ESRES

ENERGY SECURITY AND RESOURCE EFFICIENCY IN SOMALILAND

ESRES Complementary Studies – Final Report

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UKaid from the British people

WASAARADDA TAMARTA IYO MACDANTA
MINISTRY OF ENERGY AND MINERALS

M M MOTT MACDONALD

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1. Introduction

1.1 Background to ESRES

Somaliland proclaimed independence from Somalia in 1991. Though not recognised internationally, Somaliland has maintained a stable existence with a working political system, government institutions, a police force and its own currency. Despite the progress that has been made, the Somaliland government currently lacks the skills, systems and resources to ensure effective service delivery to its citizens, including the provision of energy.

Energy consumption per capita in Somaliland is among the lowest in Sub-Saharan Africa. Several sources indicate that in overall terms, charcoal, kerosene and electricity constitute an important source of fuel for households in urban and peri-urban areas, while fuel wood constitutes an important source of energy for rural areas. There is only a limited capacity for generating electricity through diesel-powered generators by Electric Service Providers (ESPs). Although Somaliland has substantial energy resources - especially wind, solar, and fossil fuels—their potential is largely under-utilised.

A Memorandum of Understanding (MoU), governing the implementation of the Energy Security & Resource Efficiency in Somalia Programme, was signed in July 2015 between the Government of Somaliland (GoSL) and the UK's Department for International Development.

The ESRES Programme supports the Government of Somaliland to improve access to affordable electricity for vulnerable communities through the promotion of renewable energies. The choice for renewable energies is based on the premise that green infrastructure investments in fragile states have potentially positive poverty reduction benefits while at the same time reducing the country's vulnerability to the negative effects of climate change. Currently the legal and regulatory framework is incomplete and there is a very low adoption rate of renewable energy technologies by the private sector in Somaliland.

ESRES will be implemented in two phases:

- Phase I (30 months): pilot-phase;
- Phase II (24 months): expansion-phase.

Phase I of the Programme consists of three components:

- Component 1: Technical assistance to the MoEM for the development of an appropriate policy and regulatory framework for the sector;
- Component 2: Pilot the development and implementation of hybrid mini-grids;
- Component 3: Create a Renewable Energy (RE) Fund towards the end of Phase I.

1.2 Achievements to Date

ESRES Phase I is now two years into implementation and the Programme has made great progress in its support to develop the Energy Sector in Somaliland.

Under Component 1, the ESRES PM supports the MoEM through a Technical Assistance Plan (TA Plan) to develop the policy and regulatory framework to ensure an enabling environment for the RE Fund investments. The ESRES Programme does not only focus on the Development of the Policy and Regulatory Framework (Pillar 1), but also additionally supports the MoEM in Human Resources (Pillar 2), mobilising other Development Partner support (Pillar 3) and ICT (Pillar 4). These Pillars help to strengthen the capacity of the MoEM to take a leading role in developing the Policy and Regulatory Framework for the Energy Sector. A key step is the approval of the Electrical Energy Act, which was reviewed with support of ESRES in 2016. It is still awaiting the Parliamentary approval. Once the Act is approved, an important step forward would be taken to regulate the investments in the Energy Sector in Somaliland more interesting for the private sector.

Component 2 of ESRES consists of an investment fund of GBP 2.5 mln to provide grants to Pilot Projects to invest in hybrid mini-grids in collaboration with the MoEM and the private sector in Somaliland. The selection of viable project concepts and Implementing Partners for the development and implementation of hybrid mini-grids during Phase I, followed a competitive process through a Call for Proposals (CfP). The objective of the CfP was to have a fair and transparent process for the selection of Implementing Partners. Six Implementing Partners have been selected for the implementation of the hybrid mini-grid Projects. The six Projects are progressing well and have already proven that there is an interest of the private sector to invest in hybrid mini-grids if leveraged with donor funding. The Pilot Project will be completed by the end of 2017 and provide valuable lessons learned for the next phase

The Complementary Studies (CS) are part of the next step of the ESRES Phase I. Together with the lessons learned developed by Real Time Learning (RTL) and the ESRES PM, it provides DFID with recommendations for the design of the Operational Guidelines for the RE Fund.

1.3 Objectives of the Complementary Studies

The objective of the Complementary Studies as per ToR is to get a better understanding of the potential for viable locations to develop hybrid mini-grids or other RE systems projects in Somaliland as well as how these projects could be designed.

These studies are complementary to the work of the Real Time Learning component and supports the development of the Operational Guidelines of the Renewable Energy Fund (RE Fund). Whereas RTL is looking at the results of the current hybrid mini-grid sites, the CS Team focused on additional sites to research the possibility of predefining locations and project concepts for the RE Fund. The CS Team also looked at whether interventions other than a standard hybrid mini-grid might be more appropriate at other potential project sites. As part of this work, the CS Team will make recommendations to the DFID and the ESRES PM on appropriate interventions to maximize impact of DFID's RE Fund during Phase II.

As noted in the ToR, the Complementary Studies will provide new ideas and approaches for designing the RE Fund, and examining the following:

- To get a better understanding of the potential for hybrid mini-grid Projects in Somaliland, in terms of the size of the Projects and the amount of economically viable locations.
- To inform DFID about the number of ESPs that are capable of implementing Projects under ESRES Phase II.
- To inform DFID on other approaches to reach Implementing Partners. Instead of having an open tender, we could tender proposed sites with (partially) pre-defined Projects. For example, in cases where no current ESP is operating this will be an alternative to extent the number of locations.
- To do research on potential sites for hybrid mini-grids powered by wind energy, as this concept has not been successfully proposed by the Applicants. It requires more technical experience in the design which we can deliver through ST Experts.
- To inform DFID whether other RE systems (micro-grids, solar homebased-systems, etc.) prove to be more suitable for some of the rural locations. By not only considering hybrid mini-grids we could then extent the scope of potential locations.

The Complementary Studies would also enable DFID to better validate the proposals that Applicants submit under the RE Fund as well as provide the MoEM with a better understanding of the Energy Sector as a spin-off effect of the Complementary Studies activities. It is not within the scope of work of the Complementary Studies to define interventions or investments for the RE Fund, it only provides recommendations of potential interventions for the RE Fund based on field data and desk research. Following the Complementary Studies, DFID will have to decide its priorities for Phase II. Based on this, the ESRES PM can start developing the Operational Guidelines for the RE Fund.

The first step in the Complementary Studies, was the Research Design which was approved by DFID on 14 July 2017. The Research Design developed the research logic which validated the research approach and objectives (Chapter 2).

1.4 Linking ESRES Phase I to Phase II

During ESRES Phase I, DFID is funding and providing technical and project management support for the construction of six hybrid mini-grid sites throughout Somaliland.

Table 1: ESRES Phase I Project Sites

Region	City	Company	RTL
Saaxil	Sheikh	Beder Electricity Company	Yes
Maroodi Jexx	Gabiley	Sompower (Alel)	Yes
Awdal	Boroma	Aloog Electricity Company	No
Togdheer	Buhoodle	Telesom Electricity Company	No
Togdheer	Burao	HECO	Yes
Sanaag	Badhan	Badhan Electricity Company	No

Since Phase I is designed to be a pilot phase, a key part of the ESRES Programme is the RTL Component. RTL is being implemented parallel to—and in collaboration with—the ESRES PM. RTL is providing key insights during Phase I that are helping to improve the implementation of Phase I as well as to inform the design of Phase II. The RTL component, however, is only able to engage with three of the current six project sites. Furthermore, DFID recognized that the conditions in—and results from—the current six sites may not be fully representative or even indicative of the conditions in other parts of Somaliland. Therefore, DFID initiated the Complementary Studies activity to provide further data and analysis to help inform the design and implementation of Phase II, particularly the planned RE Fund.[1]

[1] The activity is so named because it is designed to be complementary to the RTL component and other aspects of the ESRES program.

2. Research Design and Implementation

2.1 Research Logic

CS team addressed the following questions aimed to inform the design of the RE Fund for ESRES Phase II:

1. What types of towns, villages, and settlements are found in Somaliland and what are the conditions at these types of locations?

As a first step, the Complementary Studies research determined what types of locations exist in Somaliland. Project locations selected under Phase I were proposed by the Implementing Partners (IPs) under an open call for proposals; these are often urban areas with a relatively high population density for Somaliland. Towns and villages with lower population rates might not have existing ESPs and hence these locations were not identified under Phase I. The Complementary Studies attempted to address this by visiting a number of smaller towns and villages and gathering detailed energy usage information.

2. Given these conditions and energy requirements, what are the most appropriate renewable energy technology options for addressing them?

The team looked at the full range of the renewable energy supply curve, from pico solar systems, to hybrid mini-grids, to a large-scale wind demonstration project. Besides the renewable energy technology, the CS Team also encountered other key issues and opportunities that the RE Fund could consider addressing. Ultimately, the options selected will be determined by the objectives and evaluation criteria of the RE Fund in the Operational Guidelines.

Evaluation criteria typically seek to either maximise desirable outcomes, minimise undesirable factors, or frequently some combination of both. The criteria used or considered during ESRES Phase I included the following:

Minimise
- Levelized Cost of Energy (LCoE)
- Cost/kW
- Cost/Connection
- Cost of Increasing "Access"
- Maintenance Costs
- Maintenance Skill Required

Maximise
- Installed RE Capacity
- Number of Connections
- Productive Power
- Economic Impact
- Social Benefit
- Regional Diversity

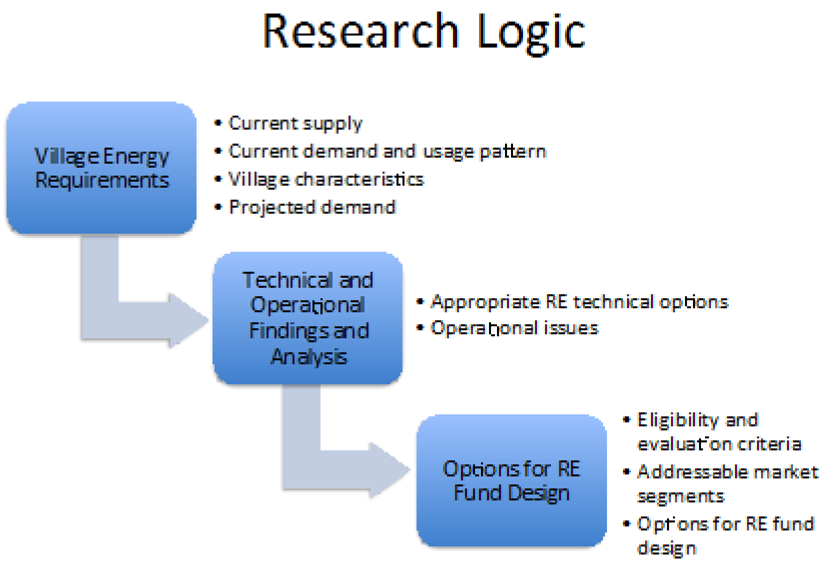
Some criteria are inconsistent or even mutually exclusive, which requires that priorities be defined. How these various criteria are prioritized will drive the selection of interventions during ESRES Phase II.

3. How should DFID design the RE Fund in ESRES Phase II to implement these solutions and address these needs?

The team proposed four funding windows and identified the potential characteristics of each window. These recommendations are presented in Section 5.

The research logic is illustrated in figure 1.

Figure 1: Research Logic



2.2 Location Selection

As noted in the introduction, the main goal for the Complementary Studies activity was to identify various types of locations in Somaliland in order to assess how ESRES can reach areas that might not be reached through the call for proposal approach taken in selecting projects during ESRES Phase I.

The CS team had originally proposed to visit the following types of locations:

- **Urban Formal Grid:** city or large town with established formal distribution system, generally including step up transformers and feeders.
- **Urban Informal Grid:** city or large town with informal distribution at line voltage.
- **Rural Formal Grid:** town or village with generation formally dedicated to distribution.
- **Rural Informal Grid:** town, village, or settlement with limited generation and informal distribution (e.g., from a cell tower, school, or clinic).
- **Rural No Grid:** villages/settlements that may have some individual generation but no distribution.

However, during the field research, it became clear that "urban" and "rural" are relative and essentially arbitrary concepts in Somaliland. Outside of Hargeisa and the five largest towns, no location can meaningfully be differentiated as urban. Since these locations have formal grids, the category of "urban informal grid" also does not exist.

Most locations in Somaliland are rural with low population density. However, the CS team found few locations without any power—even tiny villages that initially appeared not to have power had at least some residences, businesses, irrigation, systems, or mosques with private (not distributed) generation, primarily from small solar systems.

In fact, the most meaningful distinction seems to be between informal and formal grids. While there is not a sharp line between informal and formal distribution, the CS team noted some indicators. Once a system has step-up transformers and distributes power at above line voltage, it clearly represents a formal distribution system. However, there are also systems that could be considered formal that still only distribute at line voltages. The table 2 summarises the typical characteristics that define informal and formal grids in Somaliland.

Table 2: Characteristics of Informal and Formal Distribution Systems in Somaliland

Characteristic	Informal	Formal
Generation	1-2 Units, 20-50 kVA	Multiple Units, 200 to > 1,000 kVA
Transformers and Feeders	None	Sometimes
Power Availability	Generally less than 24 hours	Typically 24 hours
Customers	< 100 - 500	> 500
Metering	Many unmetered	Most metered
Tariff	Mostly fixed daily/monthly rate	Still many fixed-rate customers
Usage	Residential & small shops only	Some larger users included
Poles	Often improvised	Generally purpose-built

The CS Team also identified a few systems where the operator had segregated service such that fixed rate customers only received power 4-5 hours/day (typically from 6 to 11/12 pm), while metered customers received power for more or less 24 hours/day; this is indicative of a formal distribution system.

In the original research design, the CS team proposed visiting 6-10 sites. Ideally, these locations would have been selected based on population size and density data. Unfortunately, no reliable demographic data is available for Somaliland.[2] Therefore, in selecting our sample locations for this research, the CS Team made use of our local experts and experience gathered over nearly two years of implementation. As part of this process, the CS Team identified approximately the 40 largest cities and towns throughout Somaliland (see Annex 5). The list is indicative; but the CS Team had the following findings:

- ESRES Phase I project sites are in five of Somaliland's ten largest population centres (the smallest project site is Boohudle, which is among the top 20).
- There are therefore only perhaps 12-14 other cities and towns in Somaliland that are relatively comparable to the current ESRES project sites.
- Of these other similarly sized cities and large towns, four were among the six finalist proposals not selected during Phase I, and are therefore at least somewhat well suited to be considered for a hybrid mini-grid during Phase II.
- Therefore, as was anticipated prior to the CS commencement, most of the likely interventions during Phase II will be at sites smaller than the current Phase I sites.

As noted, the CS Team had planned to visit 6-10 sites. However, on the way to the planned survey sites, the team took advantage of several opportunities to stop at other towns and villages, which allowed the team to visit a total of 17 sites. The team also gathered some information from current project sites being surveyed by RTL, so that data can be correlated with RTL findings and perhaps extrapolated to other sites.

The sites visited are illustrated on the map on page 7.

[2] Actual population information was requested at the Ministry of National Planning and Development. They have not provided the data to the CS Team.

Sites Visited by Complementary Studies Team

2.3 Local Condition Data Collection

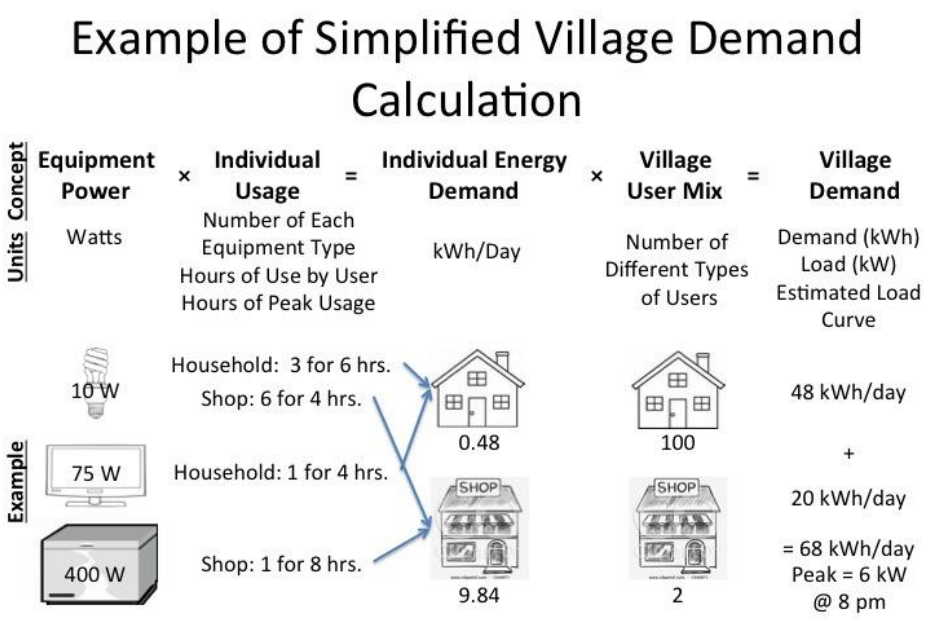
The CS Team collected data at each location selected as a sample. The main goal was to estimate the current and projected energy demand and load profile of the village. This data will be used to analyse which RE systems are most technically and economically viable for each type of location. The team gathered information on the following location characteristics:

- **Energy Demand:** assessment of the number of users, potential users, and their current and potential consumption behaviour and demand.
- **Energy Supply**: identify existing energy suppliers, including generation capacity and technologies used.
- **Local Conditions:** assessment of the population size and density and the current cost of diesel.

The CS Team developed and refined two survey instruments to gather this information: one for individual demand information and the second for energy supply and local conditions, including information necessary to calculate aggregate village energy demand and load. The Energy Usage Survey is attached as Annex 2; the Energy Supply and Location Detail Survey is attached as Annex 3.

The surveys were designed to determine the energy demand per location by taking the average demand by user type (e.g., residential and various types of commercial and other uses) and multiplying this by the number of users of each type. The average demand by user type is calculated by looking at the power requirements of appliances and equipment and individual usage patterns (number of each equipment type, hours of usage, and peak usage). A simplified example of this calculation is illustrated in Figure 2.

Figure 2: Simplified Village Demand Calculation



2.4 Respondents

The CS team conducted 96 surveys at the 14 locations visited. The number and type of respondents are tabulated below:

Table 3: Summary of Complementary Studies Survey Respondents

Summary of Complementary Studies Survey Respondents

Type	Boon	Quljeed	Kalaybadh	Bali Gubadle	Salahlay	Suuqsade	Burao	Aynabo	Erigavo	El-Afwayn	Gar-Adag	Others	Total
Generation	1	1	2	1	1	1	1	1	1	1	1	2	14
Household	8	3	3				1						15
HH w/ Business			1						1				2
Shop/Business	2			3		2	7				1		15
Restaurant			1				1	1	1				4
Hotel	2			1			1		2				6
School	1												1
MCH/Clinic	1					1							2
Hospital							1						1
Mosque								1				5	6
Cell Tower	1		1	1	1		1	1	12	1	1		20
Fuel Station			1	1				1					3
Water Pump								1				1	2
Other	1	1	1	2									5
Total =	**17**	**5**	**10**	**9**	**2**	**4**	**13**	**6**	**17**	**2**	**3**	**8**	**96**

From a gender perspective, 20 of the 96 (20%) respondents were women. However, excluding generators, cell towers, and mosques, women represented a much larger share of the respondents. 13 of the 17 households' respondents was female (76%), 5 of the 15 businesses (33%), and 2 of the 4 restaurants (50%). Anecdotally, women also had the clearest ideas of what they would do if they had access to cheaper and more reliable energy. It would therefore be interesting to conduct a further assessment how women can be drawn into the decision-making process.

