

Discussion Paper

Integrated Sustainable Rural Development: Renewable Energy Electrification and Rural Productivity Zones

An integrated approach to tackle the challenge of rural development by bringing access to renewable energy for income generation and social development.

Disclaimer: The Discussion Paper is not the official opinion of the UNDP.

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Introduction

There is a universal recognition that Energy as one of the most important inputs for economic growth and human development. However, expanding 'Access to Energy' (A2E) in developing countries, especially into rural areas of LDCs and SIDS (Least Developing Countries and Small Island Developing States) remains one of the biggest development challenges facing the world today. For the rural poor, the lack of A2E can impact their ability to rise out of poverty, but A2E can trigger new productive activities.¹

Challenges for expanding A2E:

- **Policy and Regulatory Challenges:** Among others, these challenges often pertain to a lack of long-term sectoral vision and planning, and political prioritization to make it happen.
- **Financing Challenges:** Perceived payment risk, coupled with a lack of risk mitigation tools and inadequate financing support (grants, loans, grace periods, long term interest rates etc.) makes it difficult to secure finance for rural energy projects.
- **Market Development Challenges:** These challenges pertain to lack of innovative business models, local market knowledge and resource availability to implement rural energy solutions.
- **Technical and Structural Challenges:** Insufficient base load, lack of pilot demonstration projects, poor grid conditions (or complete unavailability of the grid) leads to higher costs and inadequate design solutions.
- **Information and Capacity Challenges:** The lack of knowledge on available technologies, lack of capacity to design, manage, and operate coupled with limited local involvement and public support.

Objectives and Audience of this Discussion Paper:

The objective of this Discussion Paper is to present an innovative model for combining renewable energy rural electrification around the concept of a 'Rural Productivity Zone' (RPZ), with the objective of tackling some of the challenges in improving access to energy while encouraging sustainable development and GHG mitigation. This discussion paper provides stakeholders in beneficiary countries and donor organizations a holistic way of tackling rural energy access and rural poverty by setting up an integrated infrastructure for energy and income generation. Thus, recognizing the paradigm conflict that one major driver in lifting rural communities out of poverty is access to sustainable modern electricity services, but that the same rural communities often do not possess the income streams to pay for the often high cost of electricity.

This Discussion Paper is targeted at policy makers, regulators and implementing agencies in beneficiary countries to relook at policy, finance, technical, capacity, and private sector initiatives under rural electrification as a driver for poverty reduction and climate action. The integrated renewable energy and RPZ model encourages multilateral financing institutions and multilateral/bilateral Official Development Assistance to increase participation in the capacity development and finance of similar activities which take into account multidimensional approaches to rural electrification. Ideally the above persons and organization could use this Discussion Paper for conceptualizing a 'quick project concept', based on local conditions, and subsequently initiate policy changes, direct development aid and establish financing programs.

¹ "Renewable Energy: Access and Impact" Policy and Operations Evaluation Department (IOB), Ministry of Foreign Affairs, The Netherlands, 2013

In the fight against Climate Change, this Paper introduces a model which under the framework of a National Appropriate Mitigation Action (NAMA) can allow the inclusion of GHG mitigation targets and co-benefits that can be aligned to post 2015 Millennium Development Goals. As elaborated in the model RPZ, an integrated approach to tackling issues of energy scarcity through technology intervention, finance and capacity building can be a good basis for the development of a NAMA.

Rural Development and Rural Electrification

Rural development generally refers to the process of improving the 'quality of life' and economic well-being of people living in rural areas. The development paradigm has shifted to look beyond promoting agrarian community related development, to rethink and champion a new integrated approach involving 'social development' and 'income enhancement'.

- **Social Development:** Three of the 'social' services that are essential for holistic development of rural society are health, supply of clean drinking water, and education. Educating young girls and women on importance of family planning, reproductive health can go a long way in tackling social issues of early marriage, infant mortality and gender equality. Similarly an assured supply of clean water for drinking, cooking and hygiene contributes to the overall health and well-being of the society.
- **Income Enhancement:** A second 'pillar' for rural development is the overall economic progress of the rural society, and one way progress can be gained is by encouraging rural entrepreneurship. An increase in rural businesses (services and products) can help tackle unemployment, improve access to services, and increase average household income. For example, the generation of income opportunities through micro-enterprises is helping rural women and youth, particularly in the Indian sub-continent, to gain financial independence. These micro-enterprises were originally supported by NGOs, development organizations, self-help groups and micro-credit, and have gained significant recognition with the award of the Nobel Peace Prize to Muhammad Yunus, a Bangladesh based social entrepreneur, and economist who pioneered the concepts of microcredit and microfinance².

Rural Income Generating Activities (RIGA):

The RIGA project is a collaborative effort of FAO, World Bank and American University with the aim of promoting the understanding of the role of both agricultural and non-agricultural activities for poverty reduction and development of rural households in developing countries. This is undertaken through a two-pronged approach: (1) by setting up an innovative database on sources of income based on surveys covering 19 countries in Africa, Asia, Eastern Europe and Latin America, (2) by producing research papers and studies that investigate key policy research issues based on the RIGA data. More information of the RIGA database can be found [here](#).

Rural Electrification

Rural electrification is the process of bringing electricity supply to rural and remote areas. The challenge of rural electrification is to make electricity available to areas which lack access to the electricity grid leading to an absence of grid based power supply. The primary constraints as to why a large number of people in the world remain unconnected to the grid are typically financial and physical. While the later deals with the challenges of geography (e.g. hilly areas or large tracts of dense forest land) and availability of resources (e.g. oil/gas, water, sunlight, biomass...ect.), the prior refers to the economic challenges which developing countries face in investment funding, service costs, and revenues & collection.

² More information on these activities can be found at <http://www.muhammadyunus.org>

Global electrification scenario:

In December 2012 the UN General Assembly declared that 2014-2024 would be the decade of “Sustainable Energy for All”, noting that 1.3 billion people are without electricity. With the International Energy Agency (IEA) indicating that 95% of these people are located either in sub-Saharan African or developing Asia and 84% are in rural areas. Leading to the general conclusion that more than one billion people in rural areas do not have access to sustainable modern energy services. Asia accounts for almost half of the people without access to the grid, however this is subjective. For example in India the Ministry of Power states “a village is deemed electrified if electricity is used in the inhabited locality within its revenue boundary of the village for any purpose whatsoever”. (Source: [MOP, India](#)) Indicating that in some cases publicly available data may not necessarily provide a complete picture of the reach and magnitude of rural electrification.

In this Discussion Paper we focus on the aim that rural electrification should be to make sustainable and replicable electrification systems that provide reliable and affordable sources of energy as a fundamental human need not only for wellbeing but also for economic growth and poverty reduction.

Electricity Distribution Solutions

- **Standalone Off-Grid Solutions** provide generation at the point of consumption (e.g. a single building in an off-grid location). This solution often consist of diesel generators, or battery based renewable energy systems such as solar or wind, or a combination to create a hybrid system (e.g. solar-diesel hybrid system). While generators can be operated based on energy demand, battery based systems allow storage of energy for consumption as required. Hence, unlike full on-grid based systems a standalone system consists of several components all working together to create, store, and deliver energy for the electric demand. While standalone systems are ideal in cases of a single consumer, they may not offer the most economical solution for rural electrification. For example, Pico solar home lighting kits consist of a 5 to 10 Watt-peak (Wp) solar panels, battery bank, a small inverter and a set of LED lights; and they are designed to provide 3-5 hours of lighting a day. Typically costing \$US 100-200 per set, commonly with short warranty period (< 2yrs).³
- **Mini-Grid Solutions** are isolated systems with low generation (30 – 300 kW) low-voltage distribution grid (400V or 11kV), providing electricity to a community – typically a village or a very small town. Electricity is commonly supplied by one or several generation sources - diesel generators, solar PV, micro-hydro, biofuels generation... etc., or a combination of them. Mini-grids tackle several shortcomings of a standalone solutions and can act as a precursor to grid power, with investment costs of several hundred thousand to a couple of million \$US, depending on installed capacity⁴. They offer a “fast-start” solution to rural electrification as the power supply can be used for several types of income generating activities (e.g. operating small machinery, computers, lights etc.) thus mini-grids have the potential to introduce and integrate renewable energy solutions while providing local employment and economic development.

³ “Pico Solar PV Systems for Remote Homes”, International Energy Agency (Report IEA-PVPS T9-12:2012)

⁴ “Rural Electrification with PV Hybrid Systems”, International Energy Agency (Report IEA-PVPS T9-13:2013)

- On-Grid Solutions:** Connecting semi-rural and rural areas to the national/regional power grid offers a conceptually efficient and economical solution to providing electricity access; though it is most often hampered by the economical challenge of economies of scale (e.g. insufficient end consumers or the inability of consumers to pay for the electricity) which show insufficient investment payback ability. This is predominantly due to the overall investment costs of extending medium voltage transmission lines, which have lower losses, to rural communities with small populations. For example, investment costs for medium voltage transmission (33 - 132 kV) lines can be US\$ 25,000 to several hundred thousand \$US per km, with low voltage lines (6 – 11 kV) typically being less than US\$ 25,000 per km.⁵ In addition, the need for step-up / step-down stations can significantly increase costs.

This discussion paper focuses on the application of mini-grid solutions for rural electrification due to the ability to apply the solution to the majority of cases foreseen in the electrification of rural communities. As well due to the added advantages of scalability based on current and future demand for electricity in households and income generating commercial activities. This Discussion Paper does not address upstream and downstream activities outside this boundary nor social mechanisms within.

Electricity Generation Solutions:

There are a number of tried and tested electricity generation solutions for mini-grids which have been historically implemented in rural communities worldwide. Many have well documented experience from applications over the past ten years. A generalized comparative analysis on key decision making issues of common rural electrification generation solutions is presented in Table 1.

