GMG Market Assessment Methodology

Green Mini-Grids Market Development Program

SEforALL Africa Hub

African Development Bank

Part 2: Creation of an Opportunity Assessment Methodology

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Prepared by

PREFACE

This paper, as part of the Green Mini-Grid Market Development Programme (GMG MDP) document series, analyses the issues involved with market assessment methodologies for green mini-grids for rural electrification. These are mini-grids powered by renewable energy resources – solar radiation, wind, hydropower or biomass – either exclusively or in combination with diesel generation.

Mini-grids are not a new phenomenon in Africa. Almost all national utilities own and operate diesel-powered generating facilities not connected to the main grid, which supply electricity to secondary towns and larger villages. This solution to rural electrification inevitably results in significant financial losses for the utility, as it is required to sell power at prices much below the cost of production and delivery. Moreover, it leaves the most remote towns and villages unelectrified. The latest Sustainable Energy for All (SE4All) Global Tracking Framework estimates that the urban-rural divide in access to electricity in Africa is as high as 450 percent (69 urban compared to 15 percent rural access).

There are three principal options for providing new connections to currently unserved populations in Africa, namely i) extension of the national grid, ii) installation of separate "mini" grids to operate independently from the main grid, and iii) stand-alone generating systems that supply individual consumers. The most cost-effective approach for powering mini-grids is to use renewable energy sources, which are widely available across Africa. However, the development of GMGs is not without challenges. Barriers to the growth of private sector mini-grids in Africa include gaps in the policy and regulatory framework, the lack of proven business models, the lack of market data and linkages, the lack of capacity of key stakeholders, and the lack of access to finance.

In response to these challenges, the SE4All Africa Hub at the African Development Bank (AfDB)[1] designed and launched Phase 1 of the GMG MDP in 2015, with grant funding from the AfDB's Sustainable Energy Fund for Africa (SEFA). The GMG MDP is a pan-African platform that addresses the technical, policy, financial and market barriers confronting the emerging GMG sector. It is part of a larger DFID-funded GMG Africa Programme, which also includes GMG initiatives in Kenya and Tanzania; country-specific GMG policy development through SEFA; and an Action Learning and Exchange component being implemented by the Energy Sector Management Assistance Program (ESMAP) at the World Bank.

The International Energy Agency (IEA) has predicted (in Africa Energy Outlook 2014) that by 2040, 70 percent of new rural electricity supply in Africa will be from stand-alone systems and mini-grids. The GMG MDP, SE4All, SEFA, ESMAP and similar programmes, which are contributing to falling costs, technological advancements and more efficiencies in GMG development, will help to ensure that up to two thirds of this supply will be powered by renewables.

The goals of the green mini-grids programme, in all its aspects, are central to AfDB's mission of spurring sustainable economic development, social progress and poverty reduction in its regional member countries (RMCs). Indeed, off-grid and mini-grid solutions are a key component of the AfDB's New Deal on Energy for Africa, launched by the Bank's president in January 2016. The New Deal is a transformative, partnership-driven effort with an aspirational goal of achieving universal access to energy in Africa by 2025.

This report was prepared by Carbon Trust, UNEP and ECREEE at the request of the AfDB. It was written by Marco Sampablo and Luke Walley of Carbon Trust, Meseret Zemedkun and Dean Cooper of UNEP and Yuri Lima Handem and Sylla El Hadji from ECREEE. Carbon Trust is a mission-driven organization helping businesses, governments and the public sector to accelerate the move to a low carbon economy. The United Nations Environment Programme (UNEP) is the leading global environmental authority. The ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) is a specialized agency of the Economic Community for West African States.

The content of this report was reviewed by Jeff Felten of the AfDB's GMG team and cleared by Dr. Daniel-Alexander Schroth, SE4All Africa Hub Coordinator at the AfDB. The report was edited by Deborah Davis.

1 The SE4All Africa Hub partnership includes the African Union Commission, the New Partnership for Africa's Development (NEPAD), the United Nations Development Programme (UNDP), and the Regional Economic Communities (RECs), which are represented on a rotating basis. http://www.se4all-africa.org

Contents

EXECUTIVE SUMMARY

The African Development Bank has engaged the services of the Carbon Trust, UNEP and ECREEE to assess the potential for green mini grids (GMGs) in five[2] African countries. The engagement requirements include the definition of methodology to assess the potential for green mini-grids in Africa. This methodology will then be used to prepare five country reports that provide specific details on the GMG potential in those countries. The reports will provide important information to both national-level policymakers and potential investors in the sector.

The first phase of the engagement involved the identification and analysis of 12 methodologies (and a number of accompanying tools) that have been used to assess GMG potential in various countries, both in Africa and abroad. The phase 1 report was the first deliverable of the engagement.

This phase 2 report is the second deliverable. It builds on the lessons learned from phase 1 to propose a draft methodology that can be used to assess GMG potential across all African countries. It incorporates some of the best elements from the 12 methodologies assessed in phase 1 to create an Africa-specific template methodology that is both rigorous and flexible enough to useful to policymakers, practitioners and investors in the African GMG sector.

The phase 1 analysis found that most of the 12 methodologies were focused on assessing the potential of different electrification options through measures such as the levelised cost of energy. In African countries, however, such data are often scarce and unreliable, which meant that assessing electrification potential required a large number of assumptions and approximations as inputs into complex calculations. The methodologies therefore added little value to the existing macro-level assessments carried out by the EC Joint Research Centre (Renewable Energies in Africa report, 2011) and UNDESA UNITE (Universal Access to Electricity tools[3]), which had already presented estimates of the levelised cost of energy for various rural electrification (RE) options across Africa. Further, they did not address important factors such as regulations and market barriers. As a result, they were all found to have limited relevance for practitioners looking for detailed assessments with actionable information to help them make investment decisions about specific locations.

The phase 2 work began with stakeholder consultations to assess the level of engagement of practitioners with existing methodologies, and determine how an overall Africa-specific methodology could best address practitioner needs. A draft of the template methodology was then hypothesised which included an analysis of both the policy and regulatory landscape and the physical factors (e.g., population density, electrification rate, resource potential, distance from the grid,) specified in the original terms of reference for this engagement. The consultations indicated that most of the practitioners were not aware of the existing methodologies, which highlights the need for active dissemination of the outputs of this programme as a key factor in achieving significant impact.

The consultations also found that:

- **Physical potential is rarely the key deciding factor in investment decisions; rather, the most relevant considerations for practitioners are national policies, regulations and market size.** Most practitioners consider a combination of physical and non-physical factors, but give more weight to policy and regulatory factors and to the ability to develop local marketing networks. This is due to the higher perceived project risk from factors such as existing access to an engaged community (the possibility of main grid arrival) than from, for example, the levelised cost of solar radiation. Therefore, an opportunity assessment focused only on physical factors would not respond to the needs of practitioners.

2 Mozambique, Ethiopia, Cameroon, the Democratic Republic of Congo and Mali

3 https://un-desa-modelling.github.io/

- **Raw data are much more useful than processed data for practitioners.** Most developers saw only marginal benefits in the processed data maps, as the assumptions and specifications used in creating the maps were unlikely to be in alignment with the developer's findings on the ground. There was great consistency among the practitioners in identifying the need to apply their own assumptions, value choices, and scenarios within an opportunity assessment. Many stated that they would need to test the conclusions of each output of a tool or report under different conditions before any conclusions could be trusted. This correlated with the conclusions from phase 1 on the relevance of detailed levelised cost of electricity (LCOE) and other calculations.
- **Regular updating of all sources is crucial to the private sector's uptake up of data. This can be achieved by hosting a dedicated platform that provides links to the most up-to-date sources.** Both physical and non-physical factors, including policies and regulations, can become outdated quickly; so maintaining up-to-date sources will be key to stakeholder uptake of the outputs of this project. A single access point for the outputs of this project and the broader Market Development Programme would maximise visibility, ease of use, and uptake from practitioners. The access point could be a web portal or a dedicated site, or a window on an existing knowledge platform such as the SE4ALL Africa Knowledge Hub.

Synergies with networks of potential partner institutions and community networks are critical for the sustainability of mini-grid projects. The most resource-intensive aspects of entering a new market are typically market intelligence and gaining access to customers. Partnering with an organisation with existing access, networks and knowledge is therefore highly beneficial to developers. In fact, many developers rely more heavily on local partners and knowledge than on physical factors when making investment decisions. Existing networks are also a proxy for community engagement, as they indicate a greater probability of an engaged and coordinated community and its leaders, and a lower probability of payment defaults. Other de-risking factors in a community are the presence of micro-finance, agriculture and telecom.

