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RENEWABLE ENERGY-BASED MINI-GRIDS: THE UNIDO EXPERIENCE

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Renewable energy-based mini-grids: The UNIDO experience

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

AC/DC	Alternating Current/ Direct Current
ACP	African Caribbean and the Pacific
ARE	Alliance for Rural Electrification
BOO	Build-Own-Operate
CARICOM	Caribbean Community
CLUB-ER	Club of National Agencies and Structures in Charge of Rural Electrification
EC	European Community
EC JRC	European Commission Joint Research Centre
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EU	European Union
EUEI	European Union Energy Initiative
GHG	Greenhouse Gas
GNESD	Global Network on Energy for Sustainable Development
IBRD	International Bank for Reconstruction and Development
IEA	International Energy Agency
IED	Innovation Energie Développement
IFC	International Finance Cooperation
IIED	International Institute for Environment and Development
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
ISID	Inclusive and Sustainable Social Development

kW	Kilowatt
LCOE	Levelized Cost of Electricity
LV	Low Voltage
MDG	Millennium Development Goal
MW	Megawatt
NAWEC	National Water and Electricity Company of The Gambia
PPP	Public Private Partnership
PV	Photovoltaic
R&D	Research and Development
REN	Renewable Energy Network
RET	Renewable Energy Technology
SAGCOT	Southern Agricultural Growth Corridor of Tanzania
SE4ALL	Sustainable Energy for All
SMEs	Small and Medium Sized Enterprises
UN	United Nations
UNDP	United Nation Development Program
UNEP	United Nations Environment Program
UNIDO	United Nations Industrial Development Organization
VAT	Value Added Tax
WRI	World Resource Institute

Executive summary

Despite the considerable potential for an accelerated use of renewable energy-based mini-grids, opportunities for income generation and social and environmental benefits, progress continues to be hampered by a number of key barriers and bottlenecks. Many countries still lack sufficient technical capacities to install, operate and maintain the systems, the regulatory framework to attract project developers, and access to financing to bring sufficient scale. UNIDO's access to energy projects aim to address these issues, yet the evidence suggests that there is no unique business model that can easily and universally be replicated and scaled-up. This report will take stock of the current experience, and will draw interim conclusions on the lessons learnt, and provide guiding recommendations for designing energy access projects.

UNIDO showcases eight projects, two in Asia and six in Africa, to analyse the benefits of renewable energy as a tool for Inclusive and Sustainable Industrial Development (ISID) through building renewable energy-based mini-grids for productive uses in rural communities. The case studies are taken from UNIDO's technical cooperation project portfolio, and include Chad, Côte d'Ivoire, Guinea-Bissau, India, Sri Lanka, Tanzania, The Gambia and Zambia. The report presents the technical, regulatory, financial and business approach as well as end-user and community involvement for each case study. The projects are assessed for their ability to meet five criteria which are deemed critical for the long-term success of mini-grids. These criteria are (i) sufficient revenue to support the mini-grid; (ii) the willingness and ability of consumers to pay bills; (iii) community participation; (iv) capacity of national regulator/ utility / renewable energy agency to support and promote off-grid projects; and (v) local manufacturing capacity.

As regards the generation of ***sufficient revenues***, four out of the eight cases have sufficient revenues, ensuring that there is adequate demand for energy, that productive users or large consumers are connected, and that there is potential to increase the number of connections over time. It is also highlighted that productive activities are not guaranteed just by virtue of providing access to electricity; tailored support and guidance (e.g. through private sector development, micro-financing, etc.) is required to go hand-in-hand with the energy solution. In Guinea-Bissau, the project provided micro-credits to develop income-generating activities and encourage savings, which achieved higher connection levels among businesses. In India, there is the possibility for mini-grids to be connected to the grid in the future and benefit from feed-in-tariffs.

On the ***willingness and ability to pay***, the case of Chad shows that where the community is involved to manage tariff setting and collection, the system ensures that the costs of the operator are covered by the tariff and that at the same time, the community's needs are reflected. In Guinea

Bissau, the community was also involved in assessing the spending power of consumers, which resulted in a rapid and successful take up of electricity. In Côte d'Ivoire, households and businesses chose tariffs before the mini-grids were built, allowing the mini-grid to be designed according to anticipated demand and revenue from the selected sites.

As regards ***community and end-user participation***, experience shows that long-term sustainability of mini-grid projects can be improved with strong community participation, including ensuring there is locally available capacity to manage and maintain the operations, and that there are associated productive uses at the project site. Where feasible and preferred, the involvement of a third-party operator (private or semi-private) might be advisable.

Local manufacturing capacity supports the local economy's shift away from relying on international donors or government subsidies in the long-term. For instance, in the case of solar and small hydro, local manufacturing capacity can be used and strengthened in the areas of design, manufacture and assembly of system components in support of sustainable industrial development. Renewable energy technology centres, such as the SHP technology centre in Tanzania or India, or a network of trained local subcontractors (electricians) in Chad and Côte d'Ivoire, are able to support RE mini-grid communities and encourage their uptake in further settlements. The key is to have a critical number of projects, such as in Côte d'Ivoire, which include several villages that are in close proximity of each other and are supported by the same foundation, making it a viable business for local contractors.

On regulatory capacity, the existing framework needs to be redesigned to allow for adequate off-grid solutions. The case of Côte d'Ivoire depicts that even though many viable mini-grid sites can be identified, the regulatory and financing framework lacks incentives for their development. The financial sector only lends to projects if risks are minimized, and policymakers need to provide incentives and instruments to reduce these risks. In Chad, it has been advised to phase out fossil fuel subsidies and dedicate a minimum level of infrastructure procurement to renewables to encourage the creation of local production facilities and reduce risks for private investors. The capacity of national regulators, utilities and renewable energy agencies to develop rural energy markets can be increased in terms of technical knowledge, as in the case of The Gambia, where the project enabled the national water utility to realize the economic benefits of replacing gasoil gen-sets with solar PV systems.

The five factors considered in the evaluation reveal the many inter-linkages between regulatory, technical, financial and community objectives. An adequate regulatory framework should be able to leverage private investment, support capacity to oversee projects on the ground and to thus encourage community participation.

The replication of these demonstration projects bring the development of mini-grids to the next level and can only be realized if investments move away from reliance on donor funds. For this to happen, governments need to enact specific provisions for mini-grids that allow investors to have clarity on the regulatory environment for the foreseeable future in order to be able to design projects in a way that brings returns on investment.

The context in which the technical cooperation projects to advance mini-grid deployment take place show that a number of the countries of operation are often generally not ready for a full market approach for investments. Therefore, a private sector-led approach for demonstration projects may not be realistic in the short-term. A step-wise approach, including demonstration through donor-led projects, followed by government incentives aiming to blend with private money and/or development bank loans, is more likely to pave the way towards a sector to become sufficiently attractive in terms of size and financial returns for the private sector to take over. The case for initial support (subsidies, tax credits, etc.) for the development of a market for rural electrification is thus justified, based on arguments of long-term sectoral development and taking into account the environmental and socio-economic benefits that would come with it. These often first-of-its-kind projects aim to test modes of operation taking into account technology, policy and regulation, local participation and socio-economic benefits, based on which indications can be provided on the appropriate strategy for such projects to be scaled.

The interim conclusions should be interpreted as being a snapshot, as many of the cases have only recently been installed. The interim conclusions will be revisited in the next 12 to 18 months.

1 Introduction

The aim of this report is to review UNIDO's experience in the area of renewable energy (RE)-based mini-grid projects in rural areas, and to evaluate the lessons learnt in each case to strengthen and refine the development of future projects.

UNIDO showcases eight projects, two in Asia and six in Africa, to analyse the benefits of renewable energy as a tool for **Inclusive and Sustainable Industrial Development (ISID)** through building *renewable energy-based mini-grids for productive uses in rural communities*.

Renewable energy is an essential part of mini-grid development due to the importance of utilizing affordable and locally available resources, not only to reduce greenhouse gas (GHG) emissions, but also to create new value chains in terms of job and wealth creation, rural development and women's empowerment, technology and business innovation and improvement of the local environment. Mini-grid projects that focus on giving access to modern energy services without considering the potential and growth opportunity for local industrial development may not necessarily imply that local economic activity will be initiated or strengthened.

Energy for productive use requires an additional effort in terms of the development of small and medium sized enterprises (SMEs), links to markets, processing for adding value (e.g. for agro-food products), etc. Income generation is required to strengthen economic activity and thus sustain the benefits of energy access. An essential component to ensure this is regular collection of tariffs from consumers, which is only possible through economic development. Some aspects of economic activity in the agro-food sector (e.g. rice, cotton, maize, etc.) should ideally already be in place before the mini-grid is built. Access to modern energy can help such businesses grow and add value to the raw materials (e.g. through processing, storage, etc.) in the case of agri-businesses, or provide service shops such as smiths or barbers with electricity and light to run their business. Where there is not much economic activity, the project developers generally need to invest resources in training and capacity building of the local community in order to stimulate the creation of new businesses and income-generating activities.

Industry plays a decisive role in stimulating economic growth. Global experiences have shown that countries have reached high levels of socio-economic development through a developed and advanced industrial sector. However, industrial sector growth is conventionally linked with environmental pressures such as resource depletion, pollution at the local/regional level and negative impacts in terms of global climate change. It is precisely this conventional linkage which ISID aims to change, demonstrating that economic growth and environmental sustainability can go hand in hand.

UNIDO promotes ISID as part of a broader strategy to harness the full potential of the industrial sector's contribution to achieving sustainable and equitable human development, aiming to put ISID at the heart of each project and to promote sustainable and resilient economic and industrial growth for poverty reduction that goes hand in hand with the economic, social and environmental dimensions of sustainable development. In terms of the development of renewable energy mini-grids, UNIDO's objective is to achieve ISID as follows:

- The use of **locally available renewable energy resources** in mini-grids, leading to an environmentally sustainable framework, improving the local economy, environment and public health;
- The promotion of **renewable energy technologies** (RETs) as a means of fuelling value addition to local products in rural areas so they can benefit from global markets for industrial goods and services as well as reduce post-harvest losses;
- Development of mini-grids using **local resources, labour and manufacturing**, leading to increased local economic activity and inclusive development so no one is left behind in terms of benefiting from industrial growth, and prosperity is shared among all socio-economic groups;
- Increasing **community participation** to understand local needs and the potential for productive uses;
- Bringing in **private sector resources** to obtain much needed technical know-how and market-based approaches;
- Sensitize industries to *become* **'industrial prosumers"** by both producing and consuming renewable energy.

The below figure provides a detailed picture of renewable energy as an industry in itself and of renewable energy for industry, and how industrial prosumers are a linkage between these two areas.

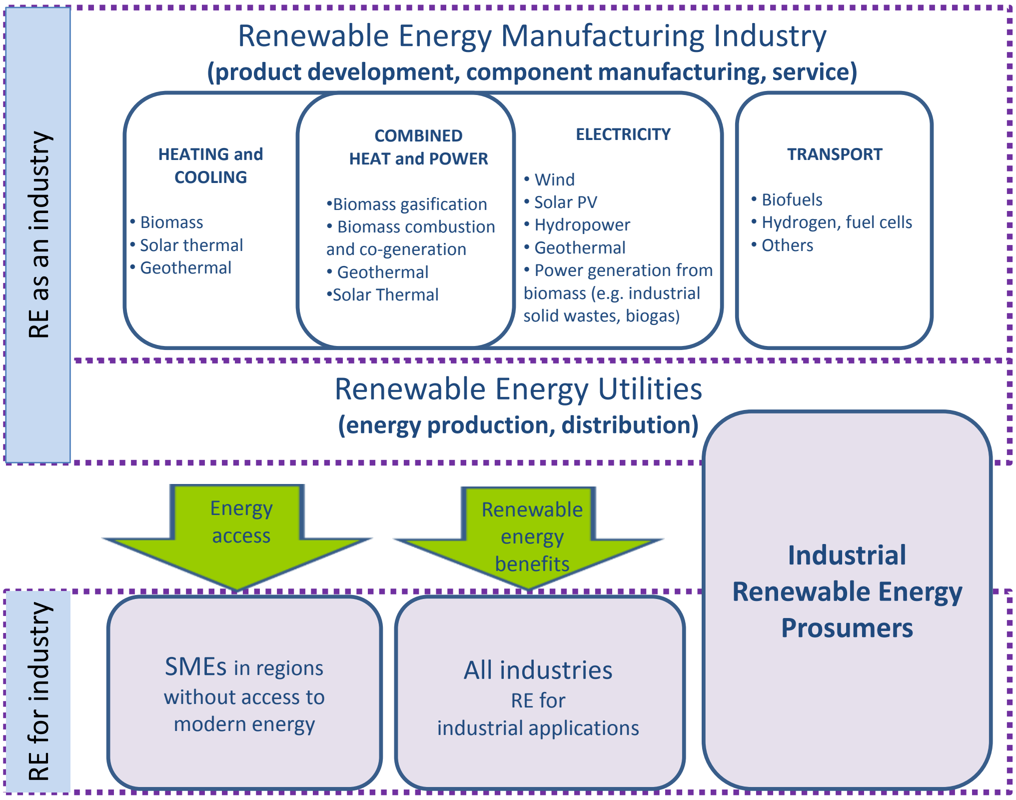


Figure 1: Renewable energy as an industry and for industry

Access to sustainable and affordable energy plays an important role in achieving ISID, as energy (electricity as well as heating and cooling applications) is a critical input in numerous industries and an essential prerequisite for effective transportation, communication and other systems that provide access to international markets. At a local level, energy access facilitates development by enhancing the productivity of existing economic activities (e.g. enhancing agricultural development by enabling irrigation, value addition through crop processing and storage) and helping rural areas evolve from mere raw material producers to producers of value added products, while providing opportunities for new income and job-generating micro-enterprises (Oyedepo, 2012).

The development of clean energy businesses and the underlying infrastructure, work force and value chains presents two opportunities for growth – the first being the creation of sustainable jobs, income and economic growth, and the second being growth in other sectors. The promotion of cost-effective **RETs for productive uses** is therefore an integral component of sustainable development and presents a major opportunity for achieving the goals of ISID.

With the rising awareness that off-grid, low-income customers can provide fast-growing markets for goods and services, and with the emergence of new business and financing models to serve them, rural energy markets are increasingly being recognized as offering potential business opportunities. Mini- or micro-grids that are typically below a few MW capacity usually service a cluster of households and businesses through an independent distribution network (i.e. off the main grid), and most commonly in remote areas[1].

The objective of this Working Paper is to contribute to the development of mini-grids and the related international debate by presenting **UNIDO's insights and experiences** in delivering renewable energy-based mini-grid projects in remote areas, especially in Africa and Asia. UNIDO's analysis of its own projects is meant to build on the existing experience, and highlight the lessons gleaned from the field, focusing on UNIDO's objective of demonstrating mini-grids as a vehicle for inclusive and sustainable industrial development.

2 The mini-grid sector: benefits and challenges

Mini-grids can be an important alternative to or enhance the effectiveness of central grid extension to increase access to reliable electricity services in developing economies.

Mini-grids are defined as one or more local generation units supplying electricity to domestic, commercial or institutional consumers over a local distribution grid. They can operate in a stand-alone mode and can also interconnect with the central grid when available. Although mini-grids can use diesel generators, renewable energy-based mini-grids (henceforth referred to as RE mini-grids) use electricity generation technologies that utilize locally available renewable energy sources like solar, wind, biomass and run-of-river hydro, thus avoiding local and global pollution. These generation technologies include solar photovoltaic and wind turbines with battery storage, biomass gasifiers and biogas digesters with internal combustion engines, micro- and mini-hydro turbines and hybrid systems (a combination of more than one generation technology). Due to their low or often zero fuel costs (except potentially in the case of biomass-based systems), RE mini-grids can be more cost effective than those utilizing diesel generators or kerosene-based lighting. The latter have little capital expenditure, but have relatively high fuel costs, volatile prices and logistic limitations (Berkeley, 2013).

The mini-grid sector has in recent years become one of the most dynamic and fastest growing distributed renewable energy sectors in both developed and developing countries. Over the last 20 years, many governments, power utilities and private industries have implemented mini-grids,

[1] As opposed to isolated or stand-alone systems that are employed in individual homes or businesses, with all energy consumed at the site of generation, e.g. solar on rooftops.

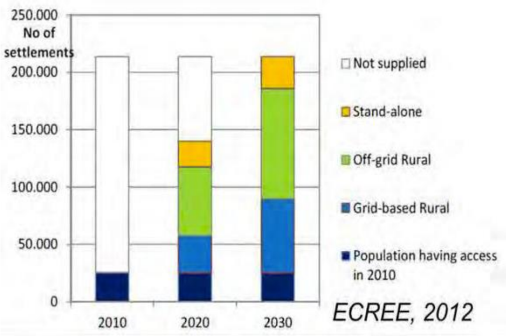
mostly diesel-based and some hydro-based. The motivation was often more political or social rather than economical. The greatest mini-grid development has been observed in Asia (IIED, 2013).

As 1.1 billion people still lack access to electricity, the need for mini-grid development in rural areas is considered the most cost-effective option in achieving universal access to electricity by 2030, as advocated by the UN-led Sustainable Energy for All Initiative (SE4ALL, 2015).

In Africa, nearly 60 per cent of people have no access to reliable electricity. To put this number in perspective, the entire continent of Africa has about 150 GW of installed power generating capacity, uses about 3 per cent of the world's electricity (mostly within South Africa) and emits only about 1 per cent of the world's carbon dioxide emissions. With 45 GW of installed capacity, the entire electricity supply of sub-Saharan Africa (excluding South Africa) is less than that of Turkey. The official electrification rate for sub-Saharan Africa is 32 per cent (REN21, 2016).

The IEA forecasts that in 2030, 1 billion people will still be without electricity: Latin America will achieve universal access; developing Asia will halve the number of people affected while sub-Saharan Africa will keep a negative trend at least until 2025. The IEA foresees an increase in the electrification rate in developing countries from 76 per cent in 2010 to 85 per cent in 2030 (IEA, 2012).

Much of the increase in the electrification rate will come through the installation of new mini-grid capacity. According to IRENA, close to 60 per cent of the total installed generation in 2030 will be off-grid (IRENA, 2012), of which around 36 per cent is expected to come from mini-grid systems, and another 20 per cent from stand-alone off-grid systems (UN Foundation, 2014).



The potentials of mini-grid development have been studied for ECOWAS countries. It is estimated that the grid will supply 75 per cent of the population of 600 million in 2030, leaving 104 million inhabitants to be supplied by mini-grids and 47 million by stand-alone systems. 96,000 localities (45 per cent) could benefit from mini-grids in ECOWAS countries. An investment of EUR 31 billion has been estimated for 128,000 mini-grids by 2030 (ECREE, 2012).

2.1 Benefits of renewable energy-based mini-grids

2.1.1 Affordability

The most expensive task of central grid extension is the electrification of rural areas. According to the World Bank, grid extension prices vary from USD 6,340/km in a densely populated country such as Bangladesh to USD 19,070/km in countries like Mali (ARE, 2011). In the case of Tanzania, it was estimated that to expand the grid for the ‘Southern Agriculture Growth Corridor’, the grid infrastructure costs could be as much as USD 20,000 per kilometre. Such high costs prevent investments in new transmission capacity (SAGCOT, 2011).

On the other hand, advances in small-size generation technologies have brought down their cost to levels often comparable with grid extension to distant rural areas, and the need to increase the penetration of renewable energy generation in existing power systems has been driving the mini-grid sector’s development. In rural areas in particular, the population’s access to electricity is considerably lower than in urban areas (the ratio is 1 to almost 8) and the provision of electric energy to small and scattered settlements is more complex (Colombo et al, 2013). Their technical evolution in the last few years, including the use of modular technology to integrate renewables, has led to a scaling up of renewable energy-powered mini-grids. Micro- and even pico-hydro stations as small as 1 kW are common in many countries, providing local communities with affordable electricity. Typically, such hydro-systems operate reliably for at least 20 years and require minimal maintenance. Nepal had over 2,500 micro- and pico-hydro systems installed by the end of 2012, with a total capacity of 20 MW (REN21, 2014).

Off-grid electrification in many parts of the world is run by diesel generators which are easy to install and run. However, renewable energy technologies (RETs) are now price competitive vis-à-vis diesel generators. As local and global environmental issues related to burning fossil fuels have gained attention, diesel generators in remote and rural areas have been replaced by the increased use of RETs, especially since RET efficiency and reliability are continuously increasing (Mandelli and Mereu, 2013).

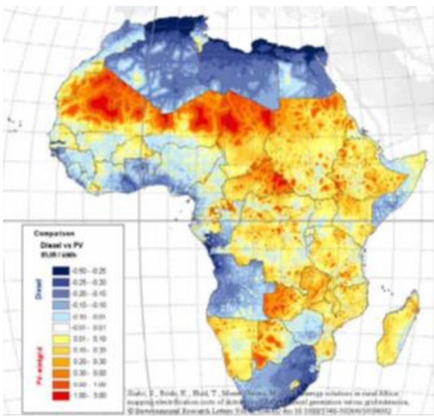


Figure 2 – Geographical comparison of electricity generated with PV and diesel systems

The European Commission’s Joint Research Centre (EC JRC, 2011) has shown that in certain parts of Africa, a solar PV panel can produce double the amount of electricity as in Central Europe and that renewable energy solutions are often cheaper than diesel generation. The map of Africa depicts that electricity delivered by off-grid PV is more economical than off-grid diesel in the yellow-red areas. This is the case both in regions with very low population density, as well as other regions that are relatively densely populated (e.g. Tanzania, South Africa). The price of diesel related to proximity of the main roads and the effects of diesel subsidies are correlated to more affordable diesel prices.

In developing countries, mini-grids offer a viable solution in densely populated areas where, despite the small per-household level of demand, the large number of households and businesses provides a load sufficient enough to justify the cost of mini-grid development (REN21, 2014).

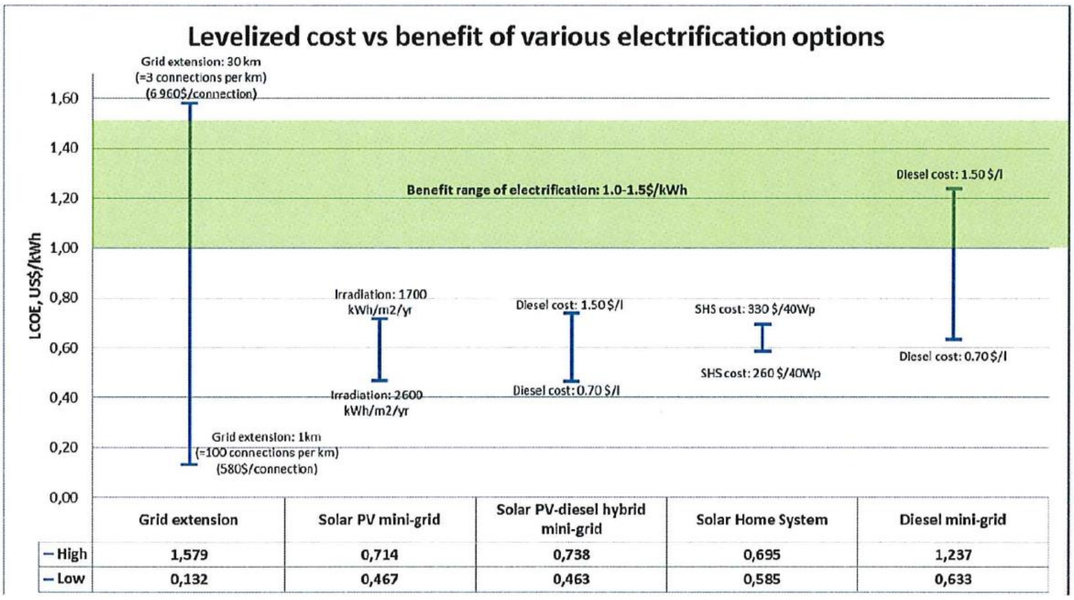
IRENA (2012) developed a Worldwide Renewable Cost Database based on the data of about 8,000 projects (proposed and implemented projects), covering grid and off-grid projects in various countries. IRENA analysed and compared three parameters: (i) investment/capital cost, (ii) levelized cost of electricity generation (LCOE)[2] and (iii) capacity factor.

