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Rural Electrification in Sierra Leone: The Role of Mini Grids vis-à-vis Stand-alone Home Systems and Grid Extension

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This technical assistance report has been produced at the request of the Government of Sierra Leone via the ECOWAS Center for Renewable Energy and Energy Efficiency (ECREEE) Help Desk. It has been supported by the Clean Energy Solutions Center and the U.S. Agency for International Development's (USAID) Power Africa initiative. Its sole purpose is to serve as the basis for structuring discussion with, and enabling further technical assistance to, the Government of Sierra Leone.

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ABBREVIATIONS

AMADER	Mali Rural Electrification Agency (L'Agence Malienne pour le Développement de l'Energie Domestique et l'Electrification Rurale)
CHC	Community Health Centre
DFID	UK Department for International Development
ECOWAS	Economic Community of West African States
ECREEE	Center for Renewable Energy and Energy Efficiency
ESMAP	Energy Sector Management Assistance Program (World Bank)
IEA	International Energy Agency
LCOE	Levelised cost of energy
MTF	Multi-Tier Framework
MWh	Megawatt hour
NREL	National Renewable Energy Laboratory
SEforAll	Sustainable Energy for All
SHS	Stand-alone home systems
SOBA	Sierra Leone Sierra Leone Opportunities for Business Action Programme
T&D	Transmission and distribution
UNOPS	United Nations Office for Project Services
US	United States
USAID	United States Agency for International Development

ABSTRACT

This briefing paper provides input to Sierra Leone's rural electrification strategy building. It assesses different pathways for providing electricity access to Sierra Leoneans currently not being served by modern power services. In particular, it discusses the role of mini grids for rural electrification as opposed to two alternatives: Stand-alone home systems and extension of the existing grid.

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THE RURAL ELECTRIFICATION CHALLENGE

1.2 billion people, 16% of the global population, do not have access to electricity (IEA 2016). In Sierra Leone, the national electrification rate is only 13%. Two thirds of Sierra Leoneans living in urban settings, and 99% of people in rural areas, do not have power access (ASD 2017). The Government of Sierra Leone (GoSL) has made it a priority target of its Renewable Energy Policy to provide sustainable and cost-effective electricity to all people, including to the 60% living in so remote areas that they are considered off-grid locations, meaning that it is regarded technically difficult and/or too costly to connect them to the national grid in the foreseeable future (MoE 2016).

Typically, electricity delivered through an established national or regional grid is cheaper on a Megawatt hour (MWh) basis than if it is supplied through off-grid solutions. However, the cost of extending the grid to sparsely populated, remote or mountainous areas can be very high, and long-distance transmission often comes at the expense of high technical losses. Grid extension is most suitable for urban zones but just a limited share of rural areas. The International Energy Agency (IEA) estimates that 70% of yet unserved rural areas worldwide are to be connected by off-grid solutions. Of the off-grid share, mini grids are suggested to deliver 65% and stand-alone home systems (SHS) the remaining 35% (IEA 2011).

Additional investment required to achieve universal energy access to electricity is estimated at between $640 and $665 billion worldwide between 2010 and 2030, with 60% of this required in sub-Saharan Africa (IEA 2011). Thus far, most mini-grid development worldwide depends on government- or donor-led initiatives, and private sector involvement has been limited (PWC 2015).

MINI GRIDS AND STAND-ALONE HOME SYSTEMS VIS-À-VIS GRID EXTENSION

Decision-makers pursuing the goal of increasing rural electrification must take several important considerations into account. Mini grids, SHS and grid extension are all options that can provide electrification to rural areas. The GoSL has set the goal of achieving 92% electricity access in 2030. It plans to reach 55% of the population through connecting them to the existing and by-then extended grid line, while 27% are to be served by mini grids and 10% by SHS (ECREEE/SEforALL n.d.).

There is no single best technology option or 'one-size fits all' pathway for rural electrification. The option of choice for a given geographical area depends largely on specific circumstances and the criteria deemed most important to decision-makers. Every project or program needs to consider individual local site conditions; national and sub-national goals; social, economic and environmental impacts; and financial requirements.