During the data collection and analysis, the CS Team noted that the information was incomplete and/or of questionable quality. The CS Team faced the following challenges in gathering and analysing the data:

- The greatest shortcoming was disaggregating the current customers and potential customers (the village user mix). Operators generally had a very clear awareness of the number of customers they had, but they generally could not differentiate between residential and commercial customers.
- The local estimates of the total number of households and businesses in a town or village were significantly higher than either the CS team's direct observation or satellite imagery seemed to indicate. This may have been the result of local residents having a broader understanding of the boundaries of the town (perhaps extending to the entire region). This lack of clarity on town and village population and mix has significantly complicated the CS team's on-going attempts to estimate and forecast demand in these towns.
- Another significant challenge in establishing usage patterns is that demand was often constrained by limited supply, not only in terms of peak load but also available time of use. For example, customers (both residential and commercial) that had a TV reported that they used it for 4-6 hours per day, but in many cases, that was because they only had power for 4-6 hours per day. Hence, the CS team made assumptions based on usage patterns in towns with 24-hour power.

Given these challenges, the CS Team has supplemented the survey information with customer billing data provided by operators. It is extremely hard to get disaggregated customer usage data because most operators do not maintain those records, and those that do have serious deficiencies in their databases and spread sheets. Berbera Electricity Company provided data that allowed the CS team to compile the following average usage disaggregated by customer type:

Table 4: Berbera Electricity Company Average Energy Consumption

Berbera Electric Average Energy Consumption per Customer by Customer Type (kWh)

Month	Residential	Business	Central Govt.	Local Govt.	Mosque	Port	Schools	Hospital & Clinics	Water Agency
Dec 2016	47	95	259	222	1,296	353	488	6,048	101
Jan 2017	49	93	259	230	1,097	467	438	4,711	295
Feb 2017	51	85	244	195	2,855	442	490	3,901	81
Mar 2017	48	95	325	222	1,628	194	1,031	418	66
Apr 2017	63	151	589	348	435	308	240	553	159
May 2017	67	176	931	396	454	390	262	609	192
Jun 2017	90	239	776	519	2,768	791	95	736	333
Average =	**59**	**133**	**483**	**304**	**1,505**	**421**	**435**	**2,425**	**175**

Source: Berbera Electricity (New Billing System), July 2017.

The data required cleaning to remove admitted and other identified errors and discrepancies, but this is the type of information that can be used to estimate and project demand for designing appropriate renewable energy solutions.[3]

[3] Berbera Electricity Company is certainly no exception to having serious issues with their customer records, but they are remarkable in one key respect: They are aware of the problems and are in the process of implementing a new system to rectify the issues.

3. Village Energy Requirements

The CS Team visited 14 towns and villages and gathered as much data on the current energy supply and demand situation as possible. The supply information, particularly in terms of existing generation capacity and availability of electricity, was quite reliable. Unfortunately, the information on current and potential unconstrained demand proved much more problematic, particularly in gathering information on total population and the village user mix (current and potential customers by type). The following sections summarise the Team's findings.

3.1 Current Supply

3.1.1 Existing Generation

The CS Team gathered generation information from 17 towns and villages.[4] In the five towns with multiple generation suppliers, the Team visited all commercial providers. The team also identified a number of captive generators (primarily cell towers) and noted their generation capacity on their individual surveys, but this capacity is not included in the town generation supply since it is not connected to the distribution system. As much as possible, the team gathered information on the condition and operating schedule/hours of the units. The total installed capacity at the surveyed sites was about 22 MW. However, it is crucial to note that only a fraction of this capacity could operate simultaneously since the units within nearly ever system are unsynchronised (although a few were operated on separate distribution systems and therefore could still operate simultaneously). The information gathered is summarized in Annex 6.

3.1.2 Availability of Electricity

Of the survey respondents, half indicated that they generally had power 24-hours/day. However, when asked if they had as much power as they would like, 60% of respondents indicated that they do not, citing that what power they get was too weak to meet their needs. This was the case for households at the end of a long distribution line as well as businesses in town. In two cases, the CS team surveyed fuel station operators who received grid power but nonetheless had to start a generator to run their fuel pumps every time a customer pulled up.

The CS Team only formally surveyed towns and villages that clearly had at least an informal distribution system. However, on the way to survey sites, the team also stopped at several small villages. At nearly all villages, the team noticed small solar panels on roofs or on the ground providing power to individual homes or businesses.

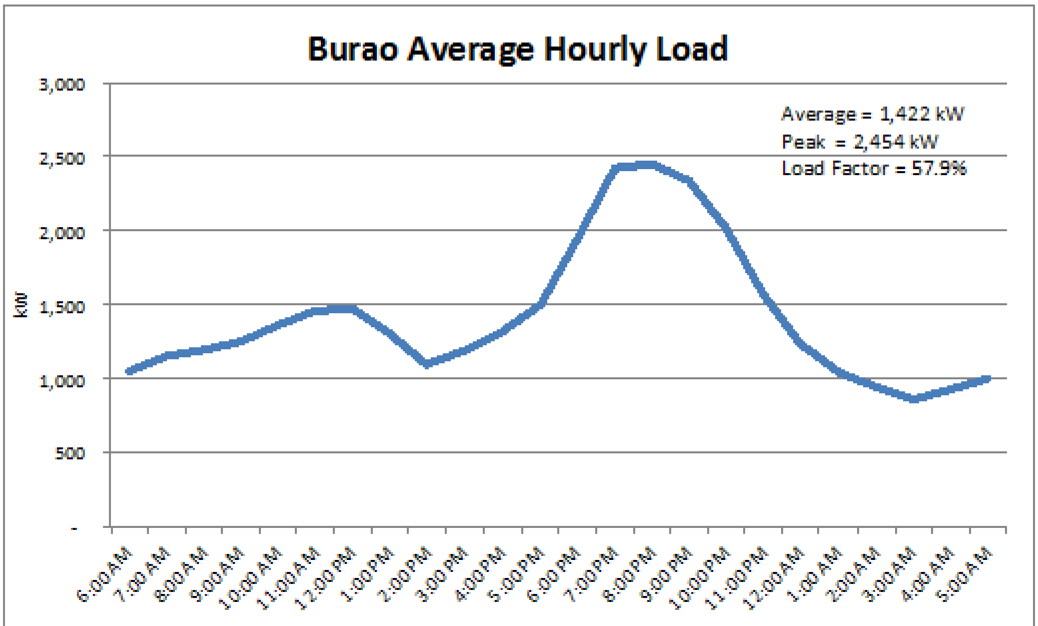
3.1.3 Estimating Typical Load Curve

Identifying the typical load curve for a town is critical for sizing and designing the appropriate generation system. Unfortunately, it was quite challenging to get reliable hourly generation data to construct load curves.[5] The problem is that very few generator operators keep hourly generation records, and the CS Team found that the records that were kept were usually incomplete and unreliable. An exception is Horn Electricity Company (HECO), the ESRES Phase I implementing partner in Burao. While their operational data gathering and reporting processes are not perfect, HECO was able to provide the data required to produce an average hourly load curve. This data results in the load curve in Figure 3.

[4] The Team stopped in a few locations along the way where they did not conduct a formal survey, but they did gather basic generation information.

[5] Since we are using generation to estimate the load curve, the CS Team is also assuming that the system is not currently supply constrained, which, given the shape of the load, seems generally reasonable.

Figure 3: Burao Average Hourly Load



Source: HECO April 2017.

This curve corroborates anecdotal information from ESPs and end users in other towns. As illustrated, and based on the CS team's surveys and empirical observations, the peak load occurs between 7pm and 9 pm. This load is primarily caused by residential and business lighting and televisions. This results in a load factor of 58%, which is quite low and represents a potential opportunity for improvement.[6]

A challenge will be to identify what additional productive uses are likely/possible during the day, given the existing capacity and current/projected evening residential peak load. For example, if a town has the capacity to serve a 40 kW peak load between 7pm and 9 pm, but the current daytime load is only 15 kW, there is the potential to increase daytime (primarily commercial) load by 20-25 kW without necessarily increasing overall generation capacity. In such cases, adding RE generation capacity would initially directly displace diesel (thereby reducing operating costs) and only later be required to serve overall increased load in the town.

Another pronounced feature of typical load in Somaliland is the sharp drop during the traditional break period between noon and 4 pm. This is a period when most businesses and offices close. This causes electricity demand to drop to baseload levels. While this represents a potentially attractive opportunity to increase energy (kWh) use without needing to increase capacity (kW), there are significant cultural impediments to increasing the productive use of this time. However, the afternoon slump can be used as an opportunity to increase the charging of batteries during the day in order to store energy for use during the evening peak period. This is specifically relevant for systems with renewable energy generation and is a factor that should be considered when designing systems that includes battery storage.

[6] Load factor is defined as the average load divided by the peak load over a given period, and it is typically expressed as a percentage. A low load factor means that there is a significant difference between the average load and the peak, which indicates potential "wasted" capacity that could be used if additional load can be added during periods of low load.

3.2 Current Energy Demand

3.2.1 Calculation Process

Actual energy consumption is equal to the energy supplied minus technical losses.[7] At a modern utility, energy supply, demand, and losses (both technical and commercial) can be documented, calculated, and reported reliably.[8] Unfortunately, although some generation operators are significantly improving their operations, none of the features of a modern utility currently exist in Somaliland. Therefore, it is complicated to calculate user consumption and demand.

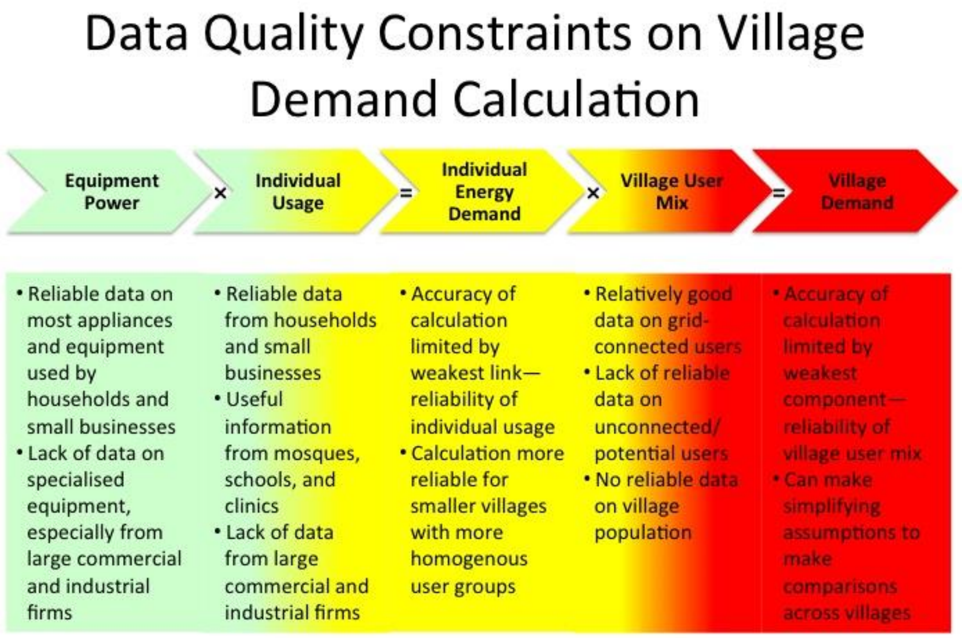
A crucial question is whether the actual consumption (the apparent demand) is the actual demand or whether it is constrained by the available supply—i.e. people are consuming what they can get rather than all that they want. This is an important distinction for ESRES to make decisions about the types and sizes of interventions during Phase II, as the systems must be designed to meet the current and projected unconstrained demand of the town or village (ideally adjusted for the price elasticity of demand—see next section). To help ascertain the situation in various villages, the CS Team asked respondents whether or not they were able to get as much power as they would like, and 60%--even those with 24-hour power—indicated that they were not.

The CS Team also attempted to calculate the unconstrained demand in the surveyed towns and villages. As illustrated previously (Section 2.3), calculating the unconstrained demand of a village required identifying the power requirements of appliances and equipment, multiplying this by individual usage to calculate the individual energy demand by user type, and then scaling this up by the village user mix (current and potential customers by type) to arrive at the total unconstrained village demand. The strength of this method is its logic and conceptual simplicity; the weakness is that the final result can only be as reliable as the weakest component of the data. In this case, the CS Team was able to gather reliable data on equipment power and reasonably reliable individual energy usage, which allows in turn for a reasonably reliable estimate of average individual energy demand by customer type. Unfortunately, the lack of reliable data on the village user mix (or even the overall population of the village) meant that it was impossible to reliably calculate the total unconstrained village demand. The data quality constraints on accurately calculating the village demand are illustrated in the Figure 4.

[7] Commercial losses still represent consumption, albeit unmetered and/or unpaid.

[8] This is made possible by SCADA (Supervisory Control and Data Acquisition) systems, substation and feeder metering, and integrated system mapping and billing and collection systems.

Figure 4: Data Quality Constraints on Village Demand Calculation



3.2.2 Results

The CS Team's research was intended to gather both individual peak load (kW) and energy demand (kWh) data. While the survey results were not fully reliable, it was generally possible to estimate typical individual peak usage for at least some customer types. As noted, this was done by identifying the energy requirements of appliances and equipment along with the usage patterns of customers. The Peak Load calculated is the sum of the items that are (or the user would like to be) operated simultaneously, which is why the CS Team surveyed users about their usage patterns. For example, if a household has a 1,500 W iron and a 2,000 W hot plate, unless ironing and cooking are happening simultaneously, the peak load would only be 2,000 W.

For businesses, however, the equipment is often operated simultaneously, although this varies per type of business. For example, a hotel's peak load will be a function of the number of rooms and the occupancy rate rather than the total number of lights, TVs, kettles, and water heaters. When lighting is a significant component of load, as it often is in Somaliland, peak usage will typically be at night. Air conditioning load, although still rare in most of Somaliland, will tend to shift peak demand to earlier in the day (although this is offset by the typical afternoon break). In some cases, such as a restaurant with a meat grinder (which uses 1,500 – 2,000 W), the peak load is flexible—the cook can generally choose when to grind the meat. In other cases, such as a fuel station or a hospital with incubators, the peak load will also be variable.

While only indicative, the table 5 presents the CS Team's estimated typical peak load by customer type.

Table 5: Estimated Typical Peak Load (kW)

Estimated Typical Peak Load (kW)

Customer Type	Individual Peak Load* (kW)	Peak Time	Appliances & Equipment Operated Simultaneously
Household--Low Load	0.090	7-9 pm	2x CF bulbs, small CRT TV
Household--Moderate Load	1.925	7-9 pm	5x CF bulbs, LCD TV, refrigerator, electric kettle/iron
Small Shop	0.260	7-10 pm	3x CF bulbs, small chest freezer
Restaurant	2.690	Flexible	6x Large CF bulbs, TV, chest freezer, blender, meat grinder
Clinic	3.890	Evening Operating Hours	4x Large CF bulbs, 6 CF bulbs, sterilizer, ECG/sonogram, computer
Mosque	0.300	Friday Prayers	PA speakers, 4x ceiling fans
Fuel Station	2.3	Evening Operating Hours	6x Large CF bulbs ,4x CF bulbs, 2x security lights, 2 fuel pumps
Cell Tower	3-6	Variable	2 BTS (2G), 1 BTS (3G), Landline Switch, FM Transmitter, Rectifyer, 2x AC

*Determining collective coincident peak load will require accurate information on the user mix and specific usage patterns in village.

The CS Team also gathered energy consumption (kWh) data. This was done in three ways:

- Asking respondents about appliance and equipment usage information;
- Asking respondents about their electricity bills;
- Collecting actual customer billing records from generation operators.

Given the challenges identified in the previous section, the CS Team sought to supplement the survey data with empirical billing data from the generation operators. This billing data largely validated the survey results. Typical billed usage by customer type is illustrated in the following table:

Table 6: Energy Consumption by Customer Type in Erigavo (kWh)

Energy Consumption by Customer Type in Erigavo (kWh)

Customer Type		Number of Customers			Average Usage (kWh/Customer)	
Somali	English	Total	w/ Recorded Usage	Usage (kWh)	Total Customers	w/ Recorded Usage
Guri	Household	4,128	2,645	44,909	11	17
Dukaan	Small Shop	255	165	2,248	9	14
Sandaqad	Household (Metal Shack)	194	84	989	5	12
Bakhaar	Wholesale Shop	46	26	547	12	21
Xafiis	Office	40	26	2,204	55	85
Carwo	Large Shop	32	27	565	18	21
Pharmacy	Pharmacy	30	19	538	18	28
Kaalin	Fuel Station	27	20	669	25	33
Maqaaxi	Tea Shop	27	19	518	19	27
Masjid	Mosque	23	-	-	-	-
Geerash	Garage	22	11	753	34	68
School	School	16	8	105	7	13
Hotel	Hotel	15	4	322	21	81
Restaurant	Restaurant	15	15	519	35	35
Tower	Cell Tower	12	12	20,833	1,736	1,736
Ceel	Water Pump	9	8	417	46	52
Bangalo	Large House	6	4	160	27	40
Nijaarad	Wood Shop	5	3	350	70	117
Hospital	Hospital/Large Clinic	3	3	704	235	235
Hayad	NGO Office	3	3	650	217	217
Total =		4,908	3,102	78,000	16	25

Source: SEPCO. Data for month of June 2017.

3.3 Village Specifications

The CS Team prepared village summary sheets for many of the villages surveyed. These sheets include the generation information, a summary of survey responses, and a map illustrating key features of the town, including the location of generation, the rough extent of the distribution system, and the locations of survey respondents and selected other locations. These sheets are appended as a separate annex to this Final Report (Annex 9).

3.4 Price Elasticity

The CS Team proposed to consider the price elasticity of electricity demand in Somaliland. Since one of the primary goals of the ESRES Programme is to significantly lower the price of electricity, the team would have liked to better understand what is likely to happen to electricity demand when the price declines sharply.

The CS Team used data from Berbera Electricity Company as they have conducted an experiment in tariff reduction over the past several years. Berbera Electricity Company was a government-owned utility until December 2014, and the official tariff was $1.00 kWh. The company was then transferred to Tayo Energy and privatised in January 2015, and Berbera Electricity Company promptly lowered the tariff to $0.70/kWh. They also committed and succeeded to reduce the tariff to $0.50/kWh in January 2016.

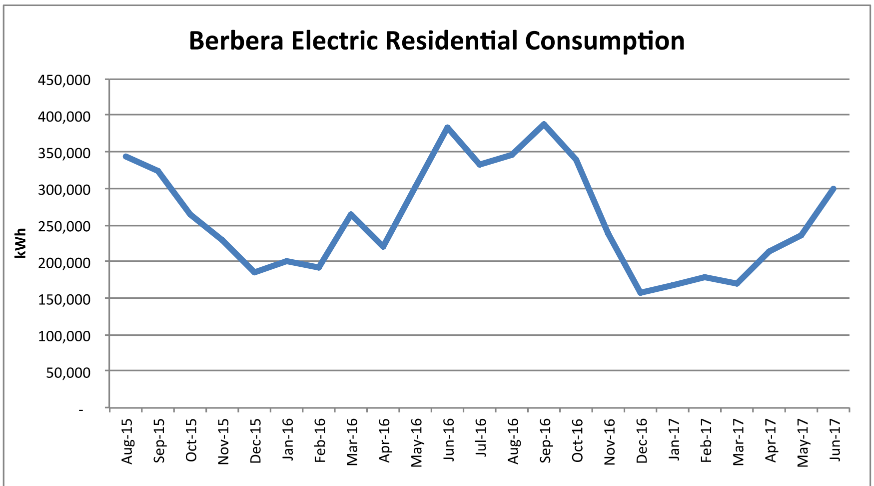
Given this history, coupled with the fact that Berbera Electricity keeps good billing records, the CS team planned to analyse these records to track the change in demand following these significant price reductions.[9] The CS team's working hypothesis was that demand would increase following the reduction in tariff from $0.70 to $0.50/kWh in January 2016. The plan was to use the data from Berbera Electricity to calculate the price elasticity of demand, which would indicate the percentage change in demand caused by the 29% reduction in price. The CS Team would then use this information to estimate the impact of the planned tariff reductions under the ESRES Programme.