Given these considerations, this report proposes a hybrid methodology that combines (a) macro-level opportunity assessments with (b) a knowledge base of raw data on physical and non-physical factors, and (c) a policy and regulatory analysis. This approach will better serve the needs of practitioners than any single approach by providing a broader knowledge base for the consideration of all necessary factors. Holistic high-level assessments of mini-grid potential will combine key indicators such as grid extension, population and the availability of RE resources. Raw data will allow practitioners to obtain actionable outputs and more sophisticated analyses by applying their own scenarios and conditions. The policy and regulatory analysis will provide developers with information about non-physical risks. Other key non-physical factors, such as mobile and payment network coverage, and the existence in the target area of agriculture and micro-finance networks, will also be considered.

In addition to the proposed methodology, this report also makes a separate recommendation for a programme to assess and certify the potential of small hydro and biomass sites. Such a programme would address the significant market and financing barriers that result from uncertainty about these resources. These assessments require significant technical expertise, time and resources, and are beyond the capacity of most site owners or mini-grid practitioners operating without support. Therefore, a programmatic assessment of these resources by organisations such as the Bank can make a significant contribution to unlocking the potential development of these sites.

After the proposed template methodology is finalised, the third phase of the engagement will be the delivery of this methodology in five pilot countries. The lessons from this pilot phase will then inform the design of a wider project to be rolled out in all of the countries in Africa.

1. INTRODUCTION

1.1 PROJECT CONTEXT

This engagement is part of the African Development Bank's Green Mini-Grids Market Development Programme (GMG MDP), which has the ultimate objective of fostering access to electricity across Africa by promoting the development of green mini-grids (GMGs). The specific objectives of the engagement are (a) the development, based on best practices, of an Africa-specific methodology to assess the physical potential for green mini-grids at the country level; (b) the application of the methodology in five pilot countries and the publication of five country-level reports based on those pilots, with a detailed analysis of the potential for GMGs in each country. It is expected that the Bank will then (c) refine the methodology based on learning from the pilots, before rolling it out in other African countries.

The *Phase 1 Report: Evaluation of Methodologies and Best Practices Available for Assessing GMG Potential* identified 12 existing methodologies and assessed their usefulness to practitioners, investors and policymakers. This *Phase 2 Report: Creation of an Opportunity Assessment Methodology* is the second output from the analytical work aimed at creating a best-practice methodology for assessing GMG opportunities in Africa. This report builds on the findings of the first report and on extensive consultations with mini-grid practitioners and other stakeholders.

2. LEARNINGS FROM PHASE 1 AND PRELIMINARY ASSUMPTIONS FOR PHASE 2

2.1 LESSONS LEARNED FROM PHASE 1

The first phase concerned the identification and assessment of existing methodologies available to assess the potential for rural mini-grid development. The methodologies were categorised as either GIS or non-GIS supported, and as either supply or demand led. The majority used GIS databases at the input stage, as well as for analysis and presentation of results and outputs. This was due to the significantly higher clarity of outputs that such spatial mapping allows as compared to traditional methods such as value tables and qualitative evaluation. The two non-GIS methodologies were higher level (broader scope, using less numerically detailed assessment), and gave country-level rankings based on the competitiveness of clean as compared to traditional energy sources and the strength of the enabling environment. The two non-GIS methodologies were the only ones to focus on the economic, political and financial factors affecting mini-grid development; while the GIS methodologies focused almost entirely on spatial mapping of physical factors such as geography, resource availability, and population density.

The most common approach was to assess the potential of different electrification options through physical measures such as the levelised cost of energy (LCOE). Commonalities included relying on data such as average annual solar radiation, population centres and density, level of demand and consumption, and the need to compare off-grid options against both grid extension and decentralised diesel generation. There was variation within this broad approach, however, with each methodology including novel aspects such as the handling of data paucity or considering demographic factors such as the proliferation of energy-efficient cook stoves or land use.

To achieve an LCOE or similar estimate, these methodologies required a large number of assumptions and approximations, due to significant data quality and availability constraints. The quality and clarity of the outputs produced were therefore limited by the quality and availability of the input data. Larger studies were able to produce detailed assessments of different factors using fieldwork, stakeholder consultations and continued engagement with the relevant ministries and national utilities. However, this kind of exercise is extremely resource intensive, requiring significant capital and time, and not feasible for most methodologies. Therefore, most methodologies relied primarily on remote data sources such as international databases, existing studies and censuses. A variety of assumptions and approximations also had to be applied. Shown for reference in Figure 1 are the final outputs of the EC Joint Research Centre's *Renewable Energies in Africa report (left)* and the UNDESA UNITE Electrification Access tool *(right)*. Both give indicative electrification solutions for regions across Africa based on the LCOE by relying on a variety of assumptions. The JRC methodology uses fixed grid extension cost per km and kWh, an approximated demand from fixed-size solar and diesel systems, and a fixed ability to pay (ATP) threshold. The UNDESA tool assumes linear investment costs by system size, a universal level of energy consumption, future grid extension based on the location of intensive industries, and an extrapolated population and demand growth to 2030.

Estimation of grid extension costs also requires multiple assumptions, particularly when designing an electrification solution for an entire region, and may result in large inaccuracies. For example, estimating the cost for extending the grid to a single remote settlement will give a substantially larger estimate than is realistic, as it does not account for the connection of surrounding villages, which will share in the cost burden. Methodologies such the Network Planner attempt to compensate for this by constructing a complete electrification system and assuming electrification of all villages in the area. However, the proposed grid structure is also highly sensitive to assumed parameters such as per capita demand and the penetration rate in villages connected to

the grid. Further, this approach does not reflect the considerations of individual developers on the ground. The European Commission Joint Research Centre's *Renewable Energies in Africa* applied a fixed grid extension cost per km per kWh. This provided a rough indication of grid extension costs for an individual village, but it was clearly a large approximation.

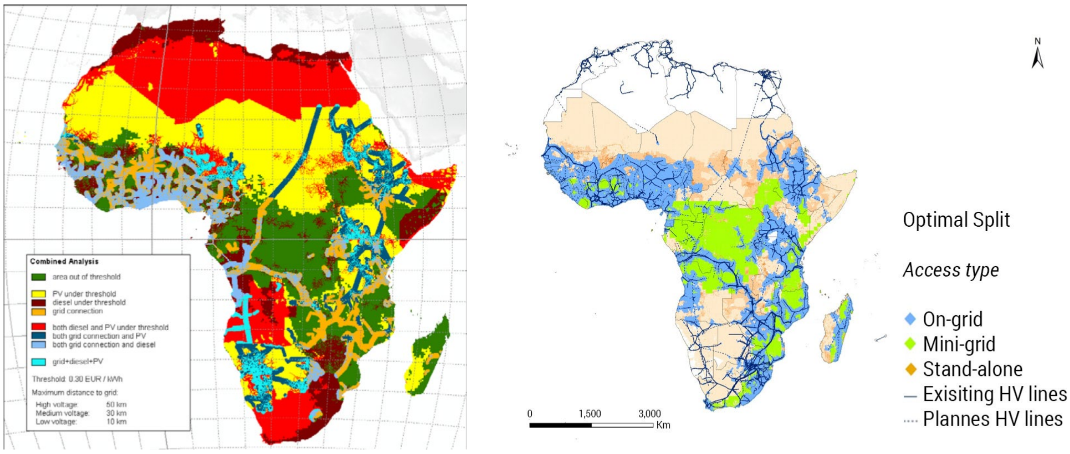

Figure 1: EC Joint Research Centre's (JRC) *Renewable Energies in Africa* report (left) and the UN-DESA UNITE Electrification Access tool.

Furthermore, most hydro, biomass and wind resources in Africa have not been not pre-identified or certified, so most of the methodologies did not account for these resources, and those that did used pre-identified sites. Therefore, the potential impact of renewables on a country's electrification options has typically been seriously underestimated. Assessing wind potential, in particular, requires highly localised site resource assessments, and cannot be adequately estimated from satellite data.

There would also be little value added in producing an Africa-wide LCOE assessment, as the EC JRC and UNDESA methodologies shown in Figure 1 were both high-level assessments of the distribution of preferred electrification solutions based on estimates of LCOE. Despite relying on a large number of assumptions and approximations at a high level, both of those methodologies gave coherent results and provided rough indications to developers and stakeholders for comparisons across Africa. Any LCOE-based assessment completed as part of this study would also necessarily be high level in nature.