The Multi-Tier Framework (MTF) developed by Energy Sector Management Assistance Program (ESMAP) and Sustainable Energy for All (SEforAll) categorises the varying levels of access to productive uses of energy, from Tier 0 (no access) via Tier 1 (light and phone-charging), Tier 2 (adding TV and fan), Tier 3 (adding medium-power appliances such as refrigerators and water pumps), Tier 4 (adding high-power appliances such washing machines and irons) to Tier 5 (adding very high-power appliances such as vacuum cleaners, water heaters and air conditioners) (ESMAP, SEforALL 2015). Typical supply technologies ("typical" meaning that supply potentials ultimately depend on an individual system's configuration) for these tiers are solar lanterns (Tier 1); rechargeable batteries and SHS (Tier 2); medium SHS or mini grids (Tier 3); large SHS or mini grids or low-capacity central grid (Tier 4); high-capacity central grids (Tier 5). For more information on individual tiers, see Appendix.

Grid-connected electricity supply provides users with the greatest possibilities in use, including for high-power commercial uses. However, in Sierra Leone and in many other places in Africa, universal grid access is hard to achieve anytime soon due to the significant associated cost and the limited electricity demand to justify it. The dominant focus of rural electrification in least developed countries such as Sierra Leone in the immediate future will therefore be on mini grids and SHS, with a view to grid extension as an aspiration and viable option in the longer term.

It is important to emphasise that a decision for a certain technology today does not necessarily prevent achieving the next technology stage tomorrow. Decision-makers should thus look at the electricity system as an evolving system. They do well to take the service needs of a community in the immediate as well as in the long-term as the key starting point of their considerations, and assess technical alternatives from there.

INDICATORS FOR EVALUATING THE SUITABILITY OF MINI GRIDS AND SHS

We have developed a list of pertinent indicators to enable the GoSL to encapsulate the various relevant factors into its rural electrification decision-making (see Table 1). This set of indicators can serve as a first reference guide when assessing mini grids and SHS alternatives at the national level; and it can be used as the basis for a location-specific, on-the-ground assessment, which will best be done in close cooperation with local communities and the chiefdoms. Indicators are divided into three groups: Service Needs, Technical Capacity and Institutional Capacity.

Table 1. Indicators to assess the feasibility of mini-grids and SHS

Indicator	Mini Grids	Small Home Systems (SHS)
Service Needs		
Quality and reliability of supply provided	High*	High*
Supported appliances	Low, medium and high-power appliances	Low, medium and limited high-power appliances
MTF Tiers covered**	Tiers 2 to 5	Tiers 2 to 4
Ability to cater for commercial productive loads	Medium	Low
Possibility for expansion due to demand growth	High	Low
Technical Capacity		
Suitability at large distances from grid	High***	High
Operation and maintenance complexity	High	Low
Infrastructure required	Distribution network incl. wires, metering; transformers for voltage transmission in larger systems	None
Levelised cost of energy	Medium****	High****
Institutional Capacity		
Level of technical expertise required	High	Low
Governance and Institutional strength required	High	Low

* In comparison with on-grid supply in SL today where blackouts are frequent
** For details on SEforALL's Multi-Tier Framework see main text and Annex.
*** Assuming sufficient population density/load demand/asset utilisation
**** Low in terms of total installation price when compared to larger systems – but medium and high for MGs and SHS, respectively, in terms of equipment costs vis-à-vis service provided

Service Needs

Quality of supply

Mini grids and conventional large national or regional grids cater to the use of high energy-consuming appliances that may not be possible to run on SHS-powered systems. The typical appliances possible with an SHS include multi-point general lighting, phone charging, and perhaps a computer or a printer. Almost all high-power appliances such as washing machines, irons, vacuum cleaners or air conditioners can only be met with elaborated mini grids or conventional grids. This is a very important consideration, as the ultimate goal is to not just provide for the most basic electricity needs, but to climb beyond connection, to the higher tiers of the MTF.

Service reliability is a salient feature of the quality of electricity supply. In least developed countries, importantly, mini grids and SHS can be more and not less reliable than the larger (e.g., national) grids, in which long-duration blackouts and power interruptions can be the consequence of intentional load shedding by the grid operation.