Table 1: Generalized Comparative Analysis of Rural Electrification Generation Solutions

Generation Solution	Investment Cost	Operating Cost	Implementation Time	Generation Stability	Comment
Grid-Connection	High	Low	High	High	Prohibitively expensive to extend to small communities after approx. 10 km of length
Diesel (Fossil Fuel)	Low	High	Low	High	Most universally implemented solution with high fuel costs and high CO ₂ emissions
Biodiesel	Medium	High	Medium	High	Only recently entering rural electrification as blended fuels or oil only application in small scale
Micro-Wind	Medium	Low	Medium	Low	Highly dependent on geographical winds speeds and requires hybrid generation or storage
Solar / Battery Storage	Medium	Medium	Low	Medium	Neutral solution, but battery replacement and environmental impact should be addressed
Solar / Diesel Hybrid	Medium	Medium	Low	Medium	Typical 30% reduction in fuel costs and CO ₂ emissions from diesel only generation
Micro-Hydro	Medium	Low	Medium	Medium	Highly dependent on close-by geographical water availability and elevation difference

⁵ Sub-Saharan Africa: Introducing Low-cost Methods in Electricity Distribution Networks, Energy Sector Management Assistance Program, 2006

This discussion paper focuses on solar generation solutions in mini-grids, due to the fact that such solutions can easily be applied in most developing countries, especially in those countries within the tropic belt where solar electricity generation potential is highest. Solar generation solutions are highly flexible in meeting demand for electricity in households and income generating commercial activities, both in initial design and in future extensions (scalability). These solutions can be designed to offer a carbon emission (CO₂) mitigation potential of 30 – 100% of the widely used diesel only generation solutions⁶.

Rural Productivity Zone (RPZ)

The creation of a 'Rural Productivity Zone' (RPZ) is based on a paradigm of an integrated approach to sustainable rural development. It consists of setting up an 'Energy System' and 'Associated Infrastructure' in a rural area that provides power for a range of activities that leads to income enhancement and social development. Economic activity results in money being generated, which in part goes into paying for the investment, operation and maintenance of the energy system and infrastructure. In addition, the provision potentially including social infrastructure for healthcare and education builds a sense of ownership and supports local capacity development leading to sustainable development.

RPZ - Energy System

The RPZ - Energy System consists of three integrated components: the energy distribution system, energy generation system, and energy end users. Energy distribution and energy generation systems are briefly described and discussed in the 'Rural Electrification' section of this discussion paper, with more technical details found in further sections of this discussion paper. End users in this context refer to a wide variety of equipment that operate on electricity such as lights, television, vaccine refrigerators, water purifiers, pumps, motors etc. which define the 'demand' for electricity. The type of equipment is dependent on the nature of the services demand, which can constitute electricity for households or income generating activities such as Small Scale Industries (SSI). Defining this demand will need careful planning based on the energy required to operate the RPZ associated infrastructure (see below) and additional loads in consultation with the local community, supporting stakeholders (NGOs, civil society, self help groups, local industry associations etc.) and technical know-how.

India's Small Scale Industries:

In most developing countries like India, Small Scale Industries (SSI) constitute a crucial segment of the industrial sector. They play an important role in employment creation, resource utilisation and income generation and help promote change in a gradual and socially acceptable manner. They have been given an important place in the framework of Indian planning both for economic and ideological reasons. SSIs and micro enterprises are characterized by manual labour and relatively lower mechanical intervention to produce goods from raw materials that can be sourced locally. Employment in SSIs can vary from a single individual practicing a trade (e.g. a tailor) to a group of individuals operating under a cooperative or for-profit enterprise (e.g. sewing shop). Other examples of SSI include the leather industry (tanneries with raw materials sourced from local animals), textile and natural fiber based industries (handloom fabrics from jute or silk), pharmaceuticals (herbal medicine), food processing and marine industry (fruit pickles, drying of fish etc.), handicrafts and organic products (candle making, honey making etc.) The equipments used in SSI such as sewing machine have low power demand making them suitable for mini-grid based solar hybrid solutions.

⁶ Note: Variation is depending on design capacity (kWp), household consumption (kWh), and storage capacity / no-storage. Design/Economic iterations indicate that displacing less than 30% of electricity consumption with solar generated power is not economically viable in most cases based on current diesel prices.

RPZ - Associated Infrastructure

The Associated Infrastructure of an RPZ consists of three components designed to give communities better access to services and SSI, thus allowing for greater rural development, though are not limited to these components. The three RPZ components are: a rural community/data center, industrial sheds and the cooperative. While these may be contained in a single or multiple building(s), the physical units are expected to be permanent structures built using local labour, local materials and local architectural principles in order to encourage a sense of community ownership and reduced external maintenance requirements. The planning and design for the type of income generating activities, associated infrastructure and the energy system must be carried out in close consultation with the local community, self-help groups, NGOs, micro-finance institutions, engineers, etc. to build a RPZ that is relevant to the local community and caters to the demand for products and services.

- **The Rural Community / Data Center:** is to house social services for the rural community in the form of a primary health center, a business center with facilities for internet, rural telecommunications, mobile charging station, education center, and drinking water facilities. Given the collective nature of villages, the rural community center can serve multiple roles, for e.g. serve as a meeting place for village elders, a TV room for adult literacy programs, a local information center for government programs and data collection etc.
- **Industrial Sheds:** are well lit and well ventilated buildings with power supply to production rooms, warehouses, and workplaces provided to the rural enterprises to undertake gainful income generation activity. The 'industrial shed' forms the single largest consumer of electricity, but helps generate community revenues, part of which goes into supporting the cost of the energy system. Housing economic activity in a single location has certain benefits such as shared common services and enhancing the spirit of cooperation. Note that the physical layout and business model for training and financing of the rural enterprises is separate from the discussion in this paper.
- **Rural Cooperative:** A cooperative can be envisaged as a "small rural mall" with joint ownership between the local community and a private retailer. The cooperative can be used by rural communities to buy and sell goods and agricultural products, as well as act as point for other goods and service providers to bring their products directly to the rural community. Similarly, wholesalers can use the cooperative to procure directly from farmers and rural enterprises. While the cooperative can take the form of a "rural mall" – its primary role is to facilitate the entire business model by providing a small commercial platform, secure private sector participation (e.g. to partly or fully own and operate the energy system) and make the RPZ benefits move visible to the community.

Case Example - Rural Shopping Malls in India:

The idea of rural shopping malls in India is driven by a variety of private enterprises (See 'References'). These malls are primarily buy and sell centers for procurement of agro-products directly from farmers negating the need for middlemen. These highly visible and branded malls provide the farmers (now with cash in hand) a 'sophisticated marketplace' to buy regular consumer goods and provide the consumer and agro-based industries (ex. seeds, fertilizers) a ready channel to make their products and services (e.g. insurance) directly available to the end consumer. The malls also provide information on daily rates from the local wholesale markets allowing the farmers to make an informed decision and building a sense of trust. Brightly coloured, well lit and ventilated the malls provide a sense of aspiration and pride to the local community. Increased interactions with 'outsiders' and experts (e.g. agriculture scientists, farm equipment sellers) creates awareness and a demand for better education and healthcare. Erratic and inadequate power supply forces the rural malls or cooperatives to depend on diesel generator – making them an ideal customer for a solar / hybrid energy system.

Overview of the RPZ

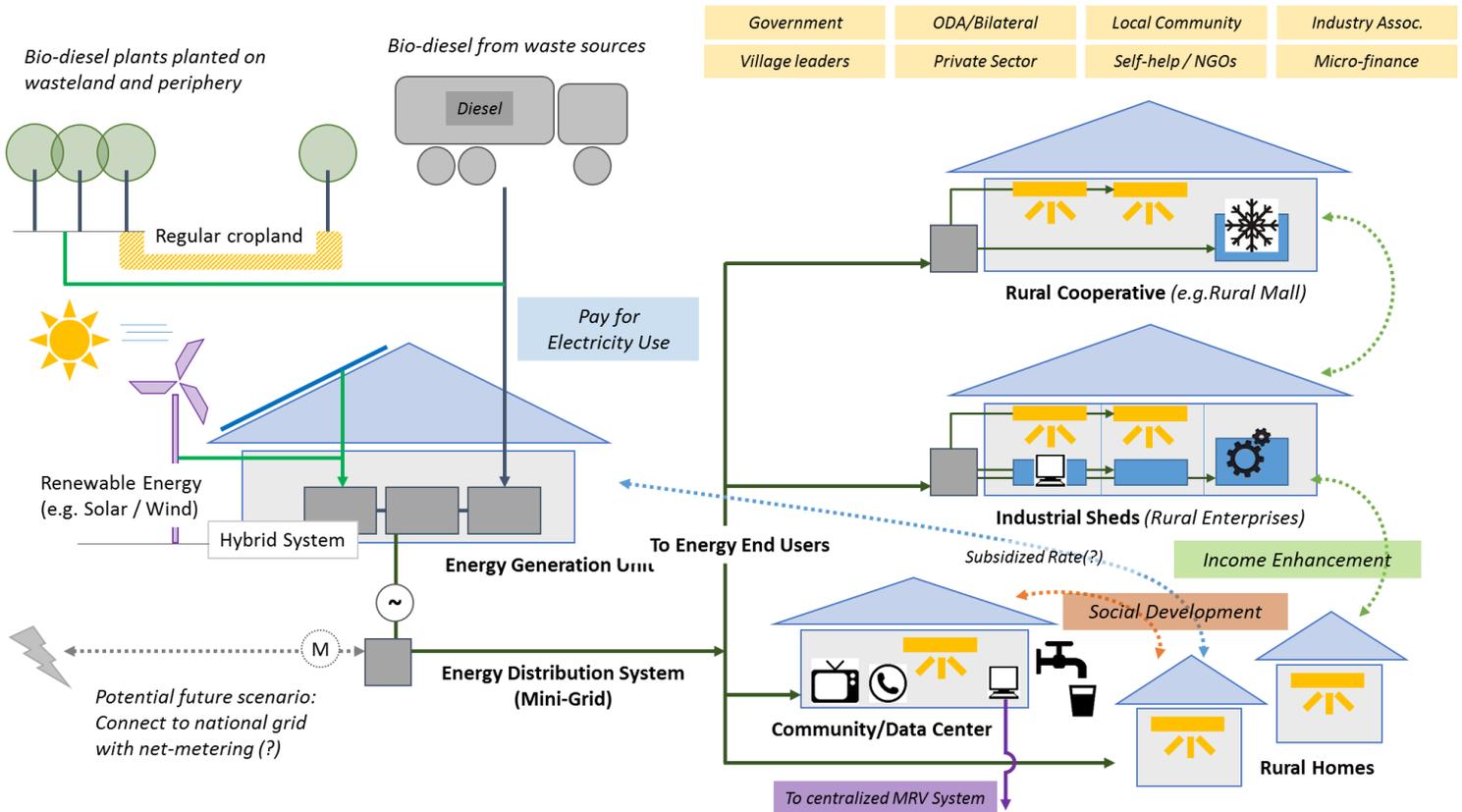


Fig 2: Flow of energy, services and finance leading to an integrated sustainable development