In creating a new methodology, there is a need to reassess practitioner requirements and examine the importance of other factors not included in the 12 methodologies assessed in the Phase 1 report. As each developer has unique informational needs based on the technology, approach and operational scope of a particular GMG project, the new methodology needs to be flexible enough to allow for a variety of specific inputs, including:

- Raw data of physical factors
- Policy and regulatory environment
- Community factors
- Experiences from other sectors
- The ease of doing business
- Market factors and access to networks

This report investigates how all of those factors would be considered in a new best-practices methodology for assessing GMG opportunities in Africa.


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3. STAKEHOLDER CONSULTATION

3.1 OVERVIEW

The project team engaged a selection of mini-grid practitioners working in developing countries to determine how this project can best address their needs. This included representatives from BBOXX, Buffalo Grid, ENCO, Firefly Clean Energy, INENSUS, MeshPower, Off-Grid Electric, PowerGen, TESE – Development Association, Trama TechnoAmbiental and Devergy. These companies include practitioners in the areas of solar home systems, solar mini-grids, charging facilities and small hydro. Their business models included sales based on licencing, ownership payment plans, and pay for use charges.

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Based on the lessons learned from phase 1, a draft of the methodology has been hypothesised for stakeholder review. It includes the following elements:

Raw data

1. Population: population density and population of settlements
2. Power network
3. Transport network
4. Hydro sites
5. Biomass sites
6. Local diesel costs

Processed data

7. Regions best served by off-grid electrification, based on threshold distances around existing and planned grid lines
8. Population best served by off-grid electrification, based on estimations of population densities within defined boundaries
9. Settlements and populations that could be reached from identified hydro and biomass sites
10. The LCOEs of mapped solar mini-grids, with the range of LCOEs as an output
11. The least levelised cost of energy option for each settlement or area, found by comparing solar, biomass, hydro, diesel and grid extension. The total population served by each option would be an output.

The hypothesis also included non-physical factors such as the policy and regulatory landscape and market analyses. Although not covered within the original scope of Bank's GMG business line, these factors have a significant impact on mini-grid development. Therefore, the hypothesis assumed that including these aspects would provide a more comprehensive and actionable analysis for stakeholders.

Through questionnaires and personal interviews, the practitioners were asked their views on the usefulness of the draft methodology, giving particular consideration to:

- Its assessment of physical potential factors
- Various aspects of the market assessment process
- Their awareness of the methodologies assessed in phase 1
- What outputs would make the new methodology most useful?

3.2 MAIN RESULTS

3.2.1 ASSESSMENT OF PROPOSED PHYSICAL POTENTIAL FACTORS

The practitioners indicated that physical potential considerations are rarely the key factor in deciding whether to construct a mini-grid. Most take into account a combination of physical and non-physical factors, but give more weight to considerations such as policy and regulatory factors and the ability to develop local marketing networks.

Resource availability was not a key factor for solar practitioners. The challenge of ensuring cost effectiveness of a solar project is more dependent on optimising the use of a mini-grid than on its generation potential, as solar radiation is generally high across Africa, and does not vary significantly across areas or over time. Practitioners said they give stronger consideration to patterns of use and market size.

Hydro practitioners emphasized that a lack of data on hydro resources limits the development of potential sites. Most countries have only a handful of pre-identified hydro sites, and many of them have not been properly assessed and certified, making it impossible to accurately assess their potential for small hydro. Further, the substantial time and financial resources required for proper assessment of a single hydro site means that it is not feasible for most practitioners. The consultations indicated that an assessment can take two to three years and cost in the range of USD30,000-50,000. Practitioners also noted that the proximity of a transmission network is critical to ensuring the financial viability of a project, as it would allow for the sale of excess power to the grid and collection of a feed-in tariff.

Most practitioners considered market size to be the key physical factor, as it directly relates to business opportunity. Population density and electrification level are the key market size indicators, but other factors include disaggregated fuel use and household income. These were not considered prerequisite conditions like some non-physical factors, but strongly affected prioritisation on sub-national level.

Most practitioners also mentioned mobile and mobile payment service coverage as key factors. A large number of developers are using mobile payment systems, a factor not initially considered by this project. The central hubs of many mini-grid and solar home systems also communicate faults or usage data to the service providers using the network. The reliance of many business models on mobile and mobile payment networks makes access to such networks a prerequisite for these providers.

The extension of the grid network, rural network tariffs and connection costs were factors considered by all developers. The location and scheduling of grid extensions are key to identifying sites for off-grid applications. Some developers noted that a nearby grid line may not unduly affect their business, particularly if high connection costs result in many customers remaining unconnected. Nonetheless, all developers closely monitor planned extensions and local grid tariffs.

Raw data are considered much more useful than processed data in assessing all of these factors. Most developers saw only marginal benefits from the most sophisticated processed data maps, notably those comparing the levelised cost of energy across regions. While the data calculations may be theoretically sound, they depend on a wide range of assumptions that may not be in alignment with a developer's findings, interests, or priorities on the ground. This is a significant problem for analyses that use a large number of factors and considerations (although it is less of an issue for high-level assessments). Practitioners showed great consistency in identifying the need to apply their own assumptions, value choices and scenarios within an opportunity assessment. Many stated that they would need to test the conclusions of each output of a tool or report under different conditions before any conclusions could be trusted. This correlated with the conclusions from phase 1 on the questionable relevance of detailed LCOE and other calculations.

The developers did see value in providing basic processed maps as references for other stakeholders, primarily policymakers and non-technical stakeholders who are not able to produce their own assessments. While developers would prefer to utilise raw data for their own detailed analysis, they noted that high-level assessments can indicate the potential for mini-grids based on key indicators such as grid extension plans and population distribution. These maps and analyses could be used to steer discussions on supportive policies, regulations and electrification strategies.

3.2.2 CONSIDERATIONS IN THE MARKET ASSESSMENT PROCESS

The most relevant considerations in the investment decision process are sound national policies, regulations and market size, and demographic factors. The existence of policy and regulatory support has a significant impact on the profitability of mini-grid projects. General policy and regulatory factors that can impact projects include regulations covering the establishment and operation of a business, import tax exemptions, and foreign capital repatriation. Specific factors could include mini-grid investment subsidies and tax breaks, connection subsidies, or institutional factors such as the establishment of a rural electrification agency or national rural electrification roadmap.

The diversity among different African countries has led to a clustering of developers in regions or countries with more proactive government legislation, visions and roadmaps. For example, mini-grid projects may be constrained as a result on sector policies establishing a national power tariff rather than a tariff disaggregated by rural/urban areas and on/off grid generation. The likelihood of supportive policies being put in place is a significant factor for practitioners. Practitioners are also likely to de-prioritise regions where a government is looking to implement large-scale grid extensions or fails to lay out a long-term vision for off-grid rural electrification.

The existence of networks of potential partner institutions and of community networks is critical for the sustainability of a project. Market intelligence and the ability to gain access to customers are usually the most resource-intensive aspects of entering a new market. Partnering with an organisation with existing access, networks and knowledge is therefore enormously beneficial to developers. Many developers rely heavily on these local partners for local strategy and intelligence, which are given greater consideration than resources and other physical factors. Existing networks are also a proxy for community engagement. These networks, particularly in the micro-finance, agriculture and telecom sectors, indicate a greater probability of an engaged and coordinated community and its leaders, which reduces the risk of payment defaults.

3.2.3 AWARENESS AND USEFULNESS OF TOOLS IDENTIFIED IN PHASE 1

As part of the questionnaire, practitioners were shown a selection of four of the methodologies analysed in phase 1 (Table 1). The developers were asked whether they were aware of them, had used them, or whether they had used other methodologies or tools.

Table 1. Methodologies and spatial maps assessed by stakeholders

Name and Author	Link
Network Planner by Modi Labs, Columbia University	networkplanner.modilabs.org
GeoSim Integrated Rural Electrification Planner, IED	www.geosim.fr
UNITE Electrification Access Tool, UNDESA	unite.un.org
ECOWREX, ECREEE	www.ecowrex.org

The vast majority of the practitioners reported not having heard of or used any of these methodologies, and only a small number had heard of one of them. Further, *most saw no more than partial benefits from using any of them in the future due to their reliance on specific assumptions and approximations*. This is a critical issue and must be highlighted. Most said that they developed their approaches in house, while others acknowledged that they could save time by using some type of existing methodology, provided it allowed them to apply their own criteria, assumptions and scenarios. Developers also raised concerns about the affordability of commercial tools.