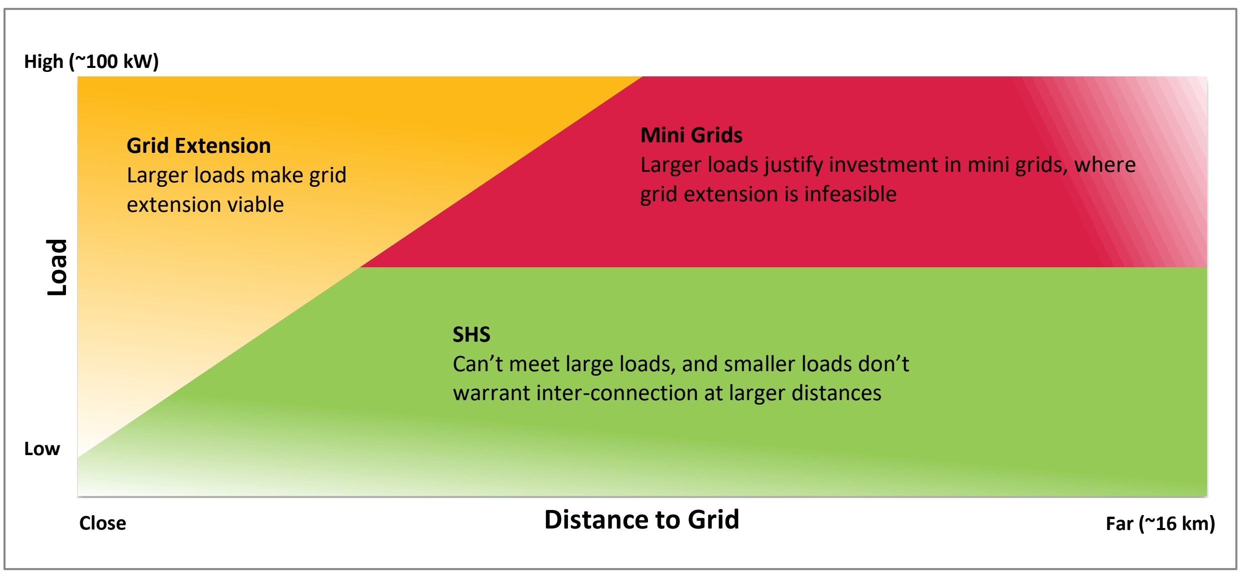
Population and load densities

High population density in villages or towns is correlated with higher load density, i.e. the kW demanded per square kilometre. Areas with higher load densities require less low-voltage line materials and labour for their installation, which reduces distribution costs and often swings the economic favourability towards mini grids. Cost savings are found to diminish at around 400 people per square kilometre (RMI 2017).

Generation size/load demands

Mini grids, due to their generation size – usually in the range of 10 kW to 10 MW – can provide for larger-scale loads while SHS usually are limited to the order of 50 W up to a few kW. This is relevant to the cost efficiency of the systems. Mini grids require a large enough cumulative load to overcome the costs of wires, metering etc., which are less significant for SHS. Once the cumulative load gets large enough, mini grids can benefit from the economies of scale in generation, and the associated infrastructure can become feasible. For still larger loads, which are often not present in rural settings, the case for grid extension becomes more viable. This relationship is illustrated in Figure 1.

Figure 1. Influence of distance to grid and load size on feasibility of technologies



Presence of productive commercial loads

The presence of a daytime productive commercial load can significantly improve the cost-effectiveness of mini grids, making them an increasingly favourable option. This is because such a load can increase the asset utilisation of the mini grid, complementing the evening peak load due to lighting and home appliances, and meaning more excess power generated during the day can be directly used.

Future demand evolution

Because they are more centralised, production facilities of mini grids are better equipped to scale up to a growing demand than those of SHS. Electricity demand growth is a highly likely scenario in countries such as Sierra Leone, as households begin to enjoy the benefits and possibilities that come with electrification. Furthermore, the financial viability of expansion may also favour mini-grid owners, as when energy usage - and subsequent revenues increase - expansion makes good business sense. For SHS conversely, this responsibility rests with the individual and can be a high burden. It can also prevent the potential for higher power appliance usage. This is an important consideration for the future, as it has an influence on the longer-term cost effectiveness of comprehensive electrification efforts.

Technical Capacity

Distance from the grid

The distance from the consumer to the grid has an enormous influence on the cost viability of grid extension in comparison. It has been found that for an 'average 500-household village in sub-Saharan Africa' with 5 kWh/month consumption, mini grids became cost-advantageous over grid extension when the distance from the grid exceeded 4 km (RMI 2017). This should be a key consideration in the selection of different technologies for rural electrification.

