for the rural context, but should be in line with the national utility's grid standards (it may also be necessary to adapt the utility's standards to the rural context and mini-grids).

The Distribution Grid Quality Issue

Sub-standard grids result in lower capital costs and lower tariffs and thus more customer connections for the same budget. Yet sub-standard grids cannot be connected to the national grid once it arrives. They can be dangerous for the consumer, and are usually not capable of supporting productive uses of electricity.

Regular control of mini-grids and their adherence to technical regulations as well as verifying compliance with construction codes and standards before becoming operational, and continuing with on-going technical monitoring are required. The disbursal of performance-based subsidies can be linked to the adherence to these standards.

C2. Quality of Service Regulation

U H P C

Quality of service has three main components: "*quality of the product, quality of supply, and quality of commercial service*" (Tenenbaum et al., 2014). **Quality of product** refers to the technical parameters stated in the technical regulations, such as the frequency and voltage of electricity, and also to the quality levels of energy generated and distributed. **Quality of supply** also refers to the availability (hours per day) and continuity (blackouts,

etc.) of supply. **Quality of commercial service** includes measures such as the number of days to connect a household, resolved complaints and reconnected customers. The quality of service regulations can be established and implemented by the regulator or REA (Tenenbaum et al., 2014). In all cases, the regulatory agency involved must establish quality of service standards that are realistic and affordable to all parties and that can be monitored and enforced (Reiche, Tenenbaum & Torres de Mästle, 2006). The regulator should establish a mechanism and a contact point for consumer complaints (Deshmukh Carvallo & Gambhir, 2013).

C3. Environmental Policy and Regulation

U H P C

Mini-grids, especially renewable energy-based mini-grids, are usually environmental friendly compared to traditional or conventional energy sources, and local environmental sustainability can be ensured with appropriate standards and norms. "*Examples include the requirement for appropriate plantations for biomass fuel supply to prevent deforestation, enforcement of recycling of solar PV panels and batteries at their end-of-life, and building standards for small hydro plants to ensure minimal impact on river flora and fauna.*" (Deshmukh, Carvallo & Gambhir , 2013) The procedures and requirements for conducting **environmental impact assessments** should be straightforward, simple and clear. Obtaining an **environmental approval** should be prompt when all the requirements are fulfilled and procedures are observed.

FURTHER READING

Below are a few selected primary and secondary sources for further information on the topic: Fiscal Policy and Regulation.

C.1 Technical Regulation (incl. Grid Connection)

Technical Regulations
RECP/EUEI PDF (2013d), "*Guidelines on Technology Choice and Technical Regulation*"

ARE (2011). *Rural Electrification with Renewable Energy - Technologies, quality standards and business models*.

Standards
Rolland, Glania, ARE/USAID (2011). *Hybrid Mini-Grids for Rural Electrification: Lessons Learned.* (Annex 2)

IEC 62257 series (2008). *Recommendations for small renewable energy and hybrid systems for rural electrification. http://webstore.iec.ch/webstore/webstore.nsf/standards/IEC/TS%20 62257-9-1!opendocument*

Grid interconnection
Tenenbaum et al. (2014). *From the Bottom Up; How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa.*

World Bank (2009). *Guidelines for Grid Interconnection of Small Power Projects in Tanzania; Part C: Appendix; Studies to be Conducted, Islanding and Protection.* *http://ppp.worldbank.org/public-private-partnership/sites/ppp.worldbank.org/files/documents/Tanzania1Guide1r0090Draft-ofor0EWURA.pdf*

C.2 Quality of Service Standards

Tenenbaum et al, (2014). *From the Bottom Up; How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa. Appendix C*

C.3 Environmental Regulation

DBSA and SAIEA (2007). *Handbook on Environmental Assessment Legislation in the SADC Region.* *http://www.commissionoceanindien.org/fileadmin/resources/RECOMAP%20Manuals/Handbook%20on%20Environmental%20Assessment%20Legislation_SADC%20Region_Nov%202007.pdf*

6.3.4 Level D – Licences and Contract Regulation

Depending on strategic policy decisions and the operator model, specific licensing, permitting, concession and contractual (e.g. PPA) requirements have to be clarified. These requirements should be adapted to local circumstances and the size of the regulated mini-grid. Very small micro-grids below a capacity of 100 kW should face less stringent licensing and contractual requirements.

D1. Generation and Distribution Permits and Licences

U H P C

Licences or permits give the non-exclusive right to generate, distribute and sell electricity. In some countries all necessary activities for operating a mini-grid are included in one licence. In others, a licence for generation and a separate concession for distribution and electricity sales are required. The owner/operator of the mini-grid (or the individual owners and operators of distribution or generation assets in the case of hybrid operator models) must have the legal right to exist and to generate, transmit, distribute and sell electricity services.[44] These rights are best granted by the responsible regulator, REA or ministry (Tenenbaum et al., 2014). In some countries the responsible regulator could also use simplified registration for systems under a specified capacity size. Generation permits and licences may be granted on an exclusive or non-exclusive basis. The licensing regime should always specify the role and duties of the providers, set information filing requirements and ensure consumer protection mechanisms (Bhattacharyya, 2013).

44) Eventual conflicts with the license granted to the national utility have to be resolved.

Both permits and licences can include detailed preconditions like land leases/permits or environmental impact assessments and specify operating conditions, e.g. service quality and tariff specifications. The licensing regime should also take into account the rights of generation and distribution asset owners in case the main grid connects to the mini-grid (Tenenbaum et al., 2014). The process to acquire licences or permits should be clear and cost-effective in order to reduce transaction costs for mini-grid developers (Deshmukh, Carvallo & Gambhir, 2013).

Permanent exemption from obtaining a licence or permit for small mini-grids, as in Tanzania (up to 100 kW), and Mali (up to 20 kW) (Tenenbaum et al., 2014 and Bhattacharyya, 2013), reduces transaction costs and thus increases financial viability of projects. **Provisional licences,** providing exclusivity for a few years to conduct preparatory activities such as assessment studies, financial structuring, land acquisition, construction, etc., are beneficial to the development of mini-grids, and also make the process of obtaining general business documents (incorporation, tax registration, etc.) and building permits easier (Tenenbaum et al., 2014). **Case by case exemptions from licensing for pilot projects are counterproductive** as they create confusion among developers and could encourage corruption. This could also prevent mini-grid owners from growing, formalising their business, raising finance or selling their business (IFC, 2012).

D2. Concession Contracts and Schemes

U H P C

A **concession is a contract between a public and private entity granting the exclusive right to invest, operate and maintain the distribution assets and sell electricity** to end-users for a given number of years in specified geographic service areas. In this area the holder of the concession also has an investment, operation and maintenance responsibility for a specified time. Thus, a concession also binds the private operator to deliver a specified quality of service and a certain number of connections or electrified population. Holding the concession for the specified area often entails favourable terms (e.g. a guarantee that no other parties are allowed to develop and operate mini-grids in the same area, preferential tariff arrangements, and possibly financial incentives).

Concession schemes, which award concessions for larger areas through competitive bidding, allow the holder to bundle/cluster mini-grid projects and reach scale fast. The **aggregation of mini-grid projects** increases efficiency in planning, financing, programme administration, equipment supply, operations and maintenance (SE4ALL, OFID, 2014) and thus reduces individual project costs and improves overall profitability. In general, governments should ensure that the size of the service areas and the terms of the concessions are suitable for local conditions, and should not grant indefinite exclusive rights (IFC, 2012). The concession is usually awarded through a competitive bidding scheme which should deliver the lowest overall cost for the most connections. The bidding can, for example, be based on a fixed subsidy level from the government with bidders competing on the number of connections and the level of service they

will provide (RECP/EUEI PDF, 2013b). As the goal is to provide access to electricity, the competitive bidding scheme should be technology neutral to increase the flexibility of project developers (SE4ALL, OFID, 2014).

The Effect of Concessions on Mini-grid Operation

A mini-grid operator under a concession has a monopoly position for electricity supply in his concession area for the duration of the concession period. This monopoly position weakens the negotiating power of the village and the end user. In parallel, the smaller the mini-grid, the more management is shifted from central management to local management. Additionally, rural electricity customers often do not have the opportunity to complain to the regulatory authority due to geographical distances or a lack of education, which further weakens their position in comparison to the mini-grid operator. Decisions taken locally by the monopolist, together with the lack of political power of the electricity customers, can result in conflicts between the mini-grid operator and its customers, which may escalate and result in the termination of electricity supply.

This is why a concession framework should include provisions for strengthening the electricity customers' position rather than implementing monopolistic schemes. Eye-level negotiations between the mini-grid operator and the electricity customer can usually solve conflicts more easily than monopolistic structures.

D3. Power Purchase Agreement

H

A Power Purchase Agreement (PPA) is a multi-year contract detailing the rights and obligations of two parties – a generator and a buyer of power (Tenenbaum et al., 2014). Power Purchase Agreements are needed when independently produced power is sold in bulk to a distribution grid operator or the national grid utility (sometimes using a regulated Feed-in-Tariff for sales to the grid operator – see Tenenbaum et al. (2014)). In contrast, when a large utility sells power to an IPP or mini-grid, this is usually done under a tariff (e.g. backup or supplemental tariffs) rather than a PPA.

In general, PPAs regulate the long-term relationship between the parties to a contract. They should be fair, binding, ban unilateral changes, and protect parties to the contract equally. Standardised PPAs are recommended, because PPAs often form the basis for grants and loans, and because they improve investor confidence, reduce administrative cost, increase efficiency, and simplify procedures (Rolland and Glania, 2011). Furthermore, the duration of the PPA should be sufficient to repay the project debt. If the national utility buys power, the PPA should last as long as the period of the Feed-in-Tariff, include an obligation of the utility to purchase all power output, and should cover the issues of deemed energy clauses and backup power (Tenenbaum et al., 2014).

FURTHER READING

Below are a few selected primary and secondary sources for further information on the topics: Generation and Distribution Permits/Licences, Concession Contracts and Schemes, and Power Purchase Agreements

D.1 Generation and Distribution Permits/Licences (IPP)

Tenenbaum et al., The World Bank (2014). *From the Bottom Up; How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa.*

RECP/EUEI PDF (2013b). *Ownership, Financing, Economic Regulation*. Chapter 2: *Mini-grid licensing procedures & standardized templates. euei-pdf.org/sites/default/files/files/field_pblctn_file/SADC%20RERA_ Guidelines.zip*

Tanzania (2014). *The Electricity Act (Cap 131); The Electricity (Development Of Small Power Projects) Rules, 2014; (Made under section 45); Arrangement of Rules. www.ewura.go.tz/newsite/attachments/article/165/The%20Electricity-Development%20of%20Small%20Power%20Projects%20-%20Rules%20-%202013.pdf*

TOOLS

Licence: RECP - Generation Licence Template; source: *http://euei-pdf.org/regional-studies/supportive-framework-conditions-for-green-mini-grids* -> Legal Template

Licence: RECP - Distribution Licence Template- *http://euei-pdf.org/regional-studies/supportive-framework-conditions-for-green-mini-grids* -> Legal Template

D.2 Concession Contracts and Schemes

Standardised concession agreement – RECP/EUEI PDF, (2013b): "*Ownership, Financing, Economic Regulation*" Chapter 5

Competitive bidding process – RECP/EUEI PDF, (2013b): "*Ownership, Financing, Economic Regulation*" Chapter 4

Mali Concession Contract – AMADER and Yeelen Kura (2001): *http://ppp.worldbank.org/public-private-partnership/sites/ppp.worldbank.org/files/documents/Mali11CONCESSION0CONTRACT0YK.pdf*

Analysis of Mali Concession Contract: RECP/EUEI PDF, (2013b): "*Ownership, Financing, Economic Regulation*" Chapter 5 Standardised concession agreement

D.3 Power Purchase Agreements (PPA)

RECP/EUEI PDF (2013b): "*Ownership, Financing, Economic Regulation*" Chapter 8 Standardised power purchase agreement

Tanzania/Kenya und Zimbabwe PPA Template (RECP/EUEI PDF, 2013f). *Zimbabwe Case Study - Gap analysis and National Action Plan.*

Tanzania Template (2009): *Standardized Power Purchase Agreement for Purchase of Capacity and Associated Electric Energy to the Isolated Mini-Grid http://www.ewura.go.tz/newsite/attachments/article/165/Tanzania%20SPPA%20Isolated%20Grid%20Connection%20-%202009.pdf*

6.3.5 Level E – Financial Support Schemes

Financial and economic aspects play an important role in promoting the development and safe operation of mini-grids. **Policy and regulation can help to create and ensure long-term stability of cash flows for operator models.** The main influencing factors include consumer payments (i.e. tariffs and connection fees), government support (grants and subsidies), finance streams from investors (equity and loans) and other fiscal incentives (tax/duty breaks, performance bonuses, etc.). The role of policy-makers and regulators is not only to establish these instruments but also to approve mini-grids which are eligible for funding or support. This is mostly done by a Rural Electrification Fund which directly provides grants and subsidies.