3.2.4 WHAT WOULD BE BENEFICIAL AS AN OUTPUT OF THIS PROJECT?

The provision of up-to-date, comprehensive and granular raw data was consistently identified as useful by developers. Most practitioners, especially the more established organisations, reported having a reasonable set of source data for their countries of operation, but not for countries in which they are not operational and may be considering. All practitioners named at least one element of their data that could be significantly improved in terms of datedness, scope or granularity. These elements included:

- details of existing community and sector networks
- population density
- grid and power extension plans
- grid extension commissioning dates
- network tariffs in rural areas
- mobile and mobile payment coverage
- relevant policies and regulations
- electricity consumption and load data
- fuel consumption (disaggregated)
- existing rural electrification projects.

These raw data elements are very much in line with those suggested in the draft hypothesis.

Regular updating of the raw data is crucial for private sector uptake. Practitioners consistently cited the lack of up-to-date data on both physical and non-physical factors as a constraint. Some form of dedicated platform could serve as a single access point for the most up-to-date information, and could also potentially be a coordination platform for various stakeholder groups. Alternatively, the Bank could provide links to up-to-date data sources on its website.

The table on the following pages presents selected disaggregated responses of practitioner consultations.

Assessment of proposed physical factors	Other elements considered in the market assessment process
• Not useful beyond country level • Non-physical factors are more important to the success of a project	Non-physical factors: • Community networks – agriculture, micro-finance or telecoms • Policy landscape • Ease of doing business • Access to finance
• Income, population density and power are considered, but not as key decision factors • Use country level indicators for country level decisions	• Mobile and mobile payment coverage • Local partner networks • National Policies • Local government rural electrification commitments and characteristics
• Geographic and demographic factors are considered after the key factors • Includes population density, grid infrastructure, resources	• Mobile coverage a pre-requisite • Local partner/licensee strength • Local partner/licensee access to local financing
• Data-centric organisation, with a suite of in-house tools to guide the decision process • Does not consider 'village dynamic' factors • Led by a partner's experience only during their creation	• Mobile coverage a pre-requisite • Income • Electricity prices • Policy and regulatory aspects such as ease of importation, tariffs, required permissions for mini-grid development etc.
• Resource not considered • Other physical factors are considered • Problem is maximising utilisation not generation of the systems	• Market size and demographic • National policies • Distance from grid • Access to mobile money is preferable
• Renewable energy potential is a key decision factor • Consumption and load patterns needed but not easily accessed • Use a suite of tools and survey's	• Disaggregated socio-economic information • Disaggregated energy consumption • National policies, strategies and master plans • On-going/planned energy access initiatives • Renewable energy potential
Physical factors considered: • Which villages and when will be electrified • Fuel consumption of the village centre (not including dispersed outliers and disaggregated to diesel/petrol / kerosene) • Locations of special infrastructure and public service • Indications renewable resources.	• Regulation: tariffs at cost covering/profitable level, grid encroachment risk mitigation • Village size: greater than 5000 un-electrified people • Currency stability • Political stability • Renewable energy components import tax exemption • Foreign capital repatriation
• Main factors were non-technical issues • Population density, grid networks and local diesel costs were considered • Coherence of such processed indicators is dependent on high details, lots of inputs and very frequent updates. • Huge risk of misleading indications if the tool/map is inaccurate	Non-technical issues: • Indictor of ease of doing business' • Corruption • Trust of authorities • Security • Subsidies on fuel

Awareness on tools identified in phase 1 and assessment of such tools	What outputs would make this a useful project?
As stated they don't consider physical factor assessments as particularly useful overall.	• Information on the existing networks in country • Forum for connecting people/communities to developers
Problem is the granularity and assumptions made – definition of electrified could be just the town centre – need to give all of the parameters and assumptions.	• More detailed maps and information - especially population data and grid and power costs in rural areas
They haven't used commercial tools to date but for future expansions it could save them a time during the intelligence gathering phase.	• Mobile coverage data • Although they have most of the data they need for their current countries of operation, would be needed for other countries
Have in-house tools, only the raw data would be really relevant. Report results usually rely on specific scenarios/ conclusions, and so they would need to test the results themselves.	• A short report with a list, and links to, the relevant policies and regulations for each country • A list of identified sites with the underlying assumptions used • Accurate grid extension data, with commission dates
Processed maps were not useful to them, but they felt it would be useful to guide policy and policy makers. They felt the tools they had seen we're either not applicable or not affordable.	Raw data on: • Population centres • Mobile money • Grid network • Existing mini-grid projects.
Most tools they were aware of focused at a national level rather than a regional or village level, and they had used the ECOWREX tool as part of their work.	• Electricity consumption patterns data and load curves with real data • Any disaggregated and granular data (socio-economic, resource etc.).
The problem is that at the time of tool or report publication the information in them is already out of date. They have their own financial and distribution network design tools, and use a commercial tool for system optimisation and design.	• Regular updating of a tool, report or information source is critical to ensure relevance • Maintain a set of contact links to respective rural electrification agencies who have the most up-to-date GIS tools • Provide the physical factors, updated and signed off regularly by the rural electrification agency
They hadn't heard of the tools given, but used PVGIS, PVSyst, HOMER and their own techno-economic simulation software.	• Policy toolkits and tools about resources • Technical aspects currently adequately addressed by existing tools available to this organisation.

4. PROPOSED METHODOLOGY

Based on the lessons learned from phase 1 and from the stakeholder consultations, the project team has concluded that the needs of mini-grid practitioners would be best served by a methodology that provides: (a) raw data on key physical factors such as population density and planned grid extensions; (b) a mini-grid specific policy and regulatory analysis; and (c) high-level, indicative opportunity assessments. Key to the adoption of this approach will be ease of access to the different elements of the methodology through a dedicated platform or website.

4.1 RATIONALE

Practitioners have a need for accurate raw data on physical and non-physical factors, as they find only limited value in processed data and in the outputs of the existing methodologies. The opportunity assessment methodologies considered during phase 1 focused primarily on physical factors, and the main outputs were measures, such as the LCOE, of different electrification options. The stakeholder consultations found, however, that off-grid developers place an equal or greater emphasis on national policies and regulations and other non-physical factors, due to their high business impact.

The proposed methodology therefore represents a hybrid approach that integrates a high-level opportunity assessment, raw data on physical and non-physical factors, and an analysis of the policy and regulatory environment. The existing methodologies do not successfully address practitioner needs because they rely on a large number of assumptions and approximations. The proposed approach builds on key factors such as population density to give indicative recommendations to practitioners and policymakers; while the provision of raw data allows practitioners to conduct more detailed opportunity assessments using their own appropriate assumptions and conditions. The knowledge base is further expanded through a policy and regulatory analysis and consideration of non-physical factors such as community networks. This three-pronged approach reflects the full range of factors that mini-grid practitioners need to consider.

Key to the success of this proposed methodology will be the development and maintenance of a platform to provide access to up-to-date data, facilitate stakeholder engagement, and promote knowledge sharing. Most physical and non-physical factors that influence mini-grid development, including the regulatory environment, are outdated quickly, which significantly affects the business applicability of information. Regular updating is therefore critical, annually or at least every two years. A dedicated platform for information developed during this project will increase the uptake from private and public sector stakeholders. It will also allow for easy aggregation and access to all information sources for each country, and can easily be combined into a coordination forum to link various stakeholder groups. If information is updated by other organisations such as rural electrification agencies, the contact details and links to these sources can also be provided to allow for direct user follow-up.

4.2 INCLUDED ELEMENTS

Building on the rationale detailed above, the proposed methodology includes:

- Raw and processed spatial mapping (physical and non-physical factors)
- Policy and legislative analysis
- Dissemination of outputs from the Market Development Programme.