The above Figure 2 provides a schematic overview of a model RPZ, which can potentially make an impact in developing and implementation a low carbon economy in developing countries. It involves several stakeholders and tackles the challenge of rural development holistically with access to energy being the key driver for socio-economic development.

While individual components can be tailor-made to suit the local requirements and its business model, the principal idea is to establish a sustainable system that generates sufficient revenues to pay for the energy use. Initial investments can be sourced through a variety of sources, e.g. the ministry of rural development, health and education can support the development of the community center, private equity participation for the rural cooperative, micro-finance for procuring equipment for the rural enterprises, and Official Development Aid/bilateral finance for the energy system. This self-sustaining nature of long term sustainable energy and new income generation can be of particular interest to international donor finance in addition to building the confidence of (in-country micro) financial institutions. Training and capacity building can be undertaken through a combination of NGOs, self-help groups and industry associations who shall also cooperate with the local community and village elders in identifying the rural enterprises. The community center in every RPZ can be identified as the single point of contact for data collection. Electricity generation from the energy generation unit can be collected and electronically transferred to a national MRV databank for estimation of GHG Emission Reductions. The development of a micro-grid provides the scope for integration with national electricity grid with daily operation and maintenance being undertaken by the locals. Most importantly, as local communities are direct beneficiaries of the energy system it will provide a sense of communal pride, ownership and prevent against theft and damage.

Suitability, Sustainability and Design of an Integrated Solar-RPZ Solution

The previous sections of this paper outline comparative advantages of solar generation systems and the use of mini-grid, plus introduces the concept of RPZs as a means for supporting income generating activities. In the following sections this discussion paper focuses on the design and operation of an Integrated Solar-RPZ Solution for rural communities. The first issue to address when looking at the potential establishment of an Integrated Solar-RPZ Solution is technical, economic, and social suitability of applying it in the rural community. The suggested minimum suitability criteria to be addressed in selecting target communities in relation to the Integrated Solar-RPZ Solution are shown in Table 2.

Table 2: Suitability Criteria for an Integrated Solar-RPZ Solution

Criteria / Priority	Technical	Economic	Social
High	<ul style="list-style-type: none"> Solar radiation potential in the area is at least 5.0 kWh/m²/day No access to micro-hydro generation potential 	<ul style="list-style-type: none"> Existing access to markets for potential goods Minimum household income stream of \$US 700 per year 	<ul style="list-style-type: none"> Existing community governance structure is in place Limited indigenous conflicts in the community
Medium	<ul style="list-style-type: none"> Optimum daily temperature range 15 - 35° C Existing know-how for household electrical installation 	<ul style="list-style-type: none"> Existing skills for micro-enterprises income generation Existing mechanisms for the collection of service fees 	<ul style="list-style-type: none"> Community is open to modern stakeholder processes Community willingness to work with development agencies / NGOs
Low	<ul style="list-style-type: none"> Existing mini-grid already exists in part or whole No access to the grid (10 to 33 kV) within 10 - 15 km 	<ul style="list-style-type: none"> Access to micro-finance in the area or community Land available of at least 1000 m², in a centralized location 	<ul style="list-style-type: none"> Existing primary education level in the community Active gender equality activities and no child labor

Sustainability Considerations for Solar Generation Solutions in Mini-Grids

After addressing the suitability of a selected location / community for the installation of for an Integrated Solar-RPZ Solution, then a next important issue to address is its sustainability. Sustainability should be addressed at the concept / inception stage, project development stages, and during the life-cycle of the installations. Some of the key sustainability concerns, but are not limited to, the following⁷:

Technical:

- The design should properly take into account size, changes in demand, and energy efficiency. Addressing these issues from the start can lead to lower investment costs and long term savings by maximizing equipment life-time. This includes performing a comprehensive demand analysis which is site specific, which may include a long term scale-up action plan (especially when integrating the RPZ concept).
- Qualified design and good quality equipment should be selected from reputable suppliers/vendors. Many equipment suppliers have a 2 to 5 year warranty on products, but it is highly recommended to extend warranty periods for equipment to 8 to 10 yrs. and that supplier services and location are taken into account. It is often seen where savings in investment cost were later outweighed by increases operational costs due to faulty equipment and design.

⁷ Issues are derived from the practical experience of the authors and augmented by lessons learned from "Hybrid mini-grids for rural electrification: lessons learned" - USAID/ARE

- Poor maintenance has historically proven to be a major factor in rural projects (electricity, water, waste, manufacturing...). Envisioning and implementing a maintenance management and sourcing structure is critical to the sustainability of rural electrification projects in the long term. A maintenance management and sourcing structure should take into account when and how minor and major equipment it to be repaired or replaced and by whom.
- Selected electrical equipment (e.g. inverters, transformers, and controls) should have proven operation in similar physical environments, particularly in relation to humidity and temperature.
- The impact of insects, vermin, and livestock should be taken into account in design solutions and equipment considerations.

Economic:

- It is highly recommended to development a simple long term financial model from inception stage which takes into account projected investment / capital expenditures (CAPEX) and operating expenditures (OPEX). This can help indicate the levels donor money, equity, and debt needed for finance. As well as help identify periods of financial risk and translates life-cycle costs into annualized consumer prices for electricity.
- A clear strategy and long term cost projection of operating expenditures (OPEX) should be devised from the concept / inception stage. This should take into account common operation and maintenance (O&M) of business operations, finance costs, labour, external services, training, maintenance, and growth. As well as changes in these aspects. For example what happens when a key technician quits, or how to pay for major equipment replacement?
- A scheme for financing should be addressed at the concept / inception stage. This should take into account projected CAPEX and OPEX costs, project development costs, and initial costs of finance. It is common that financing should also cover a first nominal period of operation, as a means to limit the impact of initial consumer payment risk.
- Private sector investment and participation can be encouraged at the financing and operations stage by offering equity or long term O&M contract to private companies. It is noted that in such cases, and particularly in rural areas of developing countries, internal rates of return (IRR) required will likely be higher than the national Foreign Direct Investment (FDI) rate of return. As an example the African countries Zambia, Namibia, and Nigeria had FDI rates of return of 13%, 14%, and 36% respectively in 2011.⁸
- The consumer affordability for the electricity must be taken into account in the inception and design stages. The magnitude of household expenditures on electric should be ganged, and the design should take this into account. A mini-grid system should not be designed to deliver 5 kWh per day to a household which can only afford 1 kWh a day.
- The RPZ component should also take into account the establishment of micro-finance schemes, and the market access of produced goods and services.

⁸ "World Investment Report 2013", United Nations Conference on Trade and Development, 2013

Social:

- A comprehensive community stakeholder consultation process should be addressed from the concept / inception stage, and especially in the design stage. The community stakeholder consultation process would at a minimum need to focus on the existing use of electricity and lighting in households, fuel using in enterprises, existing and potential income generating activities, and general concerns and knowledge level of the community. Special focus can be placed on actions for income generation for women, better education services for children... and other sustainable development issues, as these may be linked to potential finance and income sources.
- Existing community leadership and governance should be integrated into the management and operational structure of the RPZ and energy / distribution system, in order to ensure buy-in and future investments by the community.
- The method for the collection of consumer payments should be extensively addressed in stakeholder consultations in the initial development stage, as buy-in is critical. A socially acceptable and financially viable collection method should be devised with the community, and include legal principles such as contracts and actions against default.

Solar Energy for Solar Generation Solutions in Mini-Grids

Solar energy and its intensity is critical in the design and unit costs of Solar Generation Solutions in Mini-Grids. Energy sources can be divided into primary generation and storage. Under primary generation the sun provides energy during the daylight hours with different intensities based on geographical location, elevation, day of year, and weather conditions. Figure 3 shows the annual average daily solar intensity (kWh/m²/day) in Asia and Africa. The economic effectiveness of solar generation solutions truly depends on this intensity, and from a developing country standpoint is most economically effective in areas of the tropic belt with intensities of 5.0 kWh/m²/day or greater. Storage refers to recharge and discharge of batteries which can help balance the electricity supply with demand, or provide electricity during less intense sun hours and at night.