Unfortunately, this analysis proved impossible for the following reasons:

- Demand in Berbera is highly seasonal. Due to the extremely high temperatures during the summer (often in excess of 40˚ C), as well as significant penetration of AC units, power demand increases significantly during the summer. Therefore, while there was a significant increase in demand following the tariff reduction in January 2016, it could not be ruled out that this was due to a season pattern. The CS Team required at least two years (seasonal cycles) of data to determine if the demand increase was due to the reduced tariff. In fact, in comparing year-on-year demand changes since the tariff reduction in January 2016, on average demand per customer was slightly lower in 2016 compared with 2015.
- A close inspection of the billing records indicated that many customers were already paying a reduced tariff well before the official reduction. In fact, according to the records, even when the official tariff was $0.70/kWh, the effective average tariff for residential customers was $0.64/kWh. Possibly, many larger businesses and institutional customers who were receiving a discount were misclassified as residential customers in the old billing system, affecting the average tariff.
- The data provided by Berbera Electricity Company comes from two separate billing databases, with the data prior to December 2016 coming from an older system. This system has incomplete and inaccurate records. Company management and staff are confident that demand increased due to the two previous tariff reductions, although unfortunately their own commercial data does not clearly substantiate this. The management assured the CS team that the generation data (as opposed to commercial data) illustrated the increase, but unfortunately that data has not yet been provided.

Therefore, while there was a sharp increase in consumption following the tariff reduction in January 2016, it is impossible to determine if and to what extent this was due to the tariff reduction.

Figure 5: Berbera Electricity Company Residential Consumption



Source: Berbera Electric (old billing system).

[9] Berbera Electricity management and staff were extremely generous in sharing data and working with the CS team. They provided billing records going back nearly two years.

4. Technical and Operational Findings and Analysis

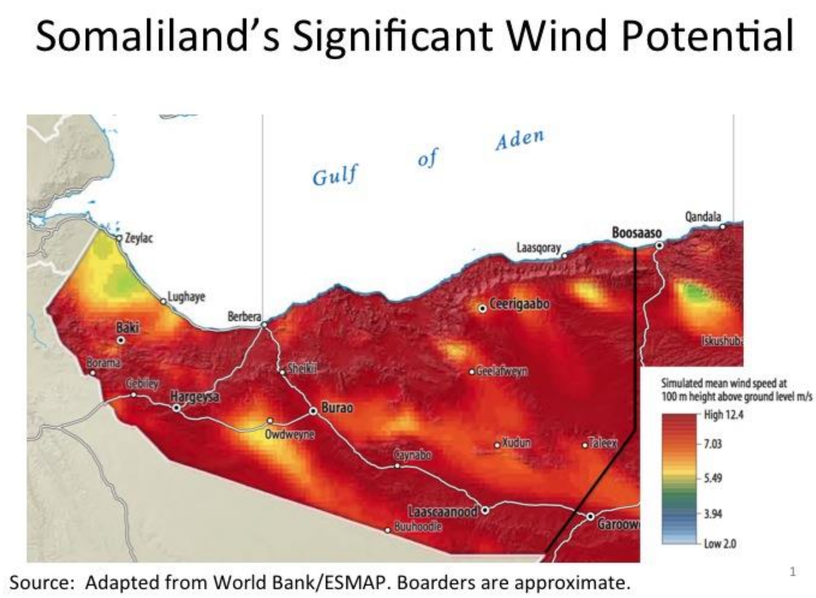
This section presents the findings of and analysis conducted on technical and operational aspects. This includes a range of aspects, from different (renewable energy) technical options to operation and maintenance. Some of the aspects where part of the Research Design, other aspects were identified along the way as key issues that provide opportunities for the RE Fund intervention.

4.1 Technical Options

4.1.1 Wind Generation

Somaliland has significant wind generation potential. World Bank analysis conducted in 2016 indicates that many parts of the country, including around the capital Hargeisa, have average wind speeds at 100m of around 10 m/s.[10] This represents a significant potential resource for electricity generation. An adapted version of the World Bank's map is illustrated in figure 6.

Figure 6: Somaliland's Significant Wind Potential



Unfortunately, previous attempts to implement wind generation projects in Somaliland have not been successful. This includes - USAID's project at the Hargeisa International Airport; World Bank projects in Borama and Erigavo; a UN project in Lasodacawo; and a private project in Berbera. The USAID GEEL project reports indicate that the turbines recently produced power for the Hargeisa International Airport site, but the project remains fraught with technical, operational, and commercial challenges.

[10] Map is provided by the World Bank, ESMAP Wind Resource Somalia, (2016). Available at: http://shuraako.org/sites/default/files/Somalia_Wind-Resource_Poster-Portrait_WB-ESMAP_Apr2016.pdf

Figure 7: Existing Wind Projects in Somaliland

The only currently functioning wind project that the CS Team found was operated by Beder Electricity in Aynabo. It consists of three 20 kW Hummer turbines, although even there one of the turbines is offline due to a partial failure of the battery system.

During ESRES Phase I, three of the selected six implementing partners had initially proposed to include wind generation in their hybrid mini-grid (along with PV), but they all reconsidered the inclusion of a wind component due to the project implementation timelines and contract negotiations with the suppliers. This indicates that, while there is interest in wind generation, the realities of implementing a wind project in Somaliland are challenging for the private sector.

As part of the Complementary Studies activity, the CS Team conducted a preliminary analysis of the technical and economic viability of various types of wind projects in Somaliland. The analysis specifically focused on whether and under what circumstances the Levelised Cost of Energy (LCoE) of wind generation would be lower than diesel or PV. The full report is included as Annex 7, but in general terms, the analysis indicated the following:

- The wind potential of Somaliland for electricity generation is significant.
- In general, there are significant economies of scale with wind generation projects. Therefore, the cost per kW of capacity and the LCoE will decline sharply with larger installation and investment in wind generation becomes interesting for projects of larger size (see Figure 8).
- The LCoE of any reasonable wind project is lower than for a comparable diesel generator.
- The LCoE for PV is generally lower than for a wind project the size of the current six hybrid mini-grids, but there are areas of Somaliland where the wind resource is so abundant (average wind speeds of 10-12 m/s) that wind could be the preferred least-cost option.

Determining the circumstances under which a wind project is the preferred option will depend on testing the validity of a number of key assumptions, including the actual average sustained wind speeds at the location, the installed cost of the technology, the load factor of the system, and the long-term operation and maintenance costs.[11] However, as illustrated in Figure 9, the preliminary analysis indicates that there are conditions in Somaliland that would make wind generation economically more attractive than PV.

Figure 8: Wind, solar and diesel LCoE cost comparison by generator size

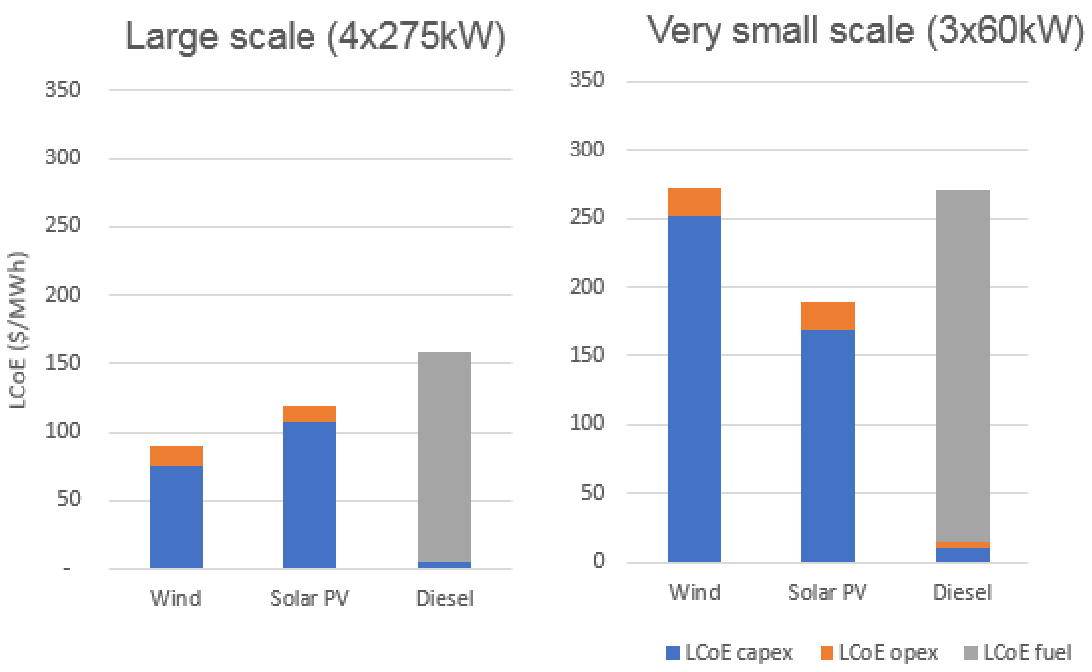
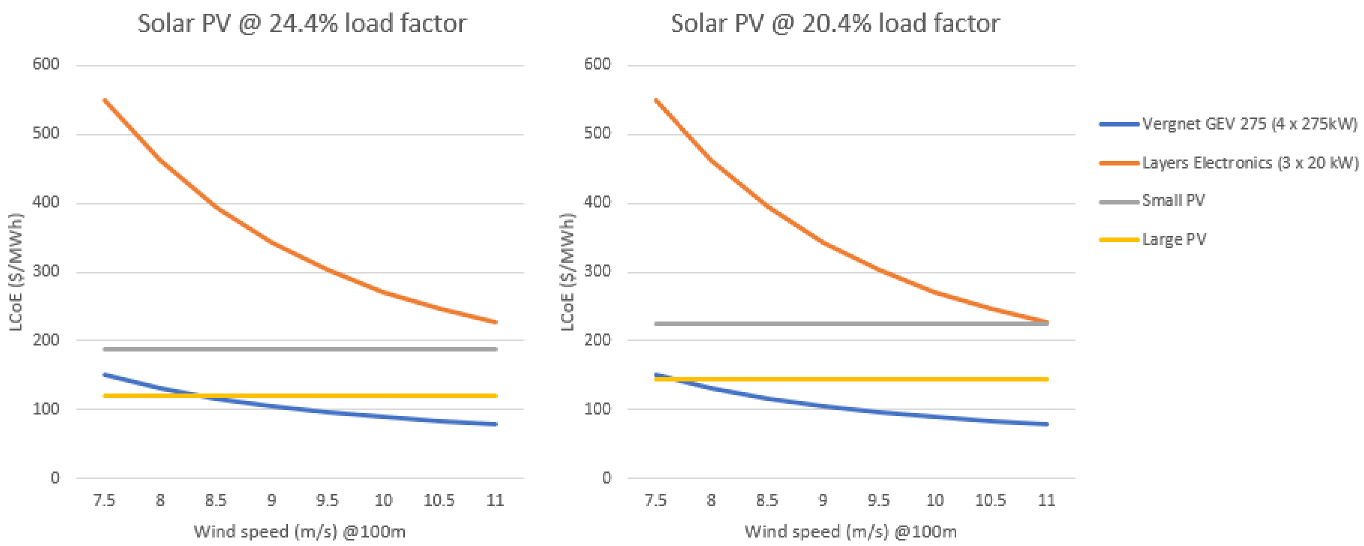


Figure 9: Wind, solar and diesel LCoE cost comparison by Solar PV load factor and wind speed (m/s)



4.1.2 Agricultural Applications

The CS Team attempted to identify the existing and potential opportunities for economic development at each of the survey sites. In most areas, the primary economic activity was livestock, fisheries and agriculture. Therefore, while providing additional energy capacity will improve the quality of life of residents and have a marginal impact on existing shops and businesses, an RE Fund funded project will typically have the most

[11] The World Bank study used to estimate the wind speeds was based on modeling satellite data. While this will facilitate identifying promising locations, the analysis will need to be tested and validated on the ground with anemometers.

economic and social impact when it provides electricity to agricultural businesses (including livestock and fisheries).

Affordable energy is required for almost any agricultural application, including water pumping, irrigation, and value-added activities, such as cold storage, processing, and packaging. Currently, given the high cost of energy in Somaliland, the energy intensity of agriculture is extremely low, so there is significant opportunity to increase agricultural productivity and value addition with the judicious application of additional energy inputs. Given Somaliland's extremely arid climate, irrigation is essential to make most agricultural production possible, and the cost of irrigation must be minimized in order for production to be even marginally profitable. Also, in order to minimize the total costs of an agricultural application, the energy generation needs to be aligned with appropriate agricultural practices (e.g., sizing pumps for drip irrigation). For example, the CS Team's preliminary research indicates that dedicated PV water pumps may represent a better solution than connecting load to a hybrid mini-grid, which allows the grid to be either sized more appropriately or connected to more appropriate load. Finally, an important advantage of an energy project linked to agriculture (or any large economic activity) is that there is a key stakeholder with a significant economic incentive to maintain and sustain the energy system.

Of course, any agriculture-related energy projects will require specific agricultural technical and economic expertise. Fortunately, at least some of these resources may be leveraged from other donor projects with a significant agricultural component, such as DFID's Promoting Inclusive Market (PIMS), the Somaliland Development Fund (SDF), and USAID's Growth, Enterprise, Employment, and Livelihoods (GEEL) project. During ESRES Phase I, there were already some examples of cross fertilisation with ESRES experience on solar power being used for the implementation of agriculture (concerning solar-powered water-pumps) and fishery projects (concerning solar-power for cold storage) funded under SDF.

Although the CS Team only looked at the prospects for solar (PV) and wind, given the significance of agriculture in the economy, it is possible that biomass could be a viable generation technology. However, since most of Somaliland's agriculture is pastoral herding, it seems unlikely that biomass could be economically gathered at a scale required for a biomass generation project. Although it was not part of the CS team's field research, informal observation indicated that any biomass is likely burned as a primary fuel.

4.1.3 LPG for cooking

Going back to one of ESRES' original mandates- reducing carbon emissions from non-commercial cooking fuels, one potential new intervention for Phase II could be to coordinate/collaborate the implementation of hybrid mini-grids with private sector LPG distribution. The rationale for this is that if ESRES turns out to be extremely successful at lowering the electricity tariff, some households might switch to electric cooking appliances, and while that represents a quality of life improvement, it also puts a significant strain on a system and perhaps would compete with/crowd out higher-value commercial uses. Therefore, if LPG distribution was promoted in parallel with an ESRES hybrid mini-grid project, it could prevent an increase in electricity demand for cooking, which would help avoid a spike in evening peak load and reduce the need to oversize the capacity of the hybrid mini-grid system.

4.1.4 The Use of Batteries

Energy storage plays a critical role in renewable energy systems. Without energy storage, solar (PV) and wind systems can only provide power when the sun is shining or the wind is blowing. While there are a variety of energy storage technologies, including pumped storage, flywheels, compressed air, and various thermal systems, the only practical option in Somaliland is batteries.

Batteries for renewable energy systems are typically one of two types: lead-acid or lithium-ion. Lead-acid batteries can be purpose-built for renewable energy applications, but they are essentially the same as car batteries, and in fact car batteries are often used as an available and appropriate technology for small-scale installations. Lithium-ion batteries are similar to the batteries used in laptops and other electronic devices, but they are purpose-built for renewable generation energy storage. Lead-acid batteries are much cheaper than lithium-ion, but they don't last as long, are not designed for deep cycling, and can fail suddenly (even explode) if not used and maintained properly. The characteristics of the two battery types are summarized in the following table.

Table 7: Li-Ion and Lead-Acid Comparison

	Lithium-Ion	Lead-Acid
Long Life time*	20 years / 7000cycles	7 years / 2000cycles
End of life: still usable	70% remaining capacity after 20 years	Sudden death
High Energy Density	140Wh/kg	30Wh/kg
High Efficiency	>To 95%	80%
Operating temperature	0 – 40°C	15 – 40°C
Maintenance	Maintenance free	Need of maintenance

Source: Saft technologies

The challenges with batteries are well known: increased technical complication, initial capital cost, system management, maintenance, and high—possibly premature—replacement cost. However, the benefits in terms of system optimization and meeting peak load requirements with minimal diesel use may often outweigh these concerns. Therefore, the CS Team conducted an assessment of how batteries might best be incorporated into hybrid mini-grid system design in Somaliland.[12]

As noted in the full report, the use and function of battery storage is determined by the primary function of the renewable energy component of the hybrid-mini-grid. The two general types of application are the following:

- **Fuel Saving.** The primary generation is diesel. The renewable energy is used to reduce diesel generator operation and fuel use.
- **Load Tracking.** The primary generation is from renewable energy. The diesel is used for load support and back up.

In a fuel-saving application, the battery system is designed to handle sudden drops in renewable generation—either from clouds passing for PV or calm winds for a wind turbine—and to allow the diesel generator to respond better to such fluctuations. For a load-tracking application, the renewable energy must be sufficient to meet load and charge the batteries (during the day for PV) so that the batteries can track the load during the night (or other specified period for wind). This also requires significantly more battery capacity and is more demanding on the battery storage system. In Somaliland, given the high capital cost of batteries, it is likely that most battery systems will be designed primarily for fuel savings rather than full load tracking.

The challenge for battery systems in Somaliland will come from the availability of suitable EPC and O&M contractors and the identification of local engineering companies that can provide engineering, installation and maintenance of the system for the long term and that can manage the relevant warranties from the company suppliers. Also, since high operating temperatures (over 30° C) significantly diminish battery life, a battery installation in Somaliland will require cooling that will increase the technical efficiency of the system but decrease its economic efficiency. In some locations (such as the coast), it may be too hot for some battery systems to be viable. The full battery storage report is appended in Annex 8.

[12] Since batteries were used in only two of the six hybrid mini-grid projects during Phase I, the CS Team thought the research and analysis would be useful in helping to inform whether or to what extent batteries should be included in hybrid mini-grid system design during Phase II.

4.1.5 Cell Towers

One of the CS Team's field visit findings is that cell towers are typically the largest energy consumer in a town or village — and the smaller the town or village, the larger the share of total energy consumption the tower or towers typically represent.[13] Tower operators can be formal ESPs, informal providers, self-generators, or customers of the grid.

The most detailed information that the CS Team could gather on cell towers was in Erigavo, where the team gathered information from 12 towers operated by three different companies. SEPCO, the local utility, was willing to share three months of detailed billing information for each tower. The towers represented about 19,000 kWh of demand from the grid (two towers relied primarily on their 6kW solar generation), which represented 25-30% of total grid demand. On average, each grid-dependent tower consumed 1,800 kWh/month, which made the towers the largest customers in the town. The towers also had a total of nearly 100 kW of standby diesel generation capacity, which generally remained idle. If this capacity could be utilized, it would provide power to about 200-400 households and businesses. This information is summarized in table 8.