Very often, renewable technologies are now the most economical solution for off-grid electrification and for centralized grid supply in locations with good resources. The following figure compares the levelized costs of various rural electrification options with the benefits of electrification (Norplan, 2013).

Mini-grids under development benefit from two trends: the declining cost of energy storage and increasing affordability of renewable energy technologies. Taken together, the price reductions make it possible to bring together variable clean energy and storage into renewable energy mini-grids that can support or operate independently from the main electricity grid.

Different renewable power generation technologies can be combined in mini-grids. The complementary nature of different renewable energy options could stabilize power supply and still be cheaper than diesel-fired generation. However, costs are site-specific. There is no single best renewable power generation technology. It is important to note that where demand is purely for lighting purposes, individual systems, e.g. solar panels on buildings, might be more suitable than putting in place a mini-grid that can be more cost-effective where larger loads are required for productive uses.

[2] LCOE is conducted on the real value of future costs, including fossil fuel, in the case of hybrid systems, operating costs, repairs and maintenance and asset replacement at end-of-life (generators, inverters, etc.). LCOE excludes the sunk cost of existing infrastructure, such as the existing power station infrastructure.



2.1.2 Income generation and job creation

One of the main forces driving renewable energy policies and development is the potential to create new industries, particularly small and medium enterprises, and generate new jobs. According to REN 21 (2014), renewable energy jobs are estimated to number 6.5 million globally, with many more indirect jobs linked to it. While many of these jobs have been created in developed economies, there is a growing role for developing countries, with China, Brazil and India taking the lead.

Case study evidence from developing countries shows significant potential for off-grid projects to create jobs and enhance local economic productivity, particularly in the sale, installation and operations and maintenance stages of the value chain. In Tanzania, the Rural Master Plan of 2005 surveyed electrified villages about the impacts of electrification (not off-grid in this case). It found that following electrification, new food processing units opened in 75 per cent of the villages, new metal construction shops in 60 per cent of the villages, new furniture maker shops in 55 per cent of the villages and new saw mills or oil seed presses in 10 per cent of the electrified villages. The survey data also indicated higher monthly incomes in electrified areas compared to similar non-electrified areas (IED, 2013).

Such developments increase the attractiveness of rural energy markets and developing economies for potential investors. As new electricity connections introduce potential for income-generating activities, such as small service shops, there is a higher likelihood of returns on investment. These are activities that cannot function without electricity and are directly linked to the service provided. However, it is noteworthy that an increase in income-generating activities is far from a guaranteed connection to the grid, and the benefits may also be lower if the off-grid scheme does not provide 24 hours, 7 days a week of power, or if the number of connections is restricted.

It is important for projects to be designed with the development of commercial activities in mind. This is because income-generating activities increase the ability for customers to pay tariffs and enabling of microenterprises can also have a large impact on poverty reduction (ARE, 2011).

2.1.3 Environmental and social benefits

Apart from the economic benefits, renewable energy-based mini-grids have environmental and social benefits. They generally replace the use of kerosene or diesel, reducing greenhouse gas emissions, as well as burning biomass in open stoves, which can have detrimental health impacts (such as respiratory disease) as well as be a fire risk in rural communities. Extended daylight hours afforded by electricity also allow people to continue working, or for children to study after sunset or for schools to provide training on subjects that require electric tools, such as computers (UNDP, 2008).

2.2 Challenges faced by investors in renewable energy mini-grid development

In order for investments to occur in renewable energy mini-grid systems, investors look at a variety of factors to ensure the success of a project. The key factors are elaborated below.

2.2.1 Technology choices and technical capacity

The intermittency (and unpredictability) of renewable energy sources is one barrier to meeting rural off-grid demand. The technology choice should theoretically depend first on their cost effectiveness, on the available local resource(s) and on the load profile of the beneficiary communities. In practice, government and/or donors often lead technology choices based on various considerations, such as promotion of a particular sector.

In the past, diesel generators have been used to power mini-grids in rural areas, but this has three main drawbacks (World Bank, 2008):

1) the high cost of fuel and its transport to the remote site
2) the need for regular, skilled human resources for the maintenance of equipment (also applies to biomass gasifiers)
3) volatility of the oil price has drastically increased fuel costs in the past.

Renewable energy technologies (RETs) are increasingly being used to avoid these problems as well as for the additional benefit of reducing negative environmental impacts, but face other limitations imposed by site specificity and the seasonality of resources. Irrespective of technology choice, attention must be paid to ensuring that the energy service is reliable, as any dissatisfaction could result in non-payment and discredit of the technologies and projects.

To ensure quality of service (i.e. no interruptions), the technical design of renewable energy mini-grids is essential. Electricity generation, storage and loads must be managed in such a way as to guarantee the power balance, i.e. ensuring a proper power reserve to face unexpected generation failures or load demand change, minimizing load shedding (disconnection of power generator) and enhancing reliability and ensuring proper voltage control. Moreover, technological choices should be complemented by the capacity and skills to manage and operate the selected equipment. Today, the consensus on best practice is that developers should not design the system based on purely technological considerations, but instead adapt to the specific characteristics of the rural community (ARE, 2011).

A UN manual on mini-grid design advises to carry out an initial assessment of interest, population density, willingness to pay, and how these factors influence the selection of a responsible management entity and appropriate generation source before even committing to install a mini-grid at a site. In particular, demand prediction is a major part of planning. The manual states: “Unnecessarily oversizing a mini-grid increases the cost that the community must cover. Under-sizing it will lead to consumer frustration and dissatisfaction with service quality, a dissatisfaction that can easily lead to the loss of consumers and the inability of the remaining consumers to cover costs” (UN Foundation, 2014).

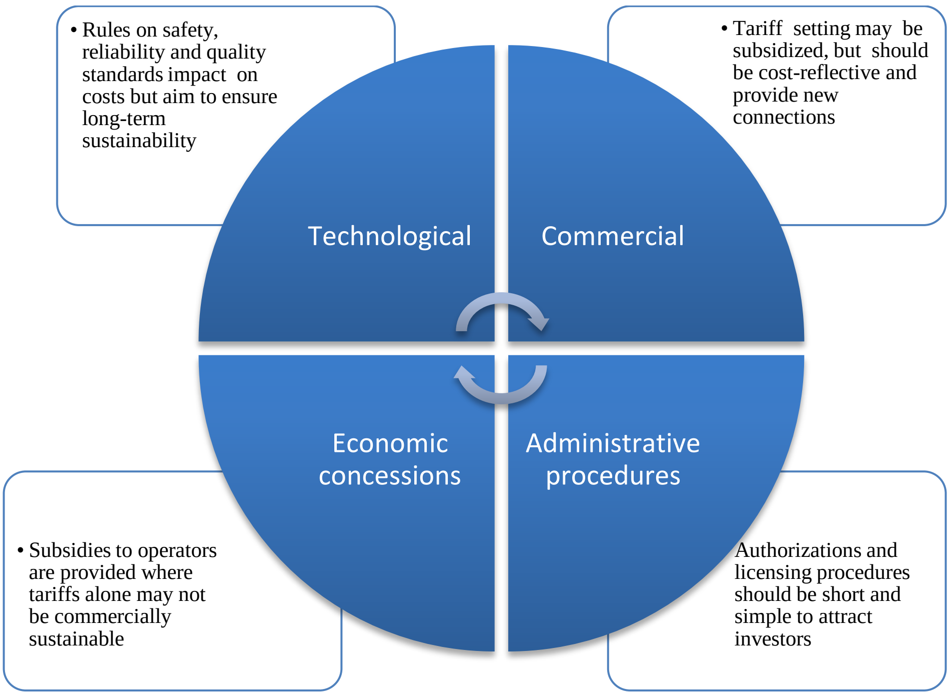
2.2.2 Policy and regulatory framework

Rural renewable energy development requires dedicated policies. Although the policy environment is changing—where governments are embracing renewable energy-geared policies—specific incentives are needed to achieve rural electrification objectives.

REN21 (2016) reports that by early 2015, at least 144 countries had renewable energy targets and 138 countries had renewable energy support policies in place. Two successful initiatives at the regional level were the establishment of trans-national renewable energy targets for 15 members of the Caribbean Community (CARICOM) and trans-national targets in place for the ECOWAS region of West Africa. Targets are insufficient on their own; some 17 of 24 low-income countries have renewable energy targets, but only 7 of them have introduced incentive schemes such as quotas, price premiums or tendering procedures to incentivize renewables. Often, this is due to the strong oil lobby, is historically established and the still continued fossil fuel subsidies in many countries.

Many low-income countries favour the use of renewable energy for off-grid solutions and are integrating them into broader rural development policies and frameworks (World Bank, 2008). Increasingly, governments are moving towards frameworks that support local private sector participation in the development and management of energy systems, and provide environments conducive to new investment.

An appropriate regulatory context can create an enabling environment for successful mini-grid projects. There are four types of regulatory rules an investor will consider: technological, commercial, economic and administrative procedures (e.g. authorizations and licensing of operations).



Renewable energy policy measures are typically taken at national level, but enabling or creating *Rural Energy Agencies* (REA) can provide a foundation for creating rural energy markets that could help stimulate and sustain rural renewable energy industries. An effective agency with power to oversee projects and which has access to continuous financing will create more opportunities for renewable energy uptake (IBRD/World Bank, 2012). The case of Kenya shows that after its Rural Energy Agency was created in 2003, rural electrification levels increased from between 3 per cent and 4 per cent to 22 per cent by 2011. The REA invested in the rural electrification grid infrastructure using internal funding, and then handed it over to Kenya Power (KPLC) for maintenance and operation. The tariff system allows KPLC to adjust tariffs to cover the costs of maintaining the system.

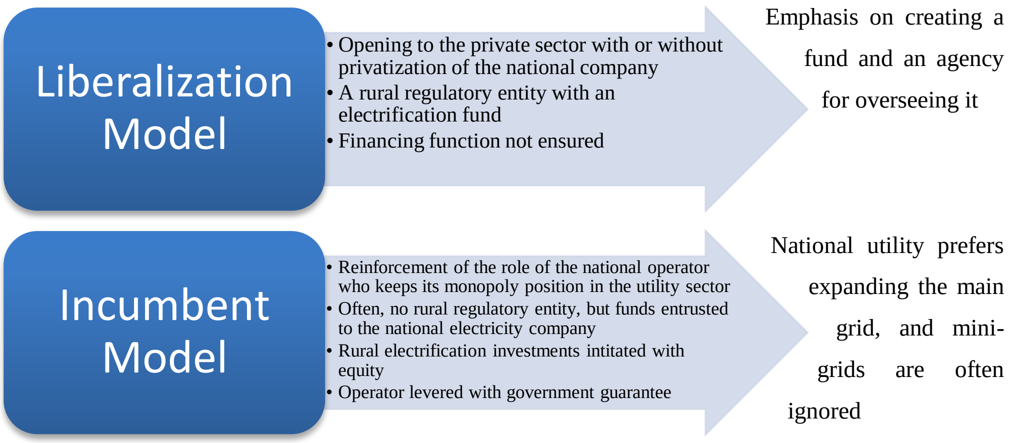
One important success factor in Kenya was the involvement of community organizations to enhance local ownership and buy-ins. Community involvement is also important for cutting the red tape for project developers who have to deal with national administrations. In general, all stakeholders need to be consulted before considering renewable energy-based mini-grid developments. Renewable energy is a crosscutting theme that has impacts on land use planning, agricultural activities, industrial applications, etc. An important success factor in developing large-scale off-grid renewable energy programmes in countries such as Brazil, China, India and South Africa was their inclusion in broader long-term rural electrification programmes that are supported politically and backed by substantial and sustained public resource allocations (FS-UNEP, 2013).

For example, Brazil's Light for All Program, completed in late 2013, was a decade-long effort to provide renewable electricity to 15 million people in rural areas (REN, 2014). The initiative included an 85 per cent capital subsidy for mini-grids with a focus on renewable energy, allowances for the use of prepaid metering, and the inclusion of rural co-operatives as implementing agencies was conceptualized and coordinated at the ministerial level and implemented through rural electricity co-operatives, with nearly 75 per cent of funding coming from the federal government and the remainder from state governments and executor agents.

2.2.3 System financing and risk management

The IEA (2012) estimates that a total of about USD 1 trillion (USD 979 billion) is needed to achieve the goal of universal energy access for all by 2030. This represents an average of about USD 49 billion per year from 2011 to 2030. Around 64 per cent of the additional investment required will be for sub-Saharan Africa, where rural electrification levels are low and a high percentage of the population still relies on traditional biomass fuels, followed by developing Asia with 36 per cent.

The main sources of financing for mini-grids derive from national governments, multilateral organizations, development aid and the private sector (Ekouevi and Elizondo-Azuela, 2013). To increase rural electrification, two models were developed.



Both models can be successful. In Tunisia, the national utility STEG increased the rural electrification rate from 28 per cent in 1986 to 98.5 per cent in 2006; in Morocco, the utility PERG increased the rural electrification rate from 18 per cent in 1995 to 95.4 per cent in 2008. Under the liberalization model, the REA of Tanzania used a dedicated Rural Energy Fund to facilitate improved access to modern energy services in rural areas, increasing access from 2.5 per cent in 2007 to 7 per cent in 2013.

Development aid is often conditioned on the opening of rural electrification services to the private sector, based on the need to mobilize private financing (Club-ER, 2010). One challenge of the liberalization model is to get private operators to mobilize additional resources to attempt to emulate the growth of other service industries such as the mobile phone industry in designing new models for serving rural energy markets.

Initially, mini-grid projects focused on technology demonstration and the immediate impact on beneficiaries. Financial viability and long-term sustainability were not a political priority for grant-based off-grid electrification. Long payback times, low returns and limited availability of secondary markets for mini-grid assets are some of the reasons why private investors see mini-grids as unattractive investments (ARE, 2015). To provide universal access to energy, there needs to be a paradigm shift leveraging private investment where capital sponsors get a good return on their investment. Returns on mini-grid investments typically lie in the range of 10 per cent to 15 per cent, much lower than the 20 per cent and above a typical investor would expect for a comparable on-grid project. To solve this problem, financing schemes must take into consideration and address the range of risks that affect all involved stakeholders. A risk management strategy should be in place when evaluating an appropriate business model.

Operational Risk

- Reduced through long involvement of the project developer, providing continuity in operational tasks
- demand management strategies such as advanced metering and awareness of energy consumption stabalize the network and reduce operational risks
- training to ensure operational skills are available locally
- ensuring resource availability (in case of biomass) through a close relationship with the supplier, where the supplier has a stake in the business, e.g. benefitting from cheap electricity

Financial Risk

- Reduced through co-financing to share risks among all actors: state, private, donors and community
- creating economies of scale, e.g. collection of several villages will reduce operational costs
- progressive investment can provide for a gradual expansion of services to reduce financial risks
- focus on income-generating investments, e.g. in case of solar energy, focus on daytime users to allow a better return on investments.
- reduce risk of non-payment through supply cuts or penalties for non-payment and resolve conflicts through established community institutions
- establishment of reserve accounts to cover maintenance and servicing costs

Governance Risk

- Community involvement during the design of the business model will ensure community buy-in.
- risks reduced when it is a local decision to start a project, with all stakeholders consulted

The Alliance for Rural Electrification (2015) published a report on managing risks in mini-grid projects. They concluded that one important risk reducing strategy is the promotion of productive uses of electricity. It also advocates the implementation of a **standardized risk management procedure** for mini-grid developers to streamline parts of their operations and reap operational and financial benefits. By developing such systems, a transparent basis could be established for financial institutions and for dialogue between different parties and stakeholders.

2.2.3.1 Access to loans

Given the sector's nascent development status, formal financial organizations are generally reluctant to lend to this sector. It is considered high risk for investors. Mini-grid projects require long-term loans (loan tenor ≥ 10 years) in view of the lifetime of the assets. Providing long-term loans is difficult for local banks because they mainly depend on customer deposits to fund their lending. Customer deposits are short-term liabilities. Banks need access to long-term financing to provide loans for electrification projects. A temporary solution to that problem is the credit line facility, such as that used by the TEDAP project in Tanzania, where banks make loans available for up to 70 per cent of the project cost (85 per cent for projects <3MW), refinanced by a Ministry of Finance credit line, up to a 15-year term.

High upfront costs also act as a major deterrent. Banks are reluctant to finance these projects without having sufficient collateral and risk guarantees. The small size of the projects makes it difficult for project developers to attract equity finance due to the perceived problems of project scalability and long payback periods (GNESD, 2014). The lack of ability to obtain loans has driven the usage of crowd funding, which is mainly used for stand-alone systems that require small-scale investments of a few thousand dollars per system (FS-UNEP, 2013).

2.2.3.2 Public sector subsidies and grants

Although new venture funds have recently emerged seeking energy access investments, experience gained from first-generation market development projects in clean energy shows that in almost all cases, significant public resources have been necessary to increase affordability, provide access to financing and remove non-economic barriers (Ekouevi and Elizondo-Azuela, 2013).

Larger scale off-grid renewable energy programmes have succeeded in addressing the intensive initial capital cost barrier through subsidy schemes to incentivize operators to adopt renewable energy technologies while developing electrification schemes in remote communities. The subsidy mechanism applied can include long tenor loans, grants covering up to one-third of the capital costs and low interest loans with grace periods. Such mechanisms in Mali, Senegal and Uganda provide up to 80 per cent subsidy on the initial capital costs, allowing private operators or energy service companies to engage in rural electrification schemes with rural energy technologies (World Bank, 2010).

Incentives can also take the form of tax exemptions. Thailand has a particularly progressive strategy in that renewable energy deployment is partly financed through taxes on fossil fuel-based energy consumption, helping to internalize some of the social and environmental costs of fossil fuels and to level the playing field for renewable energies (REN21, 2016).

Alternatively, the government may establish a rural energy fund to support such investments on a first come, first served basis. In either case, the government usually needs to subsidize a portion of the capital cost, while the community or private sector covers the balance investment cost and full costs of operation and maintenance.

2.2.4 Business models utilized for rural mini-grids

Business models describe the organizational structure of mini-grid implementation and operation. The 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 model for mini-grids. 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.

2.2.4.1 Ownership and financing structure

Ownership is usually the dominant and most decisive element in terms of what type of business model to use, as ownership is closely linked with the actor responsible for the implementation of the project and who will be responsible for the operations, management and maintenance (ARE, 2011). The four main mini-grid operator models are the utility, private sector, community and hybrid models.

In the **utility operator model**, the utility is responsible for all mini-grid operations and is usually reliant on state support to cross-subsidize mini-grids in rural areas. Utilities usually do not invest voluntarily in mini-grids because they often consider mini-grids as a non-core business.

Private operator models have a high potential for scale- up, for attracting private investments and for mobilizing the know-how of the private sector. There are two main private investor-based business models that have been utilized in the field:

Build-Own-Operate (B-O-O)

- Private investors co-finance the construction of a mini-network (production and distribution assets) with a grant for the investment costs
- Other financial contributions are sought to reduce costs, such as costs of training the local maintenance crew
- Recovery of the investment cost is through a liberalized tariff

Independent Power Producer (IPP)

- Private investors only invest in production assets. Either the state/community/donor invests in the distribution network, or the private sector in a Public Private Partnership (PPP)
- Other financial contributions are sought to reduce costs (training, for example)
- The developer can be charged with the maintenance of the distribution network
- A cost of transfer or a (preferential) tariff is negotiated to allow the operator/investor to recover its investment and operating costs

The **B-O-O model** is preferred where the combination of a liberalization of tariffs and grant investment costs is high enough to recover the investment without an additional premium on the price of electricity. Grants are provided to finance a portion of the investment costs to reduce the funds, which the investor has to mobilize in the form of equity or loans. Grant financing is typically also required to make tariffs more affordable or to oblige investors to charge low connection fees. Grants probably need to be considered in a much more creative way than just a straight investment subsidy or tariff subsidy. They could be engineered creatively as (partial) risk guarantees to cover political risk or guarantees commercial banks would want and the company cannot provide in order to access loans (IED, 2013).

Under the B-O-O model, liberalized tariffs are set, but customers have a low demand for electricity and a low capacity to pay. Their default risk is increasingly minimized by the use of prepaid meters but the risk remains that demand will turn out lower than expected. One strategy to minimize that risk is having an anchor customer with a high demand for electricity. The risk then of course depends on the business of the anchor customer.

The **IPP model** is preferred where the combination of liberalization and subsidy rates of the investment cost is insufficient to recover the investment and the addition of a premium on the price of electricity is required, e.g. through feed-in tariffs. Under both models, subsidies are given. To ensure financial sustainability, subsidies should be minimized as much as possible, and should mainly be given as investment-based or connection-based subsidies, because output-based or operational subsidies do not properly reflect the actual cost of the electricity (ACP-EU, 2012).

Where a rural area does not attract private interest, the community may become the owner and operator of the mini-grid. The **community-based model** is becoming more common. In Latin America, many small rural suppliers have the legal status of cooperatives while some of the medium-sized systems are co-owned by municipalities that own and operate their own systems. Compared to the alternatives, the owners and managers in a cooperative or community-based organization are also the consumers and therefore have a strong interest in the quality of the service and a real involvement in its management.

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 carried out by third parties, as local communities rarely have the technical and economic expertise to develop and implement mini-grids. Community-based organizations increase community self-sufficiency and self-governance and are often more efficient than utilities, which tend to be bureaucratic, but they lack the skills to develop sustainable tariff plans that cover reinvestment/depreciation, operations and maintenance costs. As a result, they require substantial technical assistance. Communities most often use the cooperative approach for mini-grid ownership and management.

Innovative multi-stakeholder or hybrid business models have emerged to encourage more private sector involvement in the sector, in particular for the development of smaller scale mini-grids. This approach benefits from the advantages of each of the models, i.e. private sector expertise, community participation and state involvement, all of which are necessary for creating an enabling regulatory and political framework.