4.2.1 SPATIAL MAPPING

A suite of raw and processed GIS maps is proposed, to be made freely available. Analysing and combining key indicators will give a holistic assessment of the potential for off-grid electrification. This will provide high-level suggestions to practitioners, policymakers and other stakeholders. Raw data will allow practitioners to apply their

own analyses to obtain more sophisticated results. The recommendation is for these maps and their raw data to be made freely available to stakeholders. Both sets of maps will be dependent on the availability of data of acceptable quality for each country, so maps for some countries may not be available. The list of proposed maps is given below:

Raw data maps

1. Existing and Planned Power Network
2. Population Density and/or Settlement Populations
3. Electrification Level of Settlements
4. Existing Off-Grid Projects
5. Average Income of Settlements
6. Average Annual Solar Radiation
7. Average Annual Wind Speed
8. Identified Potential Biomass Sites
9. Identified Hydro Sites
10. Mobile Phone and Mobile Payment Coverage
11. Any other sector networks available (agriculture, micro-finance, telecom)
12. Service demand locations (hospitals, schools, municipal buildings)

The raw data will also constitute a comprehensive database that practitioners can use for their own rigorous opportunity assessments or to apply their own scenarios and conditions. Although many practitioners reported having access to some raw data, most said the data were incomplete, not comprehensive or not up-to-date. The value of providing accurate and up-to-date information through a dedicated platform is therefore significant.

Processed data maps

Primary:

1. Split of areas for grid, mini-grid or stand-alone electrification, based on distance from existing grid and population density
2. Market potential (population), based on population and the split of areas defined in map 1
3. Market potential (USD), based on income data and consumption assumptions defined in map 2

Optional:

1. Local diesel prices, estimated from national prices and the distance to major cities
2. Lowest levelised cost of energy option, mapped for each settlement or area

Processed data maps provide indicative, non-prescriptive opportunity assessments for policymakers and other non-technical stakeholders, rather than precise or prescriptive recommendations. The maps will be able to support broader policy discussions, but will not replace or supplement the detailed analyses completed by practitioners, rural electrification agencies, or other technical stakeholders.

The optional maps may or may not be included in the country assessments, subject to discussion with the African Development Bank. The LCOE mapping has been covered by multiple methodologies to a similar level of detail and sophistication, as highlighted in section 2.1. Given the proposed hosting of the outputs of this project on a web portal, it would be easy to provide links to these methodologies' outputs or embed them within the analyses or portal. There are also budgetary constraints to the delivery of the LCOE map, which is hard to justify given its relatively lower important compared to other elements of the methodology.

Details of the calculations and methodologies behind the processed maps can be found in Annex I.

Client considerations - data publication platform

Making raw data freely and easily available would remove a major constraint to the development of mini-grids. A single access point for the outputs of this project and the broader Market Development Programme would maximise visibility, ease of use and uptake by practitioners. This access point would be an information web tool, an AfDB sub-site, or a dedicated platform with user membership and contributions. Clarity and ease of access will become increasingly important as the number of publications, sources and assessments increases. A central knowledge base will help developers efficiently identify and utilise the published resources.

There are several international references for this proposed solution, including the Lighting Africa website, as well as potential synergies with other international programmes. Lighting Africa is a joint International Finance Corporation and World Bank programme focused on developing the off-grid lighting market in Africa. It provides a good model for the recommended platform, as it provides access to a wide range of relevant information on one site, including a publication database with a variety of market intelligence reports and technical notes, and a database of quality-certified products. Synergies are also possible with other projects, such as the World Bank's Off-grid Energy Access Market Mapping Tool for Sub-Saharan Africa, currently in the tendering phase, which aims to facilitate access to information about opportunities for distributed energy servicing companies (DESCOs). Duplication and fragmentation with that project could be avoided through a joint knowledge platform, which could be linked to, or hosted by, the SE4All Africa Knowledge Hub (http://www.se4all-africa.org). These options will be explored with the AfDB in further discussions throughout this project.

4.2.2 POLICY AND REGULATORY ANALYSIS

A proposed policy and regulatory analysis would identify the strength of key non-physical factors, including the relevant policies, legislation and frameworks in place to support mini-grid practitioners. These factors can have a significant impact on the technical, financial and practical viability of a mini-grid project. The following factors are proposed:

- **Financial** (incentives, initiatives, access to finance, investment risk profile)
- **Technical** (accreditation and regulation, awareness of and access to international best practice technologies)
- **Institutional** (government prioritisation of mini-grids/rural electrification, existence of rural energy agencies or energy regulators / liberalised energy market, capacity/staffing for mini-grid activities)
- **Legal** (relevant laws and regulations, intellectual property protections, corruption/political risk)

This type of policy analysis is not new; organisations such as IEA, BNEF, REEEP and REEGLE have undertaken similar work, including work specific to mini-grids. For example, the IEA/IRENA Joint Policies and Measures Database lists the renewable energy policies and initiatives for selected countries, along with policy status and document links. The BNEF Climatescope[1] gives a clean energy country competitiveness index, based on an extensive set of indicators, and summary reports include policy overviews and selected key policies relating to clean energy competitiveness. However, both of these sources have incomplete coverage across Africa. Other sources include the REEGLE clean energy information portal, run by the Renewable Energy Policy Network for the 21st Century (REN21) and the Renewable Energy and Energy Efficiency Partnership (REEEP). This portal maintains country profiles with key statistics, policies and actors in the energy sector.[2]

The proposed analysis would utilise engagement with local stakeholders and national ministries, existing partner knowledge and secondary research. A primary aim would be to identify all sources of relevant information that are currently available, and determine common themes, unresolved issues and challenges. The results would provide a clear picture of the policy and regulatory/legislative frameworks in place in any specific location.

The value of this analysis would be in the collection and synthesis of relevant information to enable easy and relatively complete comparisons of the policy and regulatory environments across Africa. The most complete policy analysis for a practitioner would include consultation with national government ministries, and compilation of publicly released government documents relating to rural electrification. However, this level of individual analysis is not feasible for most stakeholders. The proposed analysis would provide a collated source not only of public information, but also of less accessible information such as ease of finance.

In addition, the policy and regulatory analysis would include considerations generated by other analytical work. For example, the SE4All High Impact Opportunity (HIO) Clean Energy Mini-Grids group has identified five priority areas of activity for stakeholders involved with GMGs in developing countries: increased co-ordination of actors, knowledge sharing, business models, public and private sector financing, and policy/regulation. GMG policy development initiatives are frequently led by the European Union Energy Initiative (EUEI) Partnership Dialogue Facility (PDF) hosted by GIZ and the Global Facilitation Team of SE4All. Consultation with EUEI-PDF will be undertaken to learn the lessons already addressed and to build upon the efforts of the CEMG HIO related to permits and licensing, tariff structures and future grid integration.

AFDB considerations

1. Potential overlap of business lines within the broader programme

The Bank's Market Development Programme has five business lines, with the overall objective of supporting the scale-up of investments in commercially viable GMG projects. The original focus of the Market Intelligence business line was on physical (availability of resources, population density) rather than feasibility (regulations, access to finance) factors. The proposed methodology could potentially overlap with business lines 3 and 5, which cover policy aspects of mini-grid development (Table 3). However, the risk of overlap appears small.

Table 3: Business lines of the AfDB Market Development Programme

BUSINESS LINE	BARRIERS ADDRESSED	PARTNERS
Market Intelligence	Unmade Linkages	Project Developers, Public Entities, Business/ Industry Associations
Business Development Support	Lack of Proven Business Models, Unmade Linkages	Project Developers, Customers/ Communities, Business/ Industry Associations
Policy and Regulatory Support	Policy Environment	Government, RECs, AU
Access to Finance	Business Models, Finance	Financial Institutions, Project Developers, Business/ Industry Associations
Quality Assurance	Standardisation, Policy Environment	Regulators and Industry associations; Rural Electric Cooperatives (RECs), Rural Energy Agencies

Business lines 3 and 5 address the need to support governments and national energy organisations in developing, standardising and implementing policies and regulations. This does not necessarily include an analysis of the existing policies and regulatory landscapes in different countries. There is also flexibility in the scope of these business lines, which have not yet been fully defined. Further consultation with the African Development Bank will be conducted to ensure that the development and implementation of the new methodology is fully aligned with the broader Market Development Programme.

In the case that other business lines do not fully address the need for a full policy and regulatory analysis, the authors of this report recommend that the scope of the project be extended to include a comprehensive policy and regulatory analysis as part of the new methodology.

4.2.3 DISSEMINATION OF OUTPUTS FROM THE MARKET DEVELOPMENT PROGRAMME

Effective dissemination of the outputs of the Market Development Programme – the new methodology and five country reports – will be critical to its impact. With few exceptions, none of the practitioners consulted had heard of any of the methodologies assessed in phase 1. The impact of this project will depend significantly on stakeholder engagement. Engaging practitioners and policymakers with the new methodology will require an active communication programme to disseminate the outputs of the Market Development Programme through an online platform, workshops, webinars, digital communications and conference calls with existing contacts and networks.