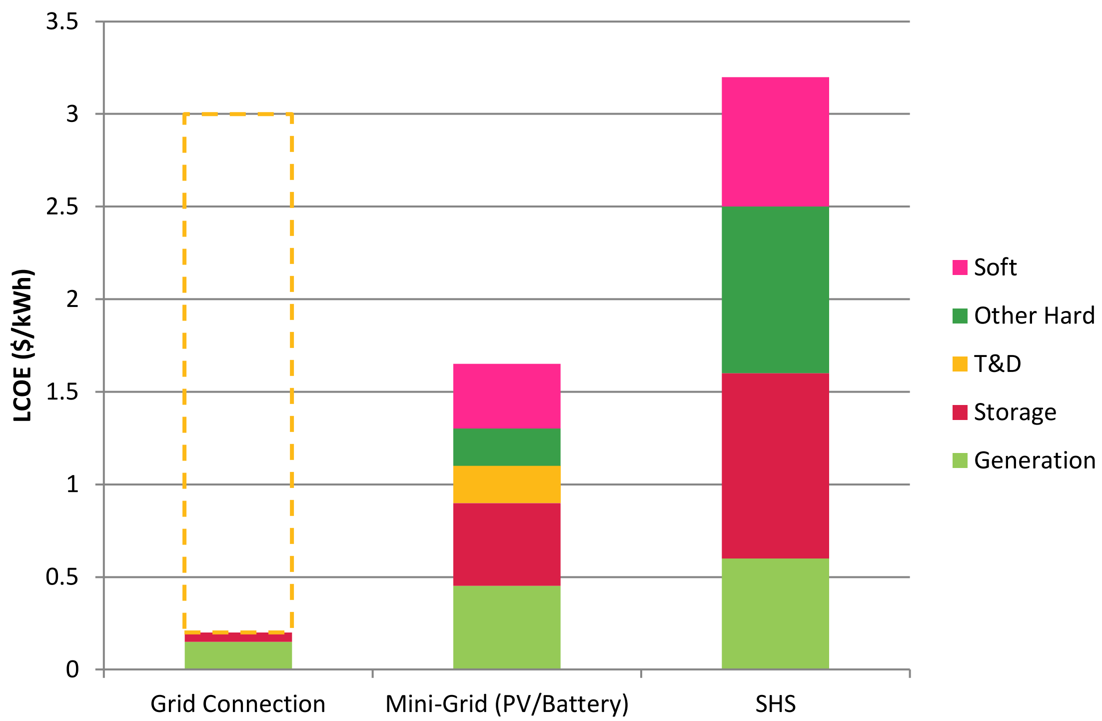
Operation, maintenance and infrastructure

Mini grids, due to the additional infrastructure required for transporting electricity from the generation source to the consumer as well as their larger system size and distribution network, have higher complexity in maintenance and operation than SHS. For SHS, e.g. solar PV systems, production and consumption are combined at the same location, and thus additional transmission and distribution infrastructure is not required.

Levelised cost of energy (LCOE)

Generation costs for centralised grid electricity production are generally cheaper than that of mini grids or SHS, though this is of course dependant on the generation source. When considering the LCOE over the lifetime of an installation, the magnitude of grid extension costs is a key determining factor on whether it turns out to be the cheapest overall option or not. This is illustrated in Figure 2 which compares LCOE estimates for a typical village of 500 households in sub-Saharan Africa. While 'soft costs' include site selection, surveying, system design, permitting, duties etc., 'other hard costs' incorporate hardware costs in addition to generation and storage; 'T&D' represents transmission and distribution costs. The LCOE of SHS is often higher than that of mini grids; however, there are several other factors that influence the cost of mini grids, discussed throughout this section.

Figure 2. LCOE for different rural electrification measures



© SD Strategies 2017. Sources: Rocky Mountain Institute and IRENA.

Institutional Capacity

Level of technical knowledge / expertise required

One of the barriers that mini grids have been faced with, and that has limited development progress, is that mini grids require an elevated level of technical knowledge and expertise for their planning, installation and operation. This can be a discouraging factor when compared to the relatively more easily installed and serviced SHS.

Governance and institutional strength

Mini grids demand a higher level of strength in both national and local governance than SHS. The production facilities for mini grids are larger, and serve entire communities rather than individual households, meaning broader regulatory frameworks as well as significant community outreach and engagement is required. There is also the consideration and application of the mechanisms the government chooses to support the development of such projects, and whether they adopt a role in project development, ownership, or regulation.

Mini grids typically require highly capable institutions for their technical operation, as well as for tariff setting and collection. On the SHS side, the main requirement is the development of quality standards and their consistent monitoring. Quality standards implemented in many places worldwide can serve as a yardstick. Governance and institutional capacity have proven to be a limitation to the widespread uptake of mini grids in many developing countries to date and is a vital ingredient for their successful implementation.