Table 8: Equipment and Electrical Demand at Cell Tower Sites in Erigavo (kWh)

Summary of Equipment and Electricity Demand at Cell Tower Sites in Erigavo (kWh)

				2017					
Operator	**Name/Location**	**BTS**	**Equipment**	**April**	**May**	**June**	**Average**	**Notes**	**GPS Point**
Golis	Berdaha	3	3 BTS, 3 Modem	2,060	2,189	2,345	**2,198**	Grid Only (Broken backup generator)	125
Golis	Power House	2	2 BTS, 1 Modem, 6 RRU	146	298	229	**224**	Grid w/ Solar (6 kW)	124
Golis	Timo -Waynta	2	2 BTS, 6 RRU, 1 Modem	177	551	608	**445**	Grid w/ Solar (6 kW)	123
Golis	Tower 1 (Tuulo Shire)	2	2 BTS, Landline Switch, 1 Modem, AC	1,924	2,126	2,230	**2,093**	Grid Only	107
Somtel	Tower 1 (HQ)	4	1 BTS (4G), 1BTS (3G), 2 BTS (2G), MBR, Internet Gateway, FM Transmitter, AC	1,877	3,330	4,062	**3,090**	Grid w/ Standby Generator (20 kVA), Co-located w/ SEPCO	134
Somtel	Tower 2	2	1 BTS (3G), 1 BTS (2G)	834	1,257	1,308	**1,133**	Grid w/ Standby Generator (16 kVA)	135
Telesom	Masjid Jaamac	2	2 BTS 3900 (3G)	1,340	1,423	1,464	**1,409**	Grid Only	130
Telesom	Tower 1 (Taqwa)	3	2 BTS 3012 (2G), 1 BTS 3900 (3G), Landline Switch, FM Transmitter	4,284	4,557	4,617	**4,486**	Grid w/ Standby Generator (2x30 kVA)	133
Telesom	Tower 2 (Beeraha)	2	2 BTS 3900 (2G)	1,361	1,431	1,455	**1,416**	Grid Only	129
Telesom	Tower 3 (NG)	2	2 BTS 3900 (2G)	1,159	1,338	1,268	**1,255**	Grid Only	131
Telesom	Tower 4 (Saylada)	1	1 BTS 3900 (2G)	432	497	466	**465**	Grid Only	128
Telesom	Tower 5 (Berdaha)	1	1 BTS 3900 (2G)	694	722	781	**732**	Grid Only	132
Total =				**16,288**	**19,719**	**20,833**	**18,947**		
Estimated Total Usage =				**65,000**	**65,000**	**65,000**	**65,000**		
Share of Total Usage =				**25%**	**30%**	**32%**	**29%**		

Tower operators that generate electricity represent a great opportunity for the RE Fund for investment in towns and villages, particularly areas where formal distribution does not exist. The intervention would be adding a renewable energy component to their existing generation (as with the mini-grids) and promoting investment in developing or improving the distribution network to nearby communities.

[13] It is, of course, the equipment associated with the tower that consumes energy, not the tower itself. Thus, the energy consumption depends on the number and type of equipment installed in the control room. The Base Transceiver Station (BTS) is typically responsible for the greatest energy consumption, and one tower will often have multiple BTSs as well as other energy-intensive equipment. While the CS gathered all the information it could on the billed energy usage of cell towers, unfortunately the tower operators never provided the information on the specific energy requirements of the equipment.

4.2 Operational Issues

4.2.1 Lack of Metering

The CS team gathered information on the number of metered and unmetered customers from 20 providers in 14 locations. Many customers lack electricity meters. Nearly 6,700 (16%) were unmetered of the approximately 41,000 customers served by the 20 providers. The following table indicates the number of metered and unmetered customers at the sites visited by the CS Team:

Table 9: Metered and unmetered customers at visited sites

Metered and Unmetered Customers at Sites Visited by CS Team

			Customers*			
No.	Location	Operator	Metered	Unmetered	Total	Share Unmetered
1	Arabsiyo	Sompower	550	50	600	8%
		Telesom	412	65	477	14%
2	Wajaale	Sompower	900	700	1,600	44%
		Telesom	4,200	1,800	6,000	30%
3	Borama	Aloog**	7,400	-	7,400	0%
		Telesom	8,200	300	8,500	4%
4	Sheikh	Beder	1,200	200	1,400	14%
5	Kalabaydh	Kayse Suleman	-	80	80	100%
		Mohammad Ahmed	-	65	65	100%
		Telesom	16	72	88	82%
6	Gabiley	Sompower	2,532	300	2,832	11%
		Telesom	2,800	200	3,000	7%
7	Boon	Telesom	156	55	211	26%
8	Aynabo	Beder Electric	300	129	429	30%
9	Erigavo	SEPCO	5,700	300	6,000	5%
10	Bali Gubadle	Mawlii Mohamed	5	107	112	96%
11	Salahley	Tawakal	7	71	78	91%
12	El-Afwayn	Telesom	300	1,780	2,080	86%
13	Gar-Adag	Barre Power Station	11	319	330	97%
14	Suuqsade	Homestar	-	100	100	100%
Total =			**34,689**	**6,693**	**41,382**	**16%**

*Data collected from April to July 2017. In some cases operators estimated their numbers. When it was possible to distinguish, numbers reported only reflect active customers.
**Aloog reports that all customers have meters, but about 1,000 still pay a flat montly rate.

In Somaliland, customers are responsible for purchasing their own electricity meters. This is due to the ESPs' lack of capital, low usage per customer, and possibly the financial incentive of charging a fixed rate to unmetered customers that results in a high effective tariff. From the customer's perspective, there is an apparent distrust that the electricity providers will provide accurate meters. The result is that many customers choose not to buy a meter. This is even though meters are extremely cheap in Somaliland, with Chinese or Indian-made meters available in local markets for just $15-25.

The lack of metering is a significant problem, particularly for the poorest customers, since unmetered customers pay an effective tariff that is even higher than the semi-official rate of $0.79/kWh in Somaliland. This is because customers without meters pay a fixed rate, typically either per day in Somaliland Shillings or per month in US dollars. The CS Team found daily rates ranging from 1,500-2,000 shillings for one light bulb to 10,000 for two bulbs and a small television. Providers typically provide power to such customers for just 4-5 hours per day (from 6 pm to 11 or 12 pm[14]), and given the average power of residential light bulbs (about 12 watts), a customer may be using as little as 48Wh (0.048 kWh) per day. This results in an effective tariff of over $3.00 per kWh.

Table 10: Examples of Fixed Rates for Unmetered Customers

Examples of Fixed Rates for Unmetered Customers

				Lamps									
Location	Operator	Daily (SLSh)	Monthly (USD)	Quantity	Avg. Power (Watts)	Hours Available	Daily Usage (kWh)	Effective Tariff (USD/kWh)	Metered Tariff	Monthly Unmetered Premium (USD)	Cost of Meter (USD)	Meter Payback Period (Months)	Net Savings Year 1 (USD)
Erigavo	SEPCO	1,500		1	12	4	0.048	3.29	1.00	3.30	15	4.5	24.56
Erigavo	SEPCO		12	2	12	4	0.096	4.17	1.00	9.12	15	1.6	94.44
Aynabo	Beder Electric	2,000		1	20	4	0.080	2.63	0.89	4.18	20	4.8	30.16
Bali Gubadle	Mawlii Mohamed	4,200		2	15	5	0.150	2.95	0.79	9.71	20	2.1	96.50

During Phase II, ESRES should consider including meter purchasing and installation as part of the Programme. This would have the following benefits:

- Eliminate the higher effective tariff paid by unmetered customers, who are typically the poorest customers;
- Facilitate increased usage as the tariff decreases and service improves;
- Standardise and professionalise billing and collections;
- Coordinate the metering with the overall energy system design, allowing more tight control over the number of connections. This will also support the implementation of an appropriate tariff structure, with a differential time of use tariff or demand charges;
- Ensure the safety of service connections;
- Promote domestic market for affordable and reliable meters;
- Allow for accurate measurement and recording of customer usage.

However, since meters are extremely cheap, even if customers have to continue paying for them, the payback period is very short—just 2-5 months in most cases—so at a minimum, the ESRES Programme should educate and encourage customers in project areas to purchase a meter.

4.2.2 Lack of Capacity

The ESPs (including the IPs) observed by the CS Team lack the commercial operating skills required to properly run a utility, especially skills in cost accounting, operations management, and billing. Most small operators of informal grids maintain almost no useful records beyond their daily collection sheet. However, even the large formal utilities lack proper operational cost accounting. At one of the ESRES IPs, the CS Team found the following issues:

- Daily generation logs do not specify unit and start at random times;
- Multiple inconsistent records for same unit;
- Obvious errors in fuel records;
- Records are all manual and not maintained in any discernible order;
- No attempt at linking fuel use with generation;
- Impossible to accurately calculate fuel cost of generation.

These issues indicate a lack of management capacity. Concerning the Phase I (and later RE Fund) IPs, this means that they are unable to produce the data necessary to successfully implement a significant tariff reduction.

[14] Several providers that offered 24-hour power to metered customers still ran a separate system for unmetered customers that only provided power in the evening. Some providers did not segregate their system and provided power to unmetered customers whenever they provided it to metered customers. In some such cases, customers just left their bulb(s) on all the time because they lacked an incentive (and often a switch) to turn off the light.

On several occasions, the CS Team provided informal capacity building to operators. In the case referenced above, the CS Team helped to redesign the operator's daily generation log report so that it captured consistent and more accurate data. In this and three other cases, the team illustrated basic Excel skills and provided data entry templates to help operators record and analyse their data. The results of these efforts produced useful data, as illustrated below, but more importantly the generation operators now have a greater understanding and appreciation of the importance properly gathering, recording, and analysing their operational data.

Table 11: Generation and Fuel Use of Undisclosed Units

Generation and Fuel Use of Undisclosed Units

Date	Energy (kWh)	Fuel Use (Liters)	Efficiency (Liters/kWh)	Fuel Cost of Generation (Cents/kWh)
July 14	5,174	1,467	0.284	18.4
July 15	5,368	1,148	0.214	13.9
July 16	5,791	1,649	0.285	18.5
July 17	5,676	1,240	0.218	14.2
July 18	5,368	1,148	0.214	13.9
July 19	6,462	1,917	0.297	19.3
July 20	5,219	1,463	0.280	18.2
July 21	5,023	1,260	0.251	16.3
July 22	5,369	1,460	0.272	17.7
July 23	5,491	1,518	0.276	18.0
Total/Average =	**54,941**	**14,270**	**0.260**	**16.9**

Cost of Diesel (USD/Liter) = 0.65

ESPs in Somaliland need significant additional capacity building. The level and detail of training depends on the size of their operation, but the key skills that the operators require include the following:

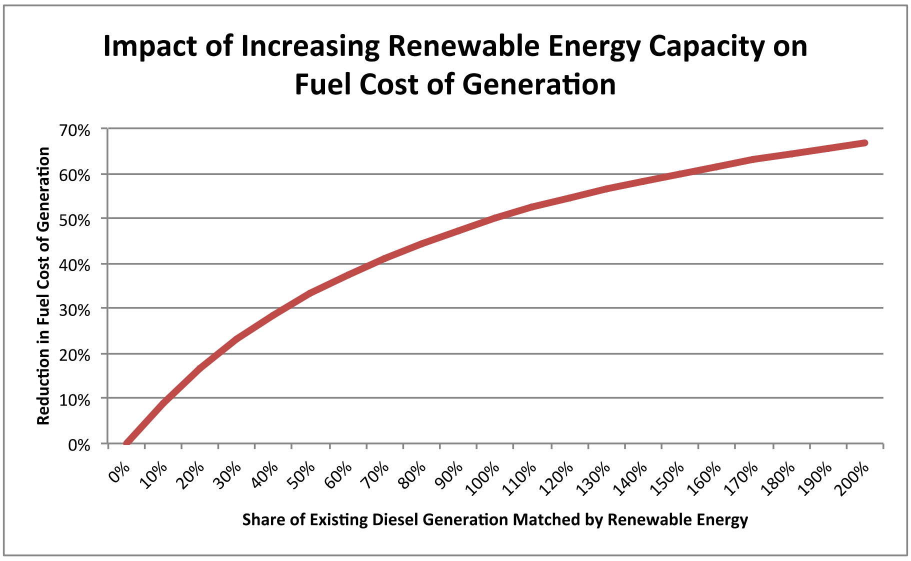
- Recording and calculating electricity generation;
- Measuring and documenting fuel usage;
- Tracking fuel costs;
- Calculating the fuel cost of generation;
- Identifying generation O&M labour costs;
- Inventorying, maintaining a usage schedule, and tracking consumables;
- Identifying and tracking other operational costs;
- Effective management reporting: Using data to manage operations and improve profitability;
- The importance of maintaining time series data.

This training is necessary so that ESPs can produce the data that both they and future regulators will need to enforce tariff reductions.

4.2.3 Potential for Price Reduction

Successfully lowering the price of electricity will be a significant challenge. Firstly, there is a diminishing marginal impact of increasing the share of renewable energy capacity on reducing the fuel cost of generation (and hopefully the corresponding tariff). For example, installing renewable capacity equal to the existing diesel capacity (so renewable capacity represents 50% of total capacity) will reduce the fuel cost of generation by 50%, but doubling this capacity will only reduce the fuel cost of generation by 67%. This is the basic principle of diminishing marginal returns, and is illustrated in Figure 10.

Figure 10: impact of Increasing RE Capacity on Fuel Cost of Generation



Secondly, there is currently only very limited visibility on the fuel cost of generation in Somaliland. This is due to the extremely poor generation and fuel use records of the IPs, which either inadvertently or deliberately makes such calculations extremely difficult and imprecise. Based on a growing amount of survey data collected by the CS team, the average fuel cost of generation is currently about $0.26/kWh (based on a diesel price of $0.70/liter and an average unit efficiency of 25%). Knowing that the indicative average tariff is $0.79/kWh and a fuel cost of generation at $0.26/kWh, the other costs and profit amount to $0.53/kWh (67% of the total tariff).

Unfortunately, there is even less transparent information on the other costs of the IPs, including O&M, distribution, technical and commercial losses, cost of capital, depreciation and administration. Without knowing these costs, it is impossible to calculate the profit required to negotiate and impose a fair cost-recovery tariff with a reasonable return on capital. Therefore, regulated and audited cost accounting and reporting is required to force the tariff down significantly below the current tariff. For example, as illustrated below, matching the existing diesel capacity of a system with renewable energy would reduce the fuel cost of generation by 50%, but this amounts to only $0.13/kWh, so unless there are concessions on other costs and profit, the total tariff reduction may only be about 15-20% (absent cost transparency and enforceable contracts or regulation).

Table 12: Estimated Impact of Hybrid Mini-grid on Generation Cost

Estimated Impact of Hybrid Mini-Grid on Generation Cost
(Cents/kWh)

	Diesel Only	Hybrid Mini-Grid*	% Change
Fuel Cost of Generation**	26	13	-50%
Other Operating Costs***	53	53	0%
Tariff =	**79**	**66**	**-16%**

*RE represents 50% of total system capacity.
**Based on diesel price of $0.70/liter and unit efficiency of 25%.
***Including O&M, distribution, technical and commercial losses, cost of capital, depreciation, administration, and profit.

The CS Team has documented some of the key issues and deficiencies in the ESPs generation cost accounting, and one of the clear findings is that they will require both carrots and sticks to properly account for their costs. The carrot of capacity building will help them improve the efficiency (and potentially profitability) of their operations as well as the stick of enforceable tariff contracts or regulations.

The CS Team successfully used the carrot approach (providing informal capacity building) to gather records and information from the ESPs, and the CS Team was encouraged by how receptive ESPs were to sharing information in exchange for technical assistance and complimentary data analysis.

5. Options for RE Fund Design

This section presents the options for the design of the Operational Guidelines for the RE Fund. It will recommend on the funding mechanism and proposes multiple funding windows for the RE Fund. The funding windows proposed are determined by the market segments that were identified in the CS research as outlined in the technical and operation findings section of the Report, as well as on the experience of the ESRES PM and RTL Team in implementing Phase I of ESRES.

5.1 Eligibility of Current Locations

One question that will have to be addressed in preparing for Phase II is whether Phase I locations will be eligible for additional investment during Phase II.

In support of including them is the fact that thanks to ESRES' engagement during Phase I, the existing IPs have now developed the experience (if not independent expertise) in implementing a hybrid mini-grid project. While DFID and/or the Ministry may decide not to consider this as part of the Phase II evaluation criteria for reasons of partner diversity or selection bias, it is likely the case that successful Phase I IPs would also be among the strongest partners during Phase II.

In addition, the initial system improvements during Phase I primarily focused on (or at least are most likely to result in) a significant expansion of connected users (primarily residential) rather than a large increase in the ability to serve larger (primarily commercial) individual loads. Since establishing this type of social return on investment is generally the first requirement of a system expansion, sites that have already implemented this step are best positioned to build on this and install additional capacity focused on economic development, which is one of the main objectives of ESRES (particularly during Phase II).

However, ESRES Phase I is demonstrating the viability (technically, commercially, and socially) of hybrid mini-grids. The assumption is that the Phase I IPs should be willing to increase their own investments in additional RE capacity and system expansion. Therefore, while Phase I sites might be attractive for additional investment during Phase II, DFID may want to increase the emphasis on leveraging private sector funding. It could then still consider leveraging new investment in Phase I locations with funding to increase the technical and commercial capacity building required to successfully manage the system.

5.2 Grant Recipient Data Gathering Requirement

One of the issues noted during the CS Team's fieldwork is the ESP's lack of capacity to gather and maintain reliable operational and commercial data (see Section 4.2.2). This lack of reliable data was also a problem during the Phase I proposal evaluation process. The CS Team therefore makes the following recommendations for Phase II implementation:

- Grant applicants who are incumbent operators (primarily for the hybrid mini-grids) should be required to provide whatever operational and commercial data they have. Ideally, this would be part of the concept note stage, which would then allow the ESRES project manager to both analyse the data as well as the operator's current data management capacity. This will in turn help identify the capacity building required in this area during the proposal preparation process. The aim is also to standardize the data reporting so that applications can more readily compared and evaluated against each other, which was a noted challenge during Phase I.
- Grant recipients should be required to gather and report their monthly operational and commercial data in a standardized format specified in the grant agreement. The data required would include basic operational information such as energy production, fuel use, O&M costs, and energy sales, ideally disaggregated by customer type (which would be facilitated if the recommendation to require meters for all customers is

adopted). The data requirements would be modified based on the type of operator or system installed. For example, agricultural projects would be expected to monitor and record appropriate water pumping and production data. Grant recipients would be monitored, coached, and provided supplemental capacity development in these areas throughout the project period.

- The RE Fund should consider investing in improved metering to facilitate the data collection. It was noted during Phase I, that the absence of smart meters makes it impossible to gather good data on the load and load curve during the day. This data is required to appropriately reduce the tariff, but also to address distribution losses and optimizing the system. Hence, investment in smart meters under the projects can have a significant impact on the outcome of the Projects funded under the RE Fund.

The purpose for these recommended requirements are two-fold: First, properly gathering, managing, and analysing operational data will help the operator run a more efficient and profitable operation, which will increase the viability of the grant recipient and therefore improve the longevity and sustainability of the grant's intended impact. For example, the intended long-term economic benefit of improving the irrigation in an agricultural area will only be realised if the operator remains a viable business, which in turn is only likely if they can monitor, manage, and optimize their operating costs.

Second, as noted previously, this data will be required to develop, implement, and enforce the tariff reductions intended under the ESRES Programme. Whether the tariff reductions are mandated by regulation or directly by contract, operators will need reliable and verifiable operational cost and commercial data to document their compliance with the agreed tariff.

5.3 Tools for Load Analysis and Forecasting

For the grant applicants to properly design their hybrid mini-grids and other systems during Phase II and for the ESRES PM to properly evaluate the proposal, it will be required to conduct load assessments and forecasting. One of the key issues identified during Phase I was the lack of reliable baseline system information to conduct this analysis. While this will continue to be an issue during Phase II, as noted above, the CS Team proposes addressing it by both requiring grant applicants to provide what information they can as well as providing them some technical assistance to improve their data reporting.

The information can then be supplemented with tables provided by the CS Team, including the following:

- List of average power requirements for over 40 common types of appliances and equipment
- Typical energy usage patterns by customer type
- Average peak load (kW) and energy consumption (kWh) by customer type

This information can be complimented with the population and village user mix to calculate the village demand. This data is more easily gathered per site and hence it is most appropriate that this tool will be used on a case-by-case bases for each proposed site. This will support the evaluation of proposals and could show if systems are appropriately sized and designed for the location proposed.

5.4 Addressable Market Segments

Phase I funded and facilitated the construction of six hybrid mini-grids. If the RE Fund only considers hybrid-mini-grid projects similar to the Phase I Projects, there might not be enough potential sites to absorb the money made available by DFID. The total funding for Phase II is expected to be £15 million, three times that of Phase I, and the available funds for the RE fund will likely be 3–4 times the amount spent on hybrid mini-grids during Phase I. If the RE fund only funded projects similar to those funded during Phase I, it could fund as many as

18–24 additional projects, and it's not clear that there are that many additional suitable sites in Somaliland.[15] Therefore, the CS Team looked into a broader range of potential interventions across the energy supply curve.