One type of contractual arrangement is in the form of **public private partnerships** (PPPs) 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. Customers are allotted energy blocks according to their energy demand requirements and capacity to pay. Another PPP approach is the concession model where the holder of a concession enjoys beneficial terms for providing electricity as a monopoly for a certain period of time (typically, from 15 to 25 years, in a defined geographical area) or a specifically designed tariff for the area. Another form yet is the Power Purchase Agreement (PPA), where the distribution and generation assets are not in the hands of one entity and a contract for the delivery of electricity is signed.

PPPs have been regularly replicated in Asian countries (REN21, 2016). There is a successful PPP in Laos, which funds a mini-hydro/solar PV and diesel grid, serving more than 100 rural households. In the project, public partners fund the capital assets, while the local energy provider finances the operating cost (IEA, 2011).

2.2.4.2 Tariffs, ability and willingness to pay

Tariff setting is often the most challenging part of developing the business model. In order to have a sustainable system, consumers must be willing and able to pay the consumed energy. The tariffs should be structured so as to balance both sustainability and affordability.

In projects where the initial capitalization is heavily subsidized, the main focus on calculating the tariffs is often affordability and willingness to pay, and the tariffs are at best break-even-tariffs. In these cases, the avoided costs such as the price of substitutes like diesel and candles are used when calculating how much customers are willing to pay.

Often it can be difficult to measure exactly what the break-even tariff is and how much it will cost to replace the scheme in 30 years' time, for example. The willingness to pay in sub-Saharan Africa was estimated to be around EUR 0.38[3] (USD 0.43)/kWh in 2010, which is higher than the prevailing grid tariffs (EUEI, 2014). Willingness to pay is, however, not a fixed value but strongly depends on the quality of service provided and the available alternatives. The challenge of weighing affordability and willingness to pay against the most cost effective tariff is also difficult. It is important to obtain specific local data to assess the actual willingness to pay (World

[3] USD 1 = EUR 0.88 in April 2016.

Bank, 2008). In many cases, the communities decide what the tariff should be, and it is important that they have the information needed to take an informed decision and to choose a financially viable tariff (ACP-EU 2012).

The tariff structure can differ:

- *Energy-based tariffs* based on actual energy consumed using a meter to provide information to the customer about how much energy was used, which gives a strong incentive for energy conservation. ***Prepaid meters*** have been used to make the cost of electricity predictable, but without time limitations, there are difficulties for planning the reliability of the system. Installing meters can also be expensive, although there are new technologies with which the customer can use a mobile phone to read the meter and report on energy consumption, as well as to purchase pre-paid units, which reduces operating costs (ACP-EU, 2012).

- *Flat rate (or power-based) tariffs* based on expected consumption where customers with higher demand buy a higher level and pay more. The advantage of this system is that expensive meters are not necessary, and that the customers know in advance how much they are going to pay. The disadvantage can be that there is no incentive for energy saving, that the electricity available for customers is limited, and that the system has a risk of being overloaded and **post-paid billing** can lead to high debts. In case of non-payment, load limiters can be used to limit the current entering the property. Load limiters are much cheaper than normal meters (EU-ACP, 2012).

- *Fee-for-service tariffs* charge for services provided rather than for unit of energy. The tariff is based on kg, hour, litre or other units of service. The price of services is often determined around the avoided cost of kerosene/diesel.

- *Intelligent tariffs* that change according to electricity demand, providing incentives for electricity usage when surplus energy is available. This stimulates consumer understanding of the technicalities and ensures load scheduling (demand side management); here, advanced metering systems are needed.

- *Graded tariffs* where the first kWh used is cheaper than higher consumption.

- *Customer class tariffs* differ according to consumer group, e.g. residents, institutions and businesses (mostly used to cross-subsidize residents).

- *National tariffs* (subsidized) may be used in villages near the project site, and it can create frustrations when a project requires customers to pay a financially viable tariff that is higher than the national tariff.

Customers also need to pay connection fees, which are important to gain the commitment of electricity consumers. To make it affordable, connections fees are often reduced and retrieved through tariffs.

Ideally, the tariff should aim to cover both the energy consumed (variable costs) and pay for fixed costs, such as connection charges, maintenance, etc. However, such a tariff does not incentivize customers to use electricity efficiently. On the other hand, fixed tariffs consisting of the energy tariff component only, like in a pay-as-you-go scenario, mini-grid operators take on high risks in terms of planning for demand. To provide the flexibility required for pay-as-you-go payment and related varying load curves, a flexible power source such as a diesel generator is required.

2.2.4.3 Productive uses of energy

Deployment of small-scale subsidized mini-grid projects has only marginally contributed to increasing energy access—due primarily to high transaction costs, a lack of long-term strategy, and a focus on meeting only basic energy needs (UNIDO, 2010). To make a mini-grid project sustainable in the long term, consumers should start commercial activities in order for the system to be able to retrieve its costs. The cost of a mini-grid built to serve a small community's electricity needs is sometimes only justified when productive loads—especially daytime loads—are large enough to supplement the night-time household loads.

Businesses and industry, so-called productive use customers, use electricity for different purposes such as agriculture, milling, rice de-husking, oil pressing, wood/metal workshops, commercial ventures such as shops, bars or anchor loads (e.g. telecom towers, mines, greenhouses, hotels). Each productive user group has distinctive loads/appliances, with specific load profiles. Grid-based electricity can improve their productivity and can increase the sustainability and profitability of mini-grid projects. Mini-grid operators should therefore seek to fill this gap and support commercial and industrial activities. The key is to ensure that the potential productive application is likely to happen once the mini-grid is built. This means identifying the likely local participant for the microbusiness early on and assisting that individual in developing a business plan and identifying financing modalities. Additionally, productive users need a stable electricity tariff regime because a spike in electricity tariffs can drive micro-businesses into bankruptcy. Therefore, financing additional generation capacity should be done by connecting additional customers or productive loads and not by increasing tariffs.

2.2.4.4 Community participation

To gain acceptance by consumers, community participation is an essential ingredient for ensuring equity and the sustainability of any decentralized electrification (GNESD, 2014). Understanding consumer needs, preferences and budgets is crucial for achieving financial viability of mini-grids, whether for use by households, businesses or community facilities.

When energy products and services are oriented towards consumer energy use and budget demands, consumers are quick to adopt them (WRI, 2013). Consumers are affected by employment and seasonal income patterns, technical capacity and after-sales service provision, traditional practices that are difficult to change, e.g. cooking with wood fuel, overcoming scepticism about distributed energy solutions that are seen as inferior to the main grid, infrastructure issues and access to financial institutions.

Inclusive business strategies that prioritize consumer involvement are essential for fostering understanding, identifying solutions and avoiding problems. Local participation in the form of village energy committees or electricity cooperatives has reportedly contributed to better project management. The earlier the community is involved in the project, the better.

The company Husk Power Systems[4] (HPS) in Bihar, India, for example, installs biomass gasification mini power plants (25kW – 100kW) that convert agricultural residue (primarily rice husks) into electricity, and builds micro-grids for villages of up to 4,000 inhabitants on a pay-per-use basis. HPS customizes energy packages and the corresponding cost structures for households, and spends time to raise awareness about the benefits of biomass-generated electricity, even though this often involves site visits, which are time consuming and labour intensive. Since 2008, HPS has provided electricity to over 200,000 people and employed 350 people across 300 villages in the State of Bihar.

Innovative multi-stakeholder business models are continuously emerging to provide customized and financially sustainable services based on renewable energy across the spectrum of rural energy needs. Yet even with a strong focus on market development and PPPs, the financing of universal energy access ultimately depends on how strategically and efficiently available public and concessional resources—as well as carbon financing—are used to attract private investment. In some cases, even with high capital subsidies, the upfront costs of technological solutions exceed by an order of magnitude the upfront payment capacity of poor households.

[4] http://www.huskpowersystems.com/innerPage.php?pageT=Community%20Impact&page_id=81

3 Case study narratives and analysis

Eight case studies are presented here. The analysis of each one will focus on the factors ensuring successful development of a renewable energy mini-grid project.

The specific challenges presented in Chapter 3, technical, regulatory, financial and business approach as well as community involvement, will be analysed for the eight cases. Successes and lessons learnt will be presented, and each project rated according to the following five criteria[5].

(i) Sufficient revenue to support the mini-grid

(ii) Willingness and ability of consumers to pay bills

(iii) Community participation

(iv) Capacity of national regulator/ utility / renewable energy agency to support and promote off-grid projects

(v) Local capacity building in design, manufacture, assembly, operation and maintenance.

Mini-grid projects that are able to meet these evaluation criteria should have a good chance of success in the long term. The eight selected UNIDO projects are evaluated for their ability to meet these criteria and look at the factors influencing their successes and failures. Table 1 below offers a snapshot of the renewable energy mini-grid projects to be analysed, and Tables 2 and 3 present an overview of the business models used and outcomes of the projects, respectively.

[5] See Annex for full description of evaluation criteria.

Table 1 Snapshot of projects

	Chad	The Gambia	Guinea-Bissau	India	Côte d'Ivoire	Sri Lanka	Tanzania	Zambia
Technology	Solar PV	Solar PV – gasoil hybrid	Solar PV	Ultra-low head micro hydro	Solar PV	Hydro – biomass hybrid	Small hydro	Small hydro, solar PV
Capacity	112 kW	60 kW	312 kW	30 kW	200kW	64kW hydro 16kW biomass	1 MW	1 MW hydro 390 kW solar
Number of grids/ connections/ beneficiaries	3/213 connections	1/ () connections	3/265 connections	3/ 3 connections (only businesses connected)	7/900 connections, 4,000 beneficiaries	1/65 connections	1/10,650 households	2/25,000 beneficiaries (SHP) and 450 households (PV)
Beneficiary	Private operator TTA	NAWEC (national water utility)	TESE Development Agency	Renewable Energy Development Agency and Irrigation Department	NGO Akwaba	Village society	Small power producers (e.g. AHEPO in Andoya)	ZESCO (national utility), REA (Rural Energy Agency)

Table 2 Business models used

	Chad	The Gambia	Guinea-Bissau	India	Côte d'Ivoire	Sri Lanka	Tanzania	Zambia
Ownership and operator	Private, market-oriented, operated by TTA on a concession of 1 year	Public, operated by NAWEC	Private non-profit-oriented, operated by community association	Public and community, IRI operates first site, other 2 to be operated by community	Community management, market-oriented, operated by CR Technology-Warex	Community management model, non-profit-oriented, operated by consumer society	Private companies, Church-based entities and community	Public operated by ZESCO and REA
Community participation	Village association co-sets tariffs with private operator	Participation of local stakeholders in project identification	Tripartite management model: ACDB, DREB (state) and community	Community participates from site selection to operation	Community management model	Community is setting tariffs for electricity supply	Some sites are community partial funding and operated and maintained.	Community participation throughout (except during project identification)
Tariff structure	Tariff linked to daily service (Wh/day)	NAWEC tariff in 2015 for Domestic Credit metering (0-300 kWh) - USD 0.323 per kWh	Tariff linked to time of use (normal and social tariffs)	Businesses pay all costs and get INR 4.4/ kWh (for electricity supplied to the grid)	Flat rate per household	Flat rate per household	FiT for sale to TANESCO, direct sale and community tariff setting	Liberal
Metering	Prepaid meters	Credit metering	Prepaid meters	None – households not connected	Prepaid meters	Prepaid meters	Prepaid meters	Prepaid meters
Financial mechanism	Investment grant	Investment grant	Investment grant	Investment grant, PPA, technology transfer	Investment grant	Investment grant	Investment, loans, grants and FIT under SPPA/T	Grant turned into soft loan

Table 3 Project outcomes

	Chad	The Gambia	Guinea-Bissau	India	Côte d'Ivoire	Sri Lanka	Tanzania	Zambia
No. of jobs created	3 permanent staff	Local workforce used for civil engineering	12 permanent jobs	27 permanent jobs	50 (4 permanent per village for O&M) + specialized sub-contractor +productive use) (estimate)	3 permanent jobs (technicians operating hydro plant)	100 during construction phase	500+
Productive activities supported	Water pumps for agriculture, and SMEs	Milling machines, tailor and welding shops	Zync plant, juice production plant	Agro-food, eco-tourism, energy services including local manufacture	Agriculture, shops	Carpentry, irrigation, shop, energy supply service, eco-tourism	Maize, rice, saw mills, agro-processing, flower farm	Lodge, shops storing frozen food, (fisheries)
Reduction in cost of energy		None	14% average	Savings of USD 4,500/year from 1^{st} site				From USD 320 (diesel) to USD 40/ month
Regulatory and institutional changes	Created the Agency, for Development of Renewable Energy (ADER), draft policy on RE mini-grids submitted for approval	Revised renewable energy law, establishment of renewable energy fund	Ongoing process to review energy policy, including creation of a regulatory agency for the sector	New policy guidelines for micro hydro, state policy on the development of hydro up to 2MW, specific grants	Strategic plan for RE, 20% target by 2030, new electricity code opens competition, fossil subsidies reduced	None	Revised national energy policy, SHP Centre, Master's programme	Revised national energy policy in May 2008
Greenhouse gas reduction	30 tCO2eq/year (estimate)	2,206.3 tCO2eq/year	409 tCO2eq/year	286 tCO2eq/year	70 tCO2eq/year (estimate)	45.6 tCO2eq/year	2,800 tCO2eq/year	6,088 tCO2eq/year

3.1 Overcoming technical and financial obstacles in chad

3.1.1 Project background

Chad's energy balance is characterized by a strong predominance of wood fuels (over 96.5 per cent), 3 per cent of petroleum products and 0.5 per cent of conventional thermal electricity. There is almost a total absence of renewables. The total installed power capacity in Chad is around 120 MW, and over 90 per cent is consumed by the City of N'Djamena, where access to electricity is around 30 per cent. The rather antiquated distribution network is the source of important technical and commercial losses and untimely power cuts. In addition to the City of N'Djamena, a dozen cities and secondary centres have mini independent networks. Throughout the country, access to electricity barely exceeds between 3 per cent and 4 per cent in total.

The overall objective of the project is to improve access to electricity for people living in rural and remote areas.

Project timeline: June 2012 – October 2015

Total financing and donors: USD 2.589 million (USD 1.758 million by the Global Environment Facility (GEF), USD 0,771 million by the Government of Chad, USD 60,000 by UNIDO)

Project partners: Ministry of Energy and Petrol (MEP), TTA Engineering Company, Village Associations

Project components:

1. Study the institutional and regulatory mechanisms to enable mini-grid development and offer recommendations: Chad is currently developing an Action Plan for New and Renewable Energy Development.
2. Feasibility studies to determine 5 pilot solar mini-grid sites and organization of training in the HOMER software for public and private agents
3. Construction of mini-grids, including elaboration of a management model and training of local actors and establishment of local associations and technical teams for operating the mini-grids.

3.1.2 Regulatory context

Chad has finalized its Master Plan of the Energy Sector in February 2012 and launched the implementation of the National Development Plan (2013-2015) in February 2014. This indicates that there is significant potential in new and renewable energies. The government created an Agency for the Development of Renewable Energy (ADER) in August 2013, but the agency does not yet have clear supervisory powers over mini-grids and lacks appropriate financing to promote further incentives for investing in renewables. Law No. 14 established a fund for the development of renewable energy, with ADER being the beneficiary of a percentage of revenues from refined petroleum[6]. However, the current low price of petrol constrains the money that is available. In addition, a decree that concerns the application of these funds is not yet in place, while subsidies for fossil fuels remain in place. There are XOF 28 million[7] (approx. USD 50,000) that have been set aside for small grants for renewable energy projects.

The Ministry of Energy and Petrol (MEP) has the lead in promoting renewables and has recently presented two draft documents, a Draft Law of Electrification for Chad that pinpoints the development of the renewable energy mini-grid sector in rural areas and the implications on the private sector, and a draft Rural Electrification Policy, which have both been submitted to ADER for validation and passing.

3.1.3 Technical challenges

One of the biggest challenges is that awareness of renewable energy technologies and management techniques in Chad is scarce. Aspects related to training and awareness-raising are paramount in any activity.

One of the first project activities was to deliver training to 35 public and private stakeholders in the HOMER software. HOMER is a computer model that simplifies the task of designing hybrid renewable mini-grids. It can be used to evaluate the economic and technical feasibility of different technology options and to account for variations in technology costs and energy resource availability[8]. Training for public and private stakeholders also included a course on the management of mini-grids based on renewable energies (44 persons trained).

Further training was carried out at the project sites, on the management of solar installations (6 persons per site), training for the maintenance and management of technical teams, and for the

[6] Chad has been involved in oil production since 2004.
[7] USD 1 = XOF 575 (CFA francs) in April 2016.
[8] www.homerenergy.com

financing of mini-grids. Twelve engineers at N'Djamena received training in technical surveillance and project maintenance.

3.1.4 Business model and financing

The business model is based on a concession from the government to a private operator to build and manage the mini-grids with liberalized prices, and a grant that covers the investment costs of the equipment.

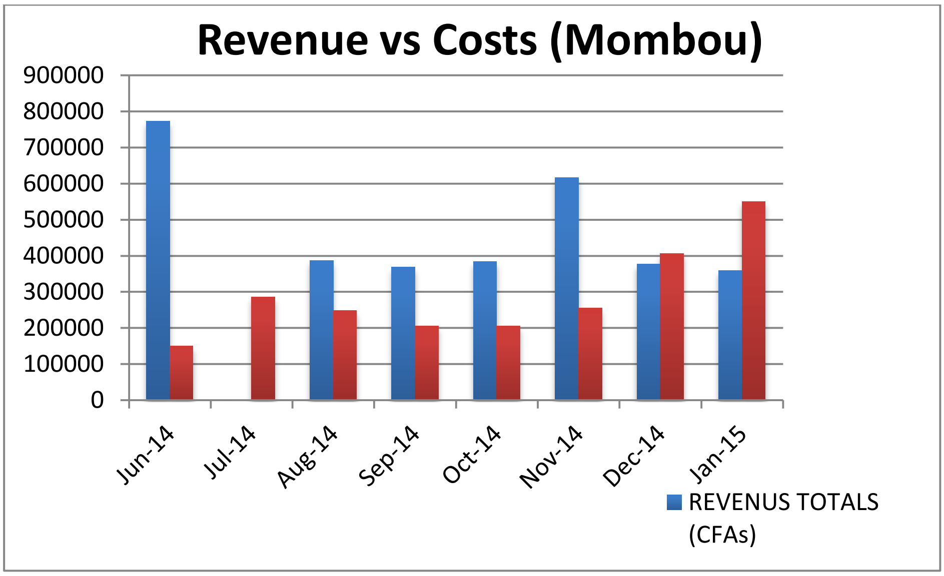
Originally, the project foresaw the building of 5 mini-grid sites. The business model envisaged that 5 sites with the simulation of larger consumers connected to the grid would make it financially viable for a private operator to maintain and operate the systems. However, more than half of the expected co-financing from the Government of Chad did not materialize. As a result, the project was reformulated to build only three mini-grids in three villages in the localities of Mombou, Douguia and Guelendeng (phase 1). The two other localities were foreseen to be Maïlao and Dourbali (phase 2).

Three PV mini-grids have been built with a total capacity of 111 kilowatts (Table 4 depicts the capacity and performance of each). At Mombou, the central PV equipment (39.6 kWp), distribution lines and connection of households with electricity meters/distributors to 133 connections have been installed. Mombou is operational since June 2014 and 11,200 kWh were generated, which offset 10 tCO_2e. At Douguia, 34.6 kW with 54 connections, started operations in June 2015, connecting mainly SMEs operating in the village, while at Guelendeng 36kW was installed with 26 connections in June 2015, providing lighting to public and administrative buildings as well as street lighting.

Table 4 Capacity and performance of mini-grids in Chad

	DOUGUIA	MOMBOU	GUELENDENG
Capacity PV (kWp)	34.6	39.6	36.7
Battery capacity (kWh)	440	440	160
LV distribution line (km)	2.7	9.7	5.9
Public lighting	11	11	30
No. connections	54	133	26
Total no. of beneficiaries	3,000	500	10,000
Electrification rate	50%	98%	13%

The chart below presents the results of the operation at Mombou in terms of costs and revenues earned.



The financial risks are evident due to the lower revenues that were collected at Mombou as the project progressed. At that rate, it will be difficult to cover the cost of future renewals/maintenance. In addition, the lack of co-financing means that there is a significant risk that operators will not be interested in the management and maintenance of the three sites. The current contractor, the Spanish engineering company, TTA, with experience in building remote mini-grids in developing countries, asserts that replication of the model in many additional villages is necessary to ensure economies of scale and to make it feasible to operate with an adequate return on investments. Involving large consumers who could act as future investors to sustain the model is also crucial. This risk relates to the observation made earlier that a certain economic infrastructure should already be in place for the business models of the mini-grids to succeed.

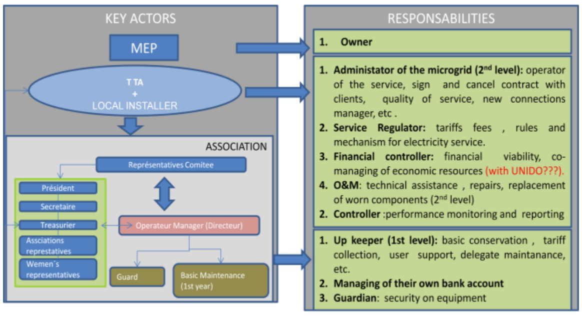
3.1.5 Community participation

UNIDO’s experience in Chad shows that private entities are more likely to be engaged, if the rules for operation, licensing and tariff design are simple. It is also important for community organizations to support such activity and be involved in decision-making.

In the case of Chad, a lack of national regulation on administrative procedures on mini-grids makes it possible for decisions to be taken at the local level. This allows for reduced costs and increased efficiency in setting rules on operations and tariffs.

In the village of Mombou, the decision reached between the developer and the community was to create tariff categories in accordance with daily service (i.e. Wh/day). The tariffs were then presented and approved by the project's Steering Committee. This model type affords more ownership to the community because the agreement is negotiated with the developer. Consequently, the village council or electricity association feels responsible for ensuring that the operator complies with the terms and conditions of the supply contract/license. Moreover, the village electricity association can assist in enforcing compliance in terms of quality of service if established in a license or grant agreement. Third, such a model can reduce the likelihood of electricity theft and unpaid invoices because the association can also play the role as partner in the operation. Theft is less likely to occur when rules are openly shared with a village body. The incentive for the village is to get results: reliable electricity supply for new and existing customers. In case of conflicts, the village association has a strong incentive to take timely action in a way that a national regulator would not.

The project aimed to support gender mainstreaming by ensuring that the local association in Mombou has 2 women out of 6 members, and that at least one woman was trained in the HOMER software.



This chart depicts the management model used in the first year of operations. The model's main feature is that a private entity (in this case TTA) is responsible for the operation of the service, with a concession on public assets, and is also in charge of the financial management of the revenues and expenses. Moreover, it supervises the economic sustainability of the entire service.

The village association enforces the quality of service assessment and tariff collection (and defines penalties for non-payment) in collaboration with the operator. Only the director, maintenance personnel and guard of the village association receive a monthly salary.

After the first year of operation, it is planned to put in place a new electricity service management model based on a concession to replace TTA as the local operator of the three existing micro-grids, and the future villages to be covered with solar PV micro-grids. In this model, the village associations are the "regulator" and collaborate on certain maintenance tasks.