Current electrification targets set by the Government of Sierra Leone are:

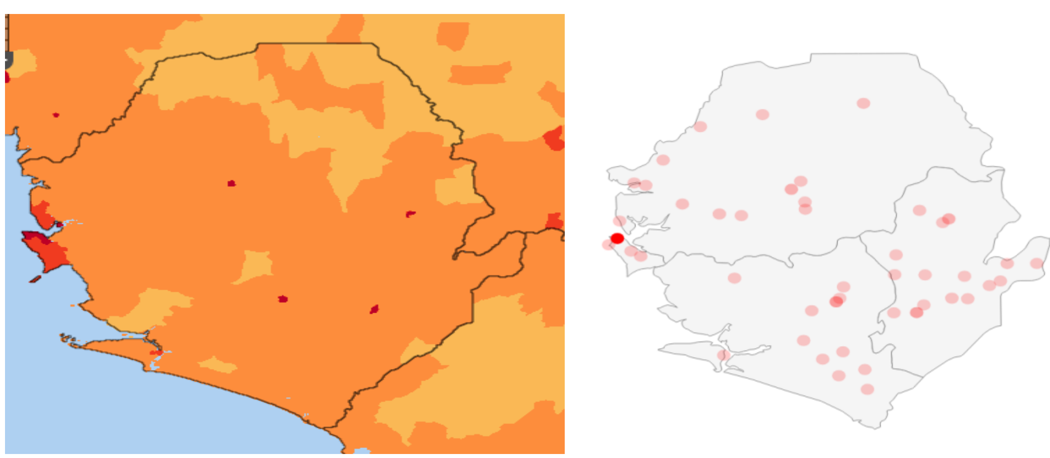
- Connection of all district capitals by 2018
- 44% electricity access by 2020, and
- 92% electricity access by 2030

It is envisaged that the 44%-by-2020 target will be met with 30% access coming from the national grid, 11% from mini grids and 3% from SHS (ASD 2017). For 2030, access numbers are to increase to 50% coming from the grid, 27% from mini grids and 10% from SHS (ECREEE/SEforALL n.d.).

As mentioned, population density is a key indicator for assessing the suitability of alternate electrification strategies. Figure 3 presents the number of people per square kilometre across Sierra Leone. It shows that the population is largely spread out across the country, with the highest density of people along the western coast surrounding the capital Freetown and in four other main centres: Bo, Kenema, Koidu and Makeni. It is important to note that these main population centres only cover approximately 25% of Sierra Leone's total population of 7,396,190 (World Bank n.d.) – evidence of the wide spread of the population across the country.

The current electricity grid in Sierra Leone connects four of the five highest populated centres (Freetown, Bo, Kenema and Makeni). It does not extend to Koidu or other parts of the country (Climatescope 2016). Table 2 shows major population areas in Sierra Leone, Figure 5 presents them geographically.

Figure 3. Population density (left) and main population centres (right) in Sierra Leone



Source: SEDAC 2017 (left) and UN DESA 2017 (right).

Table 2. Main population centres in Sierra Leone

Name	Population				
Freetown	802,639	Rokupr	12,504	Baoma	7,044
Bo	174,354	Gandorhun	12,288	Moyamba	6,700
Kenema	143,137	Kambia	11,520	Mambolo	6,624
Koidu	88,000	Yengema	11,221	Tombodu	5,985
Makeni	87,679	Gandorhun	10,678	Daru	5,958
Lunsar	22,461	Bonthe	9,647	Foindu	5,868
Port Loko	21,308	Pendembu	8,780	Masingbi	5,644
Waterloo	19,750	Blama	8,146	Motema	5,474
Kabala	17,948	Kamakwie	8,098	Bomi	5,463
Segbwema	16,532	Panguma	7,965	Tintafor	5,460
Magburaka	14,915	Pujehun	7,926	Buedu	5,412
Kailahun	14,085	Kukuna	7,676	Mamboma	5,201
Binkolo	13,867	Barma	7,529	Kassiri	5,161
Freetown	13,768	Boajibu	7,384	Hastings	5,121
Bumpe	13,580	Bunumbu	7,355	Hangha	5,007
		Sumbuya	7,074	**TOTAL**	**1,695,936**

Source: UN DESA 2017.

To achieve the grid electricity access goal of 50% by 2030, significant grid expansion needs to take place. The grid currently serves approximately 920,000 people. Figure 4 below illustrates the planned expansion of Sierra Leone's transmission grid.

