Case study: Renewable Energy and Energy Efficiency

Scaling up electricity access through GHG mitigation actions

According to IEA (2014)¹,1.3 billion people live without access to electricity close to half of whom are in sub-Saharan Africa (SSA) mostly in rural areas (<80 percent). Average electricity consumption per capita in SSA is less than that needed to power a 50 watt bulb continuously. Low income coupled with inefficient and costly forms of energy supply make energy affordability a critical issue.

- 1. Country A has a total population of 13 million with over 70 percent (9.1 million) living in rural area and only one in three among them is above the poverty line. With the rural electrification rates of only 30%, about 6.4 million in rural areas live without access to electricity in the end of 2014. Currently, uuse of inefficient and carbon intensive energy sources are common in the country:
 - Kerosene lamps, paraffin candles are used for lighting in areas with no access to grid/off-grid.
 - Mini-grids (off-grid) are powered by small diesel generators
 - Current energy mix in national grid : 84% Coal; 4% Gas; and 12% Hydro
- 2. Progressive policy makers of the country have set themselves an ambitious target to double the rural electrification rate to 60% by 2018.
- 3. In order that electricity access becomes affordable, the country has devised an innovative electrification program to provide electricity at concessional rates harnessing private and public sector finance including capital and expertise from domestic and overseas sources.
- 4. A CDM PoA with boundaries covering the entire geographic area of the country has been devised to manage the rural electrification program in the country blending sources of finance with significant leverage arising from carbon finance.

Technological options for Rural Electrification

5. The following tables (Table 1 and Table 2) provide a range of factors (e.g. cost, types of application, users etc).) that potentially affect the choice of grid and off-grid options to meet the electrification needs.

¹ World Energy Outlook (2014), International Energy Agency.

Electrication					
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 CO2 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 CO2 emissions from diesel only generation
Micro-Hydro	Medium	Low	Medium	Medium	Highly dependent on close-by geographical water availability and elevation difference

Table 1:Generalized comparative analysis of technical options for Rural
Electrification

Source: UNDP (2014)²

Table 2: Categorization of electrification options

	Stand-alone			Grids		
	DC		AC	AC,	/DC	AC
System	Solar lighting kits	DC Solar home systems	AC Solar home systems; single- facility AC systems	Nano-grid Pico-grid	Micro-grid, Mini-grid	Full-grid
	Off-grid					
Application	Lighting	Lighting and appliances	Lighting and appliances	Lighting, appliances, emergency power	all uses	all uses
User	Residential; Community	Residential; Community	Community; Commercial	Community; Commercial	Community; Commercial; Industry	
Key component	Generation, storage, lighting, cell charger	Generation, storage, DC special appliances	Generation, storage, lighting, regular AC appliances. Building wiring incl. but no distribution system	Generation + single-phase distribution	Generation + three-phase distribution + controller	Generation + three-phase distribution + transmission

Source IRENA (2015)³

- 6. Figure 1 below shows that :
 - (a) The levelised cost of electricity supply for consumers that already have gained access to a grid is typically well below the cost of supply from off-grid systems. However beyond a certain distance, the cost of grid extension becomes prohibitive, tipping the balance in favor of off-grid systems. The choice of stand-alone off-grid versus mini-grid is again

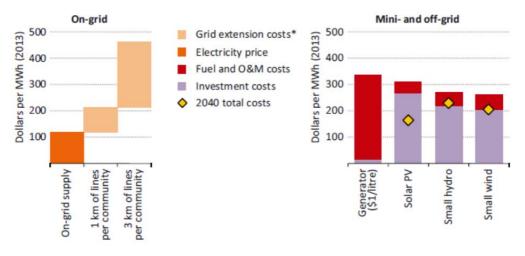
² Integrated Sustainable Rural Development: Renewable Energy Electrification and Rural Productivity Zones, United Nations Development Programme (UNDP)).

³ Off-grid renewable energy systems status and methodological issues, International Renewable Energy Agency (IRENA).

based on the density of settlement- higher density favoring the minigrid system;

- (b) Where wind and hydro resources are not adequate, Solar PV is competitive in off-grid/mini-grid applications where the alternative at present is electricity generation fueled by diesel /gasoline;
- (c) The cost of generation from renewable energy technologies is progressively dropping.

Figure 1Indicative levelised costs of electricity for on-grid and off-grid Technologies in sub-Saharan Africa, 2012



Source: World Energy Outlook (IEA, 2014)

7. In addition to the above, the comparison of cost of energy services in terms of energy access ladder provides an initial framework to facilitate categorizing and ranking energy systems and their capabilities. However, without a multi-dimensional definition and evaluation of how systems are functioning in practice, it is possible to distort the efficacy of the technologies represented on the energy access ladder. For example, an improperly functioning central grid and/or grid already suffering with acute power deficit likely serves users at a much lower level than a properly functioning solar lantern or a micro grid. As such, central grids may not be the best solution for all those who do not currently have access to electricity. A combination of various technology types would be needed to serve as a long-term solution for currently un-electrified communities.