Based on its observations in the field, the CS Team identified the following six addressable market segments:

- **Pico/Home Solar Systems:** Small PV systems that provide 10–100 W of typically DC power to an individual home or business.
- **Informal Grid Systems:** Villages with often less than 24-hour generation, line voltage distribution, and typically about 100–500 mostly unmetered customers. Investment in (hybrid) mini-grid projects would be considered.
- **Formal Grid Systems:** Towns and villages with generally 24-hour generation, more extensive distribution (sometimes with step-up transformers and feeders), and large numbers of mostly metered customers. Investment in (hybrid) mini-grid projects would be considered.
- **Agricultural Applications:** Renewable energy projects focused on promoting agricultural production and economic development, including livestock, farming, and fisheries.
- **Cell Towers:** Renewable energy projects that leverage the extensive infrastructure and expertise of telecom operators, particularly in rural areas.
- **Wind Generation:** A segment with limited current success in Somaliland. However, Somaliland's significant wind generation potential make this an interesting segment for RE Fund investment.

The current status of each segment along with identified needs or suggestions are summarized in the following table:

Table 13: Summary of Status and Needs for Somaliland's Addressable Energy Market Segments

Segment	Status	Need/Suggestion
Pico/Home Solar System	▪ Private sector actively engaged ▪ Some PV generation found in nearly every village ▪ Other donors focused on segment (e.g., USAID's Power Africa and World Bank's planned fund)	▪ Coordination/collaboration with grid-based interventions ▪ Establish guidelines for supporting grid extensions (identify point beyond which pico/home solar systems should be encouraged)
Informal Grid Systems	▪ Most villages observed had a diesel generator and at least some distribution ▪ Installed capacity typically 20-50 kVA up to 100 kVA ▪ Connected customers average about 100 up to 500. ▪ Service is limited (typically 6-11 pm) ▪ Customers lack meters ▪ Operator collects daily/monthly fee ▪ Generation only sufficient for lights, TV, and limited small appliances	▪ RE generation to reduce cost of power and increase capacity ▪ Improved distribution system to reduce losses, expand service, and improve safety and reliability ▪ Install metering to avoid high effective tariff for unmetered customers ▪ Basic technical assistance on operational cost accounting ▪ Technical assistance on improving and formalizing overall operations
Formal Grid Systems	▪ Distribution network is formally established. ▪ Of the towns visited, only Borama, Gabiley, Berbera, Burao, and Erigavo	▪ RE generation to reduce cost of power and increase capacity ▪ Improved distribution system to reduce losses, expand service, and improve safety and reliability

[15] The lack of reliable population data makes a definitive statement about the sizes of towns and villages impossible, but this conclusion is based on the CS team's local expertise and field observations.

Segment	Status	Need/Suggestion
	have step-up transformers (distribution above line voltage) ▪ Estimated average distance for line voltage distribution over 200 m, with some customers 1 km from generation or step-down transformer ▪ Multiple generators typically larger than 200 kVA up to over 1,000 kVA ▪ Generators unsynchronised but operate on shifts and generally provide 24-hour power ▪ More structured billing, but still many unmetered customers	▪ Expand metering to all customers ▪ Intermediate technical assistance on operational cost accounting ▪ Technical assistance on distribution system design and operation
Agricultural Applications	▪ Approximately 65% of Somaliland's population relies directly or indirectly on livestock production for their livelihood ▪ Livestock and other agriculture represent about 35% of Somaliland's estimated GDP ▪ Energy provision for water pumping and irrigation needs are significant ▪ Extremely limited application of appropriate technology in agriculture	▪ Since agriculture affects most of population and represents largest share of economy, agriculture-related renewable energy applications have significant opportunity for social and economic impact ▪ Energy use needs to be aligned with appropriate agricultural practices (e.g., sizing pumps for drip irrigation) ▪ Affordable energy is required for almost any value-added activity (e.g., cold storage and processing) ▪ Dedicated PV water pumps may represent better solution than connecting load to a hybrid mini-grid ▪ Agriculture-related energy projects require technical and economic agricultural expertise ▪ Potential opportunities to partner with PMIS, SDF, GEEL and other donor projects with a significant agricultural component
Cell Towers	▪ Cell towers are located throughout Somaliland—they provide near-complete coverage in even the most remote areas ▪ Towers (with the BTS equipment) represent the single-largest load (kW) in most towns and a significant share of usage (kWh)—25-30% in Erigavo. ▪ Tower operators are either formal ESPs (e.g., in Borama, Gabiley, and Boon), informal providers, self-generators, or customers	▪ Detailed inventory of existing tower infrastructure and development plans ▪ Coordination and collaboration of hybrid mini-grid project development with local tower operators ▪ Increase RE use by cell towers ▪ Design and implement projects that provide technical assistance and incentives to tower operators to

Segment	Status	Need/Suggestion
	▪ Some tower operators have installed isolated PV systems that serve as their primary source of power.	provide power to nearby communities.
Wind Generation	▪ Somaliland has significant wind generation potential ▪ Wind projects have yet to be successfully implemented in Somaliland ▪ There is a significant lack of technical capacity in Somaliland to design, implement, and manage a wind generation project	▪ Preliminary analysis indicates that a large-scale (1 MW) wind project in Somaliland can have a lower LCoE than either a comparable PV or diesel system ▪ Smaller (100 kW) projects also have lower LCoE than diesel but may be less economic than PV ▪ Donor support for international firm to provide turnkey system design and installation, including significant TVET component to ensure the technical capacity of the ESP is built to maintain and operate the system

Based on the findings summarized above, the CS team suggests that the ESRES Phase II RE Fund focus on the following four segments: hybrid mini-grids (formal/informal), agricultural applications, cell towers, and wind turbines.

The CS Team proposes to exclude pico/home solar systems. Pico/home solar systems clearly have a key role to play in meeting Somaliland's near to medium-term energy needs, particularly for rural and nomadic populations, but both the private sector and other donors are focused on this segment. Hence, there is not a need for DFID to intervene in this market segment. The CS Team therefore proposes to limit the scope of ESRES' engagement in this segment to coordinating and collaborating with private sector and donor funded projects operating in this area. This coordination will be particularly important in determining the extent to which distribution systems should be expanded to provide electricity to houses on the periphery of towns and villages.

The CS Team also proposes not to make a distinction between formal and informal grids. There are important differences between locations that have informal and formal grids. However, these are mostly differences of degree, not kind. In the Research Design, the CS Team had made a distinction between hybrid micro and mini-grids, with micro-grids being smaller and implemented with more of a standardized "grid in a box" approach at locations with informal grids, and mini-grids being larger systems requiring extensive local customization and more suited to locations with an existing formal grid. However, while this is a meaningful distinction in terms of implementation approach, it is not clear that it requires separate funding mechanisms or windows. Rather, the RE Fund should be able to evaluate hybrid mini-grid proposals based on their technical and economic suitability for their specific location. Therefore, it does not seem necessary to make a distinction.

5.5 Potential Funding Windows

The CS Team proposes to have different funding windows for the RE Fund, based on the understanding that the four market segments identified require different funding mechanisms. The CS team has identified the following four potential funding windows:

- **Hybrid Mini-Grids Project:** For projects comparable to Phase I, although perhaps of a broader range of sizes that meet the needs of sites that have formal or informal distribution systems.

- **Agricultural Applications Projects:** For projects supporting investment in hybrid or pure RE systems designed primarily to provide energy to an agricultural project, such as water pumping, irrigation, cold storage, or processing.
- **Cell Tower Projects:** For projects supporting hybrid or pure RE systems designed to be implemented in coordination and collaboration with cell tower operators. Projects will focus on leveraging existing generation by supplementing it with RE and expanding distribution to nearby communities.
- **Wind Project:** A wind generation demonstration project of a size appropriate for a location to be determined.

The CS team has prepared a rough outline of the options for the characteristics of the proposed funding windows. This includes the type of application process, location selection, the relative funding commitment from the RE Fund and counterpart, and the technical assistance required. The decision regarding the allocation of resources (the number of grants and total funds allocated to each window—and whether this will be a hard or soft allocation) will have to be determined by DFID in consultation with the Government.

Application Process

The CS Team is considering two mechanisms for applicants to apply for funds. The first is a two-stage call for proposals, similar to the process used during ESRES Phase I.[16] It seems that this approach will be appropriate for the hybrid mini-grids, agriculture projects, and cell towers. This will also require significant institutional coordination and public outreach, particularly to refine the design and increase awareness of the agricultural application and cell tower projects. For the wind generation demonstration project, due to its complexity and lack of local expertise, the CS Team proposes that the fund manager specifies the project for international tender. There will still be the crucial issue of local ownership and operation of the plant, but this will have to be determined based on the Government's wishes, the selected location, and the incumbent operator(s).

Location

The location for the agricultural applications and cell tower projects will have to be unconstrained in the call for proposals, as the fund manager will not have sufficient awareness of the existing needs and available opportunities. The CS Team proposes that the location for hybrid mini-grid projects will have to be reviewed on the size and scope of the projects that the fund is interested in supporting in relation to their location. This is to ensure that the hybrid mini-grid systems are sizable enough to create the impact ESRES is after. The CS Team recommends that indicators are set in the call for proposal documents on the relation between location size and location. Since wind projects are much more location-dependent than PV, the location of the wind project will have to be defined by the fund manager as part of the planning and tendering process.

Funding

The funding commitment from the RE Fund will depend on the total pool of resources and the relative priorities identified by DFID and the Government. However, as was the case during Phase I, the fund will attempt to leverage other resources (both from the private sector and other donors) where possible. For the cell tower projects, given that the telecom companies have their own significant financial resources, the RE Fund should focus on leveraging those resources and focusing its own resources on providing generation capacity and distribution necessary to expand service in the area around the tower. As opposed to that, the wind demonstration project would likely be entirely funded by the RE Fund, given the need for the extensive design and tendering effort and a significant capacity building and TVET component.

For the hybrid mini-grids, the RE Fund will attempt to leverage as many resources as possible from the local IP. As during Phase I, the share of the IPs contribution should be one of the project selection evaluation criteria. For the agricultural applications, the Fund will also attempt to leverage local resources, although since these projects are more likely to involve investments that local counterparts would not otherwise make on their own

[16] The RTL team may have some specific recommendations for how this process should be modified, but based on the Phase I experience, it seems clear that significant technical assistance will be required, particularly during any expression of interest, concept note, or preliminary proposal stage.

(e.g., solar water pumping integrated with drip irrigation), the RE Fund will likely bear a larger share of the financial burden.

Technical Assistance

One of the important findings during Phase I, which has been identified by both RTL and the CS team, is the general lack of capacity of the IPs and other ESPs. Hence, like the Pilot Project in Phase I, all funding windows will require significant technical assistance and oversight, including in system design, procurement, and project management. In addition, agricultural application projects will require technical and economic agricultural expertise. The CS team has particularly focused on the lack of capacity to record, report, and analyse commercial and operational cost information. These skills are crucial for tariff setting and compliance, and since reducing the price of electricity will continue to be one of ESRES' main objectives during Phase II, it will be important to develop the current and prospective IPs capacity in this area.

Technical and Commercial Losses

The implementation of the Pilot Projects during Phase I revealed that technical losses caused by the poor quality of the distribution networks leads to inefficient operation of the hybrid mini-grid systems and high prices at the consumer's end. Investment to reduce these losses will increase the impact of the projects. Improving the metering by incentivising the IP to invest in own metering is an example of an intervention. Investment in reducing technical and commercial losses is relevant for all funding windows proposed except for the Agricultural Application Projects. This would also include investment in smart metering.

Table 14: Characteristics of Proposed Funding Windows

	Window 1	Window 2	Window 3	Window 4
	Hybrid Mini-Grid Projects	**Agriculture Application Projects**	**Cell Towers Projects**	**Wind Project**
Application	Call for Proposals	Call for Proposals	Call for Proposals	Fully Specified International Tender Local Ownership (TBD)
Location	Open (with indicators on system size and location)	Open	Open	Defined
Funding	• Matching • Significant Local Contribution	• Majority • Leverage Available Local Contribution	• Contributory • Majority from Telecom Firm	• Design and Installation Fully Funded • O&M TBD
Technical Assistance	• System Design, Procurement, and Project Management • Commercial and Operational Cost Reporting • System formalization (for current informal systems)	• System Design, Procurement, and Project Management • Commercial and Operational Cost Reporting • Technical and Economic Agricultural Expertise	• System Design, Procurement, and Project Management • Commercial and Operational Cost Reporting	• Turnkey Installation w/ TVET Component • Project management support to local subcontractors and vendors
Technical and Commercial Losses	Investment required	Not applicable	Investment required	Investment required
Considerations and Challenges	• Appropriately sizing projects given limited data for load calculation and forecast • Allowing outside operators to propose projects in areas with incumbent operator • Phase II schedule will require nearly all projects to be implemented in parallel, so PM will need several regional project managers to oversee numerous simultaneous projects	• Evaluating/accepting pure social return for stand-alone borehole projects • Project management and oversight for remote/ inaccessible locations	• Technical, commercial, and contractual arrangements between telecom firms and incumbent operators • Incorporating relevant RE component—not just distribution	• Significant funding commitment • Risk of highly visible failure • Design, procurement, and installation could exceed available Phase II implementation time

5.6 Wind Demonstration Project

The wind demonstration project will require consideration for the RE Fund Operational Guidelines on how it could be operationalised. The Final Report proposes key steps to be taken for this proposed funding window.

As noted, one of the proposed funding windows is for a wind generation demonstration project. The two key factors to consider initially are the size and location of the project. The size of the project will primarily be determined by the available funding, and it must be acknowledged that wind projects are quite capital intensive. Based on the research and analysis of Mott MacDonald's wind expert, the fixed costs and economies of scale mean that the unit capital cost of wind projects drops significantly as the size of the project increases. For example, small projects (those less than 100 kW) may cost about $6,500/kW, while a large project (on the order of 1 MW) will cost about $2,500/kW. Therefore, a 100 kW project might cost on the order of $650,000 while a 1,000 kW project would cost perhaps $2.5 million—ten times the power for less than four times the cost. Indicative costs for a range of generation capacities are illustrated in the table 15.

Table 15: Approximation of Wind Generation Project Cost

Approximation of Wind Generation Project Cost

Capacity (kW)	Indicative Unit Cost* (USD/kW)	Capital Cost (USD)
100	6,500	650,000
250	4,500	1,125,000
500	4,250	2,125,000
1,100	2,500	2,750,000

*Based on estimated cost for Vergnet GEV 275 or similar turbine. Total installed cost will depend on a variety of project and site-specific factors.

The second determinant of the appropriate size of the project is the current and projected load to be served, which depends on the prospective location. Therefore, once the funding constraint is established and the associated potential plant capacity determined, a list of locations that require that capacity can be developed. Of course, given the acute lack of low-cost generation in Somaliland, nearly any location would benefit from a wind generation project, so the only practical question is where would a wind demonstration project be most effective.

Based on the World Bank's wind resource map, wind generation is feasible throughout most of Somaliland. However, in addition to being technically and economically feasible, a demonstration project should also be highly visible and accessible.[17] Prospective stakeholders need to be able to see the project in order for it to effectively demonstrate how it achieved success, which is how it will prompt and encourage additional similar projects—the underlying motivation and rationale behind a demonstration project. Therefore, the two most likely suitable locations for the wind demonstration project would be Hargeisa or Berbera. Both cities have significant wind resources, additional generation requirements, and are the two most accessible cities in the country.[18] They also both have existing wind projects that have yet to operate successfully, so a demonstration project will be able to directly apply lessons learned from their experiences to improve the chances for success. Also, the

[17] The corollary, of course, is that a failure would also be on display, which increases the stakes in ensuring that the project is a success.

[18] Crane lift capacity is also a constraint in Somaliland, which limits both the size of wind turbines and potential installation locations.

ability to compare and contrast the projects in the same location will highlight the factors required for successful implementation.

5.7 Evaluation Criteria

The final selection and definition of the funding windows will have to be determined based on DFID's programme priorities which determine the evaluation criteria. The following four impact indicators are part of the ESRES Theory of Change:

- Increased economic growth and poverty reduction in Somaliland
- Improved health and education outcomes in Somaliland
- CO2 emissions reduced from Somaliland
- Increased energy security in Somaliland

The problem is that given a resource constraint, achieving these objectives meant that the power available per connection did not increase significantly.[19] This limits the ability to achieve the desired impact of increasing economic development.

DFID will have to consider whether these impact indicators remain and how this should drive the evaluation criteria. The table 16 presents a summary of both potential evaluation criteria and corresponding possible funding windows. The table ill support DFID to make better informed choices priorities for ESRES Phase II.

As noted in the introduction, some of these criteria and related interventions are inconsistent or even mutually exclusive. For example, during Phase I additional connections were a defined criteria aimed increasing energy security in Somaliland. However, given a resource constraint, achieving these objectives meant that the power available per connection did not increase significantly.[20] This limits the ability to achieve the desired impact of increasing economic development. The reach increases economic development, one of the evaluation criteria should be maximising productive power. This will require connecting appropriate capacity to economically productive load, which in Somaliland would primarily involve livestock and agriculture. It would also require avoiding connecting as many customers as possible, which will then limit the direct social impact (as opposed to the indirect social impact that results from increased economic activity).

However, ESRES Phase II will have the resources to potentially achieve multiple objectives, and the benefit of having multiple funding windows is that as long as the evaluation criteria within a given funding window are consistent (e.g., maximizing a social benefit without trying to minimize the system cost), each window can have different objectives. For example, one window for hybrid mini-grids could have the objective of economic growth and be evaluated based on increasing productive energy, while another window could focus on maximising the social return by connecting schools, clinics, and as many households as possible. If this were coupled with leveraging existing capacity, for example from a cell tower, then the evaluation criteria could be minimising cost per kW and maximising social benefit. Given the chronic and sometimes acute water shortages in Somaliland, coupled with the central role of livestock and agriculture in the economy of the country and the livelihoods of the people, energy projects linked to water pumping and agricultural processing are most likely to have the potential to have both a significant economic as well as social impact.

[19] Average capacity per connection increased from 190 W to 240 W, which is a substantial 25% increase, but the absolute level is still insufficient for most productive applications.

[20] Average capacity per connection increased from 190 W to 240 W, which is a substantial 25% increase, but the absolute level is still insufficient for most productive applications.

Table 16: Potential Evaluation Criteria and Potential Interventions

Criteria	Potential interventions
Minimise	
Levelized Cost of Energy (LCoE)	• Stand-alone PV • Stand-alone wind turbines (typically larger capacity and more site-dependent than PV) • Technical loss reduction
Cost/kW	• Leverage existing captive capacity • New diesel generators • Distribution rehabilitation • Technical loss reduction
Cost/Connection	• Distribution expansion/extension in densely populated area
Cost of Increasing "Access"	• Solar flashlights • Pico systems
Maintenance Costs	• Leverage existing captive capacity • PV without batteries
Maintenance Skill Required	• Diesel • Distribution rehabilitation
Maximise	
Installed RE Capacity	• Large PV or wind turbine project
Number of Connections	• Hybrid mini-grid with maximum number of new connections
Productive Power	• Hybrid mini-grid with minimum number of new connections
Economic Impact	• Hybrid mini-grid with batteries • Electrify agricultural and livestock operations, including water pumping, irrigation, and processing.
Social Benefit	• Hybrid mini-grid with batteries • Electrify schools, clinics, and water pumping
Regional Diversity	• Prioritise projects in remote/under-served regions.