3.1.6 Successes and lessons learnt

At the outset, it should be mentioned that working towards a market-based model in Chad—a country where doing business has been challenging—is an effort that is likely to take longer and more than one development project. The security threat during the final year of the project made logistics and project operation particularly difficult, and this may have affected some of the project's results.

Nevertheless, the project's major success is increased awareness about the prospects of using renewable energy for electricity in Chad, not only locally, but also at government level. The government recognizes that access to electricity for the rural population will not be achieved through grid extension and is therefore particularly interested in replicating this business model.

More people now have access to electricity, and 112 kW of solar energy has been installed with 213 connections. With the help of electric metering installed in each user's residence, people learn to understand their own energy consumption. In addition, street lighting provides for more security, and connecting mosques, schools and medical centres promotes better community cohesion and care.

The flexibility and user-friendliness of the model has contributed to its success, where the contractor and community agreed to work together to manage tariff setting and collection. This system ensures that the operator's costs are covered by the tariff, but that at the same time, the community's needs are reflected in the charges for electricity.

Although not many new jobs were created, existing technicians quickly acquired a new skillset of applying their expertise to solar systems, and have thus created new avenues for income-generation and entrepreneurship.

Many of the risks were identified and mitigated from the start of the project. Regulatory tools were developed to strengthen the sector and encourage private sector involvement, and the communities were involved from the beginning. They were trained to raise awareness of RE technologies and to improve their skillsets for managing a mini-grid. The management of the project was subcontracted to a private operator to mitigate operational risks.

The project may, however, have underestimated fossil fuel price fluctuations and the government's ability to co-finance the project under different economic conditions. Moreover, the institutional framework to allow private sector operation is still not in place. The lack of co-financing ultimately meant that only three instead of five sites were developed, losing the attraction of economies of scale for potential investors.

For the project to be a success, more people need to connect to the grid and develop productive uses. Growth of productive activities is expected at Douguia in the short term, and in Mombou, water pumps have been connected for agricultural activity. However, there is a lack of knowledge and finance to develop productive activities, and there is a need for awareness and micro-finance to start businesses.

The project demonstrates that the business model can work in places where productive activities and small industries as well as certain basic infrastructure are already in place, as in the case of the sites at Douguia and Guelendeng. In Mombou, which has very little productive activities apart from farming, it will be very difficult to make the model work, as the majority of users chose the very basic tariff (light bulbs at home) and the revenues barely cover the maintenance of the system. The feasibility studies carried out beforehand to assess the purchasing power and willingness to pay overestimated the demand at the site, and needs to be more accurate, or a greater level of detail and study in the project preparation phase will be necessary, as well as more investment to support the development of productive activities.

The government should make the most of the momentum that this project has created and should consider funding or incentivizing the development of similar renewable energy projects in the future. In this regard, the ongoing work on the policy/regulatory framework is expected to provide clear options to policymakers. In some cases, the option of engaging with development banks to (partially) take on the upfront investment in mini-grids should be explored. It is also recommended to include a role for the developer to have a partial investment in equity and own mobile assets in future projects.

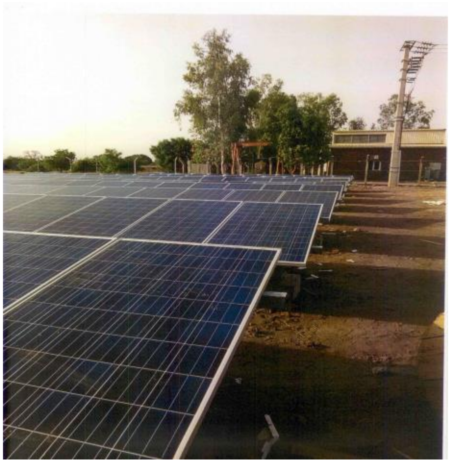
Replication elsewhere would be facilitated by collaborating with ADER to increase its role in developing and monitoring mini-grids in the country. It is recommended that ADER assumes the role of supervising the management of mini-networks and be involved in identifying future sites for replication of the project. This supervisory role can differ depending on business model, i.e. whether it is public, private or community-owned.

Assessment table

Revenue to support mini-grid	Sufficient	Cost of operator are covered by tariffs and grants for operation and maintenance, but the lack of finance prevented expansion to two more sites and to start productive activities
Willingness and ability of consumers to pay	Good	Community involved in tariff setting and collection of payments; project has high rate of payment
Community participation	Good	Community association in place from the start, population understands the benefits of grid-based electrification
Regulatory framework	Sufficient	Created by ADER; its role could be strengthened to be able to support long-term viability of the project, e.g. access to funds. A new electricity code should be passed to encourage private sector investors
Local capacity building	Sufficient	Local jobs created and new skills acquired by existing technicians; long-term approach to expand skillset beyond the project is recommended as an additional task for ADER

3.2 Renewable energy for productive uses in The Gambia

3.2.1 Project background



The Kaur mini-grid is one of six demonstration pilots implemented within the UNIDO/GEF 4 project "Promoting Renewable Energy Based-Mini-Grids for Productive Uses in Rural Areas in The Gambia". The project aims to avoid GHG emissions by developing and promoting a market environment that will stimulate investments in renewable energy in The Gambia, which, in turn, will help drive economic growth and support the country's rural electrification efforts.

The project promoter, the National Water and Electricity Company (NAWEC), operates six provincial mini-grid systems. These systems are based on light fuel oil-generating sets and are extremely expensive to operate, requiring provincial electricity tariffs be subsidized by urban tariffs. Kaur is the smallest of these mini-grid systems with 3 x 60 kW engines, and is the site of productive activities including the second groundnut processing plant in the country. The promoter, NAWEC, agreed to install and commission a 60 kW solar PV system at Kaur to replace one of the existing fuel-based engines.

Project timeline: January 2014 – May 2015

Total financing and donors: USD 478,000.00 financed by NAWEC, GEF and UNIDO.

Project partners: Gambia Renewable Energy Centre (GREC)

Project components: The overall objective is to contribute to substantial diesel fuel consumption savings and demonstrate cost-effectiveness.

1) Install a hybrid solar gasoil mini-grid system at Kaur;

2) Strengthen the legal and regulatory framework for the renewable energy sector;

3) Build capacity by training technicians on the design, installation and maintenance of hybrid systems.

3.2.2 Regulatory context

In The Gambia, the legal and regulatory framework provides an unprecedented momentum for the adoption of renewable energy solutions, including mini-grids powered by renewable resources.

Within the UNIDO/GEF 4 project, a renewable energy law was developed followed by the adoption of a Renewable Energy Act in 2013. The Act provides that companies involved in electricity generation from renewable energy resources or hybrid systems in off-grid areas, which build the required facilities to connect end consumers (private wire network), are allowed to charge electricity tariffs to end consumers up to the current national retail tariff rates determined by the authority. This is the case provided the capacity of the generating facility on such private wire networks system is not greater than 200 kW. The Act also provides for:

(1) the establishment of the Renewable Energy Fund;

(2) streamlined permit procedures to simplify the permit process for facilities using renewable energy resources. This provision requires the relevant government agencies to respond within 10 business days acknowledging receipt of any permit application and informing the applicant of any missing information required to assess their application;

(3) incentives such as exemption from import duty for all renewable energy equipment that fulfils a number of criteria.

In 2014, the Government of The Gambia, in collaboration with the New Partnership for Africa Development (NEPAD), and with support from UNDP and the EU-ACP Program adopted the SE4All Action Agenda together with an investment prospectus towards achieving SE4All goals by 2030.

3.2.3 Technical challenges

Transporting fuel around rural Gambia is challenging in terms of costs and time. When fuel is available in Kaur, light oil gen-sets operate approximately from 9am-1pm and again from 6pm-1am. Their monthly average electricity consumption is around 16,073 kWh, with daily generation varying from as little as 405 kWh (February) to 913 kWh (August).

NAWEC’s main objective in terms of installation of the hybrid-solar power system at Kaur is to save fuel, and to alleviate the difficulties related to fuel transport in rural areas of The Gambia. In addition, as solar irradiation is typically available between 7 am – 7 pm, productive users could increase their demand during the day. As of now, the solar PV system supplies the same customers the diesel system used to supply. The solar PV operates from 8 am – 2 pm, followed by a 4-hour (all) systems shutdown, and an operation of the diesel engine from 6 pm – 1 am.

The Kaur Solar PV system consists of 64.8 kW capacity PV modules and ground mounted array frames, a battery capacity of 15,000 Ah at 48V DC, inverters, control equipment, monitoring equipment, metering equipment integrated with exiting diesel generators (within the power house) connected to NAWEC's existing mini-grid.

The solar system was installed by Mohan Energy (India), which was contracted by NAWEC for this purpose. Mohan Energy engineers and UNIDO conducted on-the-job training for NAWEC staff during equipment installation. Modules included functioning of the equipment being installed and operation, maintenance and troubleshooting methodologies.

There were some technical challenges in operating the solar mini-grid, but these were resolved by NAWEC. One issue was the synchronization of the solar PV system with the diesel gen-set (100 kW) operating after sunset. The main constraint to synchronization was the fluctuation in voltage of the gen-set, which then required an Automatic Voltage Regulator (AVR) to maintain fluctuations within limits that can be supported by the Sunny Island controller.

There were also initial problems with the batteries, which cracked during off-load at Kaur. They were replaced, but due to the high temperature at the site, additional air-conditioning was necessary to properly cool them.

3.2.4 Business model and financing

The main rationale for replacing the fossil fuel-based system by a solar PV system is operational efficiency (increase in operation hours and less dependence on diesel supply) and fuel cost savings. The solar PV system was paid for by an investment grant from GEF/UNIDO and NAWEC's own resources. The installed solar PV system is modular, which allows for additional solar arrays (and associated equipment) and clusters of battery banks with inverters to be installed in the future to enable additional connections.

Prior to the installation of the 60 kW Kaur solar PV system, NAWEC operated one 60 kW generator from 8 am – 12 pm and a 100 kW generator from 6 pm – 1 am every day (note: there are two 60 kW gen-sets they used to operate alternately from 8 am – 12 pm). This means a total of 11 hours of operation per day using two light fuel gen-sets (one 60 kW and one 100 kW gen-set). The 60 kW gen-set consumed an average of 40 litres/hour. If it operates for 4 hours (8 am – 12 pm) per day, it consumes 160 litres/day, and the fuel savings for not running the one gen-set is approximately 4,800 litres per month. Given the price of fuel in The Gambia of GMD

56.59/litre[9] (about USD 1.3), the total savings per month for not running one gen-set is at least GMD 271,632.00 (about USD 6,345) and GMD 2,259,584.00 (about USD 52,783) for one year.

The savings are not directly passed on to consumers, as NAWEC sets tariffs for the region as a whole, but consumers benefit from higher reliability and availability of electricity.

3.2.5 Community involvement

There was strong participation of local stakeholders in project identification. Prior to this project, the electricity supply at Kaur was unreliable and expensive. The installed PV system is already helping NAWEC provide clean and a more reliable electricity supply to the Kaur community. Regular and reliable supplies of electricity from the solar PV system are making businesses more productive and are encouraging more residents to connect to the NAWEC's grid rather than using their own diesel generators.

As a result, the community, and in particular the women, now a have a sense of relief knowing that the milling machines in Kaur operate daily. The tailoring and welding shops can now operate safely during the solar PV system's operational hours (8 am – 2 pm) compared to availability from 6 pm – 1 am only, when the gen-sets may come in or not due to challenges such as fuel shortage or breakdowns of the gen-sets.

3.2.6 Successes and lessons learnt

The installed solar PV system in Kaur has enabled NAWEC to supply more reliable, cheaper and less polluting electricity to the Kaur community. The life cycle cost of installing PV is less than the operation of the diesel gen-sets.

The more reliable supply enables existing businesses to become more productive. The increased capacity of the system should encourage new businesses to set up in Kaur town, and allow NAWEC to increase the number of connections to the mini-grid and hence increase NAWEC's revenue base.

The GEF/UNIDO project has succeeded in building knowledge and in-depth technical capacity at the Gambia Renewable Energy Centre (GREC) and at NAWEC to allow GREC to become the focal point for renewable energy development in The Gambia, and to provide training and information to stimulate the market for renewable energy. Increased in-house technical knowledge at NAWEC should allow the utility to develop its own renewable energy projects to avoid further GHG emissions.

[9] USD 1 = GMD 42.8 (Gambian dalasi) in April 2016.

Project risks were mitigated by ensuring the community was on board from the beginning, and that adequate attention was paid to the training needs of NAWEC, who will be a key player in potentially developing further RE mini-grids. Work to create an appropriate legal framework for renewable energy mini-grids helped bring institutional partners on board. Overall, the risks of the project were not very high due to the existence of an electricity grid at the site, but replacing diesel-based generation can have enormous benefits.

Assessment table

Revenue to support the mini-grid	Good	Existing productive activities able to operate more efficiently with reliable electricity supply, encouraging new users to connect to the grid
Willingness and ability of consumers to pay bills	Good	NAWEC sets regional tariffs for all consumers; tariff has not changed as a result of the project. Consumers benefit from higher reliability and availability of electricity, leading to high willingness to pay
Community participation	Good	Community involved in project identification from the start; population understands the benefits of grid-based electrification
Regulatory framework	Good	Renewable energy policy developed as a result of the project with an investment plan in place to achieve SE4ALL by 2030. GREC's technical capacity improved through training and has become the focal point for RE in The Gambia, providing training to stimulate the market
Local capacity building	Good	Local jobs created as a direct result of the project, with capacity to expand the skillset outside the project. Good collaboration between all partners and local stakeholders

3.3 A participatory approach for mini-grid development in Guinea Bissau

Guinea Bissau relies heavily on traditional energy sources: 90 per cent of energy consumed comes from wood fuel; 95 per cent of consumers use traditional sources (candles, batteries) and electricity substitutes; and only 5 per cent of the population has access to electricity, mainly in urban centres. Some autonomous operators exist that operate without concessions and are not subsidized.

The development strategy focuses on improving semi-rural centres in order to prevent the growing population from concentrating in the capital Bissau. To provide incentives to establish renewable energy mini-grids, IPPs are supported through PPPs. This project is an example of such a partnership, with the objective of guaranteeing sustainable access to electricity in semi-rural central Bambadinca using renewable energy sources.

Project timeline: October 2012 – end 2015

Total financing and donors: USD 2,379.093 by the GEF, UNIDO, EU, ECREEE and CICL

Project partners: TESE Development Agency, Community Association for the Development of Bambadinca (ACDB), University of Lisbon, the Guinean Association for the Study and Release of Appropriate Technologies (DIVUTEC), Regional Directorate of Energy for Bafata (DREB)

Project components:

1) Designing and implementing a management model for Bambadinca Energy Service Community (Serviço Comunitário de Energia Bambadinca - SCEB) in a participatory manner
2) Awareness-raising on energy security and efficiency among the Bambadinca population
3) Provide Bambadinca's population with affordable electricity through SCEB.

3.3.1 Regulatory context

A general legal framework, Law No. 2/2007, has been set up to regulate the energy sector. The law is implemented by the Directorate General for Energy (DGE), which is responsible for issuing concessions, licensing and certification conditions for the sector. No specific rules for renewable energy mini-grids exist, but the National Energy Strategy, adopted in 2005, includes the promotion of rural electrification, including through renewable energy mini-grids. The National Strategy for Poverty Reduction also promotes the use of renewable energies in rural areas for lighting and the development of economic activities. With the support of ECREEE and UNIDO, the country has recently developed a National Renewable Energy Action Plan which awaits approval by the government.

The promotion activities mainly consist of attracting private investment through public private partnerships and allowing tariffs to recover their investments. However, there are impediments to private investments, including high duties and import taxes on renewable energy products (30 per cent – 70 per cent on top of the original cost of purchase to clear the equipment).

To overcome these challenges, UNIDO is involved in another project "Promoting Investments in Small to Medium Scale Renewable Energy Technologies in the Electricity Sector of Guinea Bissau" in partnership with the Ministry of Energy and Industry, the ECOWAS[10] Centre for Renewable Energy and Energy Efficiency (ECREEE) and TESE[11], and supported by the African Development Bank (AfDB) and the Small Island Developing States (SIDS) Sustainable Energy and Climate Resilience Initiative. The project aims to create an enabling environment for renewable energy investments[12]. One of the aims will be to develop a national renewable energy policy and action plan in the context of the ECOWAS Renewable Energy Policy of September 2012.

3.3.2 Technical challenges

To identify any technical challenges to building solar mini-grids in Bambadinca, a study was carried out by TESE in 2010 to determine the socio-economic situation, level of trade and energy consumption levels of the Bambadinca population. The study was carried out through data collection and discussions with focus groups, including the Community Association for the Development of Bambadinca (ACDB), as well as interviews with Bambadinca traders.

[10] Economic Community of Western African States.
[11] TESE Development Agency is a Portuguese non-governmental development organization responsible for co-defining the business model.
[12] Project timeline 2014 – 2018.

The economic, environmental, technical and financial feasibility of an investment in PV mini-grids was also studied, with a focus on the political and institutional framework, project location, financial scenarios with and without subsidies, energy production options and potential beneficiaries, projection of their future demand for energy and their willingness to pay, as well as environmental mitigation strategies, with an emphasis on the final disposal of batteries.

PV was found to be the best option for the region, because of its tremendous resource potential, ease of maintenance and operation and people's familiarity with the technology. The disadvantage is the high initial investment and the need for back up and storage. The economic analysis concluded that people are willing to pay for electricity as long as it is lower than the high cost of existing electricity substitutes.

The University of Lisbon (UL) provided capacity building on the sizing of energy infrastructure to SCEB (mini-grid management) with collaboration of ACDB (grid infrastructure) and the General Directorate of Energy (DGE)/Regional Directorate of Energy for Bafata (DREB) (financing and technical assistance).

SCEB training included:

- 320 hours of training in O&M and PV electricity grid, including internships at EAGB,

- 200 hours of training in administrative management, finance and trade,

- 110 hours of training in electricity and best installation practices,

- 110 hours training in operation and maintenance of low and medium voltage grids,

- Definition of service and service management procedures for implementing procedures operations and maintenance.

The project also included an awareness-raising element to inform people about the use of electricity. Posters were put up in schools and other public spaces, and SCEB had door-to-door visits to customers, and radio broadcasts and lectures were held to provide information.

3.3.3 Financing and business model

A study into the energy trends of the community was carried out in 2009, which showed that the residential sector accounted for 85 per cent of energy consumption, the commercial sector accounted for 14 per cent and the institutional sector for 1 per cent. In 2009, the residential sector spent between EUR 0.15 (USD 0.17)[13] and EUR 0.45 (USD 0.51)/ day on energy services. The commercial sector consists of 84 traders: charging cell phones, grocery stores, gas stations, tailors and restaurants. The institutional sector includes 16 public buildings, including mosques/churches, a health centre, schools, public buildings and street lighting.

TTA carried out a study in close coordination with ACDB to determine tariffs. The approach was participatory, and the objective was to have tariffs that do not generate profit but guarantee a full recovery of costs within a 20-year period. The tariffs were presented, published and later adopted by the DGE in December 2014. Tariffs are pre-paid based on the energy consumed. They are differentiated in accordance with when the energy is consumed, i.e. they differ for day and night-time use. The lowest tariffs apply from 9 am – 6 pm at 250 XOF/kWh (0.38 USD/kWh)[14], medium tariffs during the evening hours between 6 pm and midnight at 320XOF/kWh (0.48 USD/kWh) (in the social tariff, households continue paying the lower tariff during this period), and highest during the night between midnight and 9 am, at 500 XOF/kWh (0.75 USD/kWh).

The Guinean Association for the Study and Release of Appropriate Technologies (DIVUTEC) supported the project through micro-credits for households to promote adherence to SCEB, and visited domestic users to ensure payments for the agreed services, as follows:

- Helping 840 consumers of Bambadinca with registration
- Supporting 300 households with microcredit products to develop income-generating activities and encouraging savings
- Opening 250 savings accounts for adherence to SCEB payments.

[13] 1 USD = 0.88 EUR in April 2016.
[14] 1 USD = 575 XOF (CFA francs) in April 2016.

3.3.4 Community participation

The project implements a tripartite management model: ACDB (SCEB), DREB and community leaders are responsible for project implementation.

DGE/DREB:

- Concession agreement and its continuation
- Tariff approval
- Approval of binding customer contracts for energy service
- Technical assistance for the operation of the mini-grid and major repairs
- Monitoring quality and implementation of standards and technical procedures.

ACDB/SCEB:

- Technical and financial management of mini-network
- Energy credit sale and acquisition and materials management
- Accountability to the authorities and community
- Preparation of binding contracts and installation procedures
- Security of infrastructures and equipment of mini-network
- Payment of tax contributions.

Community leaders:

- Community awareness of the principle consumer pays
- Conflict resolution with end consumers
- Support in monitoring illegal connections.

It was decided to strengthen the organizational aspects of SCEB, and a statute was defined and approved by the Bambadinca General Assembly to create a Service Management Unit within SCEB. The Management Unit is responsible for the definition and organizational structure, pay scale and terms of reference of the SCEB team. The SCEB team consists of 12 staff with responsibilities in 4 areas: i) financial and commercial management; ii) operation and maintenance of the system; iii) monitoring and security; iv) prevention and conflict resolution.

SCEB started its work in September 2014. One of the first tasks was to develop supply contracts, which were previously developed with the support of legal counsel and validation of DGE by DREB. Being able to operate locally simplifies the procedure and reduces costs. The value of the supply contract is 15,000 XOF (USD 26) (home-based clients) or 30,000 XOF (USD 59) (business customers). Beyond this, customers have to comply with the safety standards of domestic installations. The SCEB therefore developed a model framework for electrical connections, whose single and three-phase scheme was approved by the DGE and became the blueprint for all installations. This framework is typified by varying only the switch according to the contracted power.

3.3.5 Successes and lessons learnt

The major success of this project is its participatory approach. From the very start, the community was involved in identifying which technology to use, the spending power of consumers, environmental conditions, etc. As a result, take up of electricity was rapid, connecting over 250 customers within 6 months (80 per cent residential, 3 per cent institutional and 17 per cent commercial), with the aim of connecting all schools and the health centre, as well as 75 per cent traders by the end of the project. In December 2016, around two years after the start of operation, SCEB has over 550 clients.

Local training and awareness-raising has allowed people to accept and support the project, and to reduce the use of traditional energy sources (candles and batteries) by 50 per cent. The approach of supporting 300 households with microcredit products to develop income-generating activities and encourage savings also resulted in higher connection levels among businesses and support for new productive uses of energy. Spending on energy has been reduced, dropping on average from 24 per cent of consumer income to 10 per cent. Overall, the participatory elements of the project could be considered a model for other projects in Guinea Bissau.

Project risks were mitigated by conducting extensive feasibility studies: economic, environmental, technical and financial. Technical training and awareness-raising activities helped ensure that the community understood and accepted the project and that they could play an important participatory role. Regulatory risks were reduced through activities to design new policy on renewable energy, but as the policy is not yet in force, regulatory risks remain, which will have an impact on investor confidence.