The Energy Access Ladder					
Products & Distribution		Service & infrastructure			
				Ŧ.	
Traditional fuels & systems		Household Solar system	Community, Off-grid systems,	Grid connection , LPG	
Wood & Kerosene	Cook Stoves & Solar Lanterns				
Higher price per unit	 Cheaper More efficient 	 Higher efficie Higher choice 			
 Higher health issues 	Cleaner	Modern form:			
Cost to Customer	\$2 /KWh	60¢/KWh	20¢/KWh	10¢/KWh	

Figure 2: Energy ladder and cost of services

Source United Nations Foundation (2014)⁴

Technologies selected for rural electrification under the programme

- 8. Based on the assessment made above, the choice among the technological options (grid versus off-grid) for electrification in the country were considered for example:
 - (a) Extension of a grid to electrify communities beyond a certain distance (> 10 km) with highly scattered consumers (low load/population density) is prohibitively expensive, therefore and off-grid solutions in such areas are opted;
 - (b) Off-grid options such as standalone solar-PV system and hybrid diesel-PV mini-grid system were chosen depending upon types of users and application (residential, commercial, SMEs). No economically exploitable wind and hydro resources in the targeted areas were identified for the purpose;
 - (c) Grid is extended to communities with high load densities and whose distance from the point of extension is not greater than approximately 10 km.
- 9. It is estimated that the rural population in the country would increase from 9.1 million in 2015 to 9.7 million (at 2 per cent per annum growth rate) in 2018. Currently, only 2.7 million rural population are electrified (30% of 9.1 million). Without any intervention through electrification, the rural population without access to electricity would increase from the current 6.4 million to 6.8 million (at 2 per cent per annum growth rate) by 2018. The program targets to electrify 60 per cent of the total rural population by 2018

⁴ Micro-grids for rural electrifications- A critical review of best practices based on seven case studies.

i.e., 5.8 million (0.6*9.7). It is assumed that the additional population that needs to be electrified by 2018 is 3.1 million (5.8 minus 2.7 million). This implies, assuming 5 persons per household, 620,000 households need to be electrified.

- 10. The program will give access to electricity services to approximately 620,000 rural households (HHs):
 - (a) 334,473 (54%) households will be electrified equally through solar home systems (SHS) and solar-powered portable lighting systems;
 - (b) 138,684 (22%) households by Hybrid mini-grids (i.e. PV-diesel hybrid);
 - (c) 146,842 (24%) households served by grid extension.
- 11. The programme will combine three CDM methodologies:
 - (a) **Component 1:** AMS-I.L "Electrification of rural communities using renewable energy" for electrification involving solar home system
 - (b) **Component 2:** AMS- III.AR "Substituting Fossil Fuel Based Lighting with LED/CFL Lighting Systems" for electrification covering solar-powered portable lighting systems (LED/CFL)
 - (c) Component 3: AMS-III.BB "Electrification of Communities Through Grid Extension or Construction of New Mini-Grids existing grids" for electrification grid and hybrid-mini-grid

Determination of Baseline incorporating suppressed demand elements

- 12. Suppressed demand for energy services is an important element to consider while setting up the baseline as ignoring the future emissions increase may lead to distorted baseline leading to suboptimal incentive from carbon finance. Fortunately through the efforts of CDM Executive Board a number of methodologies integrate suppressed demand⁵. Thus, under suppressed demand, a project developer can assume some level of future development, and thus a certain projected level of emissions, and then can propose a project to reduce those future emissions with the help of clean technology. This concept allows communities to leap-frog dirty technologies and goes straight to a low or no-emitting technology in their economic development.
- 13. The concept of suppressed demand is included in some CDM methodologies to consider situations where key services such as lighting and heating, water supply, waste disposal are only available in quantities that are insufficient to meet basic human needs before the implementation of a CDM project activity. For example, before the start of a CDM project activity, households may be devoid of access to an electricity grid and have only a few kerosene lamps in place that are operated for short time periods, or just use candles. This can

⁵ The concept of suppressed demand is included in some CDM methodologies to consider situations where key services such as lighting and heating, water supply, waste disposal are only available in quantities that are insufficient to meet basic human needs before the implementation of a CDM project activity. For example, before the start of a CDM project activity, households may be devoid of access to an electricity grid and have only a few kerosene lamps in place that are operated for short time periods, or just use candles. This can be due to low income and lack of technologies/infrastructures or resources for its implementation.

be due to low income and lack of technologies/infrastructures or resources for its implementation.