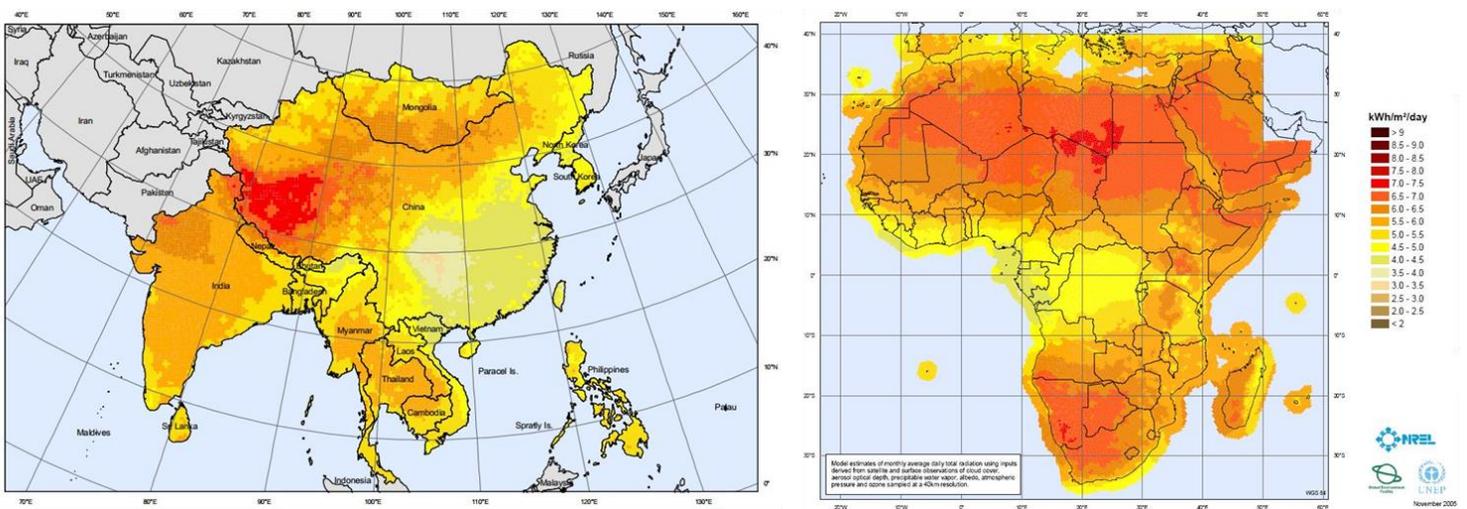


Fig 3: Solar Radiation – Flat Plate Tilted Latitude (Source: NREL/UNEP/GEF - en.openei.org)

Other Energy Sources for Generation Solutions in Mini-Grids

Other energy sources typically refer to fossil fuel generated electricity which is commonly diesel in the case of rural mini-grids. However, new efforts are being taken to use biodiesel in electricity generation, which refers to a biofuel based on vegetable oils. There are two kinds of biodiesel currently in use. The first is a blended fuel with a mix of biofuel (oil) and fossil fuel diesel, with common mix ratios of 10/90, 20/80, and 30/70. This blended biodiesel can be used in common diesel gensets. The second is to use only biofuel (oil) directly in specialized gensets, such as single cylinder generators.

Biodiesel for Electricity Generation:



In the above left-hand picture the UNDP/GEF has partnered with the Fijian Department of Energy in the Fiji Renewable Energy Power Project (FREPP). One of the show cases of FREPP are efforts to locally produce biofuel / biodiesel for power production in rural communities. The biofuel mills utilize copra to produce coconut oil as a biofuel, and blend in a 20% / 80% ratio for biodiesel. The mills produce the biodiesel at a price cheaper than imported diesel, and are a local income generating activities.

In the above right-hand picture a biodiesel based energy platform installed by Mali Folk Center in the village of Tabakoro, in southern Mali, which uses oil from Jatropha plants as an alternative to diesel fuel in a single cylinder engine. Extraction of bio-diesel from non-edible oil seeds can be undertaken locally by farmers (image to right) and results in minimum wastage in addition to tertiary benefits in the form of soap, fertilizers, and animal feed. (Sources: [FREPP](#) and [Mali Folk Center](#))

Model Energy System Design for a Solar - RPZ Solution

For the purpose of showcasing the application of the Solar - RPZ Solution concept on a national / regional level, a 'Model Design' is chosen which is scalable at the community level (e.g. larger communities) and the national level (e.g. many communities). In this manner the generalized technical and financial outputs of this Model can be utilized at a macro level by policy makers to qualify and quantify the application of such Solar - RPZ Solution in rural communities.⁹

The basis of the Model Design detailed is a hypothetical rural community who has the collective desire and need for electricity and increased income generating activities. This community has 100 households, each of which housing on the average four persons, with a total population 400 persons. The community has existing skills in manufacturing of cultural garments, production of traditional wood crafts, and has a need for a mechanical shop and grain milling based on their traditional agricultural activities.

Two options for the Model Design are envisioned for the energy system: (1) a solar & battery system, and (2) solar & diesel hybrid system. The Model Design consists of the following components shown in Table 3 and demand / generation profile shown in Figure 4. The technical design of the energy system for a Solar - RPZ Solution in a community should at a minimum take into account:

- 1) The determined demand for electricity in the community on an hourly & daily bases,
- 2) The available solar energy resources and fluctuations during the day and annually,
- 3) Use of fossil fuels (diesel) in hybrid generation or as backup,
- 4) Combined losses in the energy and distribution systems.

Table 3: Model Design for 100 Households– Main Technical Components

	<i>Solar & Battery System</i>	<i>Solar & Biodiesel Hybrid System</i>
Solar Capacity	<ul style="list-style-type: none"> ▪ 38 kWp ground mounted panels (250 Wp / panel) ▪ Required DC and AC cables ▪ 3x 15 kW combined inverter / transformer ▪ 3x 6 kW battery inverter / charger ▪ Monitoring and control system 	<ul style="list-style-type: none"> ▪ 19 kWp ground mounted panels (250 Wp / panel) ▪ Required DC and AC cables ▪ 2x 15 kW combined inverter / transformer ▪ Monitoring and control system
Additions to Energy System	<ul style="list-style-type: none"> ▪ 149 kWh battery bank (for daily non-sunlight and 24 hours back-up) ▪ 1x 15 kW diesel genset & controller (only for back-up) 	<ul style="list-style-type: none"> ▪ 1x 15 kW diesel genset & controller (for daily non-sunlight and 24 hours back-up)
Distribution	<ul style="list-style-type: none"> ▪ 400v – 1kV mini-grid ▪ 3 km of single-phase overhead cable ▪ 200m of three-phase underground cable ▪ 400v / 220v (2.5 Amp) ready-boards at households 	<ul style="list-style-type: none"> ▪ 400v – 1kV mini-grid ▪ 3 km of single-phase overhead cable ▪ 200m of three-phase underground cable ▪ 400v / 220v (2.5 Amp) ready-boards at households

⁹ Caution should be taken in reference to country specific conditions which may influence the variations in the technical and financial conditions of individual or multiple applications of the Solar - RPZ Solution. In all events, a more detailed qualification and quantification should be performed by qualified persons or companies in order to develop more precise country specific technical and financial information.

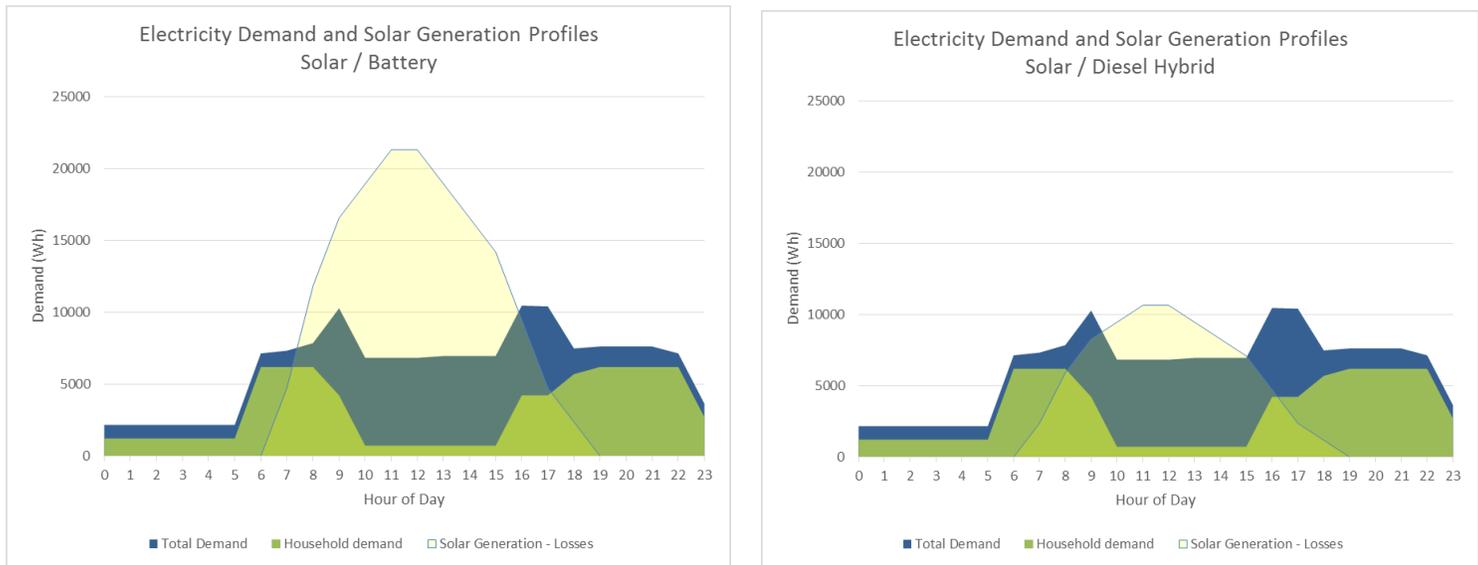


Fig 4: Electricity Demand and Solar Generation Profiles (two Model Design options)

As indicated above Figure 4 represents the electricity demand of the community in the Model Design, broken down into total demand (in blue) and household demand (in green). The difference between the two demand curves is the demand from the RPZ component, the rural community / data center, industrial sheds, rural cooperative, and peristaltic load of the energy system. The yellow overlapping curve represents the average annual daily solar power generation profile based on the two design capacities. Noting that for the Solar / Battery option the free area of the solar power generation profile above the demand is the amount of energy stored in batteries.