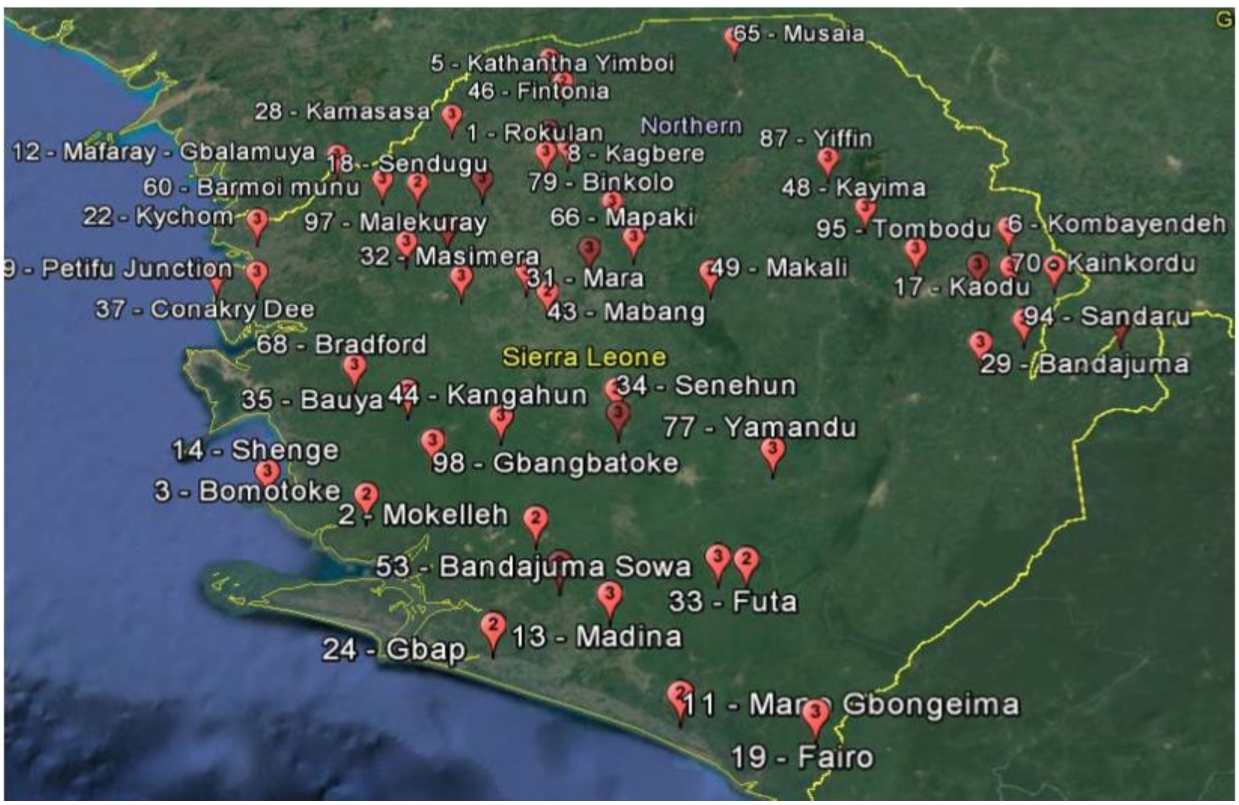
Figure 4. Planned expansion of the transmission grid of Sierra Leone

Colour code: Green = 161 kV; Blue= 225 kV; Red= 66 kV
Source: Adam Smith International, unpublished.

Multiple mini grids already exist in the country. Their exact number is unclear. Many are based on diesel generators. They exist in areas without access to the grid as well as in on-grid areas as back-up systems for grid-related power outages. There are also renewable-based mini grids. Most of them are NGO-supported or enabled by other concessional money. Welthungerhilfe, through the PRESSD-SL initiative, have installed and operated two solar mini grids, and there is also a hydro mini-grid and other renewable-based mini grids in the pipeline yet to reach financial close. The presence of significant isolated consumption and significant daytime commercial loads are rare in Sierra Leone, which limits the places where mini grids are likely the least-cost option.

In addition, a current programme led by the United Kingdom's Department for International Development (UK DFID) is also under way, which aims to provide reliable and sustainable (mostly renewable-based, but some likely complemented by diesel generators) electricity supply to 50 community health centres (CHCs) and the rural communities neighbouring them in 2017, with another 40 larger systems by 2020. These mini grids are to be operated commercially by private companies or by local community associations, to support their long-term sustainability. The 50 sites selected for the CHCs can be seen in Figure 5.

Figure 5. Sites for DFID/UNOPS CHCs to be extended to mini-grids



Source: DFID material provided by GoSL.