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Annex 1: Summary of Generation Operator Responses

Summary of Subjective Responses from Generation Operators

Town/Operator	Infrastructure in Past Year	Planned System Development	Anticipated Significant Additional Load	Challenges/Other Issues	Contact
El-Afweyn Telesom	Installed 30 poles and conductor	Expand distribution to whole town Relocate generator	None	Want to change current metal poles to concrete, but this is very expensive.	Sulemain Jama Manager 063-4208002
Gar-Adag Barre Power Station	Expanded distribution system	Would like 24-hour electricity (if get investment)	No response	One generator needs repair. Poles too weak and fall down, which is danger for people.	Adam Mohamad Operator 063-4296677 Mohamad Jama Bill Collector 063.4589380
Suuqsade Homestar	Purchased new generator	Expand distribution Install larger generator (if get investment)	No response	Distribution system too limited. Need more conductor to expand system.	Mohamad Haybe Owner 063-4443233 Abdikarin Yusef Operator 063-4446265
Bali Gubadle Bali Gubadle Power Station	Changed poles Built generator room Fencing	Expand distribution system Increase use of meters	No response	Income too low Customers not paying bills.	Mawlid Mohamad Owner 063-4428906 Khadar Mohamoud Operator 063-4422096
Salahley Tawakal	Added second generator (run one 5 days and second 2 days)	Increase height of poles and expand distribution	No response	Fuel price too high.	Muse Mohamad Operator 063-485.0535

Town/Operator	Infrastructure in Past Year	Planned System Development	Anticipated Significant Additional Load	Challenges/Other Issues	Contact
Aynabo Beder Electricity	Installed 3 km conductor to upgrade and expand system	Install solar to supplement wind power	No response	Burned out 1/3 of batteries at wind farm due to lack of technical training.	Hassan Cawil Operator 063-438.5095 Ismail Hussian Engineer 063-444.6258
Boon Telesom	Extended distribution system 100 meters	Add 2 BTS for 3 & 4G service Add 100 kVA generator	DSL for each house	None noted.	Abdirahman Mohamad Deputy Manager 063-445-2013
Kalabaydh Telesom	None	Expand distribution system New generators	No response	None noted.	Yasin Jama Nur Manager 063-460.0033
Kalabaydh Mahamed Ahmed	Replaced conductor for entire distribution system (2,500 meters)	Replace poles	None	Generator uses too much fuel.	Mohamad Ahmed Owner 063-446.6335
Erigavo Sonaag Electricity Power Company	Merged Beder Electric and Erigavo Power into one firm Extended distribution system 2,000 meters Increased connections by about 360 customers	Add second 11 kV transmission line Want to reduce fuel cost by introducing RE	Large new hotel under construction	Fuel price too high.	Jama Ahmed COE 063-393.6666 Hussain Mohamoud Head of Technical 063-420.3577
Quljeed Al-Nour	Replaced 15 kVA generator with 35 kVA generator	Extend distribution on west side of town	No response	None noted.	Khadir Abdi Osman Operator 063-487-3974 Abdi Ahmad Dahir Owner 063-445-0311

Note: These questions were added following the first field test of the survey, so they were not asked of the first group of respondents

Annex 2: Field Data Collection Form – Individual Energy Usage

ESRES Complementary Studies Field Data Individual Energy Usage

Town/Village: ____________________**Region:**____________**Date:**_______________**No.**____
Coordinates: **N**__________________**E**_________________

Type of Respondent: ☐ Household ☐ HH w/ Business ☐ Shop/Business
☐ Bakery ☐ Restaurant ☐ Hotel ☐ School ☐ MCH/Clinic ☐ Hospital
☐ Mosque ☐ Cell Tower ☐ Fuel Station ☐ Water Pump ☐ Other__________________

Name: ________________________________**Gender:**______**Contact:**__________________

HH Primary Source of Income:___________________**HH Size/No. Employees:**___________

House/Building Type: ☐ Buul ☐ Metal Sheeting ☐ Detached Concrete
☐ Attached Concrete ☐ Multi-story ☐ Other__________________

1. a. Do you have electricity 24 hours/day? ☐ Yes ☐ No
   b. If No, what hours do you typically have electricity?____________Hrs/Day:______

2. a. What time of day do you use the most electricity? _____________
   b. Does this vary significantly by day of the week, time of month, or season?
   ☐ Yes ☐ No
   c. If it varies, why and when is your greatest demand?______________________

3. a. Is electricity available as much as you would like? ☐ Yes ☐ No
   b. If No, please explain:____

4. **Summary of Equipment and Usage**

No.	Appliance/ Equipment	Qty.	Power (W)	E/A	Usage (Hrs./Day)	Peak Hour(s)	Notes
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

5. a. What are you currently paying for electricity?___________(per kWh, Day, Month)
   b. Approximately how much do you spend each month on electricity?__________

Self Generation ☐ Diesel ☐ Solar ☐ Other____________________
Capacity (kW): _____________ Operating Hours/Day:_________
Fuel/Day (Bbl or L): _____________ Fuel Price ($/Bbl or L):_________

6. a. If electricity cost only half as much, would you use more? ☐ Yes ☐ No
   b. If Yes, what would you do differently?____________________________
   ____

7. Have you considered installing a renewable energy system?
   ☐ Yes ☐ No ☐ Already Have (Describe)___________________________

8. What issues have prevented you from installing a renewable energy system?
   ☐ Awareness of Options ☐ Lack of Access to Technology
   ☐ Too Expensive ☐ Access to Finance ☐ Reliability ☐ Maintenance
   Other (Describe):____
   ____

REMEMBER TO TAKE PICTURES!

Annex 3: Field Data Collection Form – Energy Supply and Location Detail

ESRES Complementary Studies Field Data Generation and Location Detail

Date:____________________ **No.**____

Town/Village: ________________________ **Region:** ________________________

Description/Primary Economic Activity:____

____

____

Operator(s):____

[Complete and attach separate form with generation information for each operator.]

Existing Generation

Unit/Type	Capacity (kVA)	Available Capacity/Notes

Maximum Serviceable Peak Load (kW):___________

Constraints/Notes:____

____

Peak Load (kW):___________**Peak Time:**_________**Monthly Generation (kWh):**_________

Tariff: ____________**Fuel Price ($/Bbl or L):**____________**Monthly Fuel Usage:**________

[*Try to get billing information and actual records!***]**

Notes: ____

____

Existing & Potential Connections

Type/Usage	Total	Grid	Own Generation	No Power	Notes
Households					
Shop/Business					
Bakery					
Restaurant					
Hotel					
School					
MCH/Clinic					
Hospital					
Mosque					
Cell Tower					
Fuel Station					
Water Pump					

Notes: ____

____

____

REMEMBER TO TAKE PICTURES!

Distribution System:____

Metering:____

Energy Infrastructure Development in Past Year:____________________

Planned System Development:________________________________

Anticipated Significant Additional Load/Usage:____________________

Challenges/Other Issues:__________________________________

Information Sources

Name	Position	Contact

Notes: ____

Key Coordinates

Location	Lat	Long	Notes
Generator			
Furthest Connection--North			
Furthest Connection--East			
Furthest Connection--South			
Furthest Connection--West			

[*Mark on map or sketch on back.***]**

REMEMBER TO TAKE PICTURES!

Annex 4: Estimated Average Power Consumption Table

Summary of Load for Typical Appliances and Equipment in Somaliland

Cateorgy	No.	Appliance/Equipment	Average Power (W)
Lighting	1	CF Light Bulb--Small	10
Lighting	2	CF Light Bulb--Large	80
Lighting	3	LED Light Bulb--Small	5
Lighting	4	LED Light Bulb--Large	20
Lighting	5	Incandesant Light Bulb--Small	80
Lighting	6	Incandesant Light Bulb--Large	180
Lighting	7	Exterior Security Light	200
Refrigeration	1	Chest Freezer--Small	170
Refrigeration	2	Chest Freezer--Medium	210
Refrigeration	3	Chest Freezer--Large	180
Refrigeration	4	Display Refrigerator--Single Door	260
Refrigeration	5	Display Refrigerator--Double Door	750
Refrigeration	6	Household Refrigerator--Small	140
Refrigeration	7	Household Refrigerator--Large	130
Entertainment	1	Radio	20
Entertainment	2	Stereo w/ Speakers	80
Entertainment	3	Old TV (CRT)--Small	50
Entertainment	4	Old TV (CRT)--Large	80
Entertainment	5	TV--Small	40
Entertainment	6	TV--Large	60
Entertainment	7	Satelite Dish/Controller	20
Cooling	1	Fan--Desk/Floor	50
Cooling	2	Fan--Ceiling	80
Cooling	3	Air Conditioner--Small	1,100
Cooling	4	Air Conditioner--Large	1,600
Appliance	1	Electric Kettle	2,200
Appliance	2	Washing Machine--Cold Water	250
Appliance	3	Washing Machine--Hot Water	2,100
Appliance	4	Iron	1,000
Appliance	5	Blender/Juicer	430
Appliance	6	Hot Plate	1,000
Appliance	7	Double Hotplate/Stove	1,750
Appliance	8	Microwave	1,200
Appliance	9	Toaster (Two-Slice)	1,280
Hot Water	1	Hot Water Heater--Instant	2,000
Hot Water	2	Hot Water Heater--Small Tank	3,000
Hot Water	3	Hot Water Heater--Large Tank	4,500
Computer	1	Laptop	30
Computer	2	Desktop	130
Computer	3	Printer--Small	130
Computer	4	Printer--Large	550
Computer	5	Internet Router	10
Medical	1	Sonogram	800
Medical	2	ECG	750
Medical	3	Sterilizer	2,500
Medical	4	X-Ray	TBD
Commercial	1	Fuel Pump	750
Commercial	2	Air Compressor--Small (3 Hp)	2,400
Commercial	3	Air Compressor--Large (6 Hp)	4,800
Commercial	4	Welding Machine	TBD
Commercial	5	Ice Cream Machine	1,850
Commercial	6	Ice Cream Display Case--Small	250
Commercial	7	Ice Cream Display Case--Small	1,800
Commercial	8	Meat Grinder	1,500
Commercial	9	Sewing Machine	100
Commercial	10	Ice Machine	2,000
Commercial	11	Cell Tower	Variable
Irrigation		Water Pump	6,000
Mosque		Loudspeaker	100

Note: The energy consumption of some appliances must be adjusted by usage cycles or various power modes.

Compiled by ESRES Complementary Studies Team, April - August 2017.

Annex 5: Cities and Towns Ranked by Estimated Population

Somaliland Cities and Towns Ranked by Estimated Population*

				Phase I	
No.	**City**	**Region**	**Population**	**Selected**	**Finalist**
1	Hargeisa	Marodi-jeeh			X
2	Burao	Tog-dheer		X	
3	Borama	Awdal		X	
4	Berbera	Saahil			
5	Las Anod	Sool			X
6	Arigabo	Sanaag			X
7	Gabiley	Marodi-jeeh		X	
8	Badan	Sanaag		X	
9	Saylac	Awdal			
10	Sheik	Saahil		X	
11	Aynabo	Tog-dheer			
12	Oodwayne	Tog-dheer			
13	El-Afwayn	Sanaag			
14	Wajaale	Marodi-jeeh			
15	Salahley	Marodi-jeeh			
15	Arabsiyo	Marodi-jeeh			
17	Boohudle	Tog-dheer		X	
17	Oog	Tog-dheer			
19	Boon	Awdal			X
20	Qurulugud	Tog-dheer			
21	Bali Gubadle	Marodi-jeeh			
22	Hadaftimo	Sanaag			
23	Abdaal	Saahil			
24	Yagori	Sool			
25	Adhi-Adeye	Sool			
26	Kalabaydh	Sool			
27	Alaybadey	Marodi-jeeh			
28	Dila	Awdal			
29	Gar-Adag	Sanaag			
30	Geerisa	Awdal			
31	Garbadadar	Awdal			
32	Dararwayne	Marodi-jeeh			
33	Samakaab	Sool			
34	Lughaya	Awdal			`
35	Taleex	Sool			X
36	Dacar budhuq	Saahil			
37	Dhumay	Sool			
38	Lawyacado	Awdal			
39	Kalabaydh	Marodi-jeeh			
40	Suuqsade	Saahil			
41	Xidhxidh	Sool			
42	Home Start Village	Saahil			X
		Total =		**6**	**6**

*Ranking currently estimated based on local knowledge. Will suppliment and refine with any available data from Ministry of Planning.

Annex 6: Generation Capacity at Surveyed Sites

Summary of Generation Capacity

Location	Operator	Unit	Capacity kVA	Capacity kW	Notes
Arabsiyo	Sompower	Delmo	105	84	Not Working
		FG Wilson/Perkins	60	48	29,820 Hours, runs from 4-9 am
		FG Wilson/Perkins	110	88	45,878 Hours, runs from 9am - 5 pm
		Iveco	250	200	26,108 Hours, 5 pm - 4 am
		Orange Tarp	135	108	21,414 Hours, function unclear
	Sompower Subtotal =		**660**	**528**	
	Telesom	Meccalte	60	48	2015
		Meccalte	100	80	New
		Iveco	100	80	New
	Telesom Subtotal =		**260**	**208**	
	Arabsiyo Total =		**920**	**736**	
Wajaale	Sompower	Aksa Perkins	400	320	2014
		Aksa Cummins	250	200	2015, 6,128 Hours
	Sompower Subtotal =		**650**	**520**	
	Telesom	Meccalte	350	280	2013
		Caterpillar	635	508	New
		Stamford	800	640	2016
	Telesom Subtotal =		**1,785**	**1,428**	
	Wajaale Total =		**2,435**	**1,948**	
Borama	Aloog		900	720	Shift 1 run 1am-7 am
			650	520	Shift 1 run 1am-7 am
			1,435	1,148	Shift 2 run 7am-4pm
			1,600	1,280	Shift 3 run 4pm-1am
			200	160	Old/standby unit
			200	160	Old/standby unit
			200	160	Old/standby unit
			200	160	Old/standby unit
	Aloog Subtotal =		**5,385**	**4,308**	
	Telesom--Site 1		1,375	1,100	New
			1,375	1,100	New
		Caterpillar	635	508	Working
		Cummins	800	640	Used at night
		Caterpillar	1,275	1,020	Down for maintenance
		Perkins		-	Not working
	Telesom--Site 2	Caterpillar	350	280	Working
		Iveco	250	200	Working
	Telesom Subtotal =		**6,060**	**4,848**	
	Borama Total =		**11,445**	**9,156**	
Dubur		Solar		18	Not working
		Mindong Yanan	135	108	New & working
		Marelli Mutorz	40	32	Working--used as backup
		Meccalite	60	48	Working--used at second site
		Solar		6	At boarding school. Run batteries 6 pm - 7 am
	Dubur Total =		**235**	**212**	
Sheikh	**Beder Power**	Marapco	110		6 am - 6 pm
		Weichi Halvy		80	Selected to connect to ESRES solar
		Crompton	200	160	
		Iveco	60	48	
		Lister	119	95	Selected to connect to ESRES solar
		Cummins	315	252	Selected to connect to ESRES solar, 6 pm - 11 pm
	Sheikh Total =		**804**	**635**	
Kalabaydh	Kayse Suleman	ECC	20	16	Operates 5:30 pm to 1 am
	Mohammad Ahmed	Perkins	38	30	Operates 5:30 pm to 1 am
	Telesom	Marelli	43	34	Working
		Deutz	20	16	Working
		Perkins	???		Not working
		Belk	20	16	Working
	Kalabaydh Total =		**141**	**112**	

Gabiley	Sompower	Caterpillar	600	480	
		FIM	400	320	
	Sompower Subtotal =		**1,000**	**800**	
	Telesom	Meccalite	250	200	2014, runs 12 hours/day
		Caterpillar	350	280	2015, runs 12 hours/day
		Iveco	160	128	Backup (in town)
	Telesom Subtotal =		**760**	**608**	
	Gabiley Total =		**1,760**	**1,408**	
Boon	Telesom	Iveco	30	24	Run 4 am - 12 noon, then from 6 pm - 2 am
		Adpower	30	24	Run from 12 noon to 6 pm (Gen off from 2 - 4 am, ru
	Boon Total =		**60**	**48**	
El-Afweyn	Telesom	FPT	100	80	2 am - 1pm (Alternate Days)
		Stamford	100	80	2 am - 1pm (Alternate Days)
		JCB	150	120	Unclear--need to verify
	El-Afweyn Total =		**350**	**280**	
Gar-Adag	Barre Power Station	Perkins	30	24	1 - 2 pm and 6 pm - 12 pm
Suuqsade	Homestar	Asta Korea		2.50	6 - 10 pm
Bali Gubadle	Bali Gubadle Power	Perkins	60	48	4 - 11 pm
		Unknown	50	40	11 pm - 2 am
	Bali Gubadle Total =		**110**	**88**	
Salahley	Tawakal	Perkins	60	48	6 - 12 pm (5 days/week)
		Unknown	40	32	6 - 12 pm (2 days/week)
	Salahley Total =		**100**	**80**	
Aynabo	Beder Electricity	Hummer	N/A	20	Wind 12 - 6 am
		Hummer	N/A	20	Wind 12 - 6 am
		Hummer	N/A	20	Wind Not working due to battery fault
		Marapco	65	52	6 - 12 pm
		Iveco	40	32	Back up
	Aynabo Total =		**105**	**144**	
Erigavo	Sonaag Electricity Power Company				
		Site 1			
		Cummins	1,250	1,000	5 - 12 pm
		Cummins	228	182	12 - 5 pm
		Cummins	825	660	4 - 12 am
		Cummins	300	240	Not working
		Site 2			
		Marapco	165	132	12 - 5 pm (Alternate Days)
		Marapco	165	132	12 - 5 pm (Alternate Days)
		Iveco	300	240	6 - 12 am and 6 - 12 pm (on Alternate Days)
		Iveco	300	240	12 - 6 pm and 12 - 6 am (on Alternate Days)
	Erigavo Total =		**3,533**	**2,826**	
Quljeed	Al-Nour	Unknown	35	28	6 - 12 pm
Berbera	**Berbera Electricity**	G3 Aksa	1,400	1,120	6 am - 6 pm (Alternate Days)
		G4 Aksa	1,400	1,120	6 pm - 6 am (Alternate Days)
		G5	1,400	1,120	6 pm - 6 am (Alternate Days)
		G6	1,400	1,120	6 am - 6 pm (Alternate Days)
		G7	1,000	800	Unit to be installed--capacity given in kW
		Wind	N/A	66	Not yet operating
	Berbera Total =		**6,600**	**5,346**	
Total All Sites* =			**26,902**	**21,666**	

*Note that in almost all cases, the units are not synchronised and therefore cannot operate simultaneously, although in some cases units feed separate distribution systems and therefore can operate simultaneously.
Total also excludes captive generation, which in some towns, particularly those with cell towers, can be significant.
Assumed Average Power Factor = 0.8

Annex 7: Complementary Studies: Wind Report

Wind mini-grids in Somaliland

Somaliland has a significant potential for wind energy generation. Wold Bank analysis conducted in 2016 suggest that for many parts of the region, including around the capital Hargeisa, average wind speeds at 100m are around 10 m/s. However, in the recent pilot for the Energy Security and Resource Efficiency in Somaliland (ESRES) project, there have been no wind generation solutions proposed. There have been several attempts by development agencies to develop small scale wind generation facilities in Somaliland, though these have been unsuccessful. This briefing note looks at some of the key challenges for small-scale wind generation, and compares wind generation economics against solar PV and diesel generation.

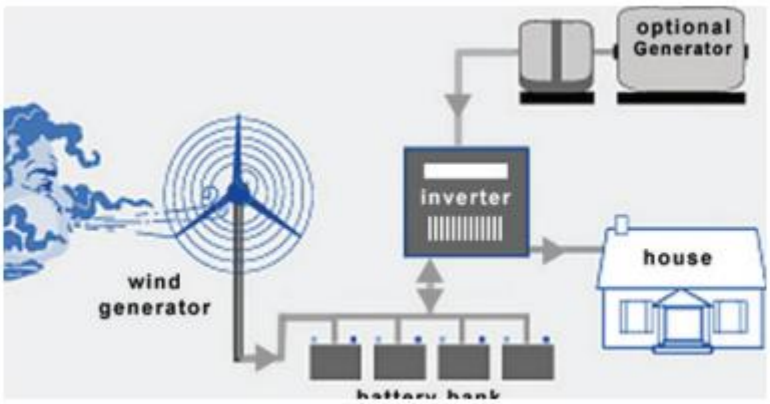
The structure of this note is as follows:

1. Overview of a small-scale wind facility;
2. Key challenges for small-scale wind;
3. Wind in East Africa;
4. Economics of small-scale wind;
5. Conclusions & recommendations.