Case Example - Kitonyoni solar power plant project in Kenya:

The Energy for Development (E4D) network worked in a rural community in Makueni County, Kenya, to establish a 13.5 kWp PV solar plant for the community. The PV solar plant provides electricity services to up to 3000 people in the community, in addition to the school, health center and 40 businesses. The solar provides modern electricity services for food refrigeration, lighting, mobile phones, and battery recharging. The PV solar plant is operated and maintained by the local cooperative. An added component is that the PV solar plant was integrated on a large canopy, which collected rain water for local consumption.

(Source: <http://www.energyfordevelopment.net/projects-2/kitonyoni/>)

Determining Energy Demand:

Most rural households and rural enterprises have a relatively lower power demand and can be designed to operate on a low voltage making it ideal for introduction of a mini-grid. Multiplying the number of Kilo-watts (1kW=1000 Watts) with the daily hours of operation (h) provides the total daily energy consumption (in Kilo-watt hours, kWh). The table below provides an indicative range for the wattage of typical electrical equipment:

- Lighting: 5 to 20 watts for CFL/LED lights, 40-50 watts for fluorescent tube lights, 25-100 watts for incandescent lamps
- Fans: 50 to 150 watts
- TV / Computers: 100 to 150 watts (based on the display technology, LED monitors consume lower watts)
- Radio, VCR, DVD players: 10-50 watts
- Refrigerator: 500 – 1000 watts
- Motors and pumps: Denoted by horsepower (1hp = 746 watts). Thus, a half hp motor = 373 watts.

Estimating energy consumption for a model household:

- 2 nos. of 11 watt CFL operating 14 hours in a day = $2 \times 0.011 \text{ kW} \times 14 \text{ hrs/day} = 0.308 \text{ kWh / day}$
- 1 nos. of 35 watt radio operating 11 hours in a day = $1 \times 0.035 \text{ kW} \times 11 \text{ hrs/day} = 0.385 \text{ kWh / day}$
- 1 nos. of 5 watt mobile phone charger operating 14 hours in a day = $1 \times 0.005 \text{ kW} \times 14 \text{ hrs/day} = 0.070 \text{ kWh / day}$
- TOTAL Daily Consumption is = 0.76 kWh

Important! This method for estimating energy consumption is indicative and the technical design for energy systems must be carried out by competent professionals. There are several factors that influence the actual electricity required. For example, a 500 watt refrigerator left switched on for an entire day actually operates its motors for $1/3^{\text{rd}}$ the time, hence the energy consumption = $500 \times 8 \text{ hours}$ (i.e. $1/3^{\text{rd}}$ of 24 hours) = 4kWh. Similarly motors have a "starting current" that is several times its 'operating wattage' and lasts for an initial few seconds. This "surge" needs to be factored in when designing the hybrid power solution.

Model Design Economics and Financing of an Integrated Solar-RPZ Solution

In Sub-Saharan Africa typical household energy expenditures are estimate to be US\$ 15 to US\$ 30 per month, with close to $2/3$ going to electricity use.¹⁰ The IEA estimates that a total of US\$ 30.6 billion annually is required to supply access to these household via on-grid, mini-grid, and off-grid sources (US\$ 11.0, 12.2, and 7.4 billion respectively).¹¹ This discussion paper presents that there is a fundamental paradox between the nominal income of rural households and the cost of supplying electricity to rural communities. Some sources focusing on developing countries indicate that annual rural household incomes are in the range of US\$ 300 to 900 from rural commercial activist such as forest products¹², and as this discussion paper presents in further sections the unit cost of renewable and fossil fuel energy can be a heavy burden on rural incomes. Thus, multi-source financing is needed in order to provide a measurable level of affordability of electricity in rural communities. This discussion paper objectively defines this level of affordability to be below US\$ 20 per month per household. This is derived as 40% of the medium annual rural household incomes indicated above, e.g. US\$ 600.

¹⁰ "Sub-Saharan Africa: Introducing Low-cost Methods in Electricity Distribution Networks", ESMAP, 2006

¹¹ "Energy for All – Financing access for the poor", International Energy Agency, October 2011

¹² "Forest Income and Household Welfare in Rural Nigeria", Ayuk et al., United Nations University, Sep 2011

"Household Dependence on Forest Income in Rural Zambia", Bwalya, Zambia Social Science Journal, Vol 2 May 2011

Model Design Investment and Operational Costs

The Model Design options (for a 100-households and RPZ) have a comparatively high costs of investment and O&M, when compared to a diesel only system when excluding the cost of diesel. The key difference in investment cost of the two options is primary that the cost of the Solar & Battery option is high due to the cost of batteries and additional solar panels (capacity) needed to charge the batteries during daylight hours. Whereas the Solar & Biodiesel Hybrid option has only enough solar capacity to cover peak demand at mid-day and no storage batteries.

Table 4: Model Design – Investment and Operational Costs¹³

Model Design Option (In US\$)	Solar & Battery	Solar & Biodiesel Hybrid	Diesel Only
Energy System Investment Cost	<u>256,000 Total</u> 38,000 PV Panels (38 kWp) 12,000 Mounting/Frame System 5,000 DC/AC Wiring 42,000 Inverters/transformers 49,000 Battery Pack 14,000 Monitoring / Control 9,000 Backup-Genset 51,000 Installation & Engineering 20,000 Housing 16,000 Other	<u>136,000 Total</u> 19,000 PV Panels (19 kWp) 6,000 Mounting/Frame System 3,000 DC/AC Wiring 18,000 Inverters/transformers 11,000 Monitoring / Control 9,000 Backup-Genset 38,000 Installation & Engineering 20,000 Housing 12,000 Other	<u>65,000 Total</u> 9,000 Genset (11 kw) 3,000 AC Wiring 10,000 Monitoring / Control 21,000 Installation & Engineering 15,000 Housing 7,000 Other
Distribution Investment Cost	<u>88,000 Total</u> 36,000 Distribution Lines etc. 15,000 Household ready-boards 25,000 Installation & Engineering 12,000 Other	<u>88,000 Total</u> 36,000 Distribution Lines etc. 15,000 Household ready-boards 25,000 Installation & Engineering 12,000 Other	<u>88,000 Total</u> 36,000 Distribution Lines etc. 15,000 Household ready-boards 25,000 Installation & Engineering 12,000 Other
O&M (annual)	<u>34,000 Total</u> 12,000 Local Staff 18,000 Energy Maintenance 4,000 Distribution Maintenance	<u>22,000 Total</u> 12,000 Local Staff 6,000 Energy Maintenance 4,000 Distribution Maintenance	<u>18,000 Total</u> 12,000 Local Staff 2,000 Energy Maintenance 4,000 Distribution Maintenance

¹³ Investment costs are indicative, and based on nominal costs of end suppliers and general developing country labor costs estimated in 2014, they do not include financing, vendor/EPC markups, taxes & duties, and variation due to specific country conditions. Operation and Maintenance (O&M) costs are annualized, taking into account periodic replacement of required equipment. The cost of investment for the community/data center, cooperative, and industrial sheds are not included.

Proposed Financing Model and Unit Costs

This discussion paper focuses a 'semi-public sector' financing model. Where the equity investment portion is shared between government agencies, development agencies, and the rural community, while debt is financed through loans funds or a credit facility (linked to commercial loans). This is only one of several different options for financing the Integrated Solar-RPZ Solution. The 'semi-public sector' model is chosen as it is deemed to represent a situation which leads to the lowest unit cost to household consumers, though it may not represent the most realistic method of finance in specific country circumstances. Insofar that in some countries it may not be possible to combine large portions of equity, or loan facilities for small project may not currently exist. The 'semi-public sector' financing model also shows the level of external involvement needed in order to keep the unit cost at an affordable level (< UD\$ 20 per month per household).

One of the primary assumptions of the PRZ is that there is a single unit price for consumers connected to the system (e.g. households, community/data center, industrial sheds, cooperative, and energy system). Then the expense of electricity consumption is paid for by each consumer directly and/or subsidized through a community or national scheme. The distribution of electricity consumption and thus expenses is shown in Figure 5 below.

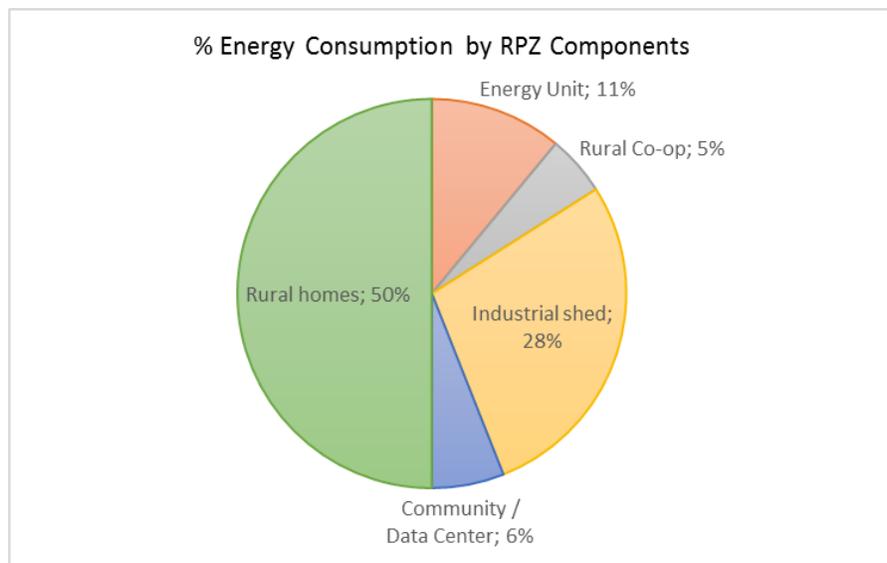


Fig 5: Estimated energy consumption of the Model Design

In financial modeling of the two Model Design options the total investment cost and operation & maintenance cost of both the energy and distribution systems are taken into account over a 15 year period. The unit cost comparison is then modeled based on different financial equity / debt ratios, depicted in Figure 6. The Debt is assumed to originate from an institutional Revolving Loan Fund which provides direct loans or credit guarantees to renewable energy projects a low-interest rates.¹⁴ The Equity is assumed to derive from several different sources with the majority coming from development aid programmes or national budget allocations.¹⁵ It is not believed to be optimum that the target community contributes to the equity of the energy and distribution system, as they will need to pay the unit price but also be responsible for investment in the community/data center, industrial sheds, and cooperative.