E1. Grants and Subsidies

U H P C

Subsidies and grants are financial support instruments that incentivise actors to provide electricity in regions and to population groups that lack the financial means to afford the full costs of electricity by themselves. In general for mini-grids, the **combination of subsidies, tariffs and connection fees has to cover all costs** incurred during planning, implementation and operation of the mini-grid in order to enable long term operation. Subsidies may also result in lower tariffs for customers.

Designing a grant and subsidy regime is challenging but essential. Grants and subsidies should be affordable for the country to allow scaling up beyond a few pilot projects and upgrading of existing mini-grids. In most countries, this means that **subsidies should be as low as possible, and as high as necessary.** In general, subsidies have to be high enough to allow affordability for customers to increase electricity access, and thus increase electricity demand and improve the economics of the electricity system, which in turn can attract more investment. Further, a dedicated agency, most often a Rural Electrification fund, has to manage these grants, approve eligible mini-grids, and monitor the proper use of these funds.

For mini-grids, these **grants or subsidies can be provided during the project planning/preinvestment phase** (for feasibility studies, business plan development, technical planning, capacity building and transaction costs), **during implementation/construction** (e.g. as capital subsidies, connection subsidies), **or during operation** (operational subsidies, tariff top-up). Subsidies can also be made available to the mini-grid operator upon reaching certain milestones (results-based subsidies). It is further recommended to include provisions for phasing out the grant and subsidy schemes (SE4ALL, OFID, 2014). Generally, it is advisable to subsidise connection fees for consumers or to use results-based subsidies rather than operational subsidies or investment subsidies. This is done by TEDAP in Tanzania, which offers results-based connection subsidies of 380 EUR for each new connection in a private mini-grid. Precedents for successful subsidy programmes include Nepal, Sri Lanka, India, and Laos (ARE, 2011).

E2. Loan Support and Risk Mitigation Instruments

H P C

As highlighted in *chapter 4.4*, access to debt is one of the key challenges for mini-grid developers. There are various **mechanisms to facilitate lending**, each of which **may be supported by policy and regulation**. These include publicly backed debt facilities to eliminate or reduce the need for commercial lenders with market risk-return requirements, loan guarantees to offset default risk assumed by lenders such as commercial banks, political risk insurance to underwrite country risks, currency exchange rate risk mitigation instruments, and broader insurance to cover commercial and other risks. A publicly backed debt or credit enhancement facility may provide or facilitate long-tenor, low-interest loans that commercial lenders would not offer on their own, and may be administered by the national REA, REF, or another public entity. One example is the upcoming European Investment Bank's Renewable Energy Performance Platform (REPP), which will provide projects with a mix of credit enhancement, results-oriented support, technical assistance, and debt financing needed to become bankable for commercial investors and lenders. Other examples include the line of credit established by the World Bank in Tanzania under the TEDAP programme or the micro-hydro debt fund in Nepal which was established by GIZ and is implemented by AEPC and two commercial banks. To date, these lines of credit have succeeded in lengthening the duration of loans offered to small power producers and mini-grid operators.

Loan guarantees provided by national banks or special facilities to commercial lenders may compensate the lender in the event of default.[45] **Political risk insurance** (PRI) available from the World Bank's MIGA or Africa Trade Insurance (ATI) may protect commercial lenders against the risk of a public utility or other governmental entity failing to perform on its contractual obligations[46] (Tenenbaum et al., 2014). Insurance for commercial and other non-political risks, while utilised in other sectors, have largely not been deployed for African mini-grid projects due to the small scale of mini-grid projects, high transaction costs, and the lack of a substantial balance sheet of most developers.

However, significant underlying commercial and political risks remain inherent in the mini-grid model and in African countries. **Governments committed to achieving private sector investment in mini-grids should actively engage in transparent and constructive dialogue with stakeholders** to identify innovative ways to address these risks and establish precedents. Such precedents will lead to increasingly replicable and scalable financing transactions.

45) Such a loan guarantee may include 50% coverage of the loan on a shared-loss (rather than first-loss) basis.

46) PRI may cover the failure to meet payment obligations, changes in law, hindrance of an arbitration process, expropriation, nationalisation, foreign currency availability and convertibility, and failure of the timely issue of licenses, approvals and consents.

FURTHER READING

Below are a few selected primary and secondary sources for further information on the topics: Grants and Subsidies, and Loan Support and Risk Mitigation Instruments

E.1 Grants and Subsidies

Tenenbaum et al., The World Bank (2014). *From the Bottom Up; How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa*.

ESMAP, The World Bank (2013). *Results-Based Financing in the Energy Sector; An Analytical Guide*.

Governmental of Nepal. Ministry of Science, Technology and Environment, Alternative Energy Promotion Centre (2013). *RE Subsidy Policy.* *http://www.aepc.gov.np/?option=resource&page=rescenter&mid=3&sub_id=18&ssid=2&cat=RE Subsidy Policy*

E.2 Loan Support and Risk Mitigation Instruments

UNEP (2004). Financial Risk Management Instruments for Renewable Energy Projects; Summary document.
Lindlein, Mostert, KfW (2005). *Financing Renewable Energy; Instruments, Strategies, Practice Approaches*.

IEA (2011), "*Risk Quantification and Risk management in Renewable Energy Projects*";

Nepal: energypedia (2014). Micro Hydropower Debt Fund Component - EnDev Nepal. *https://energypedia.info/wiki/Micro_Hydropower_Debt_Fund_Component_-_EnDev_Nepal*

Uganda: UECCC (2014). Products&Services. *http://www.ueccc.or.ug/ueccc_servs.htm*

GEF (2013). *Project Identification Form (PIF); Promotion of mini & micro-hydro power plants in Congo DR*.

6.3.6 Level F – Technical Needs and Technical Assistance

U H P C

The following sections highlight **instruments and activities that policy-makers can introduce to improve capacity** on three levels - individual, organisational and the enabling environment - in relation to mini-grids. Capacity can be defined as the ability of people, organisations and society to manage their affairs successfully. Capacity development can be defined as the process whereby people, organisations and society create, adapt, strengthen and maintain capacity over time. **Technical Assistance** can be provided **for the general public** (awareness raising), **for the workforce** (vocational training), **for the mini-grid project developers** (providing information, guidelines, and recommendations), **to financing institutions**, as well as **to the public institutions** that are in charge of the aforementioned instruments at the different levels.

Technical Assistance (TA) can be either provided by a national public entity, by a separate body, or by different national and international actors on specific activities. TA may address a range of areas:

- **Awareness raising and promotion** provide information to the general public. This may include cost information and comparison of different technologies and products, realistic grid extension plans, explanations of priority areas for grid connection, and the date on which villages can expect to be connected to the grid. This information will allow them to make an informed decision on the acceptance of mini-grids.

- Specific **human capacities** have to be developed to implement, manage, finance and regulate mini-grid projects. Governments can facilitate finance training and capacity development. The training curricula should depend on the vocation and be based on sound technical, managerial, financial and regulatory knowledge of mini-grids.

- **Accurate data** is essential because policy, regulation and project planning should be based on the reality on the ground and on current government plans. The most important data for project developers is detailed information on the national **grid extension plans**. Data on the local **socio-economic situation** of communities and households as well as **detailed renewable resource surveys** are also beneficial for policy-makers, regulators and project developers.

- **Public institutions need the capacity** to implement policy and regulations. This requires clear responsibilities, adequate financial resources, and qualified and motivated staff. TA measures to build institutional capacity should first assess the situation, subsequently identify areas of intervention, and finally implement well-designed capacity development activities (trainings, seminars, exchange programmes, etc.).

- Another effective TA instrument is the promotion of **thematic public networks**. As shown in *chapter 6.2*, there are various public institutions involved in regulating and supporting the mini-grid sector. Thus, institutionalised and regular meetings of decision makers in the public institutions that are responsible for the implementation of mini-grid policy and regulations, e.g. on a quarterly basis, is advised, and can be supported by TA measures.

- Furthermore, TA can provide **project developer guidelines**, ideally through a stakeholder consultation process. The content will typically be: (1) national definition and classification of mini-grids, (2) extracts of relevant electricity access and renewable energy policies, laws and regulations, (3) extracts of relevant non-electricity sector policies, laws and regulations, (4) descriptions of fiscal and other incentives for mini-grid development, (5) descriptions of the project development and approval process, (6) definitions of licensing procedures and requirements (7) descriptions of applicable tariff and technical regulations (RECP/EUEI PDF, 2013c).

- TA can also coordinate the **reporting structures between international donors, financiers and authorities.** The fragmented and complex reporting requirements impose considerable transaction costs on mini-grid operators. Harmonising reporting would ease the reporting burden considerably.

- TA may also support **community involvement**. The higher the participation of the community, the more likely it is that the mini-grids will be accepted. Communities can be involved in decisions, and procedures should be in place for communities to file grievances, and if needed effect changes.