On the solar lanterns and SHS side, approximately 2,000 systems had been sold and installed by 2013, with targets for 250,000 by 2017. (Powerfor 2016). Since current population in Sierra Leone is at 7.1 Million, the 2017 SHS distribution target seems to be in line with the 2020 and 2030 targets for SHS.

ADVANCING SIERRA LEONE'S RURAL ELECTRIFICATION STRATEGY

To further develop Sierra Leone's rural electrification strategy, an extensive study is recommended, gathering location-specific data across the country for the indicators already laid out above, but further detailed here:

Specific Service Needs

- Quality and reliability of supply
- Supported appliances
- MTF tiers covered
- Presence of commercial productive loads
- Possibility for expansion due to demand growth
- Populations & population densities, and demographic trends
- Load densities

Technical Capacity

- Distance from conventional grid
- Operation and maintenance complexity
- Infrastructure required
- LCOE

Institutional Capacity

- Level of technical expertise required
- Governance and institutional strength required

The collected data will inform decision-makers on what technological pathway to follow in what part of the country. This in turn will allow them to review, and if necessary, adjust the national targets set for SHS, mini grids, and grid extension. Currently, there is a lack of clarity and transparency on grid extension plans (and their progress).

Already in parallel with the acquisition and review of site-specific data, a rural electrification policy can be drafted. The GoSL has already brought this process underway. Discussion should also be started on how to implement, monitor and review policies. Outreach to local communities, national stakeholder dialogues and mainstreaming of governmental action across relevant line ministries all need to be part of ongoing electrification strategy-building.

Initial Cost Estimates

Initial calculations were performed to provide an estimate for the required investment to achieve the goals set for 2030, using data on the costs of grid extension, mini grids and SHS (SEforAll 2015). Table 3 specifies cost estimates per technology for electrification efforts in Tanzania, assuming all new access connections are made to a single tier.

Table 3. Annualised cost of electricity access provision per capita per supply type under five scenarios: Tanzania (USD per capita per year)

	All new access connections are Tier 1	All new access connections are Tier 2	All new access connections are Tier 3	All new access connections are Tier 4	All new access connections are Tier 5
Grid	n/a	n/a	14.54	31.53	54.53
Mini-grid	n/a	17.38	29.33	n/a	n/a
Off-grid	2.21	24.4	93.53	212.3	n/a

Source: SEforAll 2015.

Approximately 962,000 Sierra Leoneans (13.5% of its 7.1 million population) currently have access to electricity, and around 115,000 are expected to gain access by the end of 2017 through mini grids from the DFID Rural Renewable Energy Package and PRESSD-SL projects. This leaves just over 6 million people without access to electricity.

In Table 4, we have calculated the gap between current power access and existing electrification targets per supply method, assuming that the grid currently serves 100% of urban residents who have access and SHS 100% of rural residents who do. Please note that these calculations do not consider population growth, which is significant in Sierra Leone. Future calculations should take growth estimates into account.

Table 4. Access targets, current / provisional access, and access gaps

	Access Targets for 2030		Current access (incl. mini-grid projects)	Gap between current access and targets	No. of households (avg HH size = 5.9)
Grid	55%	3,905,000	919,876	2,985,124	504,528
Mini-grid	27%	1,917,000	115,000	1,802,000	304,563
SHS	10%	710,000	41,890	668,110	112,920
Total	92%	6,532,000	1,076,766	5,455,234	922,011

 Source: Own calculations based on GoSL targets and population and current access data from DFID and Sierra Leone Sierra Leone Opportunities for Business Action Programme (SOBA).

In Table 5, we are calculating the total investments required between 2017 and 2030 to achieve Sierra Leone's electrification targets (per supply method and electrification tier). It is important to note that these investment estimates are made for the same simplified scenarios applied in Tanzania, and not a mix like the specified 55/27/10% targets.

Table 5. Investment required 2017-2030 (USD million) per tier and supply method

	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Grid	-	-	1,031	2,236	3,867
Mini-Grid	-	1,233	2,080	-	-
Off-grid (SHS)	157	1,730	6,633	15,056	-

These estimates are by no means comprehensive. They simply provide an indication of the scale of investment required to achieve the electricity access goals set for 2030. They also reinforce the need to further detail rural electrification plans in general and targets for individual electrification tier in particular, in order to get a clearer understanding of the associated investment needs for each envisioned pathway.