1. Overview of a small-scale wind facility

In addition to the turbine itself, key components of the wind generation facility include the tower, inverter, control systems, safety systems and the optional addition of a battery bank (Figure 1 and Table 1).

Figure 1: A small-scale wind generation facility



Source: Alliance for Rural Electrification, 2012[21]

Table 1: Description of key components

Component	Description
Turbine	The wind will turn the rotor blades which are connected to the generator inside the nacelle. The generator uses the turning motion of the shaft to rotate a rotor which has oppositely charge magnets and is surrounded by copper wire loops. There are two types of turbines the Vertical Axis Wind Turbines (VAWTS) and the Horizontal Axis Wind Turbines (HAWTS) which are classified (by IRENA) according to size: • Very small <100kw • Small 100kw to 1MW • Large >1MW
Tower	There are two basic types of towers: self-supporting (free-standing) and guyed. The towers can be made of steel, concrete or composite materials. The tower height will depend on the length of the rotor blades and minimum separation between obstacles on the ground and rotor blade. Obstacles like trees would have to

[21] See: https://www.ruralelec.org/sites/default/files/are_small_wind_position_paper.pdf

Component	Description
	be accounted for any change in height during operation. Generally, the height range of the towers is between 15m to 30m for very small and small wind turbines. Most manufacturers will supply the tower and the foundation base as well so in this case its best to check certification with reputable certifying companies e.g. DNV-GL. If the tower has been certified and undergone IEC Standard tests then it should suffice to deploy on site obviously dependent on manufacturer's specifications.
Controller	Can include pitch, yaw and turbine control but will vary dependent on WTG technology.
Storage batteries	Storage batteries in figure 1 would be charged when the SMWT is producing power. When the wind stops, the batteries can then be discharged to supply power to the "house/grid".
Inverter	Needed when you have to change your DC (direct current) voltage from the wind turbine to an AC (alternating current) voltage.
Wiring	Electrical connection (power cable) from the SMWT to the house/grid or wherever the power will need to be delivered.
Electrical disconnect switch	For protection purposes in case of any fault conditions or if you need to isolate the SMWT from the load (houses, or any electrical equipment connected to the SMWT).
Grounding system	Earthing purposes to allow for an additional path to ground in the event of short circuit.
Tower foundations	Depending on the height and type of tower used will determine the depth and design the foundation will require to ensure the tower can withstand the forces from the turbine.

Source: Mott MacDonald

Grid connected and mini-grid wind turbine design differ in several areas (Table 2). A key difference is that surplus power cannot be supplied to the local grid, but must either be consumed at the time of generation, stored in a battery or wasted. The implications of this are that sizing the wind turbine must take account of expected demand, storage capacity and the size and type of other generator technologies on the system.

Table 2: Difference between grid connected and mini-grid connected wind generation

Grid Connected	Mini-grid connected
Voltage and frequency	
Voltage and frequency are defined by the grid and cannot be influenced by the small-scale WTG.	Voltage dependent on the load which in most cases would be the typical household voltage of 230 Vac. Frequency will be determined by the load which in most cases will either be a constant 50Hz or 60 Hz dependent on the specific grid power frequency.
Capacity	
The operational capacity is determined by the supply source	Operational capacity is matched to the demand
Surplus power	
Any surplus power can be fed back from the grid, therefore, low load factors which are typifying characteristics of rural electricity do not affect GC systems, since the grid acts as an infinite storage unit facilitating continuous operation of the system and also eliminating additional costs on storage.	These systems are not connected to the utility grid as a result of which they need batteries for storage of electricity produced during off-peak demand periods, leading to extra battery and storage costs, or else the excess power generated has to be "wasted".

Source: Mott MacDonald

2. Key challenges for small-scale wind;

There are two major challenges to developing small scale wind generation facilities in East Africa. The first is making the economic case against solar PV (Table 4). The second is securing the long term operation and maintenance of the facility.

Maintenance requirements include greasing, inspection for faults and checking guy wires, screws and bolts annually or bi-annually. Heavier maintenance may be required after a couple of years, which could include refurbishing the rotor blades and changing over the guy wires[22]. This kind of maintenance requires a suitably trained technician able to identify faults and fix them. Access to spare parts, especially in rural locations, is generally limited. Even when spares can be sourced, long waiting times can mean lost generation.

[22] See: https://www.ruralelec.org/sites/default/files/are_small_wind_position_paper.pdf

Given the significant maintenance challenges in isolated communities, choosing reliable turbine designs becomes more important. Vertical Axis Wind Turbines (VAWTs), as opposed to Horizontal Axis Wind Turbines (HAWTs), can offer an option with potentially lower maintenance requirements (Table 3). There are two key advantages of VAWTs: firstly, that a VAWT does not need to be oriented to the wind to generate electricity, doing away with the requirement for pitch and yaw control components. Secondly, the gearbox and generator of a HAWT is located in the nacelle at the top of the tower. For a VAWT, these key components can be located close to ground level for easier access. However, VAWTs generally have a higher capex cost, and HAWTs are generally still the preferred option.

Table 3: Comparison of horizontal and vertical axis wind turbines

Description	HAWT	VAWT
Mechanical joint points	2	1
Need of a helm	yes	no
Works with winds >25m/s	no	yes
Works with turbulent winds	poorly	fine
Resistance to hurricanes	poor	high
Relative complexity	high	low
Relative need of maintenance	high	low

Source: Mott MacDonald, also based on *Vertical-axis wind turbines: what makes them better?*[23]

3. Wind in East Africa

Small scale wind power in East Africa has not had the recent successes of solar PV. However, there have been a few large-scale wind farms developed, such as Lake Turkana (310 MW) in Kenya, Ashegoda (120 MW) and Asama (51 MW) in Ethiopia. Lake Turkana, is the largest in Africa and has 365 wind turbines (Vestas V52 850 kW), with the electrical balance of plant delivered by Siemens.

On the smaller scale, data on the use of wind power in East Africa is limited. The European Union Energy Initiative reports that there are two mini-grids in Kenya with wind power connected[24]. One in Marsabit county comprising of 500 kW wind and 560 kW diesel genset. Second in Wajir county at Habaswein including a 60 kW wind facility (3x20 kW Layer Electronics turbines), with a 360 kW diesel genset and a 30 kW solar PV facility. In Tanzania, there are at least 11 sites where locally made, very small turbines (<100 kW) have been connected to mini-grids[25]. Tanzania has a supportive policy for renewable energy connections to mini-grids, offering uprated Feed in Tariffs (FiTs) (of US$ 181/ kWh) for solar and wind of up to 1 MW capacity connecting to mini-grids.

To procure a wind generation facility, we would expect the wind turbine supplier to provide a full Engineering Procurement Construction (EPC)-wrap, so that the supplier would be responsible for finding a local engineering company to install the wind turbine and tower. Some potential wind turbine companies are listed below:

- Kestrel Wind Turbines – Kestrel are mainly in South Africa with installation in the southern African region, Europe and USA;
- Zonhan wind and solar power products –manufacturers of small wind turbines, solar panels, micro hydro turbines, inverters and controllers;
- PalmTree Power – Manufacturers of 300kW wind turbines designed for isolated grid and distribution generation applications in Africa and other developing countries;
- Bergey Turbines - who installed a 7.5 kW system in Laisamis, Kenya;
- UGE: Supply Vertical Axis Wind Turbines;

[23] See: http://www.windpowerengineering.com/design/vertical-axis-wind-turbines/?_sm_au_=inVnWTqTDfSWMWTQ

[24] See: http://www.minigridpolicytoolkit.euei-pdf.org/casestudies/kenya

[25] See: https://www.giz.de/fachexpertise/downloads/2015-karomba-presentation-tansania.pdf

- Layer Electronic – Italian company providing small scale solar and wind systems, including a 3x20kW solution for a mini-grid in Habaswein, Kenya; and
- Vergnet – French company who provide turnkey small scale solar and wind solutions in Africa.

4. Economics of small-scale wind;

Wind generation facilities become considerably more expensive in terms of $/kW as they decrease in size. IRENA quote the capex price range of $1,500/kW to $3,500/kW for large facilities (greater than 1MW), rising to between $6,000/kW and $8,500/kW for very small (less than 100 kW facilities).

In this section, we provide a simple economic comparison of wind, solar and diesel at two scales: a 60 kW facility and 1.1 MW facility. The 60 kW facility is based on the 3x20 kW Layer Electronics turbine facility installed in Habaswein, Kenya. The 1.1 MW facility is based on the Vergnet GEV 275 (4 x 275kW)[26]. This turbine is chosen for the analysis as it has been used in for mini-grids previously[27], and is one of the larger design that doesn't need cranes to install; the tower can be tilted up for installation, and lowered by just two people for maintenance and cleaning[28].

Our economic analysis uses the assumptions set out in Table. The results of our analysis suggest that at the very small scale, wind is uncompetitive against Solar PV (see Figure). However, at the large scale wind proves to be cost competitive. Note that the results are sensitive to input assumptions, particularly on cost, wind speed and solar PV load factor. Alongside this briefing paper, we provide a simple decision tool which allows the user to select required inputs and produce the Levelised Cost of Energy (LCoE) for wind, solar PV and diesel

Table 4: Economic assumptions

	Wind[29]		PV		Diesel[30]	
	Very small	Large	Very small	Large	Very small	Large
Turbine selection	Layer Electronics (3 x 20 kW)	Vergnet GEV 275 (4 x 275kW)	Small scale	Large scale	Small	Large
Capex cost ($/kW)	6,500	2,500	2,750	1,750	163	343
Opex cost ($/kW)	65	65	41	26	4	15
Discount rate	10%	10%	10%	10%	10%	10%
PV load factors	n/a	n/a	24.4%[31]	24.4%	n/a	n/a
Wind only						
Hub height	30	50	n/a	n/a	n/a	n/a
Average wind speed @ 100m	10[32]		n/a	n/a	n/a	n/a
Location	Agricultural land with some houses		n/a	n/a	n/a	n/a
Diesel only						

[26] The advantages of having several smaller turbines, rather than one large turbine, are that: less overall downtime (when one turbine is being maintained, the other can still be in use), simpler installation requirements (i.e. tilt up rather than crane installation) and transport of larger blades can be an issue for remote locations.

[27] In Eritrea, Guadeloupe and Australia

[28] See: http://www.vergnet.com/wp-content/uploads/2016/01/DC-11-00-01-EN_GEV_MP-C_275_kW.pdf

[29] Costs for wind and solar are taken as the mid-point of the ranges quoted for IRENA, see: http://www.irena.org/DocumentDownloads/Publications/IRENA_Innovation_Outlook_Minigrids_2016.pdf

[30] All diesel assumptions (apart from the fuel price projection), sourced from *Feasibility study of renewable energy based microgrid system in Somaliland's urban centers,* 2014, Abdirahman Mohamed Abdilah et al.

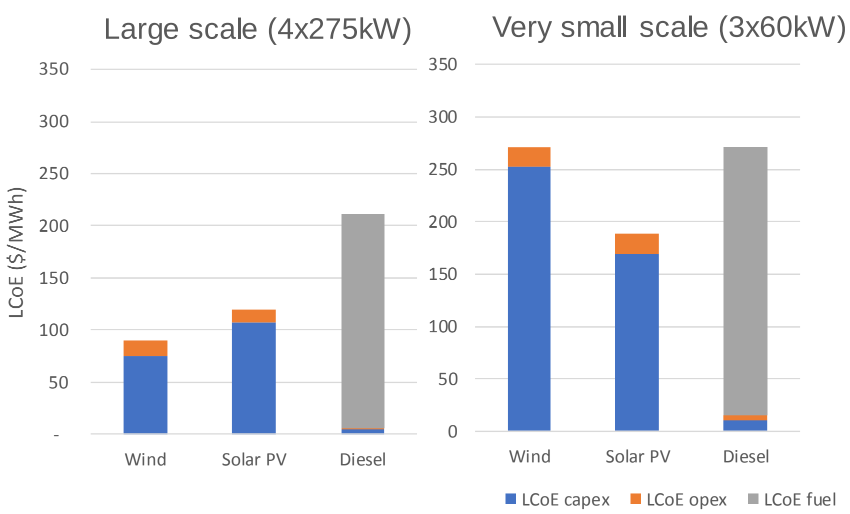
[31] Load factor for solar PV from *Feasibility study of renewable energy based microgrid system in Somaliland's urban centers,* 2014, Abdirahman Mohamed Abdilah et al.

[32] Estimated from the wind resource map produced by ESMAP for the World Bank in April 2016

	Wind[29]		PV		Diesel[30]	
Diesel price projection	n/a	n/a	n/a	n/a	IEA new policies[33]	IEA new policies

Source: Mott MacDonald, based on several sources (see footnotes)

Figure 2: Economic comparison of wind, solar PV and diesel



Source: Mott MacDonald analysis

At the large scale, wind power appears to be the most competitive, with an LCoE of $89/MWh, about 25% less that for PV at $120/MWh. However, at the very small scale, the positions are reversed – wind is comparable to diesel at $271/MWh, whereas PV is about 30% less at $188/MWhh. The analysis highlights the importance of scale when considering technology choice for mini-grids.

5. Conclusions & recommendations.

Somaliland has a significant wind resource which is worth exploring further. The key challenges for developing a project are ensuring long term operation and maintenance, and making the economic case against solar PV. Wind turbines need more maintenance and a greater level of skill to maintain. At the very small scale, wind appears to be uncompetitive against solar PV, however, at the large scale (>1MW), with favourable wind conditions (9 m/s average), wind appears to be more cost effective. There are several potential turbine suppliers who should be able to provide turnkey installations in the East Africa region. Note that this analysis has been limited to desk based research, with no additional field work taking place to establish appropriate sites or detailed costing.

For further investigation of the potential for wind development in Somaliland, we recommend the following:

1. Engage with potential suppliers to establish the willingness and capability to operate in Somaliland.
2. Identify local engineering companies that could be upskilled for installation and maintenance of wind turbines.
3. Investigate wind turbines with low installation maintenance requirements (i.e. where the towers can be tilted), that can be installed at a cost-effective scale (around 1 MW)
4. Undertake grid integration studies for the larger mini-grids to determine the capacity of wind which could be connected, or reinforcements that would allow the connection of 1 MW wind generation facility.

[33] IEA World Energy Outlook (2016) new policies crude oil forecast for 2030 is US$ 111/bbl. We apply linear interpolation to 2030 with a current price of $65/bbl, and assume a 50% premium on diesel price above crude. This translates to a current price of 61 US$cts/l.

Annex 8: Complementary Studies: Battery Report

Battery Report

1. Mini-grid main components

In this section, we will explain the main components that are required for typical mini-grid applications, their main types and features. We will focus on: PV modules, PV and battery inverters, mounting structures, batteries and the management systems.

1.1 PV Modules

Solar modules are passive elements capable of transforming the irradiance from the sun to DC power. There are three main categories of solar PV technologies:

- Crystalline silicon technology including:
  - Mono-crystalline silicon; and
  - Poly-crystalline silicon panels.
- Thin film technology including:
  - Amorphous Silicon;
  - CIGS and CIS panels (Copper Indium Gallium Selenide and Copper Indium Selenide);
  - CdTe panels (Cadmium Telluride).
- High efficiency panels.

Key features that determine the performance of PV modules are:

- Efficiency – It refers to the amount of solar energy that is converted into useful electrical energy;
- Temperature behaviour – It refers to the reduction in power output from the PV module when its temperature rises above 25°C;
- Degradation – It refers to the naturally occurring reduction of a panel's maximum power output due to ageing.

Up to date, the technologies which are mostly used in the development of large and medium scale PV plants are mainly poly-crystalline silicon and CdTe. Table 1: shows a comparative of the main technical features of these two technologies.

Table 1: PV technology specifications

Module Property	Poly-crystalline silicon	CdTe	Mott MacDonald comments
Semiconductor Material	Multiple silicon crystals	Cadmium Telluride	-
Efficiency at STC* (%)	15 – 17	14 – 16	Poly crystalline silicon panels generally are more effective in converting solar radiation into electricity, as they are a more mature technology and have undergone more laboratory testing compared to CdTe
Temperature behaviour (%/°C)	-0.40 to – 0.43	-0.29 to – 0.34	CdTe modules experience a lower reduction in power as their temperature increases.
Maximum operating temperature (°C)	85	85	Both PV technologies can withstand up to 85°C.
Degradation(%/year)	0.3 – 0.7	0.5 – 0.7	Both technologies have similar degradation rates.

Module Property	Poly-crystalline silicon	CdTe	Mott MacDonald comments
Nominal power (W)	245 – 320	100 – 117.5	
Module area (m2)	1.6 – 2.0	0.72	Multi crystalline silicon panels have either 60 or 72 (rectangular) cells. CdTe cells are stripe shaped.
Frame material	Anodised aluminium alloy	None	Frameless CdTe modules facilitate the cleaning of the panels and also have less drag against sand and dust.
Backside cover	Polymer plastic (such as PVF) or composite sheet	Tempered glass	Tempered glass is more resistant to desert storms than plastic.
Operational life	25 years	25 years	Both technologies come with a 25 year performance warranty.

Source: MM assessment

1.2 Mounting structure

PV modules can be installed on either fixed or solar tracking structures.

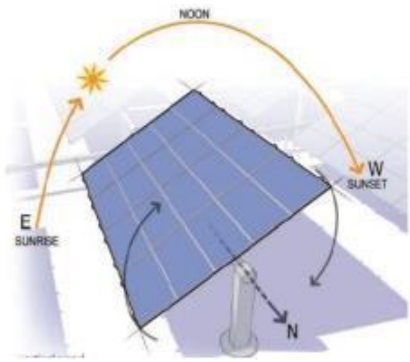
In fixed structure systems (see inFigure), the arrays of PV modules are mounted on stationary bases. The plane of the arrays is defined by fixed tilt angle and orientation which are usually chosen to optimise the amount of solar irradiation to be captured at the specific project location.

Solar tracking structures allow the array of PV modules to follow the sun's pathway, Figurewhich results in an increased collection of solar energy mainly in the early mornings and late afternoons. Solar tracking structures include Single-axis (see in Figure), which is the most commonly used, and Dual-axis systems.

Figure 1: Fixed structure

Source: Mott MacDonald

Figure 2: Single-axis solar tracker



Source: Mott MacDonald

1.3 PV & Battery inverters

The two sorts of inverters required in this type of applications will be PV inverters and Battery inverters which are briefly described in the following sub-sections.

1.3.1 PV inverters

The PV inverter transforms the direct current (DC) from the PV modules into alternating current (AC) to adapt to the grid, understanding any grid created by Diesel Generators, battery inverters or the national grid for example.

A grid-connected PV inverter will have as main features: anti-islanding protection, voltage regulation and reactive power regulation.

In the case PV inverters are used in off-grid and mini-grid applications, other features will be added such as:

- Configurable ranges of voltage and frequency to adapt them to the values of a grid generated by Diesel generators.
- Capability to modify the Maximum Power Point of the PV field from communications or evaluating directly the frequency of the grid in order to adapt the PV power output to the grid needs.

There are three different inverter design concepts; central, string and micro inverters. Medium and large-scale hybrid systems mainly use central inverters.

1.3.2 Battery inverters

Battery inverters transform the direct current from the battery to an alternative current (AC) adapted to the grid, and transform the alternative current (AC) to direct current (DC) adapted to the charge conditions of the batteries.