AFDB considerations

1. Maintenance of Information

Regular updating of the outputs of the Market Intelligence Programme is critical to its continued relevance, and should be an explicit provision of the broader Market Development Programme. Information on policies and regulations may need to be updated even more frequently than data on physical factors. The recommendation would be for the Bank to explicitly provide for the regular updating of the conclusions of this and associated reports, perhaps on an annual or at least bi-annual basis. This provision would be strongly linked with the platform recommended in section 4.2.1.

2. Stakeholder outreach

Another recommendation is for organised promotional activities to inform target groups of the existence of a single access point to access market information. Depending on budget, such outreach activities could be limited to the production/distribution of printed information, or include additional measures such as radio/TV broadcasts, or stakeholder events (national or regional) to present and discuss the related issues.

4.2.4 ADDITIONAL RECOMMENDATION - TECHNICAL ASSESSMENT AND CERTIFICATION OF HYDRO AND BIOMASS SITES

It is not feasible for most methodologies to properly assess the potential for biomass and hydro resources. This is due to two factors: a lack of pre-identified hydro and biomass sites (only a handful of sites in most African countries); and the substantial time and financial resources required to conduct proper site assessments. The exception in phase 1 was methodology H, under which site assessments were carried out by the Japan International Cooperation Agency (JICA). That agency has strong experience in delivering site assessments and had the necessary resources as part of the development of a national electrification plan for Cambodia.

The lack of properly certified site assessments is a key barrier to the development of small-hydro resources, in part because it severely limits access to local financing. Although many hydro sites are the property of farming companies and therefore already have concessions, most potential sites are un-utilised due to the time and cost involved in a full assessment, which can take two to three years and cost US$30,000 to 50,000 USD.[3] Moreover, the power ratings of many assessed sites have proven to be inaccurate, and occasionally orders of magnitude away from the result of the subsequent certified assessment. These kinds of miscalculations are a significant risk factor for investing institutions, which are likely to charge significant interest rates or refuse to provide financing.

For biomass, a key barrier to the development of sites is a lack of sustainability certification. There are a number of key considerations in the development of a biomass project, including financing, supply chain, transportation, land use competition, resource availability, technical capability and environmental impact. These factors are complicated by the distinct stages of production: crop production and harvest, pre-treatment and extraction, refining and combustion. To certify the sustainability of a biomass project, highly qualified technical experts need to assess three main risks: increased CO2 production (over the use of coal), reduced food production, and impact on ecosystems and biodiversity. Proper certification based on a careful assessment of these factors is critical for a successful biomass project.

This report therefore recommends that the Bank consider a programme to assess and certify small-hydro and biomass sites across Africa. The programme could provide proof of certification for sites the Bank has certified, as well as online access to a current list of certified sites. Such a certification programme would help to de-risk funding from local financial institutions, and would unlock major benefits for multiple stakeholders. For example:

- Government and utilities would have access to increased resources to feed into national electrification planning, and more opportunities to transition to an increased renewable mix
- Site owners would gain access to low-interest financing, and more accurate information on feasible resource potential
- Practitioners would have more information about feasible project opportunities
- Customers would have increased access to stable electricity from small-hydro and biomass schemes
- AfDB would see an increased rate of rural electrification due to the availability of pre-certified sites for developers
- Synergies will be possible with ECREEE, the ECOWAS Centre for Renewable Energy and Energy Efficiency, which will be soon adding identified small-hydro sites to its ECOWREX platform (covering the ECOWAS region).

4.3 JUSTIFICATION OF ELEMENTS NOT INCLUDED

Some of the missing elements of a comprehensive electrification assessment, as identified in the phase 1 report, are not included in the proposed methodology. These elements and the reasons for not including them are discussed in this section.

a. Small-hydro or biomass site assessments

Conducting certified site assessments is outside the timeframe and resource scope of the Market Development Programme or this assignment, and would be best addressed by a separate AfDB programme, as outlined in section 4.2.4. This assignment relies on information from relevant ministries, utilities and other data-gathering institutions. One finding of this analysis is that the quality and quantity of this information varies considerably by country.

b. Design of the infrastructure network required to electrify the proposed settlements

The project's focus on practitioners' perspectives means there is very little need to include an infrastructure element. Several phase 1 methodologies included design of a grid system for the entire region or country, but this was usually part of a proposed grid extension, and included an estimation of the total cost of electrification. While this approach may reflect a government's or national utility's interest in rural electrification, it is of little use to a practitioner looking to assess opportunities for small mini-grid developments.

c. Wind-based mini-grid assessments

The site-specific assessments of wind potential needed to determine the viability of a wind-based scheme are also outside the scope of this project. The proposed methodology will provide raw satellite data that can be used indicatively to highlight regions that are likely to have higher average wind speeds. More accurate studies exist for some countries, including programs such as UNEP's Solar and Wind Energy Resource Assessment (SWERA) programme. However, site-specific assessments will be needed in most cases.

d. Energy consumption and load patterns

Accurate assessment of energy consumption and load patterns is key to the profitability of off-grid systems. The calculations involved are highly sensitive to input parameters and variables, and their accuracy depends on a specialised system design and optimisation tools such as HOMER. Therefore, such assessments are not considered feasible in this project at the depth and scope that would be useful for practitioners.

e. Doing business factors (e.g., strength of supply chains for renewable projects)

Doing business factors such as the strength of supply chains and networks are key aspects of an opportunity assessment. However, the depth of analysis required to add value for practitioners beyond existing work is outside the scope of the proposed methodology. Existing sources such as the World Bank Group's flagship Doing Business report are recommended for a more comprehensive analysis.

ANNEX I: METHODOLOGY SPECIFICATIONS AND SOURCES

The primary focus of the proposed methodology is the provision of raw data to enable practitioners to carry out opportunity assessments using the variables and assumptions that are most relevant for their work. The methodology will also provide processed data in the form of maps, to give policymakers and other non-technical stakeholders an indication of non-grid and stand-alone electrification opportunities. The following maps are proposed:

Primary:

1. Split of areas for grid, mini-grid and stand-alone electrification, based on distance from existing grid and population density
2. Market potential (population), based on population and the split of areas defined in map 1
3. Market potential (USD) based on map 2, income data and electricity demand assumptions

Optional:

4. Local diesel prices, estimated from national prices and the distance to major cities
5. Lowest levelised cost of energy (LCOE) option for each settlement or area

Maps 1-4 are high-level maps, giving rough indications of some crucial elements such as local diesel prices or the division of a country into areas more suited for on or off-grid electrification. These maps use basic assumptions such as a limit to grid extension from the existing or planned network. Map 5 shows the mapping of the lowest levelised cost of energy option for each settlement or area, providing an indication of the areas best suited for different electrification options. However, this map may not be included in the final methodology due to limited added value over existing work (see section 4.2.1.).

MAP 1 – SPLIT OF AREAS FOR GRID, MINI-GRID AND STAND-ALONE ELECTRIFICATION

A split of areas best suited for grid, mini-grid and stand-alone electrification is defined, based on the population density and the grid extension limit. The map gives a first-order indication to stakeholders and developers as to the regions to prioritise for each electrification option. This split is mapped and accompanied by an estimation of the population within each area, using the population density of the country.

Inputs:

- Planned and existing grid network
- Population density

Assumptions:

- Assumes a set household or per capita demand
- Assumes a set threshold value of population density to distinguish among stand-alone, mini-grid and grid as the best option for an area

Calculations:

- Stand-alone areas are designated for all areas under the set population density threshold.
- All areas with a population density above the grid connection threshold are designated as grid areas, unless the distance to planned or existing grid lines exceeds the grid extension limit.
- All remaining areas are designated as mini-grid areas.

- The population density of each element of the population density map (people/km2), multiplied by the area covered by one element (km2), gives an estimate of the population living within this element.
- Addition of the population of each element for a given region gives the estimation of the population served by grid, mini-grid and standalone systems.

Reference values:

For demand, 650kWh/year corresponds to the household (HH) consumption calculated in Nerini et al. (2015) for tier 3 energy consumption, as defined in the World Bank Global Tracking Framework.[4] This level of consumption includes TVs and small appliances as well as basic lighting.

For population density thresholds, the sensitivity analysis conducted in Nerini et al. (2015) calculates the differing LCOEs of grid, mini-grid and stand-alone systems for different household densities.[5] For tier 3 energy consumption at 695kWh/year/HH, the threshold between stand-alone and mini-grid systems as the lowest-cost option is approximately 50HH/km2. The threshold between mini-grid and grid options is about 200HH/km2.