Assessment table

Revenue to support the mini-grid	Good	Costs of operator are covered by tariffs and grants for operation and maintenance; site selected with potential productive uses identified, micro-finance and/or other support available to increase productive activities
Willingness and ability of consumers to pay bills	Good	Community involved in tariff setting and collection of payments; project has high rate of payment.
Community participation	Good	Community association in place from the start, population understands the benefits of grid-based electrification
Regulatory framework	Poor (but under developed)	Government supports policy of RE mini-grid development but no regulatory framework in place yet; there are impediments to private investments, including high duties and import taxes on renewable energy products. Further measures are needed to reduce the financial risk perception by private actors
Local capacity building	Good	Local permanent jobs created with the capacity to expand the skillset outside the project. Good collaboration between all partners and local stakeholders

3.4 Technology transfer of ultra-low head micro hydropower in India

3.4.1 Project background

India is the world's fourth largest energy consumer, and it is expected that the country will be the second largest contributor to increasing global energy demand by 2035, accounting for 16 per cent of the rise in global energy consumption.

More than 50 per cent of the population has little or no access to electricity, with 24,945 villages still remaining without electricity. Many of the villages that do have access to electricity have to cope with unpredictable supply.

The project aims to transfer Japan's ultra-low head (ULH) micro hydropower (MHP) technology to demonstrate its usefulness in the State of Uttarakhand, a mountainous state in India with a 11,588 km long irrigation canal system, ideal for the generation of hydro-based renewable energy using low head-based falls. In India, over 40,000 villages and communities still lack access to the national grid. Many suffer from poor health, pollution, and poverty as a result. The advantage of ultra-low head-based technology is that it can be used to generate power from the natural falls or man-made canals without changing the course of the existing canal system and with minimal civil works. In many remote villages of India, there is strong demand for electricity services from village communities, schools, health centres, local businesses, etc. In these areas, electricity supply is either absent or negligible and demands for different electricity alternatives remain high, with ULH-MHP being a feasible solution.

Project timeline: – January 2013 - June 2016

Total financing and donors: USD 1,060,000 by the Government of Japan, UNIDO, the Government of India (in kind)

Project partners: Ministry of New and Renewable Energy of the Government of India (MNRE) and the State, Uttarakhand Renewable Energy Development Agency (UREDA), Uttarakhand Irrigation Department, Alternate Hydro Energy Centre, Indian Institute of Technology (AHEC-IITR)

Project components: This project will lead to an increase in access to renewable energy for productive uses by the rural communities in the State of Uttarakhand, India, amd consequently increase local productivity through local manufacturing and investment opportunities.

1) Three pilot installations of up to 10 kW ULH-MHP technology to demonstrate how the mini-grid systems can be implemented for productive uses;
2) Capacity building and institutionalization in the ULH-MHP sector to develop a knowledge hub;
3) Awareness raising and presenting market/investment opportunities to mainstream this new technology as a new sector.

3.4.2 Regulatory framework

The MNRE provides financial assistance for setting up small/micro hydro projects both in the public and private sector. The policy and regulatory framework is promising. A feed-in-tariff (FiT) exists for renewable energy generation. The Central Electricity Regulatory Commission (CERC) issues the rules on how FiTs are to be calculated. The tariffs are defined as the levelized cost of energy, and are derived from the specific productive life of each technology. The feed-in tariff period for most renewable energy technologies is 13 years, and can extend up to 35 years.

The FiT is applicable as follows:

States	2011-12	2012-13	2013-14	2014-15
Himachal Pradesh, Uttarakhand and north east states below 5 MW/kWh	3.90	3.59	3.78	4.14
Himachal Pradesh, Uttarakhand and north east states 5 MW-25 MW/kWh	3.35	3.06	3.22	3.54
Other states below 5 MW/kWh	4.62	4.26	4.49	4.88
Other states 5 MW-25 MW/kWh	4.00	3.65	3.84	4.16

MNRE has included the provision of subsidies for ULH-MHP technologies into its new policy guidelines for a system capacity of 100 kW, and India's Intended Nationally Determined Contribution (INDC) included the ULH sector development as a game changer for technology innovation in renewable energy. In 2015, the State Government of Uttarakhand adopted the Micro Hydro Policy on the Development of Micro & Mini Hydropower projects up to 2 MW. Under this project, a PPA was signed for the first time in India between one of UNIDO project pilot systems and the power utility for a 10 kW power system. Hydropower systems with head below 3 meters have now been recognized and defined as ULH by the national government. A Master Plan Survey for ULH-MHP has been completed to bring more attention to ULH-MHP manufacturers nationally and internationally.

During 2012-2017, the MNRE target is for 2 per cent of the total installed grid interactive power generation capacity to come from small hydropower (including micro hydro). MNRE supports the development of Micro Hydro Projects (up to 100 kW capacity) through public financial assistance (INR 125,000/kW, or around 1,879 USD/kW)[15]. In 2014, the MNRE launched an exercise to track the evolving renewable power regulatory framework and develop a repository of information. This exercise is expected to elucidate the dynamic nature of renewable energy regulations and to create a platform to share information on pertinent issues.

In addition, various policy supports are available for the ULH-MHP sector:

- The National Clean Energy Fund (2011) was created to support research and innovative projects in clean energy technologies. Any project or scheme relating to innovative methods to adapt to clean energy technology and research & development is eligible for funding under the NCEF.
- The National Electricity Policy (2005) aims to support households that fall below the poverty line (BPL) category by providing subsidies. The policy envisages a capital subsidy for rural electrification, with special preference for Dalit Bastis, tribal areas and other weaker regions. A minimum level of support may be required to make electricity affordable for very poor consumers, who may receive special support in terms of cross-subsidized tariffs.
- The National Rural Electrification Policy (2006) focuses on improved accessibility, availability, reliability and quality of electricity by considering the affordability of the customer to pay. This promotes off-grid solutions based on stand-alone systems through capital subsidies, including for distribution networks in non-electrified remote villages to be covered by stand-alone systems.

[15] 1 USD = 66.5 INR (Indian rupees) in April 2016.

Central and state governments in India have already taken specific initiatives in the micro-hydro sector. One such initiative is by the State Government of Uttarakhand, which formulated a new policy on the 'Development of Micro & Mini Hydropower projects up to 2 MW' in May 2015, with the aim of mini hydropower projects leading to grid-compatible power generation to strengthen the rural grid's quality and reach. The emphasis is on encouraging local industrialists and local governments (Panchayats) to set up MHP projects, while ensuring transparency and adequate participation of local communities. MNRE recently announced that in Meghalaya, as many as 50 mini and micro hydropower projects have been identified in different districts of the state.

According to a study conducted by AHEC-IIT Roorkee, the total potential for very low head (<5m) MHP in eight states in India (i.e. Gujarat, Karnataka, Kerala, Meghalaya, Uttarakhand, Punjab, Uttar Pradesh and Bihar) is around 100 MW (2383 sites). As part of UNIDO's advocacy effort, the ULH-MHP sector has already been integrated into the most recent policy guidelines of the MNRE, and micro hydro projects up to 100 kW have been allocated public financial assistance in the amount of INR 125,000 (about USD 1879)/kW), which can be allocated to local enterprises, individuals and community groups.

3.4.3 Technological challenges

The innovative ULH-MHP technology can be used to generate power from natural falls and man-made canals with minimal construction work required. Due to its compact structure and easy usage and installation, the system is especially well suited for decentralized power generation, which is easy in routine maintenance and operation. It is therefore an attractive solution for rural electrification, where access to the main grid is not readily available.

During the feasibility study in 2011-2012, suitable sites were identified in Uttarakhand to demonstrate the applicability of the technology. Additionally, the electricity generating capacity of the technology was tested at the existing water canal system. The ULH-MHP system can generate electricity of around 10kW at ultra-low head (below 3.0 m) with a discharge of only

0.8-3.0 m3/s. Uttarakhand has an estimated potential of 3,500 MW power from small, mini and micro hydro, while today, only 170 MW has been installed. No comprehensive survey has been conducted to assess the potential specifically of low and ultra-low head-based hydro projects in these canals. A survey jointly supported by the MNRE and UNIDO is underway (by UREDA) to assess the potential for low and ultra-low head-based hydro projects in the State. The report will serve to develop a Master Plan by the Government of Uttarakhand.

The project entailed three pilot mini-grid systems to catalyse productive activities based on ultra-low head micro hydro power (ULH-MHP) units of up to 10 kW capacity each, using existing infrastructure such as service water canals and irrigation canals. The three pilot installations chosen were Bahadarabad (Haridwar), Ambadi (Dehradun) and Kaladhungi (Nainital). The objective is the development of replicable business models of ULH-MHP mini-grid systems in the state. Regular meetings took place involving the communities and a monitoring team from the Alternate Hydro Energy Center (AHEC) at the pilot sites to identify technical issues such as machine performance and design issues to minimize unplanned/forced outages in practice. Suitable design modifications were incorporated in the system as part of the adaptation to local site conditions, such as recurring trash in the canals, which indicates that a non-automated trash rack is an important component of the hydro unit.

The first installation at Bahadarabad, commonly referred to as the IRI site (site 1), was a 10kW ULH-MHP and was completed on the campus of Hydraulic Research Station (HRS) of the Irrigation Research Institute (IRI) of the Government of Uttarakhand. The result showed a smooth operation for 67 per cent of the duration, with a canal closure of 25 per cent of the time due to maintenance work. Hence, for a total of 92 per cent of the time, there were no interruptions in the system. Installations at the two other sites included the use of locally manufactured parts to build the systems. This has caused some difficulties, for example, at the Ambadi site (site 2), during the system installation, the locally manufactured parts did not work properly. One of the key reasons was a mismatch between expected water discharge for the designed technical specification and available uncontrollable discharge during the farming period of downstream irrigation water users. The high discharge variation resulted in burning of the generator, which was replaced by the manufacturer. To solve the problem of high discharge variation, the first solution of making duct to release excess water downstream did not resolve the problem, so a bypass was proposed and completed in October 2015 by the Irrigation Department, including re-installation, internal testing and O&M training for the community by the manufacturer. A team from IIT Roorkee monitored the system for at least 3 months before handing over the assets.

At the Kaladhungi site (which is commonly referred to as the Roorkee Watermill (RWM) site) (site 3), there have been issues related to water regulation and energy load balancing, but the mini-grid is operating satisfactorily.

While the three sites are currently in operation, they have each faced a number of unforeseen technical and other issues, which have led to useful lessons learned and recommendations for future successful replication; it is clear that the technology is still very new in the India context and for nearly all stakeholders. The adaptation of the technology to the local environment has thus at times proven to be a challenge, especially for site II (Ambadi). Indeed, a number of site-specific conditions (such as water quality, water flow in irrigation canals and waste in the water) may not have been fully anticipated by the technology supplier, which was used to more standardized circumstances in Japan. Likewise, other partners and stakeholders have needed time and have had to undertake numerous efforts to fully grasp the impacts and challenges of applying this new technology in concrete situations. On the other hand, adaptation of the technology to country conditions like India's (and similarly in Kenya and Ethiopia) can be considered as one of the key drivers of this project, i.e. for this process to provide an answer to the question whether or not this highly innovative and promising Japanese technology can be successfully adapted to the Indian context, despite a number of country-specific challenges. The results of the project suggest that the answer to this question is positive, but addressing these often unexpected problems will indeed take time.

Training in the operation and maintenance of the system has been conducted for users and local stakeholders alike to ensure that expertise is locally embedded. This training was repeated at the end of the project to refresh the required skills and ensure that a critical mass has the necessary expertise. The project also identified potential institutions to provide a replication of the training programmes, and a subsidy is available for this, as well as for site selection, research and project document preparation by MNRE. Nevertheless, the long-term success of the system will depend on the ownership and commitment of the end users. This includes ensuring daily operation and maintenance, as well as financial viability of the system. A logical step to making the systems (more) financially viable is to connect them to the local grid; it provides much-needed income and avoids wasting electricity or idle machinery.

Awareness-raising events were held across the country, with over 200 visitors at the 1^{st} demo site, at exhibitions including the India-Japan Energy Forum 2014 and the Indian Renewable Energy Investment Summit in February 2015. Awareness raising articles were published in the Indian government's 'Energy Next' Magazine in January 2015 and India presented the ULH-MHP first pilot project at the SE4All Forum in New York in 2014. The State Government of

Uttarakhand includes details on the project on its website, including brochure and technology details.

These activities helped shape new policy developments as well as interest from various low head to ULH micro hydro developers. The local community is now aware of the hydro potential in canals and small streams for green energy generation, which can be used for local business activities.

3.4.4 Business model and financing

The three project sites were selected based on three important criteria: need and willingness of the community to use electricity for small enterprise development, geographical balance and technical feasibility. Furthermore, the communities at the sites got support from local NGOs to establish enterprises in order to utilize the energy for productive use. These groups have now been registered as 'cooperatives' with the government and can enter small-scale business.

The 1st demo unit of 10 kW capacity was successfully handed over to the Irrigation Research Institute (IRI) after six months of operation. To maximize the benefits of produced electricity and to optimize the benefits of production, the IRI decided to connect the hydro system to the main electricity grid to sell surplus electricity. A PPA was prepared by IRI with the Uttarakhand Power Corporation Ltd. (UPCL), the first of its kind in the State. The tariff set by the Uttarakhand Electricity Regulatory Commission (UERC) is INR 4.40 (USD 0.07)[16] per kWh from a hydro project of up to 5 MW paid to the operator (IRI or the community). This covers the operator's cost for the most part, which lies in the range of INR 2 to 10, or USD 0.03-0.15.

One issue with selling to the grid is that there is no specific scheme for 'net metering' for micro hydro generation. in the State of Uttarakhand[17] However, the Uttarakhand Electricity Regulatory Commission (UERC) decided in 2013 that: 'all renewable energy-based generating stations and co-generating stations shall be allowed to sell power through a PPA, over and above the capacity required for their own use, to the distribution licensee or to local rural grids at the rates determined by the Commission'. Therefore, dual mode operation is possible (e.g. the PPA with the distribution company DISCOM will be in charge of 10 kW), and it will purchase the electricity based on meter reading, so the generator may at times generate less electricity or use some itself and give excess electricity to the grid.

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[16] Indian rupees.

[17] Net metering allows consumers that generate some or all of their own electricity to use that electricity anytime, and not only when it is generated. Net metering uses a single, bi-directional meter and can measure current flow in two directions.

The business model at sites 2 and 3 is different from the first demonstration site, as it is based on the establishment of two specific community enterprises at the Roorkee Watermill and Ambadi sites. These groups use the electricity generated in the milling and grinding process of their farm products, which will be further marketed to secure their livelihood.

The Ambadi group consists of 12 families (out of 42 in the village) that are involved in 'organic farming' for processing through a business unit connected to the ULH unit and market rice-wheat flour and spices in the nearby markets of Dehradun with a plan to eventually export their products. No households are connected.

At the Roorkee Watermill site, out of 175 families in this rural township inside the 'Corbett National Park', 12 families are involved in 'eco-tourism'. This group will process the local spices and sell them through their 'nature shop' close to the project site. No households are connected.

Thirty community members from the first two project sites received training in 'entrepreneurship development' to use the renewable energy generated from ULH-MHP units for various productive purposes. These participatory trainings included selection of products that could be processed and marketed by user group members and finalization of marketing strategy and business models.

The groups formed at both sites have registered as community enterprises and now have access to the local financial system. SME development was co-financed at 20 per cent by the communities, amounting to INR 157,000 (USD 2,360). At both sites, they have procured processing units like rice de-husking/shelling, spice grinding and an oven and packaging machine. The ULH-MHP machines were installed in July 2015, and the groups have since started their business of processing agro-products and marketing them.

At these two sites, the hydropower systems use existing canals owned by the Irrigation Department of the State of Uttarakhand. The Project Steering Committee identified local public entities, i.e. the farmers' society and a self-help group of the community, to discuss ownership structure of the mini-grid system. This process helps provide a clear modality for future replication of ULH-MHP technology applications. It has been proposed for IRI to lease the system to the community for 10 years. It is planned that both sites will be connected to the main grid in future.

The local manufacturing objective represents an important element of the business model. The total project cost for an MHP unit using the machine imported from Japan (as at the 1st site) ranges from USD 7,000/kW - USD 10,000/kW. This cost has been reduced to USD 4,000/kW for indigenous manufacturing and can further be reduced with economies of scale.

It is planned to use the results of UREDA's Master Plan to develop additional 10-15 sites to be subsidized by MNRE to encourage further market development. MNRE provides a subsidy of INR 125,000 (USD 1,879) per kW to individuals, institutions, agencies, etc. for installation of micro hydro units (up to 2MW).

3.4.5 Community involvement

The unique feature of this project is its community-based approach; it invites proposals from local communities and entrepreneurs under the guidance of local government agencies, so that it can be owned sustainably for various productive purposes in the future. When a demand by the community comes in the form of a project, a thorough review, analysis, scrutiny and field verification survey is carried out. Ultimately, the Project Steering Committee (PSC), which consists of donors, national and state authorities and competent technical institutions, approves the selection of the site.

During the entire site selection process, in-depth community consultations take place to ensure that the energy generated will be used productively and sustainably. Due care is taken that the government agencies collaborate closely with the project team. A total of 31 proposals were received by the project team in Uttarakhand from different communities, and two sites were selected based on interest and commitment shown by the communities to contribute cash and in kind to the project and to run it sustainably.

Regular community meetings were organized at the project sites to discuss various project-related aspects and the involvement of each group member in the respective activities. The meetings covered community contribution for processing shed construction and productive asset machine procurement, baseline surveys of the villages, community involvement in ULH-MHP installation, the roles of group members in business development, marketing, financial and account management, participation in training, planning of exposure visits, etc.

3.4.6 Local manufacturing of system components

Localisation of the component: manufacturing. One of the project's parallel objectives has been to prepare the technology for larger replication by creating a platform for the Japanese technology to access the potentially large market in India and worldwide. As for the localization of technology manufacturing, the technology provider has established an India office and started local manufacturing with Indian private partners. They manufactured the turbine units and control panel that have been installed and tested in the project sites. The initial results show that the control panel can fully be manufactured locally. The local private sector can also provide after-service with locally available consumable spare parts. As for other components, the system mostly uses an imported generator and gearbox. Increased local expertise of hydraulics for this type of system and customization and adaptation of the technology solution will continue to be necessary for system and operational optimization based on the evidence of this project on required adaptation measures and improvements. Localization and learning from this process are critical aspects for tackling existing barriers and preparing for long-term sustainability of technology deployment. As regards future project design, it is suggested to include the identification of local technology and manufacturing partners, to be assessed for the quality and availability of system components (generators, control board, spare parts, etc.) and skill sets. The needs for technology component and skill transfer can be fine-tuned based on such assessment prior to project implementation.

3.4.7 Successes and lessons learnt

Three pilot sites have already delivered two 10kW capacity ULH-MHP units, the first to be connected to the main grid in the State under a PPA with a suitable utility rate. The system generates 70,080 kWh annually with an income of INR 308,352 (about USD 4,635). Its success will help reduce the PPA process for future replication. The installed system is operated and maintained by local operators.

At the Roorkee Watermill site, a farmers' development cooperative invested in processing machines that are connected to the mini-grids and has already started processing and marketing its spices.

Many lessons have been learnt from this project. The technology is very new and the technology provider has limited capacity to conduct local adaptation measures, as it is a learning process for them. Further, proper knowledge of hydraulics for this type of system will need to be collected in the country, so that operational optimization can be determined based on available technical evidence. Training, in particular in operation and maintenance, should be further replicated and knowledge transfer needs to be consolidated for local users.

For all three sites, as well as for future replication, it can be concluded that connection to the grid is highly recommendable for financial sustainability, i.e. the feed-in-tariff will generate revenue to pay for operation and maintenance, as well as for technical optimization, i.e. a regularly running of the system has technical advantages and prevents generated electricity from being wasted. The revised policy framework allows for grid connection even for small-scale capacities such as the pilots in this project. The project has greatly facilitated the contract agreements (including PPAs) with the local utility.

In general, the local counterparts were very willing to support the project in kind as well as financially. For example, MNRE and the Government of Uttarakhand provided subsidies and in kind contributions for awareness raising events, a master plan survey, office space, demonstration sites, the facilitation of administrative processes and readiness to subsidize training programmes. The local communities invested in processing machines and sheds, work force and equipment during system installation. Without their willingness and close cooperation, the current outcomes could not have been achieved.

The project determined that the support from the Irrigation Department was key, as India's water infrastructure is owned and maintained by them. The Department is in charge of all permissions for site use and ownership of assets using the infrastructure and provides support for hydropower projects and leasing services for water mills. The Irrigation Department has a growing interest in energy generation and this project showcases State level cooperation among agencies. Symbolically, the project is to supply generated electricity to the premises of the Irrigation Department offices close to the MHP units (1^{st} and 2^{nd} pilot sites).

New policy developments at the State and national level also highlight the success of cooperation with government entities. In addition to the new policies, a policy for net metering already exists. However, the policy for practical application to demonstrate the on/off-grid dual mode connection in the project is still unclear, i.e. the fact that these systems work in both 'on' and 'off' grid scenarios. While in the on-grid scenario MHP's function remains stable, the same stability needs to be ensured in the off-grid mode.

The project found that the dual mode connection is technically feasible for the pilot MHP units, and the stakeholders agree that the dual mode connection as a more sustainable option in terms of revenue generation and system optimization is necessary. It is crucial to maximize utilization as well as the output of generated electricity (e.g. selling night load to the grid for income generation under the available subsidy scheme). If such a system setup were applied, the business model would become economically more advantageous (e.g. shorter return-on-investment periods, coverage of operation and maintenance costs) and attract more investors.

Project risk mitigation was achieved through an extensive feasibility study in 2011-2012 as well as by testing the new technology at an existing water canal system. Moreover, communities were regularly involved in identifying technical issues, and any necessary design changes were incorporated in the system as part of the adaptation to local site conditions. Regulatory risks were mitigated through close cooperation with government entities to develop new policy for MHPs at State and national level.

Some risks are still present due to the fact that the technology provider has limited knowledge of local hydraulics and the adaptation measures necessary for this type of system. These risks are known and further training and surveys of the local conditions will be necessary to ensure operational optimization.

As for replication, Uttarakhand has an estimated potential of 3,500 MW power from small, mini and micro hydro, while presently only 170 MW has been installed. No comprehensive survey has been carried out to specifically assess the potential of low and ultra-low head-based hydro projects in these canals. A survey jointly supported by the MNRE and UNIDO has been completed (by UREDA) to assess the potential for low and ultra-low head-based hydro projects in the State. This report was used to develop the Government of Uttarakhand’s master plan, which identifies the most promising ULH-MHP sites for replication and scaling-up, and is available for ULH-MHP manufacturers, project developers and site owners. As a result, several national and international project developers and technology suppliers have now entered the market and concluded Memoranda of Understanding with the State government.