- 14. The concept of suppressed demand is included in CDM methodologies for the baseline calculation specifying a minimum service level. For example, in the methodologies related to rural electrification i.e. AMS-I.L./AMS-III.BB/AMS-III.AR mentioned above, suppressed demand is taken into account by applying default emission factors for intermediate technologies (e.g. high pressure kerosene lamps, portable diesel generator) assumed to be used due to the suppressed demand situation to provide the same level of service as the project technology.
- 15. Key element of the standardized approaches in the methodologies (AMS-I.L and AMS-III.BB) is the default emission factor for each tranche of renewable electricity consumed (**EC**) per end-use facility per year which reflect the reality that baseline sources would also change depending on the level of electricity consumption :
 - (a) Tranche 1: $[EC_x < 55 \text{ kWh/year}] = 6.8 \text{ kg CO}_2/\text{kWh};$
 - (b) Tranche 2: $[55 < EC_y < 250] = 1.3 \text{ kg CO}_2/\text{kWh};$
 - (c) Tranche 3: $[EC_z > 250] = 1.0 \text{ kg CO}_2/\text{kWh}$.
 - (d) For EC_k> 500kWh/y \rightarrow 1.0 kg CO₂/kWh and no tranche applies.
- 16. Methodology AMS-III.AR provides default emission reduction per portable lamp distributed (i.e. 0.092 t CO2 per household per year)

Potential GHG and sustainable development impact of the programme

- 17. **GHG Impacts:** Potential annual emission reductions achieved per household per year by each component through rural electrification:
 - (a) Component 1 (Solar home system) : 0.51 t CO₂
 - (b) Component 2 (Solar portable lighting): 0.37 t CO₂⁶
 - (c) Component 3 (Grid/mini-grid) : $0.26 \text{ t } \text{CO}_2^7$
- 18. This translates into a total emission reduction of about 140 kt CO₂/year that could be achieved, through a target of electrifying 60 per cent rural households in the country by 2018. To put this emission reduction figure into perspective, it is approximately equivalent to the avoidance of operation of a 50 MW natural gas plant for electricity production.
- 19. **Example co-benefits:** The implementation of this program contributes in:
 - (a) Increasing access to electricity in rural areas by providing access to modern and affordable lighting;

⁶ It is assumed that program will distribute in average four lamps per household.

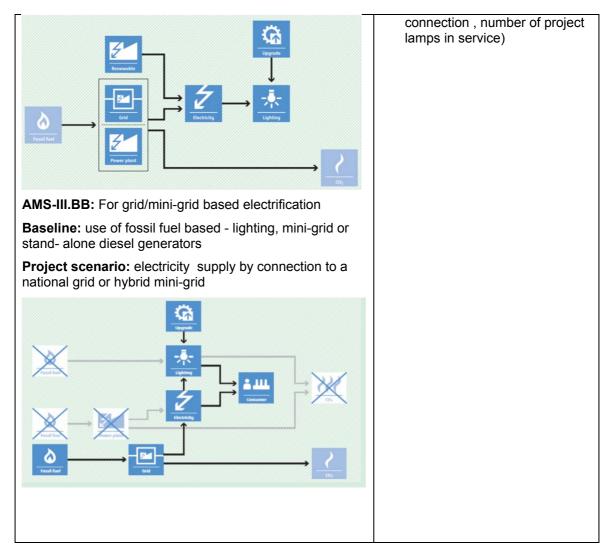
⁷ Emission reductions in the case of rural electrification through grid/mini-grid system is small as compared to renewable based electrification (here solar PV system) on account of project emissions considered due to additional electricity supply from a grid to cater rural electrification demand and operation of diesel system in a hybrid PV-Diesel system.

- (b) Enabling productive uses of electricity and income generating activities for example tourism projects, such as eco-lodges; agro-processing units, ice making units;
- (c) Improvement of living conditions;
- (d) Improvement of services in health, education and social institutions;
- (e) Economic growth in rural areas;
- (f) Increased employment;
- (g) Opportunity for adult education by running night schools and training courses;
- (h) Reduction of rural migration to cities.
- 20. On the national scale, per capita electricity service is highly correlated with improvements to the Human Development Index (HDI) showing extremely strong marginal diminishing benefits. In other words, just a few kWh beyond zero can vastly improve HDI (United Nations Development Program).

Use of CDM standards and scalability

21. Simplified CDM methodologies with widely applicable technological options for rural electrification are available.

List of methodologies	Key features		
AMS-I.L: For renewable energy based electrification	Baseline and additionality:		
Baseline: use of fossil fuel based lighting and stand-alone diesel electricity generators	 Predefined baseline and default values for baseline parameters (Standardized) Standardized additionality precedure (positive list) 		
Project scenario : electricity from renewable based energy systems (solar home systems)			
	 procedure (positive list) pertinent to rural electrification project activities available recognizing barriers due to , among others, high initial investment costs compared to baseline technology Project emissions are accounted using default values only if grid or 		
AMS-III.AR: For electrification using battery-charged LED or CFL based lighting systems	hybrid-mini-grid is used Monitoring:		
Baseline: use of fossil fuel based lighting Project scenario: Use of LED/CFL based lighting systems.	 Metering at aggregate level for small consumers or pre-paid metering 		
	 Individual metering for large consumers (consuming > 1000 kWh/year) 		
	Annual/biennial checks of equipment (e.g. grid		



22. Further work: Development of a rural electrification methodology with multiple technology types integrated into a single/modular methodology and with simplified monitoring is under development. This aims to broaden the available options for electrification, further simplify, reduce transaction cost and facilitate the development of PoAs.