GOING FORWARD

This paper presents a set of indicators for further developing Sierra Leone's rural electrification strategy. It also provides initial cost estimates for the investments required to achieve Sierra Leone's energy access goals. The development of a comprehensive rural electrification strategy including location-specific selection of electrification pathways is a complex process and one that is beyond the scope of this short paper. However, in addition to a framework for conducting site-specific assessments, important insights and lessons for further advancing electrification could be acquired.

Considering the GoSL's electrification targets and grid extension plans on the one hand and the current limited household demand for high volumes of power on the other, electrification at tiers 1 to 3 seems the most practical and economically feasible first step at least in rural, off-grid locations. A focus on SHS and mini grids here can address basic lighting and small appliance demands - the predominant energy services currently demanded. This does not – and should not – mean that the people served by SHS and mini grids will be confined to lower tier access forever, but rather that their access level can be built up over time, as their demands grow, and grid-extension progresses.

Existing mini grids in Sierra Leone have exclusively been financed through the provision of grants. Project developers with in-country experience question the financial viability of privately funded, commercially developed mini grids under current conditions. Efforts are being made to reduce the risks perceived by banks on mini-grid projects, however their inclination to lend remains limited, rendering debt financing unlikely in the near term. Financial viability of solar-powered mini grids depends on the presence of daytime productive commercial loads which is currently lacking in most parts of Sierra Leone. This hampers the economic competitiveness of mini grids with their alternatives, most importantly SHS.

Naturally, as grid extension plans materialize, the areas near power lines should be connected to the extent possible (i.e., financeable and demanded by the communities), providing for Tier 5 access. The 55% target for grid access by 2030 may warrant some reconsideration in time, as cost estimates demonstrate that SHS can more efficiently meet community demands. Thus, a strategy focussing on SHS will reach more rural communities and people at the same price and in a shorter time period. As demands evolve and grow, and grid expansion continues, there is the potential to interconnect SHS installations and mini grids to the national grid (possibly under a net-metering payment scheme), to allow them to contribute energy to the national grid and pull from the later in times of high local demand and low on-site generation. Again, demand and its associated tier of access should be the primary driver for fine-tuning the electrification efforts over time, possibly employing a staged approach to increase quality of service gradually and in line with community needs.

There are additional, location-specific rationales to further define the rural electrification strategy. The international interconnection line planned to connect Sierra Leone to Liberia and Guinea is an example. If it gets built, towns and villages close to that line could be easily and cost-effectively connected. Population dynamics and urbanisation, as well as the associated climate, environmental and social impacts of projects, should also be given consideration. This could see a supplementary emphasis on the transition of existing fossil fuel based mini grids, to utilize renewable energy sources.

It is evident that dependable political and institutional environments are a pivotal precursor and platform for rural electrification. Policies supporting mini grids, technical standardisation and regulation for SHS, and the development of domestic knowledge and skills for the installation of mini grids and SHS are key ingredients not only for the provision of electricity service, but for the longer-term sustainability of access to reliable, high-quality electricity.

There is enormous potential to learn from the rural electrification efforts of other countries. In the African landscape, Mali is often cited as the country that has had most success in developing isolated mini grids (PWC 2015). A key feature of their success has been that AMADER, Mali's Rural Electrification Agency, has been assigned responsibility for the major decisions made in relation to mini grids. On top of this, most of these mini grids received initial capital cost subsidies (~570 EUR per new connection), also stimulating their extensive rollout.

Following this report, Work Package 1.2 - to be completed by National Renewable Energy Laboratory (NREL) - will conduct an assessment and comparison of the various business models and critical considerations over the lifetime of mini-grid projects. Our following report - the outcome of Work Package 1.3 - will review the effectiveness of existing policies and institutions, and formulate and communicate a policy toolkit for the advance of rural electrification in Sierra Leone.

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ANNEX

Multi-tier matrix for measuring access to household electricity supply

		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
1. Peak Capacity	Power capacity ratings (in W or daily Wh)		Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
			Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
	OR Services		Lighting of 1,000 lmhr/ day	Electrical lighting, air circulation, television, and phone charging are possible			
2. Availability (Duration)	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening		Min 1 hr	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
3. Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration <2 hrs
4. Quality						Voltage problems do not affect the use of desired appliances	
5. Afford-ability					Cost of a standard consumption package of 365 kWh/year < 5% of household income		
6. Legality						Bill is paid to the utility, pre- paid card seller, or authorized representative	
7. Health & Safety						Absence of past accidents and perception of high risk in the future	

Source: ESMAP and SEforAll, 2015.