Assessment table

Revenue to support the mini-grid	Good	Cost of the operator are covered by tariffs and grants; Sites selected with potential future customers in mind (only businesses are connected), some of which are co-financed by the communities
Willingness and ability of consumers to pay bills	Good	The local community is aware of the hydro potential in canals and small streams for green energy generation, which can be used for local business activities
Community participation	Good	Community association is in place and has participated from the start, the population understands the benefits of grid-based electrification
Regulatory framework	Good	Regulatory framework is clear, supports enabling environment for mini-grids and provides sufficient finances, powers and training of lead actors to supervise the management and development of mini-grids. Regulatory measures designed to structure/standardize tariff setting and reduce financial risk perception by private actors
Local capacity building	Good	Awareness-raising activities helped shape new policy development and interest from private sector MHP developers. Local jobs have been created and local manufacturing of turbine parts, with capacity to expand the skillset outside the project, is taking place. Good collaboration between all partners and local stakeholders.

3.5 The importance of the national regulatory framework in Côte d’Ivoire

3.5.1 Project background

The installed capacity of 1,210 MW of electricity in Côte D’Ivoire is evenly divided between thermal plants and hydroelectric power. One-third of the population of Côte d’Ivoire have access to electricity. To provide access to the remaining two-thirds, the current national plan makes provision for decentralized grids powered by fossil fuels without considering the environmental impacts. Specific targets for the renewable energy share of national consumption exist: 15 per cent by 2020 and 20 per cent by 2030. This project aims to showcase the potential for solar-based photovoltaic mini-grids in order to increase energy access to rural communities.

Project timeline: May 2013 – April 2016

Total financing and donors: USD 4.19 million (USD 863,691 by GEF, approx. USD 3,000,000 from the EU, Akwaba Foundation and its partners, and approx. USD 325,000 from UNIDO[18]).

Project partners: Akwaba Foundation, Azimut 360

Project components:

1) Review of legislative framework to enable renewable energy-based mini-grid development and offer recommendations on incentive schemes for private project developers

2) Identify a portfolio of viable and bankable projects for the installation of PV mini-grids

3) Construction of mini-grids, including elaboration of a management model and training of local actors at project sites.

3.5.2 Regulatory context

A new Electricity Code was passed in March 2014. It opens up to competition all activities (except dispatching) and provides a legal basis for effective integration of the renewable energy sector. It also promotes the development of self-generation and affords greater flexibility for tariff setting for independent renewable energy producers. In addition, to encourage investments

[18] Including UNIDO’s co-financing of the Investment Promotion Forum.

in renewable energy production, fiscal and tax advantages for investors have been introduced (e.g. VAT for solar energy materials has been reduced to 9 per cent, exoneration of tax on business profits, and as much as a 50 per cent reduction in customs duties). Ministerial Decree No. 569/MMPE/MEF of December 2012 modified electricity tariffs to better reflect consumption and thus reduce subsidies to the fossil energy industry. This measure helps renewable energy providers compete with fossil-based producers of electricity.

These measures demonstrate the existence of political will and vision for the development of renewable energies, but the legal and institutional framework lacks specific implementation regulations for renewable energy uptake. Moreover, existing institutions have a weak capacity for the promotion of renewable energies and lack procedures for standardized operations for renewable energy production.

One of the components of this project was to formulate a comprehensive proposal to build a more “investor-friendly” legislative framework. In this respect, UNIDO organized a high-level renewable energy panel in January 2014 as part of the Investment Promotion Forum in Abidjan, bringing together ministers of environment and energy, private sector enterprises and international investors, as well as the African Development Bank. The panel concluded that an incentives package of measures is necessary, including the promotion of PPP models to attract investors, PPAs and a long-term obligation to purchase electricity, as well as a compensatory mechanism to manage risks, such as in case the national grid absorbs the mini-grid.

In addition, the focus should be on creating an agency or an organization dedicated to the promotion of RE mini-grids with well-defined powers, and a fund provided in the form of subsidies or equity participation in the projects. It would also be useful to define precise specifications for operators regulating technical standards, equipment used, the conditions of access to the national network, etc.

3.5.2 Business model and financing

UNIDO carried out feasibility studies on 11 localities in Côte d’Ivoire[19], and analysed types of business models that could be used. Based on this analysis, it was concluded that business models, management systems and pricing and usage rules for mini-grids have to be applied on a case-by-case basis, because important differences exist between the villages in terms of organizational capacity, willingness to pay and business activities.

[19] The sites were pre-selected according to criteria based on ease of access, population density, social cohesion and risk of conflicts, community motivation, income, energy spending, willingness to pay, potential for productive uses and cost of energy.

It is estimated that the total spending on energy (excluding cooking) in the villages studied varies between XOF 865,000[20] (USD 1,503) and XOF 7,240,000 (USD 12,579). This is an income scale indicator for the private sector operator, who is most likely to invest in several rather than just one locality. Commercial and income-generating activities promote the economic aspects of the project, as they are generally willing to pay more than households, and their daytime consumption balances out households' night time needs. Such 'anchor' customers can stabilize the income of a mini-network operator.

Customers in general have limited willingness to pay for connection and installation costs, meaning some form of subsidy to the operator may be necessary, otherwise people will not subscribe to the service. Also, the monthly variability in people's income should be taken into account as people often perform seasonal work and their income may decrease by up to 33 per cent on average in the most difficult months. Therefore, a system needs to be in place to deal with bill payment fluctuations.

The analysis indicated that customers would accept a tariff system that differs from the national rate; only a minority of 8 per cent resisted a higher rate than charged by the national electricity company, CIE. The main concern was to save on current energy costs, the quality of service provided and the method of billing, i.e. payment of the given total amount per month rather than price per kWh.

The average national tariff for domestic consumers in Mbana, where there is little artisan activity, is between XOF 65-70 (USD 0.11-0.12) /kWh, and at Hannié, where business customers have settled, between XOF 80- 90 (USD 0.14-0.16) /kWh. With production costs for PV calculated to range between XOF 240-540 (USD 0.42-0.94) /kWh, it is clear that investment subsidies are necessary to cut production costs per kWh. The tariff has to take the customer's willingness to pay as well as the production costs into account.

Many different strategies are possible:

- Concessions for an operator to manage several localities to realize economies of scale
- A community contribution to reduce construction costs
- A network that first covers only business customers, who utilize the network during the day and have a higher willingness to pay, to maximize the tariff and reduce the need for subsidies. However, the community's priorities must be taken into account, as public lighting might be paramount to support the project.

[20] 1 USD = 575 XOF (CFA francs), in April 2016.

Reducing capital costs is also important. In the 11 localities studied, a 1 per cent reduction in interest rates on loans can result in a tariff reduction of XOF 10-20 (USD 0.02-0.04) /kWh.

Two strategies are proposed:

- Involve local investors who are willing to accept a lower return on investments
- Provide concessional interest rates for the debt component of mini-grid projects.

The type of grant can have an impact on the selected technology: subsidizing investment costs does not necessarily lead to lower production costs. In fact, hybrid systems have high operating costs because of the use of diesel, and therefore have a smaller operating profit. Such systems may require a larger grant. Investment subsidies decrease the importance of the cost of capital in relation to operating costs, and therefore promote capital-intensive technologies such as PV.

Although the 11 sites have not yet found an investor, UNIDO advised that it would be beneficial to promote sites that have a potential for productive activities, as these can decrease the cost of production. The highest costs of production are foreseen in Mbana and Groguida-V1, which have relatively little trade activity (in a scenario that only takes the existing equipment into account), which leads to a higher fraction of overnight charges. It is therefore interesting to encourage productive activities, not only because business tariffs are higher, but also because it can have a significant impact on the cost of production.

Another interesting solution for private investors could be public funding of the distribution network combined with liberalized tariffs, where production is not subsidized. The grant would cover fixed assets to reduce the gap between the tariff and cost of production. The investment cost reduction strategies mentioned must also be applied to improve the feasibility of such a scheme.

Site selection depends on a range of criteria, as discussed above. It is difficult to prioritize, but given the attributes, the two localities in Grand Lahou, Dokpodon and Groguida V1, are the most promising for developing PV mini-grids. Dokpodon has very easy access, a good level of craft activities and potentially low production costs. Groguida-V1 is a more challenging case due to recent conflicts there, but it has the advantage of an existing distribution network, and an existing community organization that is able to support the project.

The three localities in Béré are recommended as second place, although the population's willingness to pay is relatively low. However, the sites have relatively easy access, the level of motivation and organization at Missidougou and Tamafrou is high, and a potential anchor customer base exists in Sononzo. Their proximity to one another also creates the possibility of a concession area for an operator.

To demonstrate the feasibility of solar mini-grids in rural areas, UNIDO teamed up with the Ministry of Finance, the EU and a local NGO, Akwaba, to build 7 PV mini-grids in the Bounkani (ex-Zanzan) region in the villages of Kapkin, Ganse, Boudou Koromambira, Zamou, Solokaye and Kape[21]. The Italian Consortia CR Technology – Warex won the contract for installing the mini-grids. The project will install 7 solar photovoltaic pilot sites: 200 kW with 600 connections (households and SMEs), bringing electricity to about 4,000 beneficiaries in off-grid isolated communities. Pilot sites have been selected on the basis of their potential to use the generated energy for productive uses that will create income and are beneficial to local schools, hospitals, small businesses, households and the general public.

Extensive feasibility studies were carried out to determine demand and the ability of each type of entity to pay based on four different tariffs (fixed per month):

- Economy – XOF 750 (USD 1.3)/month – usage 8.36 kWh/month - electricity used for charging and lighting
- average – XOF 1,500 (USD 2.6)/ month - usage 16.72 kWh/month, electricity used for TV and satellite as well
- comfort – XOF 3,000 (USD 5.25)/month - usage 33.44 kWh/month, includes the use of a fridge or ventilator as well, and
- boutique – XOF 3,500 (USD 6.08)/ month - usage 58.52 kWh/month, mainly for small businesses using class A fridge-freezers as well as ventilation, or for households that want more comfort, such as additional lighting and extra TV usage, a ventilator and fridge with higher power.

Public service entities, such as schools, religious and health centres, as well as water pumping stations and street lighting are offered a different tariff, which is based on their estimated monthly usage. A survey allowed each potential consumer to choose which tariff he or she is likely to sign up for. This helped estimate the operator’s potential revenue.

[21]UNIDO’s financial contributions relate to the acquisition and installation of solar equipment in three of the seven sites.

A rate of growth of 1 per cent/year was also calculated into the tariffs to take a growth forecast of energy demand over the next 15 years into account, except for villages where the majority of households have chosen to keep the most basic tariff to start with. For these, an annual growth rate of 2 per cent – 3 per cent was calculated.

By the end of 2015, all seven villages had carried out work to build 'energy houses' that will host the operational centre for the mini-grids as well as the electrical distribution lines. The plants have been operational since April 2016.

3.5.3 Community participation

The Ministry of Energy wants to establish community management models to be applied to the mini-grid project from the start. The community plays an important role in the preparation and operation of the mini-grid, but the presence of a professional operator (WAREX) decreases the risk of mismanagement. For all seven sites in the Zanzan region, a local association was created and made responsible for basic maintenance of the solar installation and economic management of the distribution centre. The community also played part in deciding the tariff structure.

The operation of the system in the long term is ensured through the creation of a local organization that will be in charge of maintenance and the formation of a local cooperative of young technicians selected from the local villages.

To promote community acceptance of the project, improving the quality of life of the villages was prioritized by enhancing community services (electrification of health centres, schools, administrative buildings, hostels, installation of public lighting and providing battery charging facilities for those not connected to the grid), with a view to also reducing migration to large cities.

3.5.4 Successes and lessons learnt

The project has successfully raised the profile of renewable energy as part of the government's priorities and contributed towards the revision of the regulatory framework. National partners at the central and local government level as well as the private sector (including banks and other financial institutions) were involved in promoting the project.

Work on the review of the regulatory framework helped elucidate the obstacles to the promotion of renewable energy mini-grids. The Directorate of New and Renewable Energies of the Ministry of Mines and Energy is a key partner in the monitoring of project progress at the national level, and has helped in identifying local private sector providers to be trained for setting up of power delivery services (including installation and maintenance of equipment) in rural areas.

Some work still needs to be done to further improve investor climate, such as creating a dedicated rural renewable energy agency with its own funds, putting in place financial incentives such as subsidies or co-financing projects, encouraging PPPs and establishing clear rules for the private operator on tariff mechanism access to the grid, etc.

The feasibility study of 11 specific sites were evaluated for their ability to host PV mini-grids, and identified the importance of designing business models on a case-by-case basis, depending on electricity consumer type, their willingness to pay, ease of access, community motivation and organization, etc. Business models, tariff structures and management systems may not be directly applicable from one site to another. The practical demonstration of solar PV mini-grids in the Zanzan region, with a 200 kW capacity, will create awareness of technical capacities, test the business model and provide electricity for around 4,000 people.

The Zanzan project used a participatory approach with strong involvement from the community from the start, where a village association is responsible for the operation of the mini-grid. Community involvement is strong, the local NGO has been involved from the beginning, local government support is very good and it is extensively involved in the project. TTA supervises any serious maintenance, but locally subcontracted experts are in charge of basic O&M. Economic activity is being promoted: blacksmiths and hairdressers who can work at night, shops able to freeze food and drinks, as well as tourism, as Zanzan lies around the national park of Comoe. Water pumps will be provided as part of the project.

Government wants to replicate the project, the Ministry of Environment is placing great emphasis on the costs saved for the government in the areas of education or health, where lighting in schools attracts teachers and hospitals have a freezer for vaccines. The Ministry of Energy, on the other hand, is putting its effort into grid extension rather than mini grids, but is looking for international investors to do so.

In order to replicate the project and up-scale to more villages, it is recommended that a dedicated agency promotes rural renewable energy, with authority and funding prescribed by law, to sign contracts and mobilize financing. Private investment should also be encouraged through legislation that provides a contractual and financial framework for PPPs. This would facilitate transparency and provide assurance to private investors about the process and modalities of participation in a renewable energy project.

Implementing legislation to regulate mini-grid development has been drafted by the EU, e.g. to regulate aspects of the technology used, technical and maintenance standards, conditions of access to the national network, including operators' obligations, etc., but lacks sufficient political support. A financial mechanism to fund renewable energy development, such as that introduced by the new Electricity Code on the possibility of granting derogatory pricing to independent producers and self-producers, are also contested.

Assessment table

Revenue to support the mini-grid	Good	Sites were chosen for their potential to use the generated energy for productive uses that will create income and for their proximity to achieve economies of scale. Cost of the operator covered by tariffs and grants
Willingness and ability of consumers to pay bills	Good	Community involved in tariff setting and collection of payments, but it is too early to determine whether the rate of payment is sufficient
Community participation	Good	The Ministry of Energy supports community associations in taking decisions on operations and maintenance to ensure sustainability of the project. A community association has been in place from the start, the population understands the benefits of grid-based electrification
Regulatory framework	Sufficient	The legal framework shows will and vision to develop renewable energy mini-grids, but lacks a dedicated rural renewable energy agency with its own funds and clear rules for the private operator
Local capacity building	Sufficient	Local jobs created or sustained, but no long-term business plan to expand the skillset outside the project, little collaboration between stakeholders.

3.6 The importance of local support in a remote area in Sri Lanka

3.6.1 Project background

Electricity generation in Sri Lanka is primarily run by hydropower and thermal heat from conventional sources.

Over 96 per cent of households use grid-connected electricity and another 2 per cent are connected through off-grid systems.

The biggest challenge is to continue to place greater focus on renewable energy sources to replace imported conventional ones. The Sri Lanka Sustainable Energy Authority initiated a project to extend access to 160,000 remote rural homes through renewable energy generation in order to reach the national target of 20 per cent of electricity generation from new renewable energy resources by 2020.

The project is to provide a hybrid renewable energy solution for rural electrification using locally available and environmentally friendly renewable energy sources (SHP and a bio-gasifier). It also aimed to provide training to those living in the village community to supply sustainable energy for the strengthening of rural income generation.

Project timeline: April 2005 – December 2014

Total financing and donors: USD 417,821 by UNIDO, the Government of Austria, the Government of India

Project partners: Ministry of Industry and Commerce, Sri Lanka Sustainable Energy Authority, United Rural Electricity and Power Producers and Consumer Society of Kaikawala and Meemure

Project components: The objective is to install a hybrid mini-grid in an un-electrified remote rural village – Meemure village – about 200 km from the City of Colombo.

1) Installation and commissioning of a mini-grid using small hydropower and a biomass gasifier at the selected site of Meemure, a remote village of 400 people.

2) Capacity building, including training manpower for local power production and strengthening of rural commercial activity.

3) Establish Renewable Energy Community Development Centres (computer-based), foster rural enterprises and rural energy access.

3.6.2 Regulatory context

The National Energy Policy and Strategy (NEPS) of Sri Lanka, adopted by Parliament in 2008, emphasizes the promotion, development and use of renewable energy.

The Government Development Policy Framework, published in 2010, forecasted that 20 per cent of electricity generation would come from new renewable energy sources by 2020, with a target of 10 per cent by the end of 2016. The project itself was supported by the Sri Lanka Sustainable Energy Authority, which aims to electrify rural remote areas of Sri Lanka.

3.6.3 Technical challenges

The area is very remote, therefore, the design of the renewable energy mini-grid system had to ensure that locally available resources were used in its design. A hybrid system using small hydro and biomass gasification was developed to ensure provision of electricity during both the rainy and dry seasons as a base-load energy generation.

Local farmers were using Gliricidia tree species for green fences and cultivation of peppers. This fast growing wood species was also available as feedstock in the village area. A dendro bio-gasifier system was tested for this type of feedstock. However, more awareness was required for the appropriate collection and preparation of feedstock, but also the capacity for regular operation and maintenance needed further strengthening. For example, people in the village collected the feedstock but it was difficult to meet the technical requirements due to inappropriate size and moisture contents. The system has also broken down on occasion due to inappropriate operation. In addition, in the past few years, the rainy season was unusually long and the SHP could generate electricity throughout the year. Therefore, the bio-gasifier did not need to be utilized in the dry season. Through several trials and trainings, it was evident that the bio-gasifier needs sophisticated inputs for sustainable electricity generation.

The construction of the SHP plant followed, including transmission and distribution lines, and started providing electricity in December 2013.

The remoteness of the site meant that the project was difficult to supervise. The hydro site was often unattended and not maintained by the community. Training sessions were provided to local operators on both hydropower and bio-gasifier operations and maintenance, including monitoring with a logbook, as well as irrigation infrastructure monitoring and water use management, and established an ongoing two-person operation staffed by local residents. For the SHP plant, it was important to stop the turbines daily and lubricate the bearings and moving parts (as it did not have automatic means of lubrication). As a result, it was important to employ a local expert near the village, for after-service and advisory support and to enable a self-sufficient management scheme.

3.6.3 Business model and financing

The investment grant was used to procure energy systems for mini-grid development, operation and maintenance training and 6-months maintenance after the project end. The maintenance was paid to identify the realistic cost of operation and maintenance once the SHP was operational. In those first 6 months, it was decided to put in place a fixed tariff that is paid per household, without metering, to cover the cost of the operator (LKR 252,000/year; USD 1,741[22]). After the first 6 months of service, the contractor proposed another tariff system to ensure the long-term maintenance of the network (an additional LKR 45,000/year; (USD 311). This means that each of the 65 households will pay LKR 380.69/month (USD 2.6), that is LKR 57.61 (USD 0.4) more per month. A decision has not been made on whether to agree to this model.

It is clear, however, that tariff setting should be analysed and recalculated based on the utility rate of the machines and real operational costs, as well as in relation to inflation. The society has also been advised by UNIDO to add a contingency amount, but it remains to be seen whether they will agree to this.

3.6.4 Community participation

The community has been active from the beginning of the project. The community received training on energy services, but only began to fully support the project when it experienced the benefits of having electricity. A local society was set up to manage and oversee the mini-grid's operations and maintenance, as well as tariff setting and collection. The community also helped refurbish and excavate the canal.

[22] 1 USD = 145 LKR (Sri Lankan rupees) in April 2016.

3.6.5 Successes and lessons learnt

Sixty-five households, including shops, out of 115 gained access to electricity and now enjoy the benefits of having electricity. The hybrid mini-grid with small hydropower (output capacity of 64 kW) and biomass gasifier (18 kW) system, with about 2 km distribution lines has been delivering around 13 kW of electricity to the community since 2013. Electricity is generated by SHP from 5 pm – 7 am, and a local operator has been on a 24-hour standby since.

The community is fully involved, has received training in mini-grid operation and maintenance, and all assets were transferred to the United Rural Electricity and Power Producers and Consumer Society of Kaikawala and Meemure – to own, operate and maintain the sustainable energy infrastructure.

The project also helped rehabilitate and improve about 2 km of existing irrigation channel infrastructure. Individual irrigation gates to paddy fields and water intake from a natural river were improved. A modality was established for scheduling water use for the purposes of paddy field irrigation and electricity generation using the small hydropower system. Local operators now regulate water use.

The project evolved and was drastically transformed over time to achieve the current results. This is perhaps attributable to the various conditions and prerequisites of the multiple objectives of the project, not only in the initial stages of the project but also during implementation.

The project highlights the importance of having responsible local partners directly involved in the day-by-day operations of project measures and community engagement, especially with regard to such remote communities. Local partnering helps build community trust in the project and ensures satisfaction of implementation results.

Another important lesson is to ensure that the most appropriate technology is chosen following site identification. The choice of the dendro plant as a back-up to the hydro plant in the low water season had to be carefully reviewed, as it was found to be complex to operate and maintain. The project could have done more to reap the benefits of the bio-gasifier, i.e. develop a biomass supply business, where households would have been paid for biomass collection and supply. The proposal did not materialize, mainly because of unusual weather conditions in the past 2 years, which allowed the SHP to operate the entire year.

The business model, and in particular tariff setting, were developed late in the project. The local community agreed to a simplistic model with fixed tariffs and no metering, as they have not fully understood its advantages. UNIDO has provided advice on this issue and one positive outcome is that the community is fully engaged in the process of tariff setting. With experience in running of the mini-grid, it is anticipated that the community is able to adopt the model to account for the need of the long-term maintenance of the grid.

Some of the major risks of the project related to its remoteness. It took some time before a local coordinator was appointed to oversee the project and ensure that people understood the benefits of the mini-grid. In addition, it is still a challenge to increase people's capacity to develop productive uses and to ensure that the bio-gasifier is able to operate. Regulatory risks were low, as the Sri Lanka Sustainable Energy Authority is very active in supporting the development of RE mini-grids.

Assessment table

Revenue to support the mini-grid	Sufficient	The operator's costs are covered by tariffs and grants for the operation, but not for long-term maintenance, this needs to be rectified for the long-term viability of the mini-grid
Willingness and ability of consumers to pay bills	Good	Community involved in tariff setting and collection of payments; project has high rate of payment
Community participation	Sufficient	Community association is in place, but late involvement in project cycle
Regulatory framework	Good	Regulatory framework is clear, supports an enabling environment for mini-grids and provides sufficient finances, powers and training of the lead actor to supervise the management and development of mini-grids
Local capacity building	Sufficient	Local jobs created, but no long-term business plan to expand the skillset outside the project or to increase people's capacity to develop productive uses

3.7 Institutional and technical capacity building in Tanzania

3.7.1 Project background

Tanzania has a population of around 53.5 million and approximately 15 per cent of the total population has access to electricity from the national grid. About 70 per cent of the total population lives in rural areas where only less than 4 per cent has access to electricity. Extending the national grid to many parts of the country including rural areas is not financially and economically feasible. De-centralized renewable power generation distributed through mini-grids and micro rids, instead of traditional grid-connected generation has become an important potential contributor to solving the energy access challenge.