FURTHER READING

Below are a few selected primary and secondary sources for further information on the topic: Technical Project Support

F.1 Technical Project Support

Guidelines for Project Developers
The World Bank (2009). *EWURA Guidelines for Developers of Small Power Projects in Tanzania.* *http://ppp.worldbank.org/public-private-partnership/library/ewura-guidelines-developers-small-power-projects-tanzania*

RECP/EUEI PDF, (2013c), "*Guidelines on Planning & Development Process and Role Clarity*"

Data management (grid extension plan, socio-economic data, resource maps)
Islamic Republic of Afghanistan, Ministry of Energy&Water, Renewable Energy Department (2014). Projects. *http://arbm-mew.gov.af/renewable-energy/*

Data management Uganda: GIS Working Group (2014). Energy Utilities of Uganda. *http://www.gis-uganda.de/Energy-GIS/*

Resource maps
Basics: OpenEI (2014). Renewable Energy Technical Potential Toolkit. *http://en.openei.org/wiki/Renewable_Energy_Technical_Potential_Toolkit#tab=Solar*

IRENA (2014). *Global Atlas for Renewable Energy enlarges. http://irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=374*

IRENA (2014). *Studies of Renewable Energy Potential. https://irena.org/potential_studies/index.aspx*

Human Capacity Development (incl. Training, Certification)
Link: IRENA, IRELP (2014). *http://irelp.irena.org/home/indexMetro.aspx?PriMenuID=1&mnu=Pri*

Enabling Institutions (Capacity and Network Development)
OECD (2006). *The Challenge of Capacity Development; Working Towards Good Practice. www.oecd.org/dataoecd/4/36/36326495.pdf*

GTZ (2009). Capacity WORKS; The Management Model for Sustainable Development
https://www.giz.de/de/downloads/gtz2009-en-capacity-works-manual.pdf

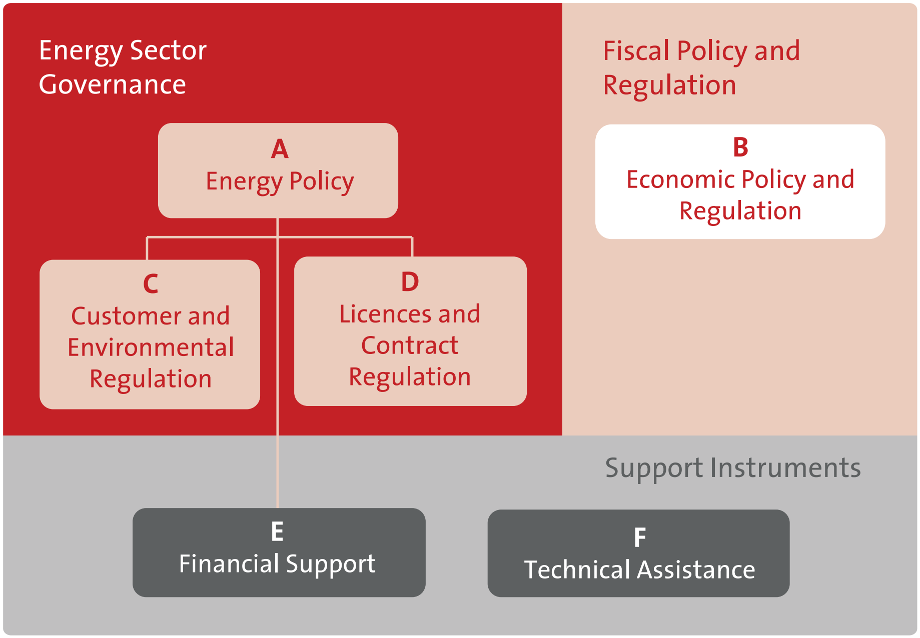
7. Process for Creating an Enabling Policy and Regulatory Framework

The policy and regulatory instruments presented in Chapter 6 are embedded in a broader process of designing and implementing a mini-grid policy and regulatory framework. This process can follow various paths, led by decisions and actions from policy-makers and regulators.

An overview of the main linkages between the different policy and regulatory levels is given in the graph below.

A schematic path for each instrument (from level A to level E) is displayed on the next pages on a step-by-step basis. This process serves only as a model, as it is not exhaustive, and has to be adapted to national economic, social, environmental, and political circumstances. The processes described are on a political decision making level, on a regulatory level, or on a working group level.

Figure 11 Overview of policy and regulatory levels and their linkages



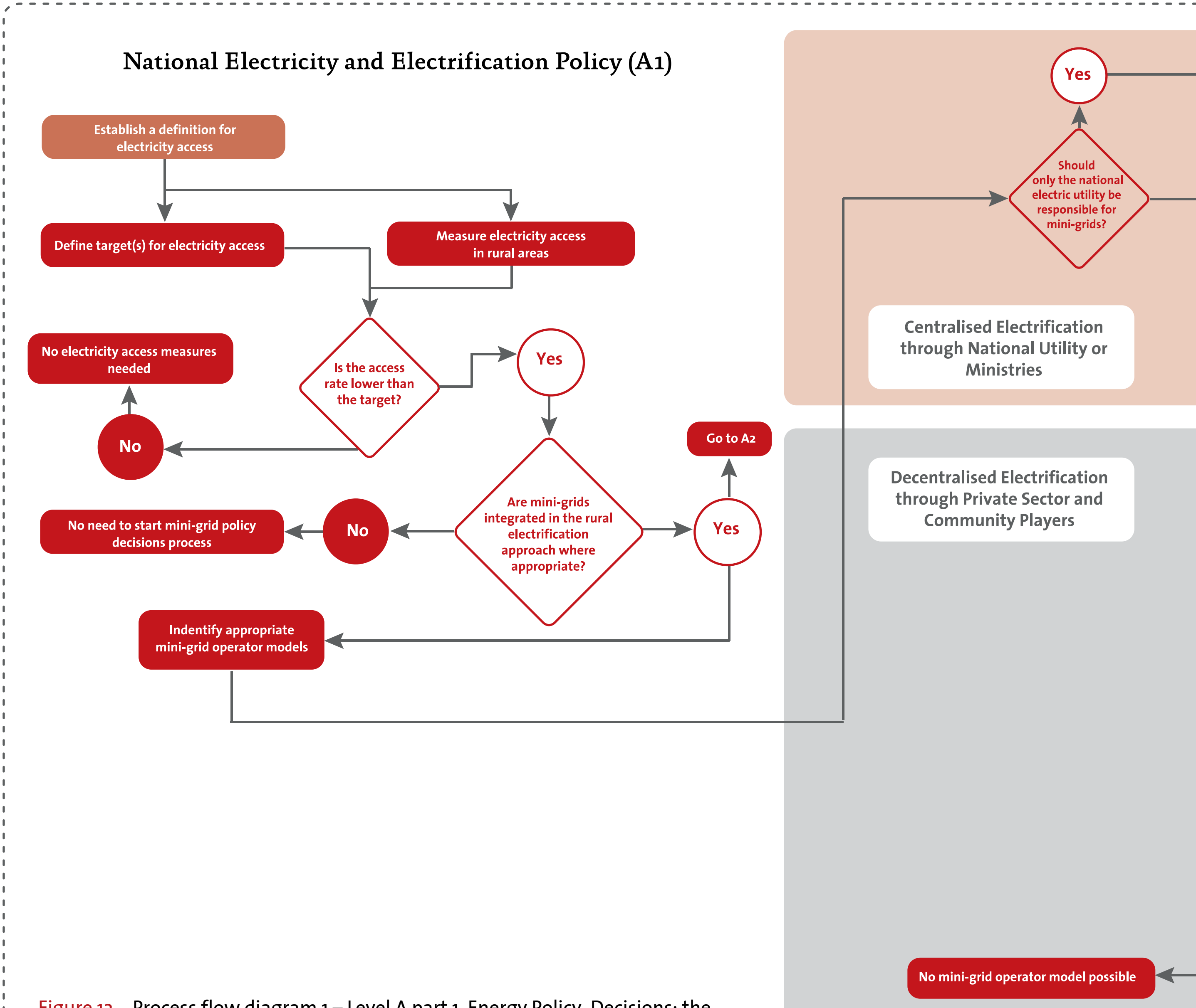
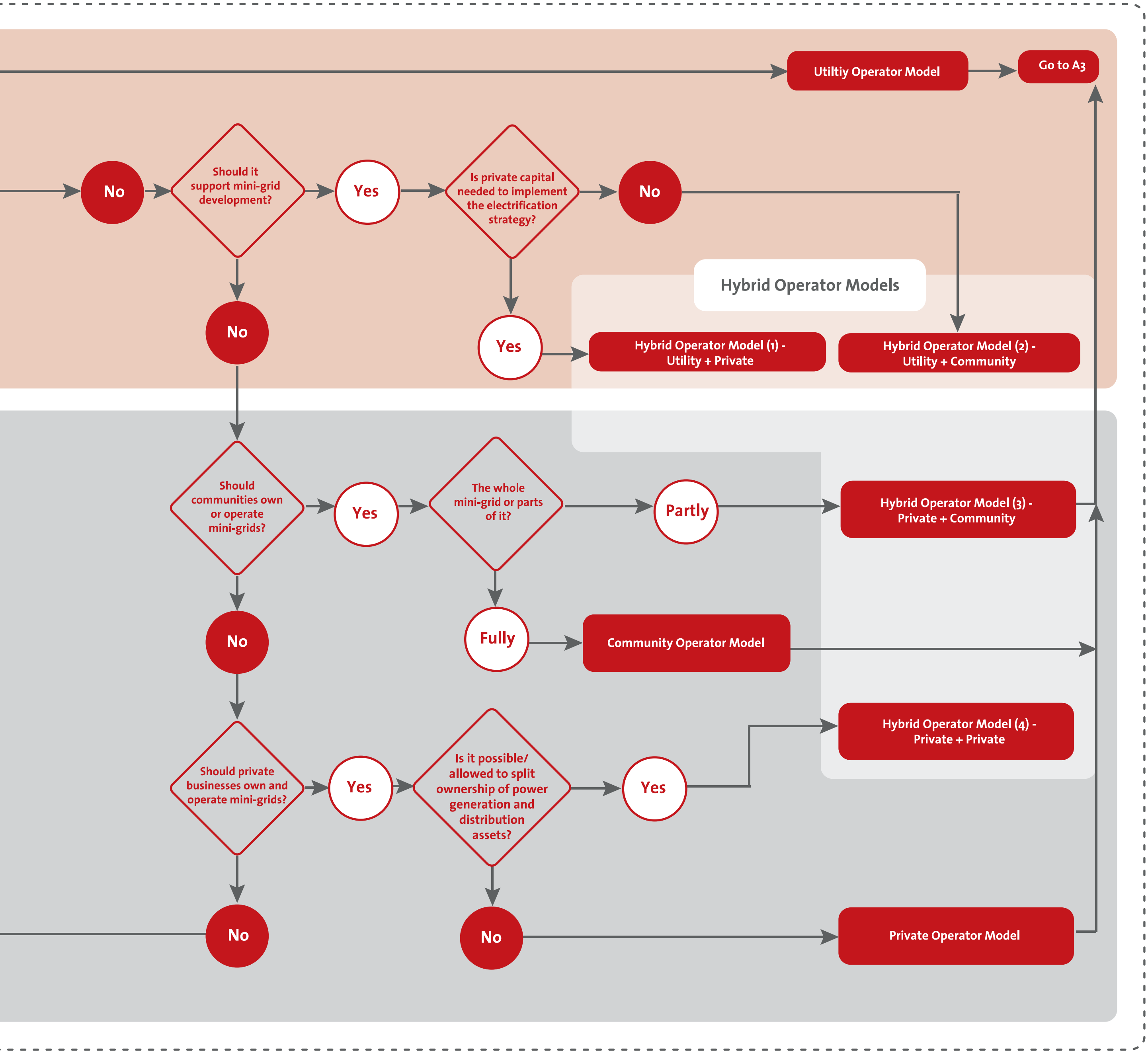


Figure 12 Process flow diagram 1 – Level A part 1, Energy Policy, Decisions; the process is for policy-makers (for more information please refer to the corresponding sub-chapters in chapter 6.3.)


