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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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ENVIRONMENT AND ENERGY

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THE DEVELOPMENT CONTEXT

Introduction

There is a universally 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 pertains 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 the 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 microfinance[2].

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 capacity[4]. 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 were 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 (CO_2) mitigation potential of 30 – 100% of the widely used diesel only generation solutions[6].

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 this discussion paper. End users in this context refer to a wide variety of equipment that operate on electricity such 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.