¹⁴ For the purpose of the financial model at 10 year loan is chosen at a combined rate of 8% (interest and fees).

¹⁵ Private sector / commercial sources of equity which require rates-of-return are not addressed in this 'semi-public sector' financing model, but are assumed to be a part of the community's investments in the community/data center, industrial sheds, and cooperative.

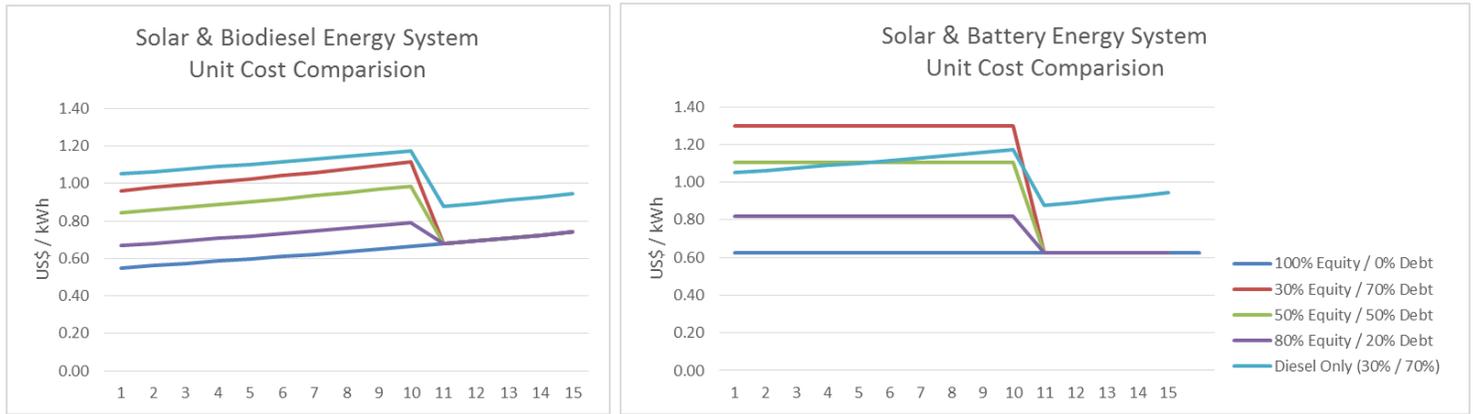


Fig 6: Unit Price Over 15 yrs with grant / finance alternatives (two Model Design options)

The Model Design options of the energy system and distribution costs indicate a high average cost of electricity production and distribution of between US\$ 0.63 – 1.08 per kWh dependent on the financing options chosen, with the alternative diesel leading to average cost of US\$ 0.88 – 1.04 per kWh.¹⁶ Based on the Model Design’s household electricity consumption of 0.76 kWh per day, then rural households would need available monthly income of US\$14.40 to US\$24.60 for purchasing electricity on a monthly basis. In order to achieve an affordable level (< US\$ 20 per month per household) of electricity the financing model indicates that equity needs to be greater than 50%. The financing model also indicates the renewable energy solution Model Design will lead to a lower unit cost than a diesel-only solution when equity is at least 30% for the Solar & Biodiesel Energy System, and at least 50% for the Solar & Battery Energy System.

Carbon Emissions Mitigation (Baseline Setting, Sustainable Development Indicators, and MRV)

Mitigation in GHG emissions needs to be measured against a ‘baseline’ which in the case of many energy projects can be determined based on a historical consumption pattern. The practical challenge in implementing rural electrification and RPZs is that the per-capita emissions of the rural poor are so low that there is practically very little emissions (e.g. kerosene lamp, small generators) from historic consumption that can be reduced. Within the field of Climate Change, the UNFCCC’s Clean Development Mechanism (CDM) overcame this challenge by introducing a concept known as ‘suppressed demand’ in baseline determination.

In considering suppressed demand, one takes into consideration the energy consumption (and hence the emissions generated) if the rural poor had the same income levels and access to services (or ‘satisfied demand’) as others in the country or region. While the understanding of satisfied demand may be subjective and not applicable for all technologies, the UNFCCC has developed a ‘Guidelines on the Consideration of Suppressed Demand in CDM Methodologies’ that provides guidance on how emission mitigations can be calculated under a suppressed demand scenario. The figure 7 below provides a pictorial overview of how these calculations can be achieved.

¹⁶ Not including financing, country variations, and private sector margins

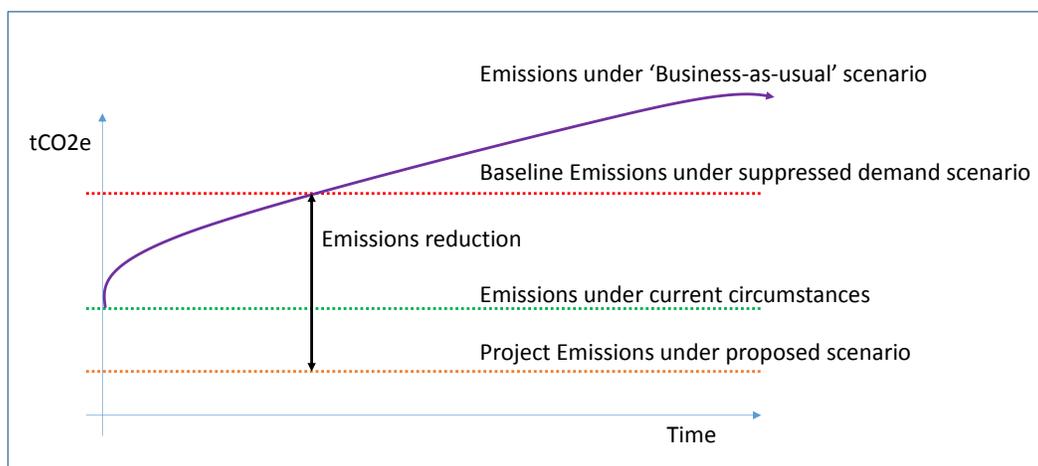


Fig 7: Suppressed Demand Concept for Emission Reductions

As a general guidance for determining GHG mitigation, the CDM as well offers several conservative methodologies for estimating GHG mitigation (reductions) for rural electrification projects, and these include:¹⁷

- AMS-I.A: Electricity Generation by the user
- AMS-I.F: Renewable energy generation for captive use and mini-grid
- AMS III.AR: Substituting fossil fuel based lighting with LED lighting systems
- AMS-I.L Electrification of rural communities using renewable energy
- AMS-III.AW Electrification of rural communities by grid extension

AMS I.A and I.F directly apply to rural electrification projects and has several projects registered under the methodologies with the CDM, including Programme of Activities (PoAs) which combine many individual projects into one programme. AMS III.AR is specific to the use of a technology (LED lighting systems) and AMS-I.L and AMS-III.AW have only recently been approved. AMS I.L applies to projects that install renewable electricity generation technologies in communities with no access to electricity but where 75% of consumers must be households. The methodology incorporates the concept of suppressed demand and is designed to be easy to apply. AMS-III.AW applies to projects that bring electrical power to rural communities that do not have access to a grid and is applicable for projects that involve the extension of the existing national grid that is mostly supplied with electricity from renewable energy-based power plants.

Any determination of GHG mitigation should take into account the specific project conditions when selecting the most appropriate methodology for the estimation of GHG reductions. . For example in the case of the Model Design options, GHG mitigation can be as high as 65 tCO₂ per year and as low as 46 tCO₂ per year.¹⁸

¹⁷ <http://cdm.unfccc.int/methodologies/SSCmethodologies/approved>

¹⁸ Utilizing the most conservative baseline from AMS I.F for a 10 kW load, emissions factor of 1.2 kg CO₂ / kWh for Solar & Battery System and 1.4 kg CO₂ / kWh for Solar & Biodiesel System with 30% biodiesel in the blend. Note that is pure diesel is used then the GHG mitigation for the Solar & Diesel System is 33 tCO₂ per year.

Sustainable Development Indicators for an Integrated Solar-RPZ Solution

Apart from fulfilling the energy demand of the local rural community, an Integrated Solar-RPZ Solution influences several associated environmental, social and economic conditions in the community. This situation indicates that a modern, assured and sustainable supply of energy is a huge opportunity for economically challenged regions in a developing country. In order to evaluate the associated impact of an Integrated Solar-RPZ Solution in a community, qualify and quantify this impact, sustainable development (SD) indicators need to be identified. It is highly recommended to apply SD indicators which fit into national goals or those of organizations financially supporting the Integrated Solar-RPZ Solution, or downstream activities in the community. As an example five potential SD indicators are presented in Table 5, and are derived from the UN Global Compact's "Issue Briefs" series on the post-2015 development agenda and related sustainable development goals.