Utiltiy Operator Model
Go to A3
No
Should it support mini-grid development?
Yes
Is private capital needed to implement the electrification strategy?
No
No
Yes
Hybrid Operator Models
Hybrid Operator Model (1) - Utility + Private
Hybrid Operator Model (2) - Utility + Community
Should communities own or operate mini-grids?
Yes
The whole mini-grid or parts of it?
Partly
Hybrid Operator Model (3) - Private + Community
No
Fully
Community Operator Model
Hybrid Operator Model (4) - Private + Private
Should private businesses own and operate mini-grids?
Yes
Is it possible/ allowed to split ownership of power generation and distribution assets?
Yes
No
No
Private Operator Model

Rural Electrification Strategy and Plan (A2)

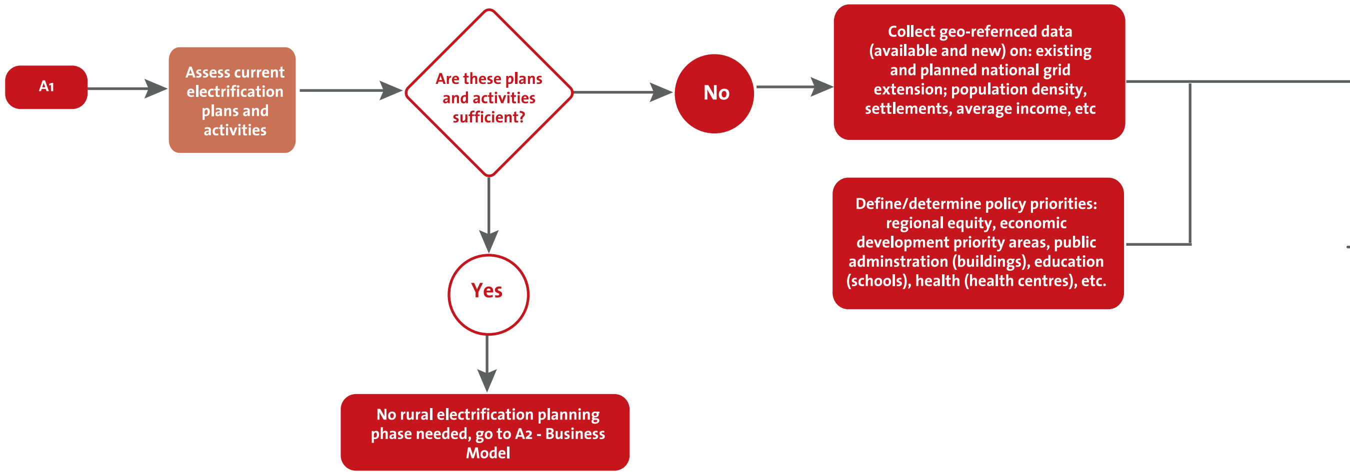
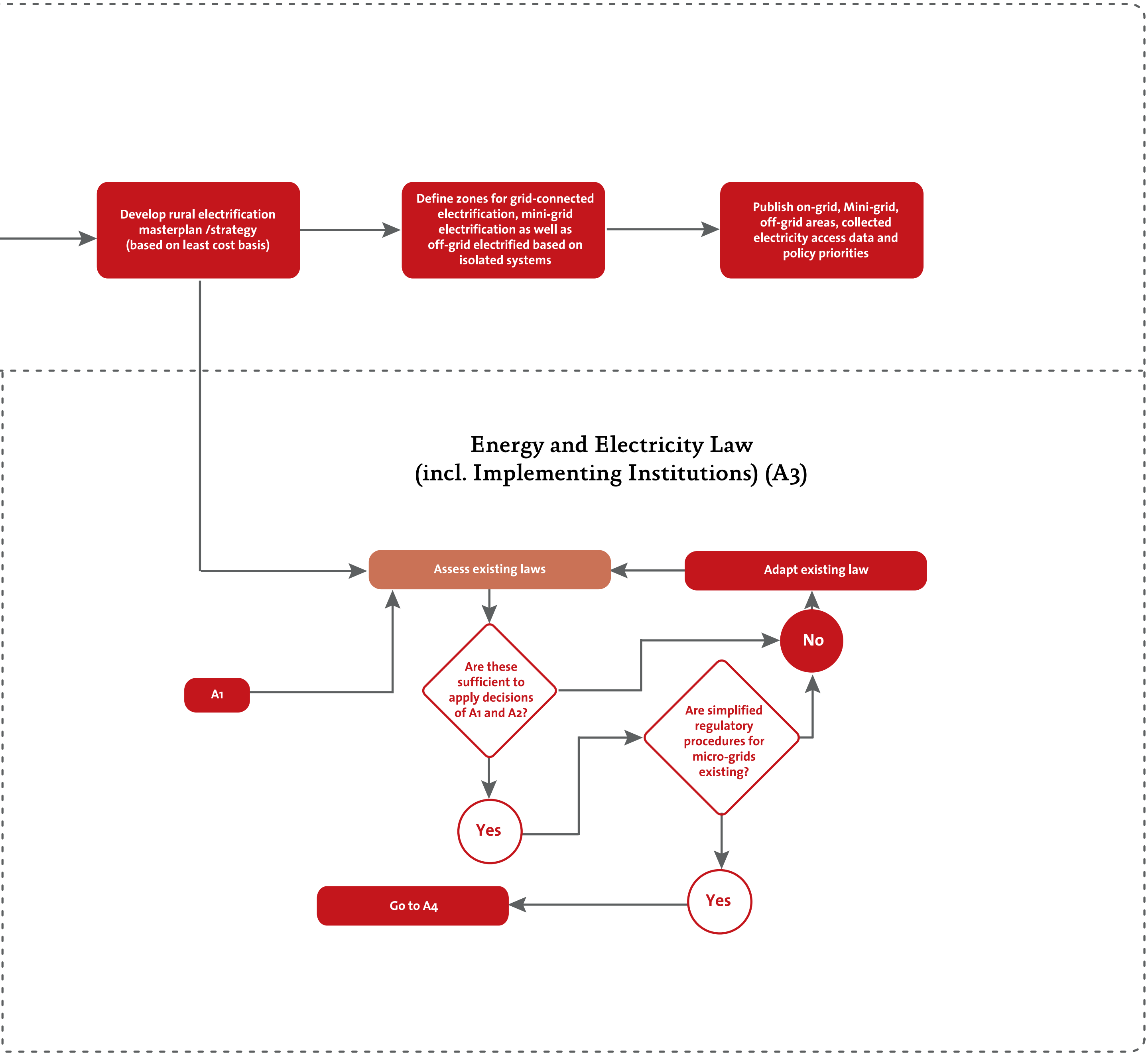


Figure 13 Process flow diagram 2 – Level A part 2, Energy Policy, Decisions; the process is for policy-makers (for more information please refer to the corresponding sub-chapters in chapter 6.3)


Develop rural electrification masterplan /strategy (based on least cost basis)
Define zones for grid-connected electrification, mini-grid electrification as well as off-grid electrified based on isolated systems
Publish on-grid, Mini-grid, off-grid areas, collected electricity access data and policy priorities
Energy and Electricity Law (incl. Implementing Institutions) (A3)
Assess existing laws
Adapt existing law
A1
Are these sufficient to apply decisions of A1 and A2?
No
Are simplified regulatory procedures for micro-grids existing?
Yes
Yes
Go to A4

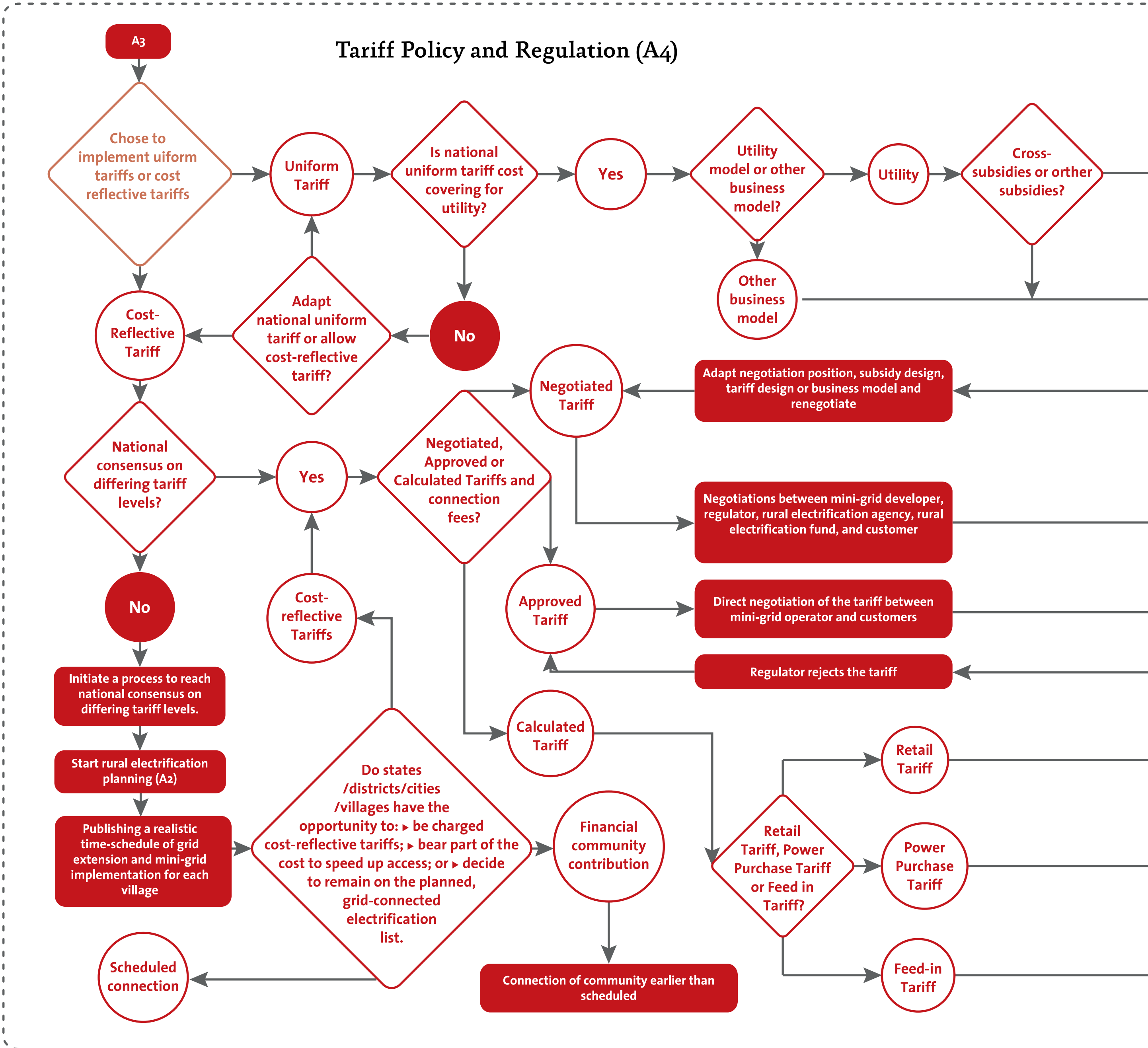
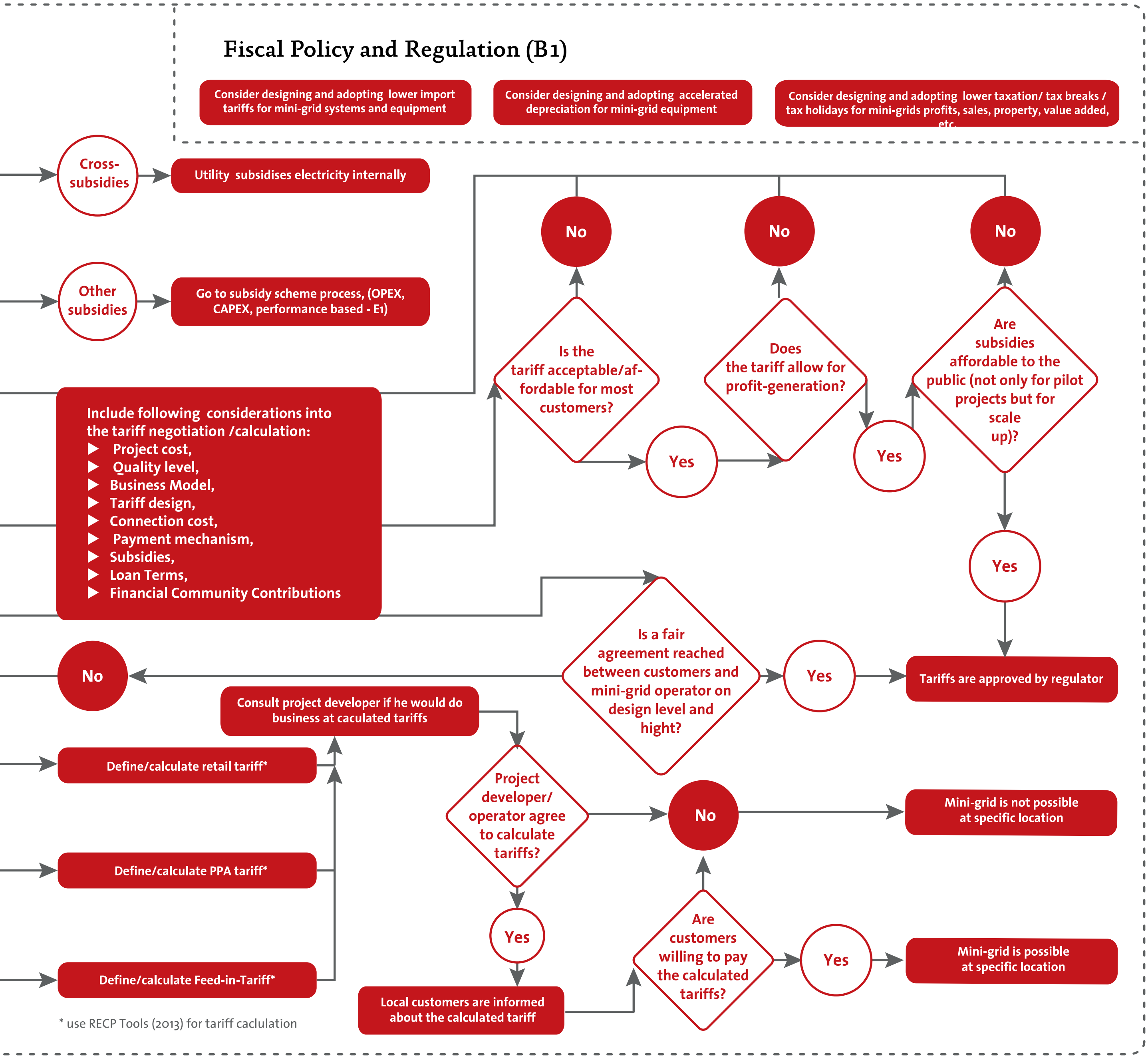