The maximum extension limit for medium voltage lines is taken to be 50km[6].

MAP 2 – MARKET POTENTIAL (POPULATION)

This map gives an indication of the market potential in terms of the customer base for an off-grid development or product. The level of accuracy depends on the availability of settlement-level electrification data. If this information is available, then the market potential is given by the number of un-electrified people in each settlement. If not, then the number for each settlement is estimated using the rural and urban electrification rates for the country, or the regional electrification rate if this is available.

Inputs:

- Settlement populations
- Settlement, regional or national-level electrification rate

Assumptions:

- If the electrification rate of each settlement is not known, it is inferred from the lowest-level data on electrification rates for that country.
- Average household size is based on research and local consultations.

Calculations:

- The potential market for each settlement is the population of that settlement multiplied by the ratio of un-electrified to electrified households.
- The potential market in terms of number of un-electrified households is calculated using an assumption about average household size for that type of settlement.

MAP 3 – MARKET POTENTIAL (USD)

The market potential in annual revenue is estimated from the market potential by population in map 2, and the income and energy consumption of this population. The income and energy consumption is calculated using available data, or using assumptions based on research and local consultations. If data are available on the per capita or household spending on fuel, then this will be assumed to be the ability-to-pay; otherwise, ATP will be estimated from the total income and/or energy consumption of the household.

Inputs:

- Market potential (population), from map 2
- Household or per capita income
- Household energy consumption

Assumptions:

- If data are not available, then the income and energy consumptions will be estimated from research and local stakeholder consultations.
- If data are available on per capita/household spending on fuel, then this will be assumed to be the ability-to-pay; otherwise ATP will be estimated from the total income and energy consumption of the household.

Calculations:

- The market potential (USD) is the market potential (population) multiplied by the ability-to-pay threshold.
- If the annual current spending on fuel is known, then this is taken as a proxy for ATP. If income data are available, then ATP will be estimated from the total income and the per capita spending percentage on fuel. If energy consumption data are available, then ability-to-pay will be estimated by multiplying the annual energy consumption (kWh) by the regional electricity cost ($/kWh). If energy consumption and income are available, the lowest estimate of the previous two calculations will be taken as the ability-to-pay.

MAP 4 – LOCAL DIESEL PRICES

The local diesel price is estimated by adding an estimated transportation cost to the national diesel price. This is done using the European Commission Joint Research Centre's (JRC) Global Accessibility map, which gives an estimation of the travel time to the nearest major city (defined as a city with a population greater than 50,000). The fuel is then assumed to be transported via van to the rural consumer. This calculation is used in map 5 for the levelised cost of energy for diesel generation in rural areas.

Inputs:

- Time to travel to the nearest major city – JRC Global Accessibility map[7]
- National diesel price

Assumptions:

- The accessibility map is generated by assigning an average speed to each element on the geospatial map (e.g., slope or land cover), and to each mode of transport (e.g., road or railway). The total travel time from the nearest major city is then calculated.
- Transportation cost is equal to the market price of diesel plus the cost of transporting the fuel from a major city to the local settlement.
- The fuel is transported by van, with a set volume of fuel carried on each journey. The van must complete the return trip, and is given a set fuel consumption per hour of travel.

Calculations:

- The transport cost, Pt ($/litre) = 2 Pd c t / V,
- where Pd is the national price of diesel ($), c is the fuel consumption in litres per hour, t is the time (in hours) taken to travel from the nearest major city and V is the volume of fuel transported.
- The local cost ($/litre) = national price ($/litre) + transportation cost ($/litre).
- This local cost in $/kWh is given by local cost ($/litre) multiplied by the generator efficiency (litres/kWh).

Reference values:

- The original source for this calculation, S. Szabo et al. 2011,[8] uses the following values:
- Volume of diesel transported, V=300 litres
- Vehicle consumption, c = 12 litres/hour
- Generator efficiency = 0.093 litres/kWh

MAP 5 – LOWEST LEVELISED COST OF ENERGY OPTION

This map considers grid extension, stand-alone and mini-grid systems utilising solar, biomass, small hydro and diesel resources. All reference values provided in this section are indicative; the values chosen for a country assessment will be decided on a country-by-country basis from partner knowledge of the local context, existing research, and local stakeholder consultations where possible.

The population density of each element of the population density map, multiplied by the area covered by one element, gives an estimate of the population living within this element. The addition of the population in the elements of each region gives the estimation of the population served by each electrification option.

CALCULATIONS COMMON TO ALL LCOE ESTIMATES

Estimating the un-electrified population density

The population density of un-electrified households is approximated using the total population density and the rural electrification level.

Inputs:

- Total population density map
- Rural electrification rate

Assumptions:

- A reasonable estimate can be made for the density of un-electrified households using the rural electrification rate.

Calculation:

- The density of un-electrified households is estimated as the overall household density multiplied by the rural electrification rate (%).
- If the population of that grid element is required, then the area of the element (km2) multiplied by the population density (people/km2) gives the population estimate.

In the same way, the un-electrified population of a settlement will be estimated from the total settlement population and the rural electrification rate.

Investment period

Many projects, especially those involving large infrastructure development, will take more than 10 years to become operational, but all LCOE estimates are obtained for current, not future, values. However, the level of granularity involved in the other aspects of the LCOE calculations means accounting for population growth over this period is not considered significant.

Discount rate

The discount rate used to calculate the levelised cost of energy for each project will be agreed upon with the Bank following in-country and desk-based research. Flat or distinct rates for different options will be applied as deemed appropriate.

GRID EXTENSION LCOE

The high capital cost of implementing grid infrastructure means that a grid would never be extended to only one village. However, the algorithm normally used to estimate this cost does not give a realistic cost of energy estimate, as the surrounding rural villages would then be much closer to the grid and therefore able to share in the cost burden.

In any case, this project is concerned with comparing the costs for a single development. An estimate of these costs, first utilised by the EC Joint Research Centre (methodology A, assessed in phase 1), gives an average extension cost per km per kWh. This estimate mitigates the need to calculate the number of people/ settlements reached by the grid extension, as it calculates an approximate cost of energy based purely on the length of required extension.

Inputs:

- Existing and planned grid network
- National grid cost of energy ($/kWh)

Assumptions:

- A fixed grid extension cost ($/km/kWh)

Calculations:

- The final cost of energy for a settlement being electrified by the grid is the national grid cost of energy ($/ kWh) + grid extension cost ($/km/kWh), multiplied by the distance from the settlement to the nearest grid line (km).

Reference values:

The grid extension cost is given as approximately 1.5c$/km/kWh (original estimate in rupees).[9]

SOLAR LCOE

The cost of solar energy is calculated by using the annual solar incident radiation to work out the generation possible for a set solar system power rating. The result is then multiplied by the capital/investment cost of the system get the levelised cost of energy. This calculation is for a simplified household system and assumes that the total system cost is linearly proportional to its size. It does not apply to a larger system used by more than one household.

Inputs:

- Annual solar incident radiation

Assumptions:

- Neglects the tilt of the solar panel relative to the incident radiation
- Total system costs are linearly proportional to its size
- A fixed utilisation value does not allow for the relative utilisation of a system used by multiple users as opposed to one household
- Uses the average radiation from the lowest radiation month so as to take into account daily and annual variations in solar intensity (including during the night)
- Calculates the cost of energy based on the cost per system size (kWp), a fixed operational cost, the solar incident radiation and performance characteristics

Calculations:

- The annual average incident radiance is taken (kWh/m2/year), and converted into a generation ratio (kWh/ kWp/year) using the yield of a solar panel (kWh/kWp) and a performance co-efficient and utilisation ratio.
- The investment cost in $/kWp divided by this generation ratio gives the cost of energy when combined with an operating cost over the lifetime of the system. This is calculated through equation 1 below.

$$LCOE = \frac{Total\ discounted\ costs\ (Capital\ costs + Operational\ costs)}{Total\ discounted\ lifetime\ energy\ production}$$

Equation 1

Reference values:

The typical yield of a solar panel is 15.6%, with a panel with an area of 1.6m2 being rated at 250Wp, and the performance co-efficient of a solar panel rated at 75%.[10]

Nerini et al. (2015) uses a fixed operational cost of 2% of the capital cost, and assumes an average system lifetime of 20 years for mini-grid systems and 15 years for stand-alone systems.[11]

SMALL HYDRO AND BIOMASS LCOE

There are technical and resource constraints on accurately assessing the potential of small hydro and biomass sites, and the cost estimates for developing such sites vary considerably depending on the site characteristics. The cost estimates for small hydro and biomass sources will therefore be done on a case-by-case basis, with inputs provided by the developer or, if necessary, set through consultation and research.