Figure 2: View of the 500 kW turbine installed at Andoya power plant

Tanzania is one of the pilot countries that were selected to prepare investment plans for the Scaling up Renewable Energy Program (SREP) in October 2012, to catalyse the large-scale development of renewable energy to transform the country's energy sector. One of its priorities is the development of off-grid electricity using renewable energy sources. The main objective is to leverage private sector investment for renewable energy-based rural electrification.

Project timeline: *March 2012 to December 2017*

Total financing and donors: USD 13,463,500 funded by GEF, UNIDO, Ministry of Energy and Minerals, Rural Energy Agency

Project partners: Ministry of Energy and Minerals, College of Engineering and Technology, University of Dar es Salaam, Andoya Hydro Electric Power Company and Rural Energy Agency

Project objective: The overall aim is to create a better environment for increasing access to modern and clean energy services in rural Tanzania, to improve rural livelihoods and to create a conducive environment for developing mini hydro resources by removing existing barriers through the following project components:

1) Techno-economic feasibility studies for the identified demonstration sites;

2) Increase awareness among decision makers, consumers and other relevant stakeholders about the potential of mini hydropower-based mini-grids and for strengthening their capacities;

3) Demonstration of micro/mini hydropower plants at the identified sites;

4) Develop a viable business model to enhance the development of mini hydropower-based mini-grids.

3.7.1 Regulatory context

Tanzania has the necessary enabling regulations in place to promote private sector investment in renewable energy. It has developed an ambitious plan for promoting energy access and targeted 30 per cent connectivity by 2015, involving the connection of 250,000 new customers per year starting between 2013 and 2017. The Ministry of Energy and Minerals (MEM) established a framework for the development of small power producers (SPPs), ranging from 100 kW to 10 MW, and utilizing renewable energy sources (SEI, Renetech, 2012). The goal is to accelerate electricity access and promote the development and operation of small power projects among investors.

Tanzania has had a feed-in tariff scheme in place for SPPs since 2008, which is adjusted annually by the energy regulator EWURA, and is the average of the avoided cost of supply (cost for small-scale diesel generation) and the total incremental cost of mini-grids. They are undifferentiated by renewable energy technologies and there is no guaranteed price over the long-term, even if a PPA is signed for a 15-year period. Within the standardized FiT scheme, there are tariffs for feeding into isolated mini-grids; for 2012, this was set to TZS 480.50[23] (USD 0.22) per kWh (Renetech, 2012). FiT for SHP was prepared by EWURA in collaboration with other energy stakeholders and approved by the government in April 2015.

This new framework makes it considerably easier to predict the revenues from a new plant, particularly for smaller installations, and reduces time for obtaining permits. Projects under 1 MW are exempt from EWURA licensing, and the SPP programme relies on standardized documents as much as possible to minimize the need for case-by-case negotiation. For licensing and tariff approval, EWURA has proposed to rely on the economic and technical reviews undertaken in electrification grant reviews carried out by the Rural Energy Agency (REA).

[23] 1 USD = 2,185 TZS (Tanzanian shillings) in April 2016.

The REA was established in 2008 under the Ministry of Energy and Minerals to oversee the implementation of electrification projects in rural areas using the Rural Energy Fund as provided in the Rural Energy Act. REA has a number of tools, mainly funded through the TEDAP[24] programme, including matching grants of up to 80 per cent for prefeasibility and feasibility studies, performance grants of up to USD 500/connection in rural areas that currently do not have grid access, loans of up to 70 per cent of the investment cost (85 per cent for projects <3MW) and up to 15-year loan terms with a grace period of 5 years.

A guideline on installation and management of mini hydro mini-grids has been initiated as part of the project, and Tanzania is also preparing a viable business model for rural mini hydro mini-grids.

3.7.2 Project achievements

The technical capacity of Tanzania is favourable for building small hydropower (SHP) mini-grids in Tanzania. Much of this is due to the project's technology transfer programme and its extensive training and capacity building component.

Technology transfer training was conducted in May 2014 in Bandung, Indonesia. A total of seven participants from potential private institutions were trained on the fabrication of T-15 crossflow turbines with a capacity of up to 125 kW from ENTEC. The participants were given a license to manufacture the T-15 crossflow turbine on their own. One of the turbines fabricated by the participants during the training in Indonesia was a 68 kW capacity turbine that will be installed at the Salala demonstration project site in Ludilu, Makete district, Njombe region, Tanzania. Since the training in Indonesia, those who received training have been fabricating the micro turbines locally. Four turbines have already been fabricated, with one of them running for around one year. The fabricated turbines include one with a 10kW capacity, two with 50kW each and one with a 80kW capacity.

Figure 3: Participants at the MHP technology training in Tanzania

During the course of 2014, other training courses took place in Tanzania for river and water basin authorities and practicing engineers. Four experts from the College of Engineering and Technology (CoET) at the University of Dar es Salaam and from the Rural Energy Agency (REA) also received training on SHP development in Austria

[24] Tanzania Energy Development and Access Program supported by the World Bank and GEF.

in May 2013.

Furthermore, in October 2014, UNIDO inaugurated the Small Hydropower Technology Centre at the CoET, University of Dar e Salaam, with the aim of training experts, planners and relevant stakeholders on SHP, advise SHP developers and perform quality assurance of locally produced turbines. The Centre is designed to be a one stop shop that will deal with all matters related to small hydropower in the country, with a focus on information dissemination, training, capacity building and advisory/consulting services.

The institutional capacity in Tanzania is now well equipped to prepare feasibility studies and SHP mini-grid projects. The Rural Energy Agency, which is co-financing the project, is undertaking a mapping exercise for all mini hydropower sites in Tanzania for the creation of a mini hydropower atlas for Tanzania. This will assist in the further identification of sites in Tanzania.

The demonstration component was formulated to support the development of the identified demonstration mini/micro hydropower sites with a cumulative installed capacity of at least 3.2 MW (3,200 kW). The project has been able to surpass this commitment by supporting a total of eight projects with a cumulative installed capacity of 4,881 MW being an increment of around 1,681 kW from the original committed capacity. Also, the project is in the process of conducting a feasibility study of two additional sites as of November 2016.

3.7.3 Business model and financing

REA has been facilitating various private sector initiatives on mini hydropower mini-grids in Tanzania. It has been providing performance grants to the private sector to facilitate the initial stages of projects to actual project implementation. A total of 45 projects have been supported, out of which five have been implemented.

From the UNIDO/GEF-supported SHP demonstration projects, eight sites are in the implementation stage; three sites (Andoya, Kiliflora and Mbingu) are nearly completed and the electro-mechanical equipment has been installed, and for five other sites, the equipment has been delivered to the site and the construction work is ongoing.

Detailed feasibility studies, business plans and environmental impact assessments were carried out at the potential sites Andoya, Kiliflora, Tandala, Mpando, Lupali, Salala.

The eight demonstration sites received support from GEF-UNIDO in the form of incentives, including direct procurement of electro-mechanical equipment or partial support for such equipment. The project developers (private sector, NGOs and local communities) are finalizing the mobilization of the rest of the finances. The tariff structure will be based on consumption with prepaid metering. The commissioning of all plants is expected before the end of 2017.

In Andoya the business model aims to first connect the villages to the main grid before starting work on the SHP. This will accustom people to being connected to the grid and to pay for electricity, which is a third of the cost of diesel, and should thus enhance acceptance of the SHP construction. AHEPO, the hydro-power operator, has a design capacity to generate 1 MW. Presently, a 500 kW turbine is installed at the power plant, and has been generating electricity since 19 March 2015. AHEPO is connected to the mini-grid network at Mbinga and supplies Lifakara, Kilimani and Mbangamao villages as well. AHEPO had fed the mini-grid with about 110,000 kWh by mid-April 2015. Any excess generation once the power plant is in full operation will be sold to TANESCO.

In Kiliflora, the business model builds on a large anchor customer, a flower farm that is expected to be supplied with 99 per cent of the electricity during high season, while only 10 kW will be used for rural electrification; in the low season, more capacity will be provided to the villages for rural electrification purposes.

The other projects aim to enhance productive uses of electricity, and villages have been pre-selected partly because productive activities are already in place, such as maize, saw and rice mills.

Site	Total installed capacity	Business model	Investment subsidy from UNIDO/GEF	Planned connections	Productive uses
Andoya (connected to main grid)	1 MW	Private investment with subsidy from REA and Revenue from FiT (TANESCO) and direct sale to H/H. Direct subsidy from UNIDO/GEF to cover part of the equipment cost	USD500,000	Sale to Grid Direct sale to 3 villages – 759 households	Maize, rice mills, saw mills, small businesses in village
Kiliflora	230 kW	Private investment in civil works and distribution lines. Electro-mechanical equipment supplied by UNIDO/GEF	USD 134,100	Flower farm, only 10 kW for village activity	Flower farm
Madope	1.7 MW	Direct subsidy from UNIDO/GEF to cover part of the equipment cost	USD 500,000	8 villages – 5,097 households	Saw mills, small businesses in villages
Salala	68 kW – turbine built by Tanzanian technicians as part of technology transfer from Indonesia	Community-owned operations. Funds from REA and UNIDO/GEF used	USD 90,000	248 households	(no information)

Ijangala	360 kW	UNIDO/GEF support for equipment supply through direct procurement	USD 230,700	1,168 households	(no information)
Mpando	320 kW	UNIDO/GEF support for equipment supply through direct procurement	USD 219,100	1,920 households	(no information)
Lupali	353 kW	UNIDO/GEF support for equipment supply through direct procurement	USD 194,500	1,459 households	(no information)
Mbingu	850 kW	Local church/convent-owned, originally built by NGO donations to the convent	USD 187,121		

3.7.4 Successes and lessons learnt

The project is a pioneer in providing a market environment that stimulates investments in SHP mini-grids. The private sector and industries are fully supported by the Government of Tanzania through REA and in particular through the Rural Energy Fund. The new feed-in-tariff under development for renewable energy sources will give further impetus for more investments in renewable energy mini-grids.

The project shows that a strong enabling environment is crucial for attracting private sector investment. The capacity building programme supports such developments as well, by creating local know-how and expertise to gain confidence in implementing the mini-grid projects and create awareness about the available potential for investments. The capacity of the private sector to manufacture mini hydro turbines locally is an achievement that is expected to promote the quality of installations in the country.

Collaboration between all partners and local stakeholders was good prior to the start of the project. This has facilitated the communication and timely implementation of the project.

Despite these favourable conditions, achieving financial closure is an issue. Another grant or incentive is still necessary to achieve financial closure of the project. While power plants get sufficient attention from various quarters, distribution lines is an area where further consideration is required.

Evaluation table

Revenue to support the mini-grids	Too early to assess	While private sector-led plants are generating sufficient income, community-based or church-based plants are still struggling to establish a robust tariff and collection system
Willingness and ability of consumers to pay bills	Good	Community is involved in tariff setting and the collection of payments. The project has a high rate of payment
Community participation	Good	Community association has been in place from the start, the population understands the benefits of grid-based electrification
Regulatory framework	Good	The regulatory framework is clear, supports an enabling environment for mini-grids and provides sufficient finances, powers and training of the lead actors to supervise the management and development of mini-grids. Regulatory measures designed to structure/standardize tariff setting and reduce financial risk perception by private actors have been introduced
Local capacity building	Good	Local jobs and manufacturing created or sustained as a direct result of the project, with a capacity to expand the skillset outside the project. Good collaboration between all partners and local stakeholders

Figure 4: View of the mini-grid network at Mbinga, Ruvuma Tanzania

3.8 Government support in demonstrating renewable energy in Zambia

3.8.1 Project background

The project was formulated in response to, and in support of, the Zambian National Energy Plan’s goal to increase rural electricity access from (the then) 2 per cent rural population to 15 per cent by 2010, and the target has been set for 30 per cent electrification by 2030. Zambia is almost 100 per cent reliant on hydropower for its electricity grid capacity (1.9 GW in 2012), of which some is exported to neighbouring countries via the Southern African Power Pool (SAPP).

The barriers preventing rural electrification include the high cost of the long distances involved in transporting power to rural areas, the absence of legislation to facilitate the establishment of local mini-grids, the weak skills base for maintenance, installation and management and insufficient information about energy options.

Project timeline: May 2006 – December 2012

Total financing and donors: USD 4,198,457.00 funded by Zambia Electricity Supply Corporation (ZESCO), the GEF and UNIDO

Project partners: The Rural Energy Agency (REA), Ministries of Energy and Water Development, Environment, Finance and Industry, the Rural Electrification Authority (REA), the Energy Regulation Board (ERB), Development Bank of Zambia (DBZ)

Project components: The project was to establish three mini-grids powered by renewable energy sources (solar, biomass and small hydro) in rural communities.

1) Designing and establishing a legal, institutional and policy framework;

2) Building national and local capacities to promote renewable energy-based mini-grids;

3) Planning and setting up innovative project financing mechanisms and structure;

4) Implementing three pilot renewable energy-based mini-grids (one hydro, one solar and one biogas) to demonstrate different business models.

3.8.2 Regulatory context

During the project, Zambia revised its National Energy Policy, including a section on renewable energy, but has not yet developed:

- a pricing policy for mini-grids
- a detailed renewable energy plan.

The Department of Energy (DoE) has set up a Renewable Energy Division, but with relatively volatile staffing numbers, at times as low as one staff member. The Rural Energy Agency (REA) is mandated to facilitate the formation of appropriate institutions to generate, distribute or supply electricity to specific localities in rural areas as stipulated in the Rural Electrification Act No. 20 of 2003.

3.8.3 Technical challenges

Technical capacity had to be developed within the public sector as well as the beneficiary community. The project made extensive use of south-south exchange, supported study tours and exchange of information and on-the-job capacity building between Zambian stakeholders and relevant organizations in China, India, South Africa, Columbia, Brazil, Mexico and Senegal.

In the hydropower project’s initial phase, it was identified that design changes to the mini-grid were necessary, as there would otherwise be no power for five months per year during the dry season. The hydro mini-grid was originally designed to deliver 800 kW during the wet season and 300 kW during the dry season, as the project was designed as a “run-off” without a dam. As part of a detailed feasibility design study, UNIDO contracted a team of hydropower experts from China who determined that a better solution could be achieved if the “run-off” was changed to a small dam. The redesign resulted in an up-scaling of the project to 1 MW during the wet season and 800 kW during the dry season. To develop key technical skills locally, ZESCO staff were trained in China and worked alongside the Chinese contractor through the installation work.

The solar project also experienced some technical difficulties in the initial stages due to the quality of the materials delivered by the contractor which had a turnkey contract with REA. A number of quality faults in the solar mini-grid were found. At delivery, all equipment arrived in opened, not original boxes; the monitoring equipment was missing from the control boxes sending too high voltages directly to the system; light bulbs came with a five year warranty but proved faulty after 3 days to 3 months, and had to be replaced with better ones.

For the bio-gasifier project, ZESCO and Copperbelt Energy Company (CEC) staff attended a study programme at the Indian Institute of Science.

Trainings in financial evaluation and the management of projects also took place and were mainly attended by staff of the Development Bank of Zambia (DBZ), who also received on-the-job training by being involved in the appraisal of the three pilot projects.

Steps were also taken to initiate collaboration between Glamorgan University, UK, and University of Zambia (UNZA) at Lusaka to develop a renewable energy course for graduate engineers in Zambia, as well as to establish solar PV and thermal manufacturing and training in Zambia together with the establishment of a regional Knowledge Transfer Centre based at the School of Engineering at UNZA. This has not yet been realized, but discussions are still ongoing.

3.8.4 Business model and financing

In order to evaluate the project's social and economic impacts, a baseline survey of the Shiwang'andu area was conducted under UNIDO's auspices in May 2011. The project area begins some 81 km north of Mpika town where a gravel road branches off the Great North Road (GNR), the main traffic route in Northern Zambia.

Three demonstration sites were designated:

1. Small hydro mini-grid at Shiwang'andu
2. Solar PV mini-grid at Mpanta
3. Bio-gasifier plant at Kitwe.

All three sites were selected based on productive activities being carried out. At Shiwang'andu, a tourist lodge and a large farm wanted to make further investments that would require cheap and reliable electricity. The national grid currently ends some 40 km from the hydropower site, the idea being that the plant will be connected to the national grid.

The bio-gasifier site at Kitwe was selected because of an already existing timber plant that produces wood waste that could serve as feedstock for the bio-gasifier. The solar PV site at Mpanta was chosen for its good solar radiation as well as to demonstrate the feasibility of connecting grass thatched houses, which is not usually the case in electrification projects.

The three sites were to be financed through new and innovative financial and institutional structures, which were to encourage private investments by setting up a Risk and Replication Management Fund (RRMF). The project contributed funds to start up a revolving loan scheme for renewable energy. The reason three different types of renewable energy technologies were selected was to demonstrate and learn from the development of various types of RET mini-grids.

The RRMF was used to provide loans to the three pilot plants. In 2007, DBZ was appointed to establish and manage the fund, train staff and put in place fiduciary standards and assist in creating a financial market for renewable energy in Zambia.

The objective was to convert the GEF grant made available for the pilot project into a soft loan. This consisted of a 0 per cent interest loan, a grace period and a 5 to 8-year payback period. The loan to the pilot projects is to be repaid to the DBZ and then transferred into a revolving fund that could be reused for new renewable energy mini-grid investments.

a. The small hydro project grant converted into a soft loan of USD 568,000 to ZESCO.

b. The solar PV project received a soft loan of USD 646,000, and was taken up by REA.

c. The bio-gasifier project has received a soft loan in the amount of USD 798,092 with no grace period and an 8-year payback period. The loan agreement was signed in January 2013, but has not yet been released to Copperbelt Energy Company.

At the end of the project, it was proposed for the RRMF to be converted into the Zambian Renewable Energy Fund to be capitalized by other donors and the government for future projects.

3.8.4.1 Business model of the small hydro mini-grid at Shiwang'andu

The mini-grid project was implemented by the national utility ZESCO. The Zambia Electricity Supply Corporation raised 86.5 per cent of the financing for the project while the project grant that was converted into a soft loan covered around 13.5 per cent of the project costs.

The mini-grid plans to connect Kapisha Lodge, settlements and shops in the immediate vicinity as well as Shiwang'andu Farm. There are about 150 homes and four schools along 40 km of distribution lines and no settlements with more than 30 homes. The mean annual income in the area is ZMK 12,500 (around USD 1,300)[25].

The expectation of the project was that the largest electrification effects on smaller businesses will come from productive uses at several levels such as shops, workshops, mills, restaurants, medical centres and medium sized enterprises, such as Kapisha Lodge and Shiwang'andu Farm, which could also work as economic development agents in the area by increasing employment opportunities and demand for local products. A baseline study was carried out prior to the start of the project, which helped measure the positive results of the electrification project in the area.

Tariffs for electricity users are fixed at a flat rate per month.

3.8.4.2 Solar PV mini-grid in Mpanta

The solar mini-grid is owned by REA and closed the financial gap between the loan received and the total project costs. The plant was built with a capacity of 390 kW. A total of 480 users are connected (around 2,300 people benefit from the connection), free of charge, including a local clinic, a church and other communal facilities.

At the start, the solar project was characterized by weak community engagement during the planning stages. The project faced some 'teething problems', as only about 45 per cent of the monthly fees were collected. The collection rate improved through campaigns to improve community ownership and awareness-raising about energy services. REA is providing financial support to the plant in the meantime to enable it to meet its monthly overhead costs.

To encourage community participation, acceptance and ownership of the project, REA set up a community-based model for the operational management of the plant. An existing organization, Kafita Cooperative, was engaged to manage the plant, carry out operations, maintenance and sales and marketing activities.

The Energy Regulation Board (ERB) granted REA provisional licenses for the generation and distribution of electricity and approved the proposed monthly fees in consultation with the Kafita Cooperative. The tariffs are cost reflective. Consumers pay a flat rate of 30 ZMK/month (USD 5) for 8 hours of electricity per day.

[25] 1 USD = 9.6 ZMK (Zambian kwacha) in April 2016.

REA's role is to support and build capacity in the local cooperative to effectively manage the plant and once this has been achieved, REA might consider transferring full ownership of the project to Kafita or tender the management of the plant to a private operator.

REA has three staff members who are responsible for the plant's day-to-day operations. Members of the cooperative's executive committee and the three staff members at the Mpanta plant underwent training to build capacity to better manage the plant. Areas of training included business management skills, basic technical aspects of the plant and corporate governance.

The micro finance scheme targeted 280 women who ventured into entrepreneurship, enabling them to sustain their families while increasing their ability to pay for regular access to electricity. Investment subsidies were provided for a grinding mill, fish ponds, poultry and an ice plant. The income from these subsidies supplemented the operations and maintenance costs of the plant to ensure its sustainability.

The project offered women an opportunity to access energy at a low rate of EUR 3.75/month while the micro finance schemes built their capacity to create small businesses such as selling cassava flour at the fishing camps or to trade it for fish to provide their families with a balanced diet. A tariff collection strategy of adding small amounts to the price of essential goods sold by shops helped pay part of the tariffs and to thereby reduce the burden of paying the entire rate at once. The project's total income is estimated at EUR 54,700/year from tariffs and community investments. The project won a prize from WAME (World Access to Modern Energy) for promoting awareness, research and best practices in the modern energy gap.[26]

3.8.4.3 Bio-gasifier mini-grid

The Copperbelt Energy Company (CEC) took up the bio-gasifier pilot project at a late stage of the project. The CEC has organized financing with a grant/soft loan of USD 798,092. There was sufficient fuel from sawmill waste. The planned 1 MW plant has not yet been built due to late internal decision making in the company.

3.8.5 Community participation

A Project Steering Committee (PSC) was set up to oversee project implementation under the chairmanship of the Department of Energy (DoE) in Zambia. This PSC comprised government departments and agencies (including the Ministries of Energy and Water Development, Environment, Finance and Industry), the Rural Electrification Authority (REA), the Energy

[26] http://www.wame2015.org/case-study/1076/mpanta-solar-mini-grid-project-winner-of-the-wame-call

Regulation Board (ERB), local administration, the financial community, the public utility, civil society and the private sector.

Local communities were engaged relatively late in the process at the three sites and as a result, the project lacked stakeholder awareness. The later involvement of the local community assisted in the implementation of the project.

3.8.6 Successes and lessons learnt

The project was successful in engaging the Government of Zambia in the development of the first SHP plant since independence and to initiate the development of mini-grids for rural electrification. The establishment of these grids has received much attention and seems to have contributed to an increase in awareness of the benefits and practical knowledge of the mechanisms for developing renewable energy mini-grids. Government staff, including ZESCO and REA, received training in sustainable energy regulation and tariff setting, and both are very much engaged in developing further renewable energy plants and have put up own resources to do so. If successful, the revolving fund set up by the project will enable ongoing investment in renewable energy projects in coming years and turn into the proposed Zambian Renewable Energy Fund.