Figure 14 Process flow diagram 3 – 3nd part of Level A, Energy Policy and Level B Economic Policy and Regulation; process is for policy-makers (for more information please refer to the corresponding sub-chapters in chapter 6.3.)



* use RECP Tools (2013) for tariff caclulation

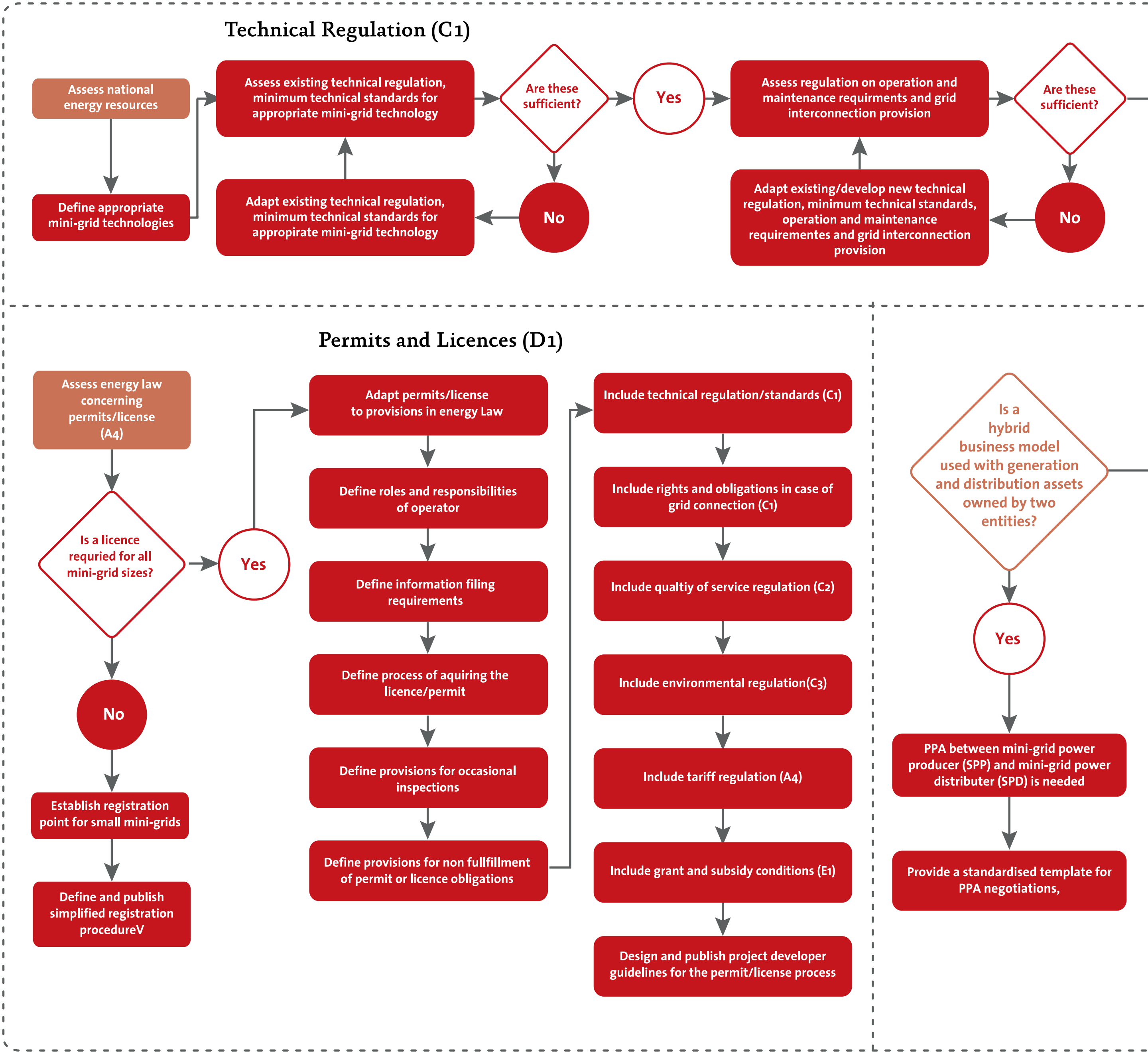
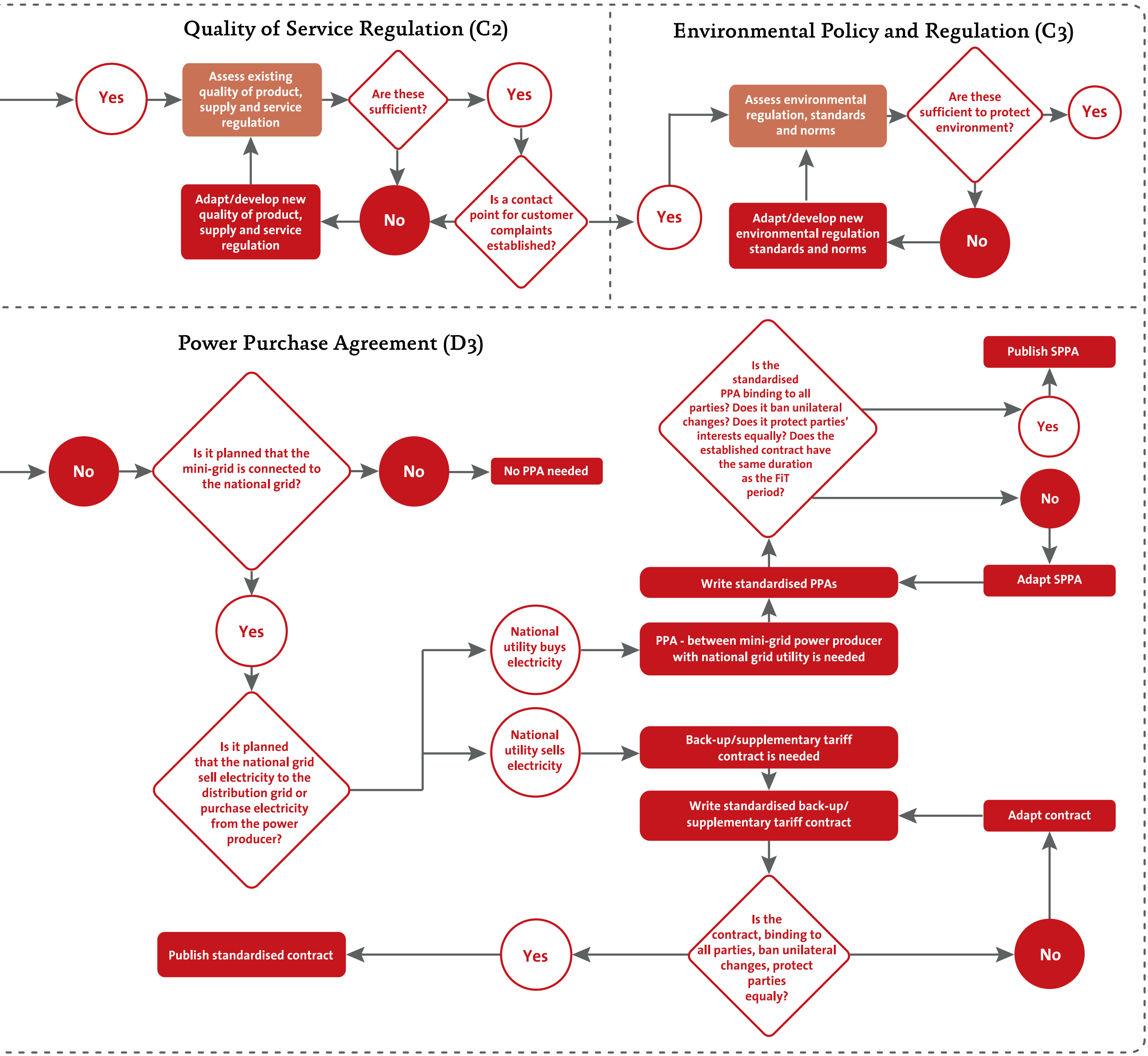


Figure 15 Process flow diagram 4 - Level C, Customer and Environmental Policy and Regulation and Level D, Licences and Contract Regulation; process is mostly for regulators (for more information please refer to the corresponding sub-chapters in chapter 6.3.)