Inputs:

- Location of potential sites with associated power ratings and cost estimates

Assumptions:

- There will be an applied utilisation factor to account for the fact that the resource is unlikely to be utilised fully. This will set depending on key factors such as the possibility of connecting to the grid to sell excess capacity.
- The population to be served by a particular site will be within a circular area of a fixed radius.

Calculations:

- The annual generation is given by the power rating multiplied by the number of hours in a year and the utilisation factor.
- The number of households served by the site is estimated by the generation (kWh/year) divided by household demand (kWh/year/HH). The population density is then used to find the radius of area from the site, which covers this number of households. There is a maximum radius applied.
- If the number of people within the maximum radius is less than maximum number of households that can be served by this resource, then the LCOE will be calculated using the amount of consumed energy, not including the excess unless a grid connection is possible to sell excess capacity.
- The levelised cost of energy is calculated using the investment costs, operation costs and generation as in

$$LCOE = \frac{Total\ discounted\ costs\ (Capital\ costs + Operational\ costs)}{Total\ discounted\ lifetime\ energy\ production} \qquad \text{Equation 1}$$

Reference values:

A reference of demand is given in Nerini et al. (2015), using 650kWh/year as corresponding to the calculated household (HH) consumption for tier 3 energy consumption as defined in the World Bank Global Tracking Framework.[12] This level of consumption includes TVs and small appliances as well as basic lighting.

Small hydro:

Nerini et al. (2015) use a fixed operational cost of 2% of the capital cost, and assume an average system lifetime of 30 years.[13] The maximum distance from source is set at 10km.

The IED National Electrification Programme Prospectus (2014) uses a maximum radius of 20km.

Biomass:

Nerini et al. (2015) use a fixed operational cost of 10% of the capital cost, and assume an average system lifetime of 15 years. The maximum distance from source to settlement is set at 10km.

The IED National Electrification Programme Prospectus (2014) uses a maximum radius of 20km.

DIESEL GENERATION LCOE

The local diesel cost, calculated as described in map 4, is combined with investment and operational costs to give a levelised cost of energy. This calculation uses a reference generator suitable for the local context, due to the large variation in lifetime, power rating, generator efficiency and costs with different types and grades of generator.

Inputs:

- Settlement size or population density
- Local diesel cost, as detailed in map 4

Assumptions:

- A reference generator is used in each location across the country
- The lifetime of the generator is determined through the operational lifetime in hours and the number of hours of operation per year, with the number of hours of operation per year determined by the generator rating and the total demand
- There is a fixed level of demand per person or household, and a stand-alone system serves one household. Diesel mini-grids are not considered

Calculations:

- Capital costs ($) = investment costs ($/kW) * generator size (kW)
- Total operational cost ($/year) = operation costs ($/year) + production cost ($/kWh) * demand (kWh/year)
- Hours per year usage (if generation equals demand) = total demand per year (kWh) / generator power (kW), with a maximum of 12 hours per day operation
- Lifetime (years) = lifetime (hours) / annual usage (hours/year).
- The levelised cost of energy is then calculated using the investment costs, operation costs and generation

$$LCOE = \frac{Total\ discounted\ costs\ (Capital\ costs + Operational\ costs)}{Total\ discounted\ lifetime\ energy\ production} \qquad \text{Equation 1}$$

Reference values:

Methodology E from phase 1, Nguyen K. Q. (2007),[14] used the following values:

- System lifetime – 8000 hours
- Generator power – 450W
- Demand per household – 0.3kWh/day = 110kWh/year

A further reference of demand is given by Nerini et al. (2015), using 650kWh/year as corresponding to the calculated household (HH) consumption for tier 3 energy consumption as defined in the World Bank Global Tracking Framework.[15] This level of consumption includes TVs and small appliances as well as basic lighting.

ANNEX II: QUESTIONNAIRE TEMPLATE

IDENTIFICATION

Country: ________________________ Date: ___/___/______

Name of the organisation: ____

Address of the organisation: ____

Description of the organisation: ____

____

Name of personnel completing the questionnaire: ____

Occupation / responsibilities of personnel completing the questionnaire: ________________________

Email and/or phone number of personnel completing the questionnaire: _________________________

POLITICAL AND REGULATORY FRAMEWORK OF THE ENERGY SECTOR IN YOUR COUNTRY/COUNTRIES IN WHICH YOU OPERATE

Are there initiatives at the national level for clean mini-grid deployment?

☐ yes ☐ no ☐ I don't know

If yes, please give details (planned and realized activities):

____

____

Do you think that this regulation allows rapid development of clean energy mini grid in the country(ies)?

☐ yes ☐ no ☐ I don't know

Which actions are needed accelerate deployment of clean energy mini-grids in the country(ies)?

____

____

____

☐ Funding R&D for clean mini-grids in the country(ies)?

☐ Better coordination of activities in energy sector

☐ Reduce or suppress taxes on equipment

☐ Focus on training

☐ Subsidise clean mini-grids projects

If others, specify:

____

TOOLS TO SUPPORT YOUR WORK IN THE DEVELOPMENT OF MINI-GRIDS

When entering a country with which you are not operationally familiar:

What information is needed to assess the potential for mini-grid development?

____

____

What information or methodologies/tools would be most useful to aid your assessment of this potential? Please describe the key aspects of this information or methodology/tool that are required by your organization to aid in the assessment of mini-grid potential:

____

____

Do you currently use any tools or sources of information to help assess this potential? What are they?

____

____

Are there any particular pieces of information or analysis not adequately addressed by existing methodologies/ tools, which would be beneficial to your organization?

____

____

The Carbon Trust has been engaged by the African Development Bank to develop a methodology to help developers to assess the potential for mini-grids in African countries. Below is a list of selected opportunity assessment methodologies identified during this project:

Name and author	Link	Example of use for rural electrification
Network Planner by Modi Labs, Columbia University	http://networkplanner.modilabs.org/	F. Kemausuor et al. Electrification planning using Network Planner tool: The case of Ghana - http://www.sciencedirect.com/science/article/pii/S097308261300121X
GeoSim Integrated Rural Electrification Planner by Innovation Energie Developpement	http://www.geosim.fr/	Tanzania National Electrification Program Prospectus - http://www.ied-sa.fr/index.php/en/documents-and-links/publications/send/3-reports/33-national-electrification-program-prospectus.html
UNITE Electrification Access Tool by UNDESA	https://unite.un.org/sites/unite.un.org/files/app-desa-electrification/index.html	Mentis et al. (2015) – A GIS based approach for electrification planning – A case study on Nigeria - https://www.researchgate.net/publication/286243175_A_GIS-based_approach_for_electrification_planning-A_case_study_on_Nigeria
ECOWREX by ECREEE	http://www.ecowrex.org/	In progress is a project to combined this currently mapping only tool to include levelised cost of energy estimates for different types of mini-grids (solar PV, small hydro, hybrid etc.), using IntiGIS software by CIEMAT - www.ciemat.es/portal.do?IDM=271&NM=2

Are you already familiar with any of these methodologies? ____

____

How useful are they? Why? ____

____

Do you use a tool not mentioned above? ____

THE USE OF GIS MAPS

The proposed methodology could include a selection of GIS maps to support decision-making. An indicative list is given below. The maps would show the major settlements and existing and planned grid infrastructure in a country, as well as:

- Population density
- The regions best served by grid or off-grid electrification, based on threshold distances around existing and planned grid lines
- The regions best served by grid, mini-grid or stand-alone-based systems, defined by thresholds in population density, with grid extension limits based on threshold distances around existing and planned grid lines. The total population served by each option would be the output
- Identified hydro and biomass resources mapped. The total population served by these resources would be an output
- The LCOE of solar mini-grids mapped, with the range of LCOEs as an output
- Local diesel costs
- The best option, by cost of energy, shown for each pixel. This would compare solar, biomass, hydro, diesel and grid extension. The total population served by each option would be an output
- Best option, by cost of energy, with constraints applied to chosen solution based on the level of demand required by services such as hospitals, schools, government buildings. The total population served by each option would be an output, as well as the range of LCOEs for each option for that country.

Please indicate how useful each of these maps would be to your organisation for the assessment of the potential for mini-grid development in a new country:

____

____

____

____

Are there any maps not listed that would be important to include?

____

____

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