The project was found to have a high level of national ownership, reflecting its high strategic relevance. The extent of ownership and national pride in the project was demonstrated by the fact that the President of Zambia was present at the commissioning of both the hydro and the solar mini-grids. The capacity of participating government bodies, ZESCO, REA and the DBZ has been increased. A training programme was conducted to build capacity and to train technical staff of DOE, REA, ERB and ZESCO to formulate and implement renewable energy projects in the country.

The project has had an important catalytic effect in the development of several new mini-grids in Zambia, particularly SHP and solar mini-grids. Preliminary information on the replication plan was put together and the Ministry of Mines, Energy and Water Development has started planning for solar (Mumbwa), biomass (Lukulu) and mini hydropower (Chilinga) plants. The plans have been incorporated into the Sixth National Development Plan. Additionally, ZESCO is now planning to construct four SHPs in the rural areas of Zambia, and REA is working on two further solar PV mini-grids. Thus, the project can be said to have had a replication effect, contributing to increasing awareness, interest and commitment to renewable energy by the Zambian government.

The SHP plant was operational by the end of 2012, and the Lodge reported around 40 per cent reduction in energy costs, as it replaced diesel (USD 0.04/KWh for hydro-electricity vs. USD 0.99/KWh for diesel-generated electricity), and local hammer mills are paying around USD 50/month as opposed to USD 300/month previously spent on diesel. Shops that started stocking frozen meat and milk reported increased financial turnover with the arrival of hydropower and they benefit from longer working hours. One local businessman when interviewed said he is now making about USD 200/day as opposed to the USD 30/ day he made before his shop was electrified. Shop, restaurants and hair salons have popped up to service the growing population and traders passing through, and due to an increase in the population, businesses are now earning more profit than they did previously. School passing rates have improved due to pupils gaining access to computers and lighting for evening study. Thirteen permanent jobs were created at the SHP site, as well as five jobs at the village chief's business, and 500 potential new jobs at the farm, as well as 100 government jobs that were created through the process of promoting renewable energy in Zambia. Local businesses are also using fewer trees for energy purposes, resulting in lower carbon emissions.

ZESCO also planted about 80,000 young fish (fingerlings) worth around USD 25,000 to encourage the locals to maximize the usage of the dam, which resulted in income generation for the locals and the establishment of a village committee to foster good fishing practices. This village committee is used to educate people to use water sustainably and to stop using poison to catch fish.

At the beginning of its operations, the main outstanding issue at the SHP plant was its underutilization. The community and small enterprises had been waiting for the electricity to arrive before engaging in important investments in electric equipment. If local demand had continued to be low, connection to the national grid would have been considered. If connected to the national grid, the feed-in tariffs in place to supply electricity to the main grid could improve the plant's financial viability.

The solar plant was also successful in promoting productive activities, created new income-generating opportunities and connected 480 buildings, benefitting around 2,300 people. However, REA ended up with the unintended double role of providing policy and distributing funds for rural electrification, but also as the owner of the solar mini-grid. As a result, the community is disengaged from the ownership and the rate of payment is inadequate.

To reduce the risks associated with the mismanagement of funds, the cooperative opened an independent bank account for the proceeds from the solar project, which will be audited by

REA. This is because REA will not be financially responsible for meeting the Operations and Maintenance (O&M) costs associated with the plant. It is expected that the plant will generate revenue from the monthly end-user fees it collects to cover its O&M costs.

Without payment by households for the electricity, it is questionable how long REA will be able to keep the plant running. The project's success will fundamentally depend on the ability to collect fees that can cover the costs.

The financial viability of the two mini-grids has not yet been reached and it remains an open international discussion whether rural electrification is not a legitimate subject of subsidies in countries with large percentages of population without electricity. Implementing sustainable mini-grid systems requires understanding the social and economic dynamics of a particular community and to take the level of innovation the mini-grid requires into consideration. Development projects such as the one in Zambia tend to be the first projects of their kind in a country involving high level risks. Social impacts and the replication factor of this type of project are as crucial as economic considerations.

The sustainability of the revolving fund is of utmost importance in the development of new projects. The longevity of such projects requires a longer term engagement from project donors to provide technical assistance, even when a project ends, to ensure dedicated funds are not lost and that the fund succeeds in providing future support to new renewable energy projects. The fund established at DBZ is working and is collecting repayments, but to achieve longevity of the fund, UNIDO recommends the Zambian government to convert the revolving fund into a Zambian Renewable Energy Fund.

Assessment table

Revenue to support the mini-grid	(no information)	Costs outweigh tariffs, limited customer base or productive uses
Willingness and ability of consumers to pay bills	(no information)	Community was not involved from the start in tariff setting and collection of payments; as a result, only 45 per cent of the fees have been collected at the PV site, and although productive users have benefitted from cheaper electricity at the SHP site, there is an insufficient number of connections for household consumers, even after tariff reductions
Community participation	(no information)	The project demonstrated a high level of national ownership
Regulatory framework	Sufficient	The leading actors, ZESCO and REA, are very much engaged in developing further RE plants, and have the capacity and resources to do so, but need specific regulatory tools for promoting RE mini-grids to reduce risks for private investors
Local capacity building	Sufficient	Local jobs created, but no long-term business plan to expand the skillset outside the project, little collaboration between stakeholders

4 Conclusions and lessons learnt

Despite the considerable potential for an accelerated use of renewable energy-based mini-grids, opportunities for income generation and social and environmental benefits, progress continues to be hampered by a number of key obstacles and bottlenecks.

Many countries still lack sufficient technical capacities to install, operate and maintain the systems, the regulatory framework to attract project developers, and access to financing to bring sufficient scale. UNIDO's experiences with energy projects aims to address these issues, yet the evidence suggests that there is no unique business model that can easily and universally be replicated and scaled-up.

UNIDO's current projects on RE-based mini-grids demonstrate that there are several ways to design a project, with public, private or community ownership and different tariff structures within the framework of varying national and local policies to support the sector and different technological choices.

Eight projects were evaluated based on five factors that were deemed critical for the long-term sustainability of mini-grid systems:

(i) Sufficient revenue generation to support the mini-grid

(ii) Willingness and ability of consumers to pay tariff

(iii) Community participation

(iv) Capacity of national regulator/utility/renewable energy agency/Rural Electrification Agency to promote and mainstream off-grid projects

(v) Local capacity building in design, manufacture, assembly, operation and maintenance.

The following table presents the overall evaluation of the eight projects.

	Sufficient revenue	**Willingness and ability to pay**	**Community participation**	**Regulatory/financial capacity**	**Local capacity building**
Chad	Sufficient	Good	Good	Sufficient	Sufficient
The Gambia	Good	Good	Good	Good	Good
Guinea-Bissau	Good	Good	Good	(not clear)	Good
India	Good	Good	Good	Good	Good
Ivory Coast	Good	Good	Good	Sufficient	Sufficient
Sri Lanka	Sufficient	Good	Sufficient	Good	Sufficient
Tanzania	Good	Good	Good	Good	Good
Zambia	(not clear)	(not clear)	(not clear)	Sufficient	Sufficient

(i) Sufficient revenue

Revenues are sufficient when the operator's costs are covered by tariffs and grants. Looking at the case studies, four out of the eight projects have good revenues, ensuring that there is adequate demand for energy, that productive users or large consumers are connected, and that there is potential to increase the number of connections over time, or that there is an opportunity for future connections to the main grid or by connecting several mini-grids to achieve economies of scale.

Productive activities are not guaranteed just by virtue of providing access to electricity; tailored support and guidance (e.g. through private sector development, micro-financing, etc.) must go hand-in-hand with the energy solution. In some cases, such as Guinea-Bissau, the project provided micro-credit products to develop income-generating activities and encourage savings, which achieved higher connection levels among businesses. In India, sites were selected with specific business customers in mind, some of which were co-financed by the communities to ensure that the businesses become a success. In addition, the Indian mini-grids have the opportunity to be connected to the main grid in the future and benefit from feed-in-tariffs.

To take advantage of micro-credit associations and/or savings and credit cooperatives, commercial banks and financial intermediaries must be better informed about renewable energy technologies and project profiles.

In Zambia, while public financing was leveraged to reduce financial risk perception by commercial banks, no private investor engaged in the project. As a result, the project had to include public entities to cover the necessary investments, and new connections have been slow. While in other cases the project was largely driven by a major customer's request for grid electrification, there was a large discrepancy between the size of the SHP and eventual demand. To mitigate such an outcome, better market analysis is necessary for investors to have clarity about the risks of different business models, including what factors foster an enabling environment and how the socio-cultural context might affect the business model.

This warrants more than a simple feasibility study at potential sites; project developers need to consider the legal structure, presence of local associations, capacities and skills of local stakeholders and carry out a detailed assessment of existing local needs/income/industry to validate and refine the business model. Furthermore, the development needs to clearly define what the energy will be used for, i.e. productive activities, private households, municipal infrastructure such as schools and hospitals, etc. Where industry is asking for a mini-grid to be built, such as in the case of Kiliflora in Tanzania, or a commercial lodge in Zambia, an alignment between the specific load an anchor customer can guarantee and the needs of the local community around the grid must be considered in order to have the possibility to scale up the operations or to mitigate any conflicts that might arise from the grid not reaching certain areas of a region. In Sri Lanka, revenues will only be sufficient and the project will only become sustainable if the community agrees to pay an additional premium for maintaining the system. At present, the tariffs do not reflect these additional costs, largely due to the lack of an early dialogue with the community about the business model.

Table 4 shows that the late involvement of the main target users has a direct impact on revenues. In both Sri Lanka and Zambia, where revenues are not yet sustainable, communities may not have been sufficiently involved early in the project. By contrast, in India, the local communities were involved during site identification to determine in which locations the population was eager to establish local businesses using electricity to generate more income and increase productivity, with a commitment to invest back into the local community. The India case was more straightforward in the sense that the use of energy was intended for one main user (i.e. spice grinding; rice processing and research facilities) per mini-grid site, yet consultations with the key—if not all—prospective users of energy is crucial, and should be initiated as early in the process as possible.

(ii) Willingness and ability to pay

Willingness to pay largely reflects the community's knowledge about the benefits of electricity and their ability to be involved in setting tariffs. The case of Chad shows that where the contractor works together with the community to manage tariff setting and collection, the system ensures that the operator's costs are covered by the tariff, but that at the same time, the community's needs are reflected. In Guinea Bissau, the community was also involved in identifying consumer spending power, which resulted in rapid and successful take up of electricity. In Côte d'Ivoire, the households and businesses themselves chose tariffs before the mini-grids were built[27]. This allowed the mini-grid to be designed according to the forecasted demand and revenue from the selected sites.

(iii) Community participation

The projects highlight the importance of being familiar with the community's needs and enabling it to participate in the project from the start. The experience from 8 case studies shows that the long-term sustainability of mini-grid projects can strongly be improved with proper appreciation of community participation, including ensuring there is locally available capacity to manage and maintain the operations, and that there is adequate end-user commitment (awareness) and associated productive uses at the project site (i.e. potential for income-generating activities).

The local community is crucial in ensuring that enough revenue is available and that people are willing and able to pay for electricity.

The project in Sri Lanka shows that without community support and involvement, the project will experience delays, and insufficient understanding of sustainable operations of the mini-grid may lead to inadequate tariffs to cover necessary maintenance costs.

The local community needs to be empowered to:

- Be aware of the benefits as well as of the costs related to the provision of electricity
- Understand the technical aspects of the mini-grid and the importance of its maintenance and sustained revenues
- Be involved in setting the tariff structure to ensure willingness and ability to pay tariffs

[27] It is worth noting that the regulations for tariff setting and the type of entities that can act as mini-grid operators are currently the subject of discussion at policymaking level. This discussion has been triggered by the project's mini-grids.

- Understand the opportunities of using electricity for productive uses and be able to acquire the relevant skills/ financing to take advantage thereof.

Typically, the community will need specialized and long-term support on the technology side (operation and maintenance, replacement of components, of the energy system, the distribution system and connections) as well as on the financial management of the system (fee collection, tariff setting). Where feasible and preferred, the involvement of a third-party operator (private or semi-private) might be advisable.

(iv) Regulatory capacity

Apart from empowering and training key local partners and ensuring the financial viability of the mini-grids, an enabling regulatory framework needs to be put in place to ensure and facilitate replication. Indeed, the **regulatory framework** needs to be redesigned to allow for adequate off-grid solutions. The case of Côte d'Ivoire depicts that even though many viable mini-grid sites have been identified, the regulatory and financing framework lacks incentives for their development. As mentioned, the financial sector will only lend to projects if risks are minimized, and policymakers need to provide the incentives and instruments to reduce these risks. In Chad, it has been advised to phase out fossil fuel subsidies and dedicate a minimum level of infrastructure procurement to renewables to encourage the creation of local production facilities of RETs and reduce risks for private investors.

Capacity building of national regulators, utilities and renewable energy agencies to promote off-grid projects is crucial in the development of rural energy markets. Their capacity can be increased in terms of technical knowledge, as in the case of The Gambia, where the project enabled the national water utility, NAWEC to realize the economic benefits of replacing gasoil gen-sets with solar PV systems. In Chad, empowering ADER to supervise mini-grids is also a good step towards improving investor confidence.

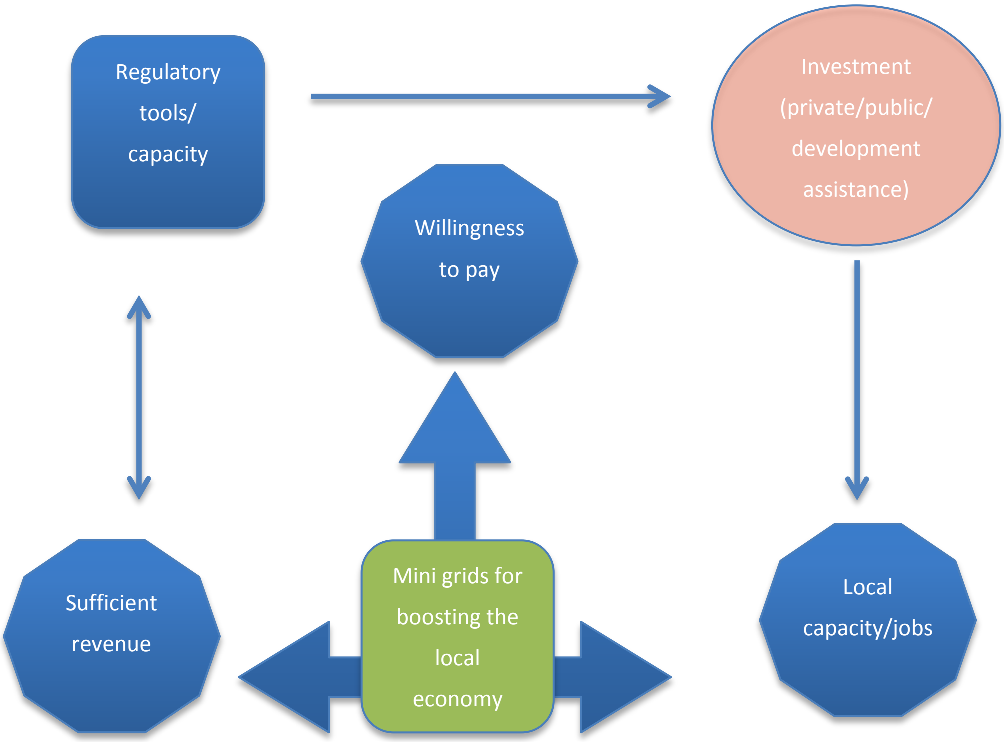
Their capacity can also be supported by strengthening financial and regulatory mechanisms, such as the creation of rural electrification agencies and funds, supporting local champions and financing long-term renewable energy programmes. In Tanzania, the Rural Electrification Agency has succeeded in financing several mini-grid projects due its access to funds and clear rules on how those funds can be accessed.

(v) Local capacity building

The rural energy market can be structured in a way that the entire value chain benefits from the implementation of mini-grids. In the case of solar PV and SHP, the supply chain is important and **local capacity building** in the areas of design, manufacture, assembly, operation and maintenance can lead to sustainable industrial development. In the case of biomass, the collection, storage, pre-processing and distribution of biomass feedstock and residues can be organized and their transport and processing mechanized, e.g. pelleting, briquetting, drying, etc., to ensure sustainable management of biomass resources and increasing energy security.

The development of renewable energy markets should be supported by associated development of local manufacture/assembly of renewable energy equipment supply chains and clusters to reduce equipment supply costs. Establishing renewable energy technology R&D centres could also serve as hubs for training purposes. Such is the case in Tanzania and India, where the private sector's capacity to locally manufacture mini hydro system components is an achievement that is expected to strengthen manufacturing capacity and create local jobs. Other emerging economies such as Brazil, China and India, have already developed significant manufacturing capabilities, and others can learn from these countries, adapting these capabilities to local conditions. Nationally manufactured content in projects and tenders could also be considered, where possible.

The five factors considered in the evaluation reveal the many inter-linkages between regulatory, technical, financial and community objectives. An adequate regulatory framework should be able to leverage private investment, support capacity to oversee projects on the ground, and thus encourage community participation. Strong early involvement of the community and of key users can contribute to the project's financial stability as well as the technical capacity on the ground. Community participation can also help attract investment in case the investor finds high willingness to pay and envisage a mini-grid expanding over time.



In pursuing ISID, the overall enabling framework must include regulatory tools and regulatory capacity to encourage investments in mini-grid projects. **Investment (private/public/development assistance)** will be key for the ability to up-scale renewable energy mini-grids. This was not part of the above evaluation, because investments in these projects mainly relied on ODA.

The replication of these demonstration projects and the development of mini-grids to the next level can only take place if investments move away from reliance on ODA. For this to happen, governments need to enact **mini-grid-specific provisions** that allow investors to have clarity about the regulatory environment for the foreseeable future to be able to design projects in a way that brings returns on investment. This includes differentiation of tariffs according to the needs of the mini-grid, and a mindfulness of the population's willingness to pay for the energy, creating sufficient revenues to achieve returns on investment from the uptake of electricity for productive uses. At present, investors often do not know which tariffs to charge; in some countries, such as Côte d'Ivoire, it is difficult to divert away from national tariffs that are used for the national grid (and subsidize fossil fuels). In many developing countries, there is a tendency to reduce electricity tariffs, but this proves unattractive for investors. To achieve financial sustainability, tariffs should aim at being cost-reflective, and this is one of the first challenges of attracting private investors.

The blue areas of the chart relate to the evaluation criteria that were considered in this study. Community participation is important as it determines whether or not bills are paid, whether the grid is financially viable or whether the locals have the capacity to sustain it in the long term. A number of design issues were evident in the different cases (technical, financial or regulatory), but the projects show that renewable energy mini-grid models are viable where the key design elements include a focus on stimulating the local economy, in particular as regards **increasing productive activities**.

Each community covered by these projects is different, and project developers need to be mindful of the end-users' ability in terms of income generating potential and willingness to pay for the energy, creating sufficient revenues to achieve returns on investment from the uptake of electricity for productive uses. If the potential for productive activities is not realistically analysed, the project could fail due to underutilization of the grid or because of the inability of people to continue paying bills once the subsidies diminish over time.

Local capacity building is important to support the community so it no longer needs to rely on international donors or government subsidies in the long term. Renewable energy technology centres, such as the SHP technology centre in Tanzania or India, or a network of trained local subcontractors (electricians) in Chad and Côte d'Ivoire are able to support RE mini-grid communities and encourage their uptake in further settlements. The key is to have a critical number of projects so that local contractors are able to sustain their own livelihoods by focusing on RETs. In Côte d'Ivoire, there are 7 villages close together which are supported by the same NGO, making it a viable business for the local contractors.

UNIDO's eight case studies reveal that although the focus is often on the challenge of leveraging private investment, the success of such projects often comes down to whether the end users are able to sustain the grid. The emergence of productive uses that generate income is a key element and the end users should be engaged from the very start of the project by the regulator, the project developer and investor to deliver ISID.

The context in which the technical cooperation projects to advance mini-grid deployment take place show that a number of the countries are often not ready for a full market approach to investments. Therefore, assuming a private-sector-led approach for demonstration projects may not be realistic; a step-wise approach, for instance, including demonstration through donor-led projects, followed by government incentives aiming to blend with private financing and/or development bank loans, is more likely to pave the way towards a sector to become sufficiently attractive in terms of size and financial returns for the private sector to take over. The case for initial support (subsidies, tax credits, etc.) for the development of a market for rural electrification is thus justified, based on arguments of long-term sectoral development and taking into account the environmental and socio-economic benefits that would come with it.

This demonstrates that the rationale for projects of rural electrification may not primarily be to identify sizeable and bankable investment projects, despite this being the long-term target to reach sufficient scale and attract private sector interest.

Rather, these often first-of-its-kind projects aim to test modes of operation, taking into account technology, policy and regulation, local participation and socio-economic benefits based on which indications can be provided on the appropriate strategy for such projects to be scaled.

Social impacts and replication factors in these types of projects are thus as critical as are economic considerations, particularly in countries with large percentages of population without electricity.

5 Annex - Criteria for evaluating projects

(i) Sufficient revenue to support the mini-grid

Good:	Costs of the operator are covered by tariffs and grants Site selected with potential future customers (ideally for productive uses or large consumers) in mind/identified/confirmed Concessions for several mini-grids to realize economies of scale; micro-finance and/or other support available to start/increase productive activities
Sufficient:	Costs of operator are covered by tariffs and grants for operation and maintenance, but little capacity for expansion Productive use of energy identified but with little financial or other support to start activities
Poor:	Costs outweigh tariffs, no reserves, limited customer base or productive uses

(ii) Willingness and ability of consumers to pay bills

Good:	Community involved in tariff setting and collection of payments and project has high rate of payment (> x %)(85?)
Sufficient:	Community involved in tariff setting and collection of payments, but rate of payment is not consistently high (seasonal variations, dependence on few customers, etc.)
Poor:	Low rate of payment, community not involved in tariff setting or collection

(iii) Community participation / involvement

Good:	Community association (or platform for involvement) in place from the start, population understands the benefits of grid-based electrification
Sufficient:	Community association in place but late involvement in project cycle
Poor:	Late involvement of community with no proper structure for dialogue, little understanding of benefits of grid-based electrification

(iv) Capacity of national regulator/ utility / renewable energy agency to support and promote off-grid projects and to mitigate risks for investors.

Good:	Regulatory framework is clear, supports enabling environment for mini-grids and provides sufficient finances, powers and training of the lead actor to supervise the management and development of mini-grids. Regulatory measures designed to structure/standardize tariff setting and reduce financial risk perception by private actors
Sufficient:	Lead actor supervising the project in place, but lacks capacity to support the project's long-term viability, e.g. tariff setting, access to funds
Poor:	No clear regulatory mechanism to support mini-grid projects

(v) Local capacity building in design, manufacture, assembly, operation and maintenance

Good:	Local jobs and manufacturing created or sustained as a direct result of the project, with the capacity to expand the skillset outside the project. Good collaboration between all partners and local stakeholders
Sufficient:	Local jobs created or sustained, but no long-term business plan to expand the skillset outside the project, little collaboration between stakeholders
Poor:	Few local jobs created, no possibility to expand skillsets further afield, no collaboration between stakeholders.

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