Quality of Service Regulation (C2)
Yes
Assess existing quality of product, supply and service regulation
Are these sufficient?
Yes
Is a contact point for customer complaints established?
No
Adapt/develop new quality of product, supply and service regulation
Environmental Policy and Regulation (C3)
Yes
Assess environmental regulation, standards and norms
Are these sufficient to protect environment?
Yes
No
Adapt/develop new environmental regulation standards and norms
Power Purchase Agreement (D3)
No
Is it planned that the mini-grid is connected to the national grid?
No
No PPA needed
Yes
Is it planned that the national grid sell electricity to the distribution grid or purchase electricity from the power producer?
National utility buys electricity
PPA - between mini-grid power producer with national grid utility is needed
Write standardised PPAs
Is the standardised PPA binding to all parties? Does it ban unilateral changes? Does it protect parties' interests equally? Does the established contract have the same duration as the FiT period?
Yes
Publish SPPA
No
Adapt SPPA
National utility sells electricity
Back-up/supplementary tariff contract is needed
Write standardised back-up/ supplementary tariff contract
Is the contract, binding to all parties, ban unilateral changes, protect parties equaly?
Yes
Publish standardised contract
No
Adapt contract

Concession Contract and Schemes (D2)

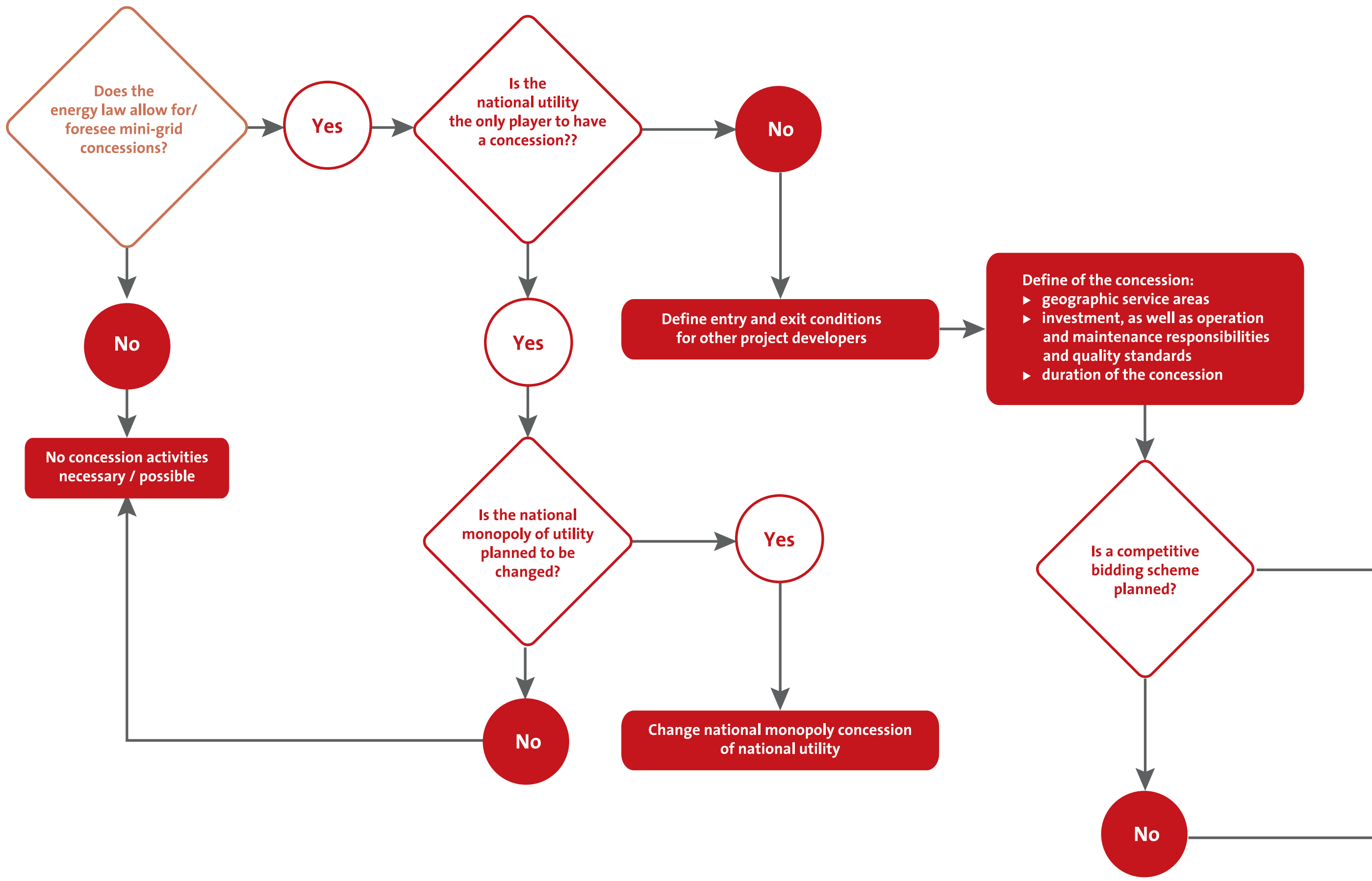
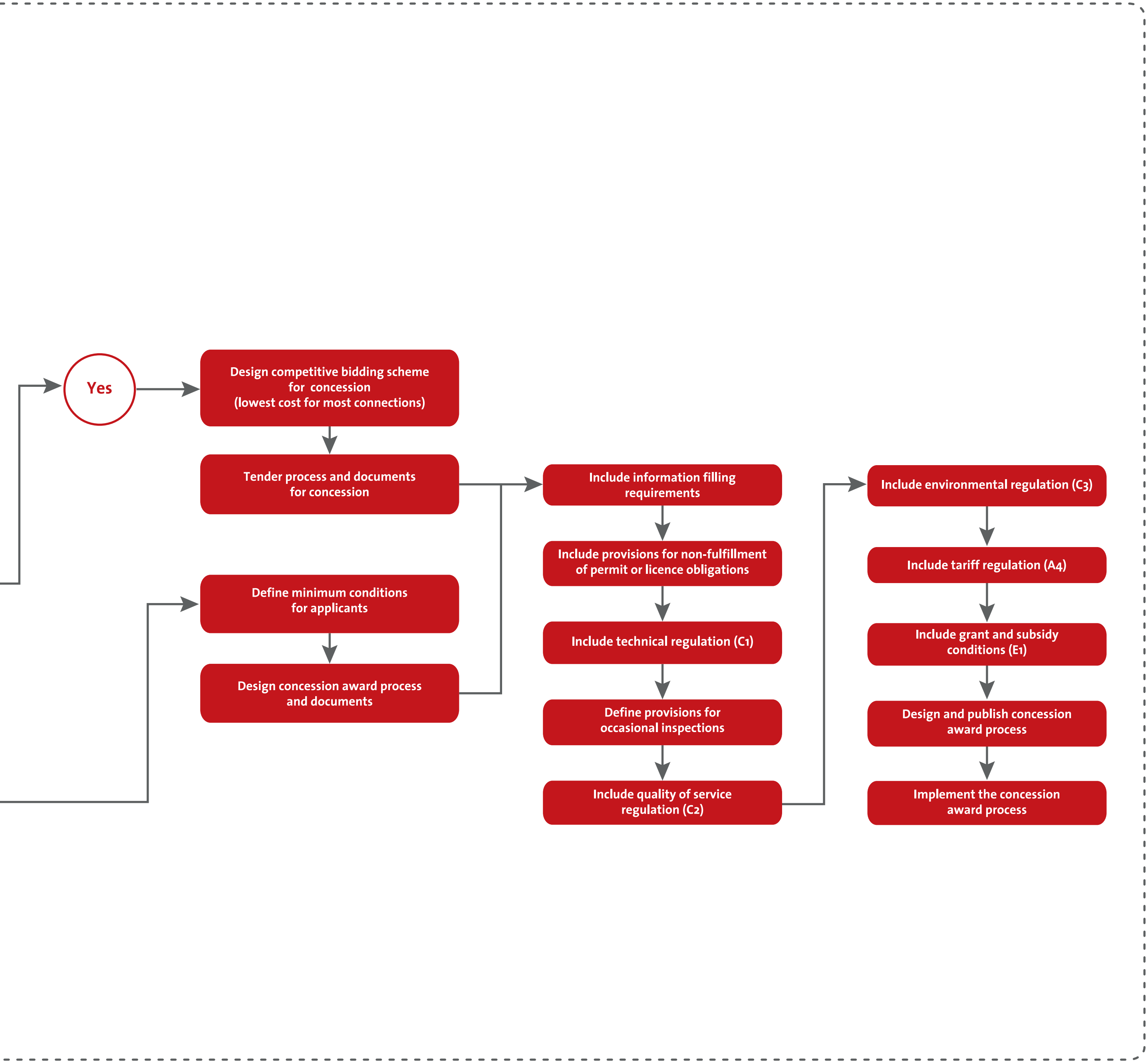


Figure 16 Process flow diagram 5 - Level D, Licences and Contract Regulation; process is mostly for regulators (for more information please refer to the corresponding sub-chapters in chapter 6.3.)



Yes
Design competitive bidding scheme for concession (lowest cost for most connections)
Tender process and documents for concession
Define minimum conditions for applicants
Design concession award process and documents
Include information filling requirements
Include provisions for non-fulfillment of permit or licence obligations
Include technical regulation (C1)
Define provisions for occasional inspections
Include quality of service regulation (C2)
Include environmental regulation (C3)
Include tariff regulation (A4)
Include grant and subsidy conditions (E1)
Design and publish concession award process
Implement the concession award process

Grants and Subsidies (E1)

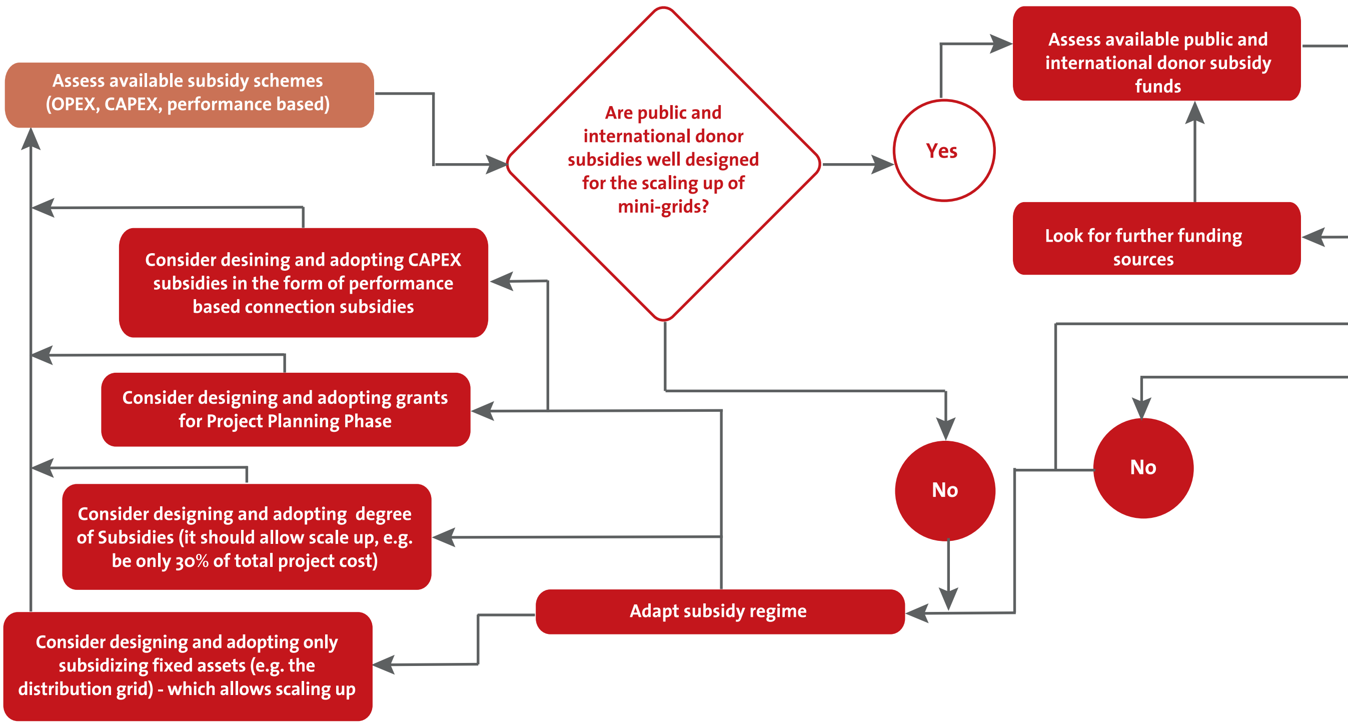
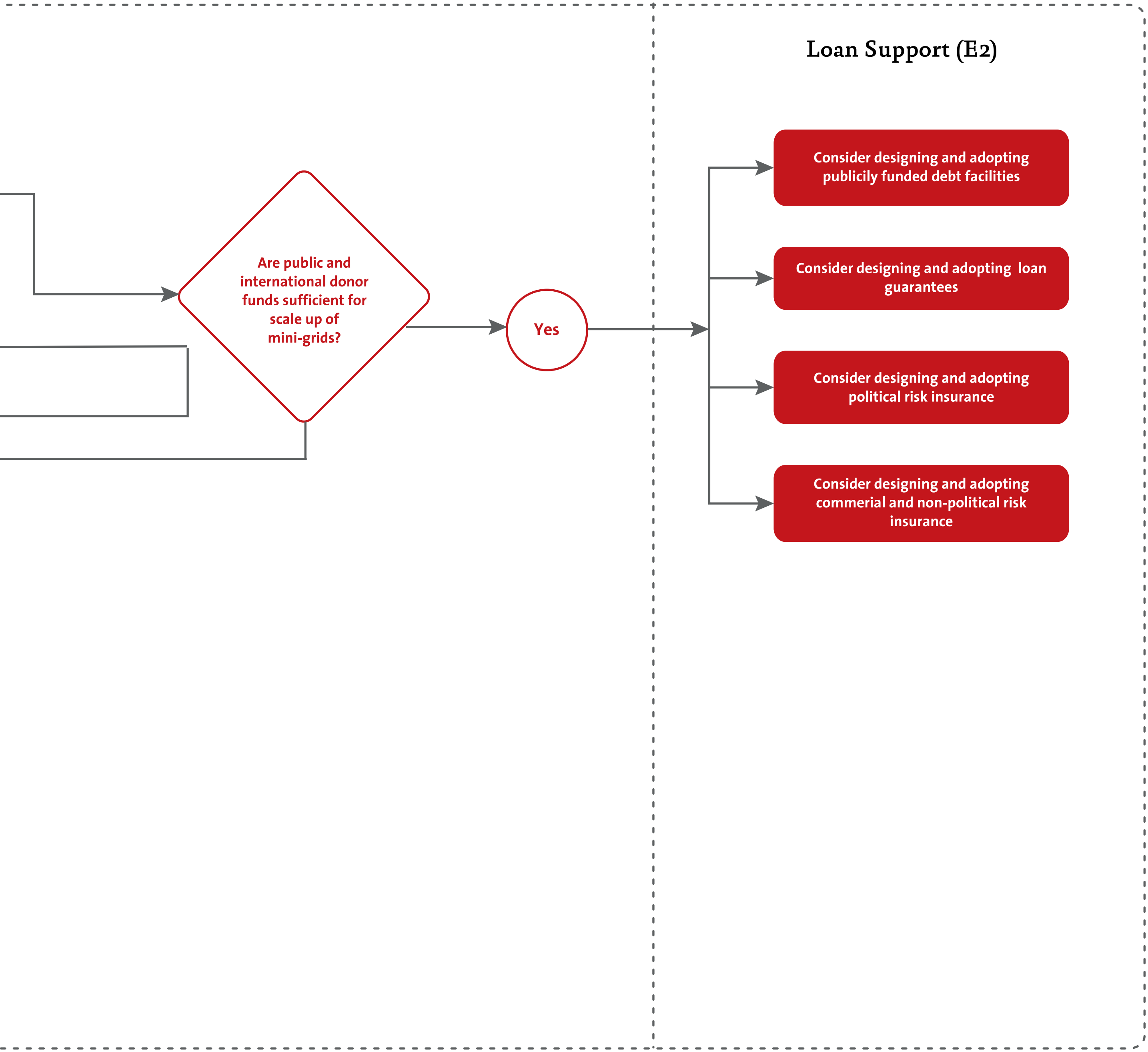