Table 5: Potential Sustainable Development Indicators

Indicators	UNGC Post-2015 Agenda Global Priorities	Parameter Measured
SD1: Employment	<p><u>Goal 1:</u> End poverty and increase prosperity via inclusive economic growth</p> <p><u>Target:</u> Create jobs through decent work sufficient to keep unemployment below 5 per cent, including women as a group, and below 10 per cent for youth.</p>	No. of adults employed
SD2: Access to Finance	<p><u>Goal 1:</u> End poverty and increase prosperity via inclusive economic growth</p> <p><u>Target:</u> Ensure full access to private finance, including basic savings, loans and growth capital products, on fair terms including for women and marginalized groups</p>	<p>No. of loans accessed</p> <p>Total value (US\$) of loans accessed</p>
SD3: Young adults employment	<p><u>Goal 2:</u> Quality education for all</p> <p><u>Target:</u> Increase the percentage of young adults with the skills needed for work</p>	No. of young adults employed
SD4: Women's ownership	<p><u>Goal 3:</u> Achieve women and girls' empowerment</p> <p><u>Target:</u> Full and equal access of women to ownership, property rights and land titles.</p>	<p>No. female owned businesses</p> <p>No. female owned homes</p>
SD5: Access to electricity	<p><u>Goal 7:</u> Sustainable energy for all</p> <p><u>Target:</u> Universal access to modern energy services</p>	No. persons with daily access to electricity / community population

When selecting SD indicators it is important address the following key questions:

- Is there existing data available (in reasonable quality) in the community or in national statistics which can form a quantitative or qualitative baseline for each specific SD indicator chosen for use? If the data is not available can the data be collected in the community at a low cost?
- Can new quantitative or qualitative data be gained in the community for each specific SD indicator in the future, and is this data collection culturally acceptable and financially viable for the community?
- Will the quantitative or qualitative data gained for each specific SD indicator be unbiased, and what are the methods to be introduced to minimize bias?
- Can the quantitative or qualitative data gained for each specific SD indicator (both baseline and post-implementation), and conclusions drawn from these, be verified by third parties?
- Will reporting the outcomes of the SD indicator over time have negative social impacts in the community or country?

The inclusion of SD indicators, especially in MRV which is covered under the next section, is critical to one of key aspects in financing the Integrated Solar-RPZ Solution. This key aspect is the ability to gain Official Development Aid and other forms of development finance, such loans from Multilateral Development Banks, for financing the Integrated Solar-RPZ Solution. The different types of institutions behind these forms of development finance are increasingly requiring that money spent be linked to measured positive development impacts, often linked to the Millennium Development Goals or post-2015 development goals. In simple terms the more SD indicators are identified and measured the higher chance of finance especially in relation to climate change mitigation.

MRV Concept Model for an Integrated Solar-RPZ Solution

It is envisioned that the communities employing the Integrated Solar-RPZ Solution do so under a countrywide framework of a low emission development strategy (LEDS) for rural electrification. An essential part of such an LEDS is the monitoring and evaluation of outcomes of the strategy, policies and related actions. In this manner a Monitoring, Reporting and Verification (MRV) system will ensure that GHG mitigation and sustainability indicators are linked to the LEDS, which may ultimately be linked to the UN's post 2015 Development Agenda and potential allocation of finance from domestic and/or international sources. Essentially MRV systems are integral to developing and implementing a LEDS and specifically National Appropriate Mitigation Actions (NAMAs).

In the case of the Integrated Solar-RPZ Solution, the community / data center and assigned community members can act as a single point of contact for collecting data required for GHG mitigation and SD indicator measurement and verification. The data would then be sent to a national database center under an appropriate authority (e.g. NAMA coordinating agency) for evaluation against national targets, and be reported and verified. Establishing a MRV system is thus essential to ensuring the overall impact and effectiveness of the Integrated Solar-RPZ Solution is communicated and recognized with national and international stakeholders.

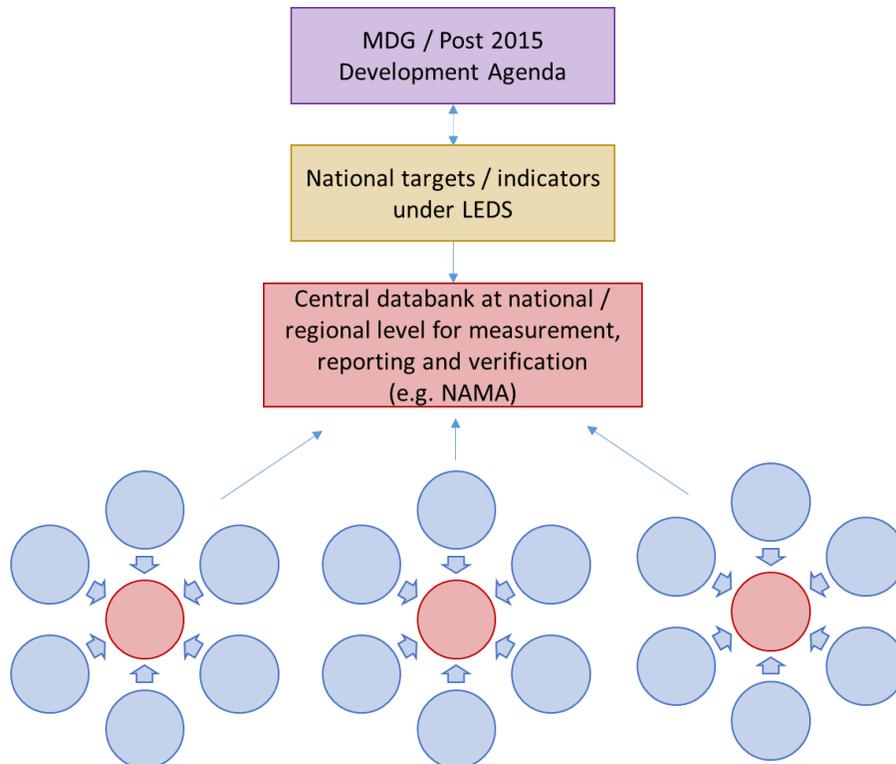


Fig 8: LEDS and NAMA Data Utilization

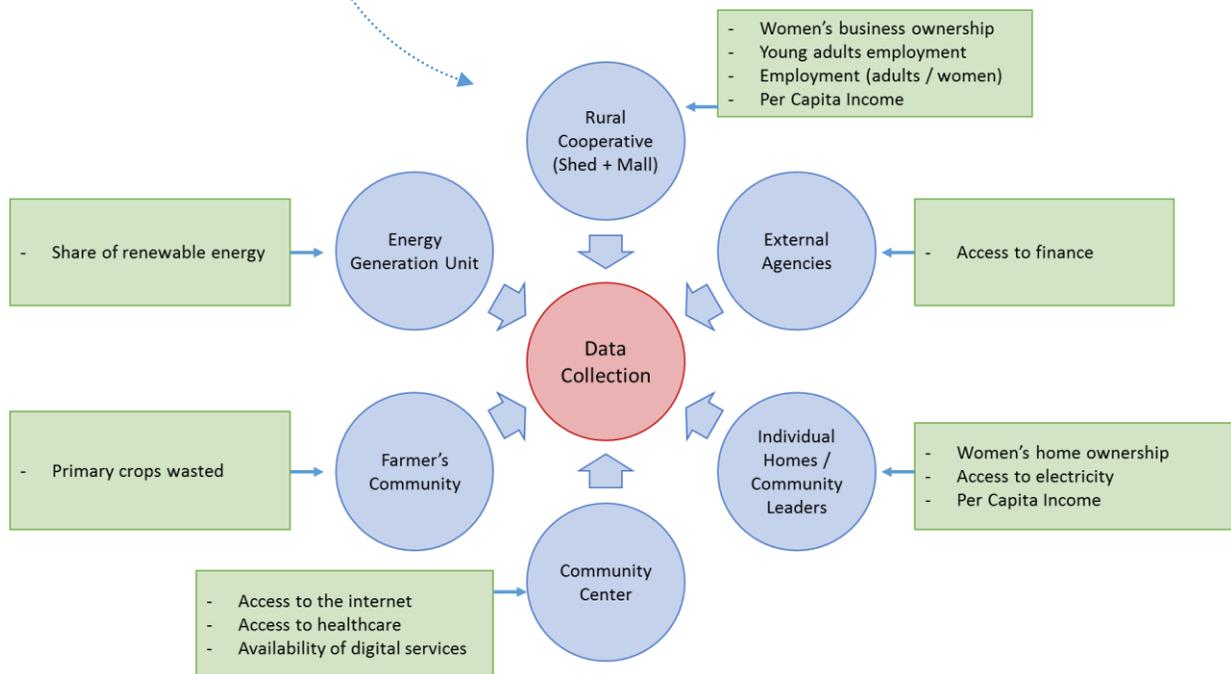
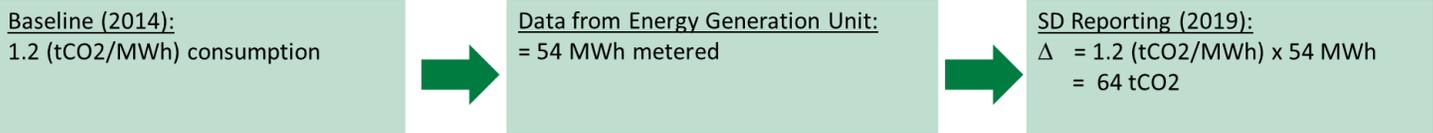


Fig 9: MRV Concept Model (data gathering)

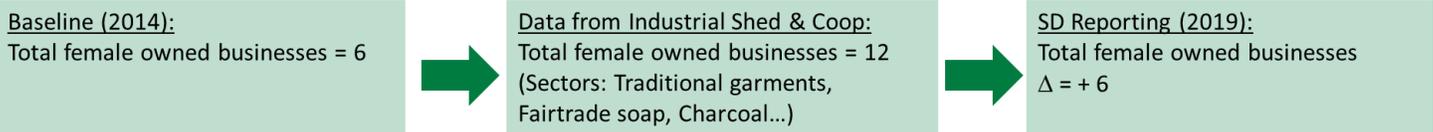
The advantage of the MRV Concept Model shown above is that it limits the burden for information collection, where each of the units under the Integrated Solar-RPZ Solution can equally contribute towards the data sets that are in line with their regular activity. These data sets reflected are gathered during the daily activities of each unit. For example, the rural cooperative can keep a record of the economic commerce in the community, the community center can track educational activities, and the industrial sheds can record number of working men and women in the rural enterprises. Table 6 gives an example of three potential key SD indicators (baseline, data, and reporting).