Figure 17 Process flow diagram 6 – Level E, Financial Support Schemes; process for policy-makers and regulators (for more information please refer to the corresponding sub-chapters in chapter 6.3.)



Loan Support (E2)
Are public and international donor funds sufficient for scale up of mini-grids?
Yes
Consider designing and adopting publicily funded debt facilities
Consider designing and adopting loan guarantees
Consider designing and adopting political risk insurance
Consider designing and adopting commerial and non-political risk insurance

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Annex I: Mini-grid Technology

This section discusses the basic elements of mini-grid technologies. It also provides links to further information.

In this publication we define mini-grids as involving small-scale electricity generation (from 10kW to 10MW), and the distribution of electricity to a limited number of customers via a distribution grid that can operate in isolation from national electricity transmission networks and supply relatively concentrated settlements. “Micro-grids” are similar to mini-grids but operate at a smaller size and generation capacity (1-10 kW).

A mini-grid has five basic features:

1) **Power Generation:** In this system, fuel is converted to electricity. It includes
   - the generator(s), which can be a diesel generator set and/or renewable energy based generators, in particular, PV, wind, run-of-river hydro or biomass
   - power conditioners, which include voltage convertors, rectifiers, and AC/DC inverters
   - energy management technology, such as a dispatch system

2) **Storage:** Not all types of mini-grids require storage; for example, well-sized diesel generators and hydropower systems usually run continuously. However, energy storage might be needed in the case of higher penetration of variable renewable energies, i.e. solar and wind. In this case, excess electricity is stored to ‘regulate’ the system while it is in use. In smaller mini-grids (i.e. under 300 kW) battery banks are typically used. In some larger systems, it is possible to apply storage systems from pumped hydropower (stored in elevated reservoirs).

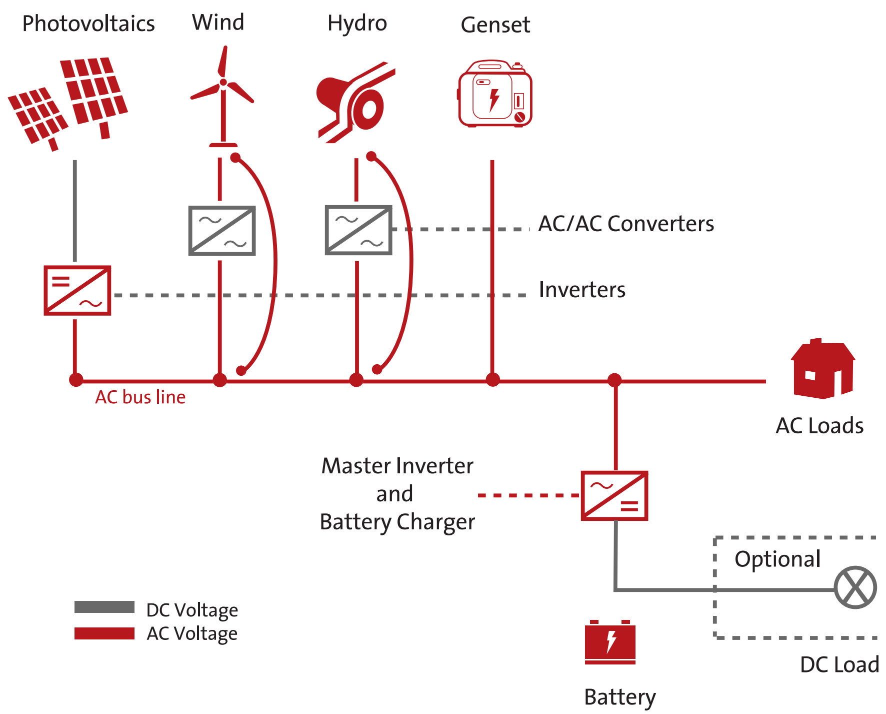
3) **Distribution:** A distribution network carries electricity to the consumers. System designers must decide on the type of distribution system (AC, DC, earth return, single or three phase, etc.). This decision impacts the cost of the project and will determine the types of appliances that can be utilised. It also influences, on the longer term, interconnection conditions. Usually electricity use is metered and recorded, so that the operator can bill consumers according to their consumption.

4) **User or application subsystem:** This includes all the equipment located on the end-user side, such as meters, internal wiring, grounding, and the electricity-consuming appliances.

5) **Smart management systems:** Such devices enable better system control and management of tariff collection. It also sets the stage for mini-grid growth, energy efficiency measures and eventual grid connection. Often, mini-grids integrate **smart management concepts** to improve efficiency, for which they increasingly use Information and Communication technology (e.g. smart meters). For instance, mini-grids have strong incentives to pursue demand-side management and to optimise mini-grid system design (reduce capital cost for generation units). Also, ICT allow the automatisation of the tariff collection process by interlinking tariff payments with the widespread telecommunication network, allowing people to pay bills via their mobile phones.

Often, main attention is given to the power production unit, though the distribution networks and electronic equipment present a large part of the investments costs.

Figure 18 Schematic AC mini-grid system with system components, adapted from ARE (2011)



All mini-grids require experienced operators who can manage and repair the power generation and distribution equipment, or who know when it is necessary to ask for technical assistance. Other people are assigned to collect payment from consumers, although smart billing technologies are rapidly automating this process.

Mini-grid Power Distribution Fundamentals

Power generation in the mini-grid system is only half of the equation. Depending on the technology, 35%- 55%

of a mini-grid system cost is incurred in the distribution and metering network. As such, a discussion of distribution networks and metering is equally important. They are considered very briefly below.

In mini-grids, electricity is generally distributed on a **low voltage level**. Some larger mini-grids have a medium voltage backbone to reduce losses during transmission over some kilometres. **Medium voltage levels** usually do not exceed 20 kV whereas medium voltages of around 12 kV are most widely used. Mini-grids can use overhead or ground lines, depending on the soil structure, road material, density of houses, and trees in the village. This has an impact on structural materials needed (e.g. poles, cables, etc.). Mini-grid distribution systems use **three-phase or one-phase lines** depending on the energy demand, productive uses, and the geographic extent of the village. They usually use a radial distribution system instead of a meshed system because of easy planning, operation and maintenance. The down side of **radial distribution systems** is the lack in redundancy; if a line fails, the customers witness a black-out. In all cases, connection lines to the customers can be counted as part of the distribution system. Household installations can be pre-financed as part of the distribution system but are at the same time separated from the distribution grid, as their ownership is usually transferred to the owner of the house, whereas ownership of other assets stays with the distribution grid owner. The point where the distribution grid connects to the household installation is called Point of Common Coupling (PCC).

Types of Mini-grid Technology

Several mini-grid technologies already exist in Africa, some being more prevalent than others. Mini-grids service a large number of people across the continent, meeting power demand needs beyond just lighting and phone charging. The energy source impacts the system's design, capacity, energy storage needs and cost. They are the basis of the four categories outlined in this section: (1) Diesel, (2) Hydro, (3) Biomass, and (4) Wind/Solar PV/Hybrid.

DIESEL MINI-GRIDS

Generator sets (gensets), powered by diesel or heavy fuel oil, have been used all over Africa to power mini-grids in remote villages, tourism resorts and business centres. Operating schedules depend on load requirements, fuel supply and the consumers' ability to pay. Diesel mini-grids are common in Africa and thousands are in operation all over the continent.

Typical Uses	Village electrification, off-grid power and power back-up.
Size	10 kW to 10MW
Experience and Level of Maturity	**Utility operator:** Where geographic coverage of the national grid is limited, sizable towns are served by a mini-grid. Power companies or rural electrification agencies typically subsidise connections so that consumers in these areas pay the same prices as grid-based consumers (this is common practice in Africa). **Private operator:** Mini-grids operate on a sustainable private basis, with consumers typically paying a daily or weekly fee based on the number and types of appliances they use *(e.g Somalia)*.

Benefits	Challenges
▸ Relatively low capital investment ▸ Well-understood technology with widespread technical operating and maintenance capacity ▸ Easily 'hybridised' with solar PV and/or wind, which can be added to lower fuel costs ▸ Commercial business models have been developed ▸ Potential for bio-diesel fuels	▸ Escalating costs for fuel and maintenance ▸ Carbon emissions ▸ Diversion/theft of fuel reduces efficiency and greatly increases costs in some business models ▸ Intermittent use times, through regular scheduled or random blackouts

Numbers in Africa	Thousands in use all over Africa

HYDRO MINI-GRIDS

Energy from cascading water is converted to electric power by turbines in pico, micro or mini-grid systems which are especially prevalent in Cameroon, the Democratic Republic of the Congo, Ethiopia, Kenya, Rwanda, Tanzania and Uganda.

Typical Uses	Village electrification, energy for plantations and missions
Size	Up to 3MW
Experience and Level of Maturity	Hydro power mini-grids build on a mature technology and are traditionally used to power remote settlements and religious missions in mountainous areas. Asia has a much more active micro/mini-hydro market; in the past Africa had many small-town and mission settlement hydro mini-grids in operation. Recently, there has been renewed interest in hydro-based mini-grids in Africa's tea sector and for rural electrification.

Benefits	Challenges
▸ Mature technology ▸ Low-cost power ▸ No diesel fuel needs	▸ Requires constant hydro re-source ▸ Location-specific ▸ Often locations are already close to the main grid ▸ May not be economically viable when community is located far from hydro-power source.

Numbers in Africa	Dozens of sites: Cameroon, Ghana, Kenya, Malawi, Mozambique, Swaziland, Uganda, Tanzania

BIOMASS MINI-GRIDS

Solid biomass fuels (bagasse, wood fuels, peat, etc.) are converted to produce gas or combusted directly in generators. Biogas based systems combust an aerobically produced methane from organic waste (algae, agricultural waste, etc.). Other systems generate steam by burning biomass in boilers, and using the steam to turn a turbine. Liquid biomass fuels (which are burned in standard engines) include ethanol and biodiesel

Typical Uses	Energy for sugar and wood plantations, sawmills and the agro-industry.	
Size	Gasifier based systems up to 1MW. Combustion based systems more than 1MW (smaller combustion systems are only tried out in pilot projects)	
Experience and Level of Maturity	Biomass technologies are mature and often employed by sugar and timber plantations to reduce power expenditures. If this technology is used efficiently, large quantities of excess power can be sold to the utility. However, this is only possible if suitable feed-in tariffs are agreed upon and where the generation unit is connected to the grid or a mini-grid. Use of biomass power for mini-grids in community electrification in Africa is less common, other than supplying employees' homes around existing factories or mills; it is increasingly seen in Asia (particularly in India - which uses gasifier systems). *See MGPT Case Study of India.*	
	**Benefits**	**Challenges**
	▸ Relatively low cost power for combustion based systems ▸ For agro-processing companies, some control over on-site fuel feedstock	▸ Medium to high cost for gasifier based systems ▸ Limited African experience to use this technology for rural electrification ▸ Location-specific
Numbers in Africa	Hundreds of sites: Cameroon, the Democratic Republic of the Congo, Ethiopia, Kenya, Rwanda, Tanzania, Uganda.	

HYBRID AC-COUPLED INVERTER MINI-GRIDS

AC-coupled inverter-based mini-grid systems manage a combination of solar PV, small wind, battery and/or diesel systems for supply to small distribution networks. They typically comprise a battery.

Typical Uses	Rural Electrification
Size	2kW to 300 kW
Experience and Level of Maturity	AC-coupled inverter hybrid technology incl. battery has seen considerable technical advancements and increased use since 2008. A fall in photovoltaic module prices combined with advances in inverter, power management and metering devices has greatly increased end-use opportunities in inverter mini-grids. This type of technology is likely to see rapid development because it is adaptable to fairly small sizes (a few kW) and it can replace or be combined with diesel generators. In addition, many areas with low energy access are located in regions with high solar and wind potential.

Benefits	Challenges
▸ Flexible systems - can use various fuel sources ▸ Solar has rapidly falling investment costs per kW ▸ Lower diesel fuel consumption and lower reliance on external fuel needs (energy security) ▸ Ease of operation and maintenance because of solid state technology (solar, inverters)	▸ Wind/Solar/Diesel hybrids require considerably more expensive investments when battery storage is used ▸ Data needed for reliable assessment of renewable energy potential

Numbers in Africa	Rural energy agency-led investments in hybrid mini-grids are common in Mali, Senegal and Namibia; smaller NGO initiatives exist in Kenya. Existence of private sector owned systems.

Annex II: Case Studies

In the past five years, various mini-grids have been promoted in Africa. The installation of mini-grids is driven by a number of objectives, including political, economic and even partner-state programmes. Private and community-built mini-grids are also seen, however these are usually driven by economic motives.

A variety of operator models have been used to install mini-grids around the continent – ranging from concession to anchor-client or NGO-driven to utility operated. Still, adequate policy frameworks for mini-grid projects are yet to be developed in most countries. As elaborated in the case studies, the actual technical and economic performance of these systems has been quite mixed. However, lessons are being learnt and general trends are emerging.

Virtually all mini-grids in Africa operate on Government or donor-subsidies.

The portal site contains detailed analysis of eight mini-grids that contain a broad representation of operator models, geographic locations and generation technologies. These are presented below with links to each detailed case study.

Table 11 Case studies on mini-grid models; *link: minigridpolicytoolkit.euei-pdf.org/casestudies*

Location	Mini-grid Technology and Operator Model covered in the case study	Details
Cape Verde	AC-coupled wind-PV-diesel hybrid mini-grid Community Model (donor led grant-based)	Solar/wind diesel hybrid applied in a remote island for rural electrification. Relatively expensive donor-provided demonstration programme.
India	Biomass-PV Mini-grids Regulated Private sector PPP model (Subsidised private sector model with reducing subsidies and semi-commercial roll-out)	Indian experience in hundreds of off-grid communities with special relevance to Africa.
Kenya	Diesel gen-set with solar additions Model: national utility led model	Diesel mini-grids as examples of the most prevalent type of mini-grids in Africa. The case study explores how the addition of PV to a diesel system can im-prove performance (on-going KPLC projects).

→ *Table continues on page 130*

Location	Mini-grid Technology and Operator Model covered in the case study	Details
Namibia	AC-coupled hybrid inverter technology Hybrid (utility and community aspects, and system design optimisation)	Hybrid diesel-PV mini-grid as an example of the importance of project design, whereby ideological considerations are proven to be not very practical.
Rwanda	Mini-grids that are subsequently connected to the main grid Model: regulated private sector-led installations (incorporated into the national grid)	Privately created micro hydro plants and mini-grids showing that local organisations can be strong en-ough to develop, finance and operate micro hydro plants; the initial systematic assistance pays off as these project developers are now techni-cally and financially capable of replicating their experiences. The regulatory framework is crucial, which in this case prevented the mini-grids from being built.
Senegal	AC-coupled hybrid inverter technology Hybrid (concession model)	Mini-grids as a representative case study for the West African experience of government-subsidised PV/diesel hybrid mini-grids to fill- in areas not ser-viced by the national grid.
Somalia	Unregulated private sector-led	No alternatives planned so the private sector stepped in
Tanzania	Gas-fired generator mini-grid (biowaste, biogas, etc.) Model 3b: regulated private sectorled (anchor client-led model in-corporated into national grid)	Tanzania experience of Tanzania Wattle and their biomass based mini-grid.

Abbreviations and Acronyms

ABC	Anchor-Business-Community
AC	Alternating current
AECF	Africa Enterprise Challenge Fund
AEEP	African-EU Energy Partnership
AFD	Agence Française de Développement
AfDB	African Development Bank
AICD	Africa Infrastructure Country Diagnostics
AMADER	Agence Malienne pour le Développement de l'Energie Domestique et l'Electrification Rurale
ANEEL	Agência Nacional de Energia Elétrica
ARE	Alliance for Rural Electrification
AREF	African Renewable Energy Fund
ASER	Agence Sénégalaise d'Electrification Rurale
ATI	African Trade Insurance
AU	African Union
CAPEX	Capital Expenditure
Club-ER	Club of National Agencies and Structures in Charge of Rural Electrification
CRSE	Commission de Régulation du Secteur de l'Electricité
DC	Direct current
DCA	Development Credit Authority
Dev	Development
DFI	Development Finance Institutions
DFID	Department for International Development
DIV	Development Innovation Ventures
DRC	Democratic Republic of Congo
EEP	Energy and Environment Partnership
EnDev	Energising Development
EPC	Engineering, Procurement, Installation and Commissioning
ERM	Environmental Resources Management
ESMAP	Energy Sector Management Assistance Program
EU	European Union
EUEI	EU Energy Initiative
EWURA	Energy and Water Utilities Regulatory Authority Tanzania
EXIM	Export-Import Bank
FiT	Feed-in tariff
FMO	Netherlands Development Finance Company
GDF	Gaz de France
GEF	Global Environment Facility
GIZ	German Federal Enterprise for International Cooperation
GMG	Green Mini-Grid

GSMA	GSM Association – association of mobile communication operators
GVEP	Global Village Energy Partnership
HOMER	Hybrid Optimisation of Multiple Energy Resources Software
hrs	Hours
IEA	International Energy Agency
IED	Innovation Energy Development
IEG	Independent Evaluation Group
IFC	International Finance Cooperation - a member of the World Bank Group
IFU	Investment Fund for Developing Countries
IMF	International Monetary Fund
IOB	Policy and Operations Evaluation Department of the Dutch Ministry of Foreign Affairs
IPCC	Intergovernmental Panel of Climate Change
IPP	Independent Power Producer
IRR	Internal Rate of Return
KfW	Kreditanstalt für Wiederaufbau/ Development Bank
km	Kilometre
KPLC	Kenya Power and Lighting Company
kW	Kilowatt
kWh	Kilowatt hour
LCOE	Levelised cost of energy
m	Million
MGPT	Mini-Grid Policy Toolkit
MIGA	Multilateral Investment Guarantee Agency
MW	Megawatt
MWp	Megawatt-peak
NEPAD	New Partnership for Africa's Development
NGO	Non-Governmental Organisation
O&M	Operation and Maintenance
O&M&M	Operation, Management and Maintenance
OECD	Organisation for Economic Cooperation and Development
OFID	OPEC Fund for International Development
OGE	Off-Grid Electric
OMC	OMC power – Indian project developer
OPEC	Organisation of the Petroleum Exporting Countries
OPEX	Operating Expenditures
OPIC	Overseas Private Investment Corporation
PDF	Partnership Dialogue Facility
PE	Private equity

PEP	Projektentwicklungsprogramm/ Project Development Programme
PPA	Power Purchase Agreement
PPP	Public private partnership
PRI	Political risk insurance
PV	Photovoltaic
PVPS	Photovoltaic Power Systems Programme
REA	Rural Electrification Agency
REACT	Renewable Energy and Adaption to Climate Technologies
REDMP	Rural Electrification Master Plan in Namibia
REDP	Rural Energy Development Programme in Nepal
REF	Rural Energy/Electrification Fund
REN21	Renewable Energy Policy Network for the 21st Century
REPP	Renewable Energy Performance Plat-form
RERA	Regional Electricity Regulators' Association of Southern Africa
RESCO	Renewable Energy Service Company
RET	Renewable Energy Technology
RLI	Reiner Lemoine Institut
S&EA	Southern and Eastern Africa
SADC	Southern African Development Community
SBI	Sustainable Business Institute
SE4ALL	UN's initiative: Sustainable Energy for All
SETC	State Economic and Trade Commission - China
SHS	Solar home systems
SIDA	Swedish International Development Cooperation Agency
SME	Small and Medium Enterprises
SPD	Small Power Distributors
SPP	Small Power Producers
SPV	Special Purpose Vehicle
TA	Technical Assistance
TEDAP	Tanzania Energy Development and Access Project
ToR	Terms of Reference
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
VAT	Value-Added Tax
VP	Venture Philanthropy
W	Watt
WTP	Willingness to pay

For more information,
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