Table 6: Selected SD Indicators (Baseline, Data Gathering and Reporting)

GHG emissions / mitigation



Women's ownership



Access to Finance



Innovative Use of the Solar Hybrid Solution (Integration with telecom services)

According to a study by the World Watch Institute, as of 2013 more than 3.4 billion people or nearly half the world's population own at least one mobile phone. By 2010, more than 90 percent of people worldwide were covered by a mobile phone signal. The number of mobile subscriptions—that is, the number of active accounts that have access to a mobile network far surpasses the number of phone owners and in the developing world this figure is expected to cross 100 subscriptions per 100 people in 2014 due to the increasing use of multiple mobile devices.

However as the market saturates, these growth rates are expected to slow down and the future of the mobile phone industry will be less about adding new subscriptions and more about improving existing services. The infrastructure on which mobile networks operate are telecom towers and a significantly higher percentage of telecom towers are located in far flung rural areas. In developing countries where electricity supply is often erratic, these telecom towers operate through diesel generators (DG sets) and energy consumption accounts for almost 70% of the network operating cost. This makes sustainable energy use a key issue in mobile network infrastructure.

Initial sector efficiency measures focused on combining services of various telecom operators to share mobile network infrastructure, and reduction energy demand. This is often done through leasing arrangements or in buying capacity on the infrastructure. Still the transportation of large quantities of fuel to multiple rural locations, coupled with regular maintenance of DG sets, results in high O&M costs. The introduction of Solar PV-DG hybrid solutions offers a viable alternative for DG-only stations, as use of solar energy reduces the wear and tear of DG sets apart from corresponding lower fuel consumption, thus lowering overall long term O&M costs. Even though the investment cost increases, the net lifetime costs become lower.

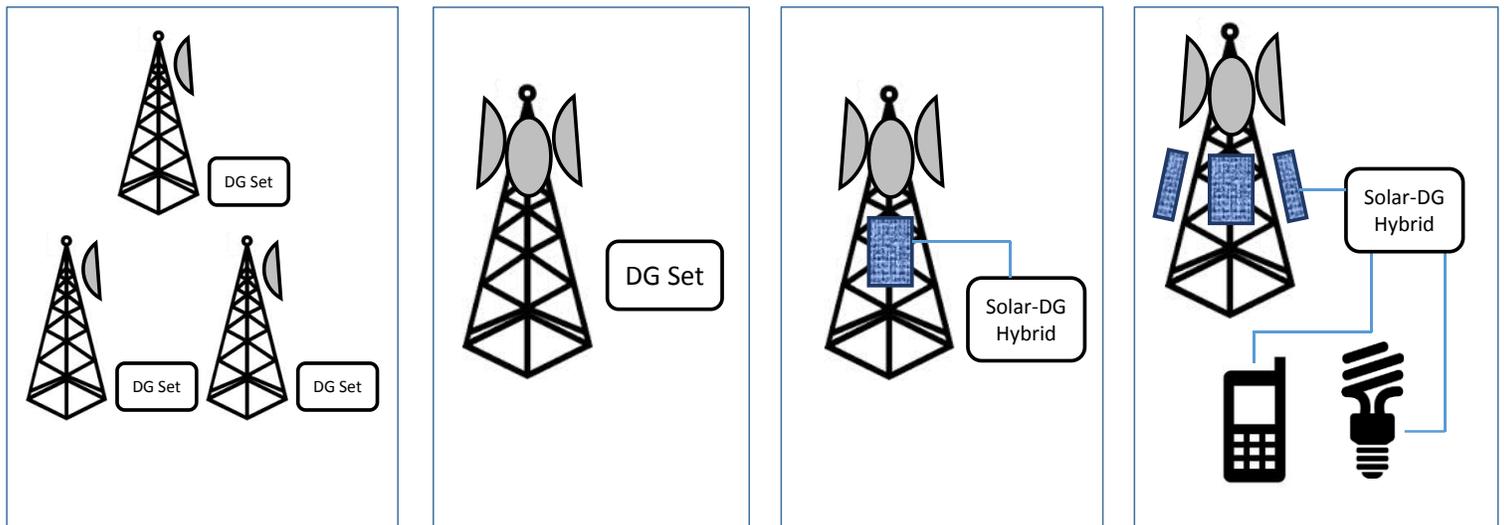


Fig 10: Innovation in energy solutions for telecom towers

The next big innovation in improving the sustainability in this sector is in extending the boundary of the energy infrastructure to provide electricity to rural locations. While the reach of mobile telephones to rural areas has already been discussed, the provision of mobile charging stations can be a small but essential step in up-scaling telecom services by the inclusion of energy services. This concept has been branded as Community Power from Mobile (CPM) by GSMA a mobile telecom industry association, who has prepared an informative concept paper on the subject.¹⁹ In general the CPM provides telecom companies a win-win situation as it improves mobile usage and builds brand value while providing an opportunity to combine corporate social responsibility with sustainable development and ensure greater customer access. Noting that in rural communities the improved usage of mobile phones provides opportunity for commerce as services like 'digital wallet' can allow individuals to take advantage of electronic commerce transactions (e.g. payment of bills, transfer on money, etc.). The CPM concept relies on the overall capacity of mobile tower stations which commonly have a demand load of 3 to 5 kW, but with a DG set capacity as high as 15 kVA (approx. 15 kW). In this concept GSMA estimates that the average over capacity is approximately 5kW, which is enough to in theory charge 5000 mobile phones.

There is a clear opportunity to expand upon the CPM concept and integrate it with the Solar - RPZ Solution. In this manner a telecom operator can share in the power infrastructure and economics of a fully integrated Mobile – Solar - RPZ Solution. There are two business models which are possible in this context: (1) where the telecom operator builds, owns, and operates [BOO] the combined Mobile – Solar - RPZ Station and charges the rural community for the generated electricity, or (2) a cooperative or private company BOOs the Solar - RPZ Station and sells the electricity to the telecom operator, who as well “leases” space at the Solar - RPZ Station. Table 7 below indicates from of the benefits gained by the two different models.

Table 7: Potential Benefits of Intigrated Mobile – Solar - RPZ Solution

Party	Option (1) Telecom BOO	Option (2) Community BOO
Telecom Operator	<ul style="list-style-type: none"> • Extension of revenue streams as excess power is sold to the community • Captive electricity consumer base for mobile and energy services • Greater CSR and community profile 	<ul style="list-style-type: none"> • Not responsible for the energy infrastrcutre, plus investment and O&M costs • Greater CSR and community profile
Community	<ul style="list-style-type: none"> • The energy generation unit is operated by an experienced company (telecom operator) who has permanet staff and solutions to ensure reliable electricity sypply • Greater chance of establishment as the telecom operator will likely have greater access to finace 	<ul style="list-style-type: none"> • More secured revenue stream based on the telecom operator’s elec. demand • Additional income stream from leasing of space for the base stations • Ability to lease base station space to more than one telecom operator • Additional revenue streams allow for greater access to finance

¹⁹ GSMA, “Community Power from Mobile-Charging Services”

Suggested Resources

Commercial Solar System Design Tools and Data:

- Sunny Design from SMA http://www.sma-america.com/en_US/services/solar-design-tools.html
- REFUdesign <http://www.refudesign.com/Default.aspx>
- OpenEI (solar energy geographical data sets) <http://en.openei.org/datasets>
- Open PV Project by NREL <https://openpv.nrel.gov/>
- System Advisor Model by NREL <https://sam.nrel.gov/>

Alliance for Rural Electrification (www.ruralelec.org):

- "Rural Electrification with Renewable Energy" ARE http://www.ruralelec.org/fileadmin/DATA/Documents/o6_Publications/ARE_TECHNOLOGICAL_PUBLICATION.pdf
- "Hybrid Mini-Grids for Rural Electrification: Lessons Learned" USAID/ARE http://www.ruralelec.org/fileadmin/DATA/Documents/o6_Publications/Position_papers/ARE_Mini-grids_-_Full_version.pdf
- "Hybrid power systems based on renewable energies: a suitable and cost-competitive solution for rural electrification" ARE http://www.ruralelec.org/fileadmin/DATA/Documents/o6_Publications/Position_papers/ARE-WG_Technological_Solutions_-_Brochure_Hybrid_Systems.pdf

United Nations Convention on Climate Change – Clean Development Mechanism (<http://cdm.unfccc.int/>)

- Approved Small Scale Methodologies for determining GHG Emission Reductions (Baselines and Project Emissions) <http://cdm.unfccc.int/methodologies/SSCmethodologies/approved>
- Guidelines for the consideration of suppressed demand in CDM methodologies http://cdm.unfccc.int/Reference/Guidclarif/meth/meth_guid41.pdf

Energy Sector Management Assistance Program (ESMAP)

- Sub-Saharan Africa: Introducing Low-cost Methods in Electricity Distribution Networks <http://www.esmap.org/node/946>

Groupe Speciale Mobile Association

- Community Power from Mobile-Charging Services http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/07/charging_services.pdf
- Green Power for Mobile <http://www.gsma.com/mobilefordevelopment/programmes/green-power-for-mobile>

Rural Malls - Example

- ITC Chaupal Sagar: <http://www.itcportal.com/media-centre/press-reports-content.aspx?id=627&type=C&news=CHAUPAL-SAGAR-Unlocking-rural-markets>

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