After the Battery management system (BMS), the inverter implements the second level of control, managing the battery charge and different charge algorithms required; this depends on the technology of battery such as: Li-on and Lead-acid. Moreover, they incorporate functionalities to ensure the operational lifetime of the battery, verifying parameters like the State of Health (SoH) State of Charge (SoC) and Depth of Discharge (DoD) of the batteries.

1.3.3 PV & Battery inverters specifications

Table shows the specifications that PV inverters and the Battery inverters share each other when the inverter concept is with central inverters.

Table 2: PV & Battery inverters Main Specification

Parameter	Typical Value	Mott MacDonald Comment
Nominal AC Power	300 – 1000kW	It is foreseen that an increase up to 2500kW is attainable;
Configuration	Modular or Conventional (Single Block)	The modular configuration of inverters, whereby, for example, a 1000kW inverter may consist of 4 units of 250kW, provides ease in installation and maintenance.
Installation	Indoors or outdoors	The inverters can be installed either indoors (within a cabin) or outdoors. Considering the high temperatures experienced in Somaliland, adequate means to control the inverter temperature is a key design parameter. Outdoor and indoor installations will have to incorporate suitable ventilation systems, for which regular maintenance is necessary; in addition, outdoor systems may require some means of shading in order to keep the temperature within an acceptable range.
Operating Temperature	-10ºC to 50ºC (without de-rating) 50ºC to 55ºC (with de-rating)	Inverters are usually able to operate efficiently within a temperature range up to 50ºC. Beyond this degree, inverters switch to temperature derating mode in order to reduce the stress on the electrical components.
IP Protection	IP54 (electronics equipment) IP43 (connection area)	For this kind of application at least IP54 rating to electronics equipment of the inverter should be selected which provides protection from dust and splashing water. A lower

Parameter	Typical Value	Mott MacDonald Comment
		protection (IP43) is sufficient for the connection area.

Source: MM assessment

1.4 Batteries

In this section, we will explain briefly the Battery Management System (BMS) and the two most important technologies of the batteries for off-grid and mini-grids.

1.4.1 Battery Management System

The BMS is the first level of supervisory control that is directly connected to the battery modules. The main function of the BMS is to monitor the cells to maximise performance and ensure the safe operation of the system. Modern BMS for large scale storage systems may vary to some degree depending on the battery technology employed as certain operating parameters are more critical for some systems compared to others. Lithium ion batteries require accurate thermal monitoring and control to ensure thermal runaway does not occur. The BMS typically employs algorithms to estimate the state of charge of the batteries and in most cases is able to estimate the state of degradation to optimise performance based on the system life cycle. In most cases, the BMS is supplied as part of the complete battery module by the battery manufacturer as it is technology and system dependent.

1.4.2 Lead Acid Batteries

Lead acid batteries are used typically in small and medium scale mini-grids applications. The battery is highly scalable with respect to power and energy ratings which ranges from low kW to multi MW systems. The standard lead acid battery operates with moderate cycle efficiencies of >70% and a long life cycle up to 15 years depending on the operating conditions. It has a relatively low cost range when compared to the other battery types and the major cell components (mainly lead) can be efficiently recycled at the end of product life with up to 97% recovery rates.

The life cycle of the battery can be severely limited when operated at high discharge resulting from the formation of a lead sulphate layer on the negative electrode. This phenomenon is not completely reversible during the recharging process and leads to a reduction in electrode surface area and poor life cycle performance. Other limitations include the operating temperature range and the rate of charge. Operation at >40°C leads to lower life cycle performance and charging the cell at high current densities enforces hydrogen generation that leads to a further reduction in cycle efficiency and an explosion hazard.

1.4.3 Lithium Ion Batteries

Li-Ion battery systems have very good energy and power densities ranging from 200 to 500Wh/kg and 150 to 500W/kg and is a good candidate where the application requires fast response times, small dimensions and weight. The systems can achieve high cycling efficiencies (>95%), maintain low standby losses and deliver good tolerance towards cycling. The estimated lifespan of the systems can range up to 15 years with more than 3000 cycles.

Li-ion systems are rapidly gaining market share when compared to competing technologies. The main drawback of the system is the capital cost, particularly the energy capital cost, that has until recently limited the deployment for bulk energy storage applications. As the technology reaches full commercialisation, it is expected that the costs will become more comparable with competing technologies for larger installations and turn out to be the technology of choice for most applications.

1.4.4 Lithium-Ion and Lead-Acid technology specifications

Table 3 shows the main features of the technologies Li-on and Lead-Acid.

Table 3: Li-on and Lead-Acid comparative

	Lithium-Ion	Lead-Acid
Long Life time*	20 years / 7000cycles	7 years / 2000cycles
End of life: still usable	70% remaining capacity after 20 years	Sudden death
High Energy Density	140Wh/kg	30Wh/kg
High Efficiency	>To 95%	80%
Operating temperature	0 – 40°C	15 – 40°C
Maintenance	Maintenance free	Need of maintenance

Source: Saft technologies

*Information related to lifespan and cycles have to be carefully analysed due to these parameters vary with the DoD and temperature.

1.4.5 Battery technology suppliers

Potential battery technology suppliers are listed in the table below.

Table 4: Battery technology supplier

Supplier	Technology	Application	Comments
EXIDE	Lead acid (OPzS and OPzV)	Load tracking	Presence in Africa in small scale projects.
Tesvolt	Lithium-ion	Load tracking	Experience in Rwanda for an offgrid ESS of 2.5MW – 2.5MWh.
Aquion Energy	Aqueous Hybrid Ion (AHI™)	Load tracking	Experience in Kenia with two 106kWh off-grid-plus-storage-microgrids.
Saft	Lithium-ion	Fuel saving and Load tracking	Experience mainly in South America offgrid projects. Example: 5MW – 1,3MWh in Puerto Rico.
Tesla	Lithium-ion	Load tracking	Wide experience in several application. Example: solar PV utility scale project on Hawaiian island with an ESS of 13MW - 52MWh, for shifting solar production.

Source: Mott MacDonald

1.5 Energy Management System and Grid Measure unit

Energy Management System (EMS) is the device in charge to receive the inputs of voltage/current of the grid measure unit and command the inverters to reduce or increase the power supplied. When an Energy Storage System (ESS) is added the EMS also will be in charge to control it.

The main controls of the EMS performed on the plant will depend on the application. Manufacturers have developed standard software to control each application during the last years, allowing a quick configuration of the system in field, however as per the specific requirements of the plants, ad-hoc solutions could be required. Applications where the software is more advance are: Integration of PV in Diesel Generator grids with and without ESS, capacity firming and load levelling.

If a communication connection between the EMS and the Power Generators to allow the devices to share the value of their parameters is not possible, a grid a measure unit will be required, that basically will be formed by current transformers to measure the current and voltage connections to measure the voltage to know the different values of the grid in real time.

2. Applications

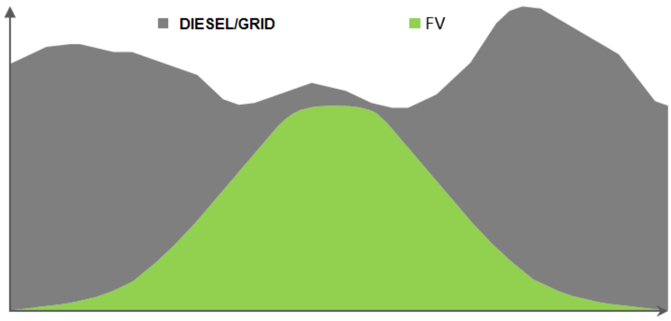
2.1 Type of applications

The following three (3) applications are the most used for medium and large off-grid and mini-grid applications.

2.1.1 Fuel Saving Application (Diesel + PV)

This application is suitable for heavy industries as well as villages and towns that use Diesel Generators to feed their consumptions. With typical requirements from hundreds of kilowatts to tens of megawatts, these industries and villages are shifting from Diesel Generation solutions to a Hybrid Solutions based on Diesel Generation & PV in order to bring economic and environmental benefits, reducing the consumption of conventional energy sources, increasing the service life of power generators, as well as decreasing the periodicity of maintenance work. Figure shows how the PV generation (see in green) helps to reduce the Diesel Consumption (see in grey) for a daily load profile.

Figure 3: Fuel saving PV & Diesel generation

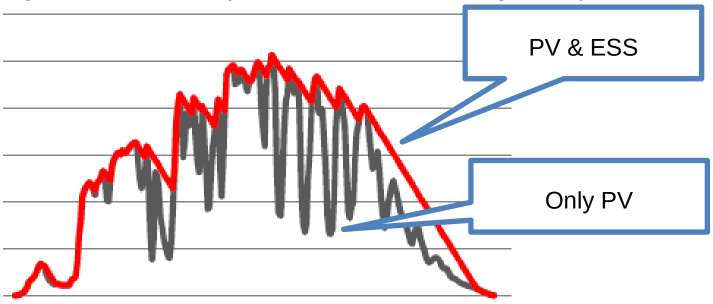


Source: Zigor corporation

2.1.2 Fuel Saving Application (Diesel + PV + Batteries)

Depends on different technical and financial factors, we can find solutions that integrate storage in addition the PV to increase the PV penetration and improve the grid stability. The battery is dimensioned to be able to handle severe drops of PV generation due to clouds passing and allows the Diesel Generator to respond better within its time response. As shown in Figure the PV & Battery solution (red line) smooths the severe PV power drop owing to the intermittent passing of clouds.

Figure 4: PV & Battery and PV behaviour facing cloud pass



Source: Ingeteam

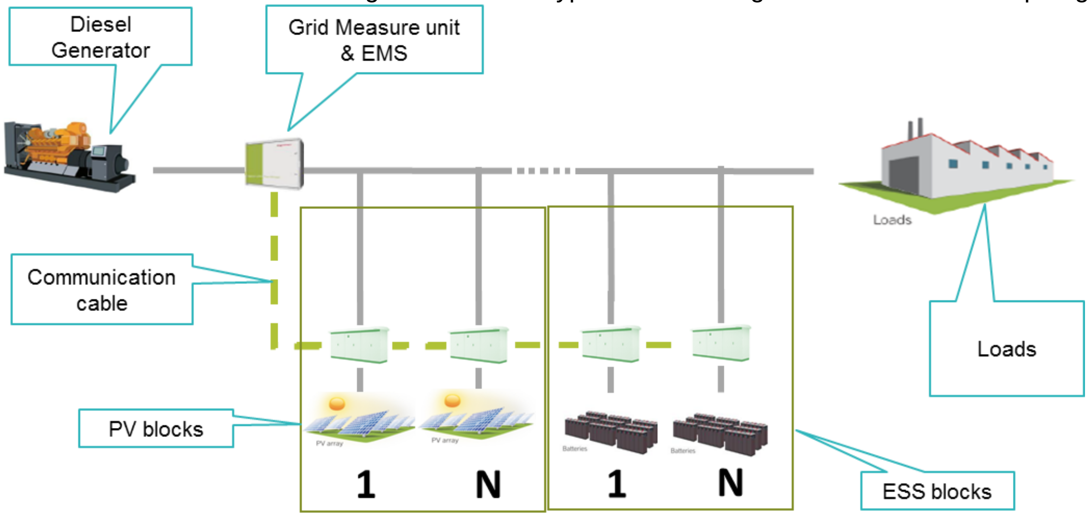
2.1.3 Load tracking Application (Diesel + PV + Batteries).

In this application, the PV energy is in charge to support the Diesel Generator and provide energy to the batteries during daytime and the batteries are in charge to track the load during the night or another specific period. This type of solution is more demanding of battery energy than the Fuel Saving application (Diesel + PV + Batteries).

2.2 Topology

Figure shows the topology that the Fuel Saving and the Load tracking applications require. In the case of fuel saving applications the batteries could be optional.

Figure 5: Mini-grids typical generation topology



The topology shows how the PV blocks and the ESS blocks are connected to the existing grid formed by the Diesel Generator to feed the consumptions.

We have to take in consideration that the Diesel Generation could consist in several units which works sequentially.

PV Blocks includes PV modules and PV inverters. The PV inverters further the standard specifications, will have to modify the MPP(Maximum Power Point) when the EMS requires it.

ESS blocks consists of batteries, the Battery monitor system (BMS) and bidirectional inverters (battery inverters) that will allow the charge and discharge of the batteries and adapt the output to the requirements of the connection point.

The Grid Measure Unit is connected to the grid generated by the Diesel Generator to provide the values of the current and voltage of the system in real time.

The EMS gathers the real time data from the Grid Measure Unit, the PV inverters and the ESS to control the PV output and the ESS output according to the application requirements.

2.3 Operation modes

The operation mode varies depending on the application, as shown in the below table.

Table 5: Operation modes under different conditions

Events	Fuel saving (Diesel + PV)	Fuel saving (Diesel + PV + Batteries)	Load tracking Application (Diesel + PV + Batteries)
PV power less than the loads	The PV plant will not have any constraint and the inverters will search the MPP of the plant to maximize the energy production.		
			The batteries will provide part of the energy required
	The Diesel Generator will cover the rest of the energy required from the loads.		
		The EMS will prioritise the charge of the batteries.	

Events	Fuel saving (Diesel + PV)	Fuel saving (Diesel + PV + Batteries)	Load tracking Application (Diesel + PV + Batteries)
PV power greater than the loads	The EMS will require the PV inverters to reduce the PV output power.	If the batteries are charged, the EMS will require the PV inverters to reduce the PV output power.	
Abrupt reduction of PV generation	The Diesel Generator has to be able to provide the energy required to the loads, hence the spinning reserve has to be taken in consideration in the design phase.	The EMS will require the ESS to provide the energy and ramping-down with the foreseen slope to allow the Diesel Generator to maintain the stability of the system. Once the system has recovered the EMS will control the charge of the battery, to be ready for the next event.	

Source: Mott MacDonald

2.4 500 kW Hybrid comparison

Table 6: shows a base case comparison between the three applications explained above. To undertake this exercise, we have assumed a load profile for a 500kWac hybrid facility output. The figures shown are indicative and could change after a more deepen analysis for the specific projects.

Table 6: 500kW Hybrid Comparison

	Fuel saving (Diesel + PV)	Fuel saving (Diesel + PV + Batteries)	Load tracking Application (Diesel + PV + Batteries)
Consumption			
Peak (kW)	350		
Average Peak consumption (kW)	245		
Average Low consumption (kW)	70		
Diesel			
Diesel generator power (kW)	**500**		
Diesel generator energy (MWh/year)	1188		
PV			
PV power (kWp)	125	200	500
Solar resource (kWh/kWp)	1600		
PV energy (MWh/year)	196	314	800
Storage			
Technology	Lithium-Ion		
Storage time (h)	-	0.5	2.5
Storage power (kW)	-	155	245
Storage energy (MWh/year)	-	29	224
System penetration	16%	26%	65%
Costs			
PV (KUSD)	140 - 155	225 - 250	580 - 620
ESS (KUSD)	-	50 - 55	370 - 400

Source: Mott MacDonald

The assumptions stated in Table are the following:

- The Diesel AC output capacity is 500kW
- Based on the Diesel capacity we have define the key load parameters (peak, average peak consumption and average off-peak consumption).

- We have considered a peak and off-peak consumption period of 9 and 15 hours respectively.
- The expected energy of the Diesel Generator is based on the consumption profile assumptions.
- The PV power have been define according a conservative cryteria
- We have considered a fix mounting PV plant with an optimum slope and azimuth in a random specific location of Somalliland.
- The PR calculated by PVGIS tool (European Commission) is 74%
- The Storage technology selected is Lithium-Ion.
- The storage has been defined as per the application requirements according the common market practice.
- The costs have been define according our in-house knowledge of the market.

3. Construction indications

Below we show a list of elements that are needed to take in consideration when developing and building this type of projects:

1. Site accessibility, with respect to roads, ports and airports access, transport of heavy equipment, site ingress and egress, and required space and infrastructure necessary to facilitate constructability and correct operation of the Solar PV and ESS facilities;
2. Local climatic conditions, especially in Somaliland the ambient temperature will be an important factor in the design and construction phase. It will be required to assure that the PV inverters, Battery inverters and the batteries can be maintained within their temperature range, using the appropriate air ventilation and/or air conditioning system.
3. Ground conditions, including a review of the relevant geotechnical and geohydrological studies also in relation to the solution envisaged for the structures foundation and the batteries location;
4. Water supply facilities and effect on cleaning regime of the plant;
5. To procure the hybrid facility we would expect a full turnkey Engineering Procurement and Construction (EPC) Contract, moreover we would expect to have the same manufacturer for the PV inverter, Battery inverter and the EMS to guarantee the software integration.
6. All the equipment must have the certification and warranties updated. We highlight that the typical warranties for the inverters should be at least 5 years and the batteries will depend on the type, having 1 – 2 years for lead acid batteries and 5 – 10 years for Lithium-Ion.
7. During the construction, the EPC contractor must follow the manufacturer instructions. Typically, battery manufacturers provide containers with the batteries, the BMS, the air conditioning system, all cabling, setting and testing which will do easy the battery facility installation. If not, the design and construction of the battery room will be an important task during the project.
8. After the construction and apart from other type of tests, the operation mode will have to be carefully tested.
9. Prior the construction all the permits will have to be achieved.

4. Operation and maintenance indications

Below, we show a list of elements that should be taken in consideration for the operation and maintenance of this type of projects:

1. During the whole plant life-time we expect a full O&M Contract to be in place for the operation and maintenance of the plant.
2. The plant needs to be equipped with a monitoring system functioning 24 hours per day every day of the year, and additionally on-site monitoring should be provided to monitor the key hybrid system parameters such us SoC (State of Charge), DoD (Deep of Discharge) SoH (State of Health) for the ESS, the PV generation, PV curtailment, etc;
3. The structure of personnel dedicated to the plant O&M should be defined, including the number of staff on site and their qualifications. We note that, in case local staff is contracted, it must be provided with the necessary training by the experienced O&M Contractor. Taking in consideration the country

specifics, we recommend the use of low maintenance components for all the hybrid facility specially in the battery and the mounting structure side.

4. As part of the plant O&M, a schedule of the preventative maintenance activities should be compiled, so to ensure that they will be performed regularly and prevent unnecessary plant downtime, Specific preventive actions related with the control temperature will be important such us:
    a. The temperature control on the battery room;
    b. Temperature control inside the inverters;
    c. air conditioning and/or air ventilation work;
5. A procedure to perform any corrective maintenance should be defined, together with the relative response time. We would expect that different response times are defined according to the severity of the fault;
6. Monthly reports should be issued, reporting on the plant performance, weather conditions, maintenance activities performed, incidents occurred and spare part management;
7. A list of minimum spare parts stock to be kept on site must be issued as part of the EPC and O&M contracts. The necessary spares must be stored in a dedicated location on the site, and in such conditions to assure they will not be damaged or exposed to conditions that could cause deterioration. With regards to the PV spares it should be noted that, as the hybrid facility is designed for remote locations, a larger spare part stock should be kept on site that normally observed for standard PV plants, due to the difficult or time-consuming site accessibility, with regards the ESS, we recommend avoid having batteries stored due to the fact that even if they are not connected to the system, they would need to be charged in regular basis in order to have them ready for operation as when needed.
8. A cleaning strategy and cleaning regime must be elaborated in accordance with the ambient conditions and availability of water supply.

5. Conclusions & recommendations.

1. Somaliland is inside of the sunbelt which implies high rates of solar irradiation. Solar irradiation usually matches quite well with consumption profiles for this type of locations allowing the hybrid system to reduce the battery storage.
2. Currently, thanks to satellite databases, the energy yield assessment for a specific locations can be undertaken with a moderate uncertainty which is very useful to deploy hybrid strategies that require to be run in the short term.
3. Lithium-Ion storage technology is suitable for fuel saving and load tracking applications, for medium and large projects. This type of batteries are gaining the market battle to the Lead-acid technology. Although there are no many references of these type of applications available in Africa. The technology is mature.
4. The challenge in Somaliland will come from the availability of suitable EPC and O&M Contractors and the identification of local engineering companies that can provide engineering, installation and maintenance of the system for the long term and that can manage the relevant warranties from the company suppliers.

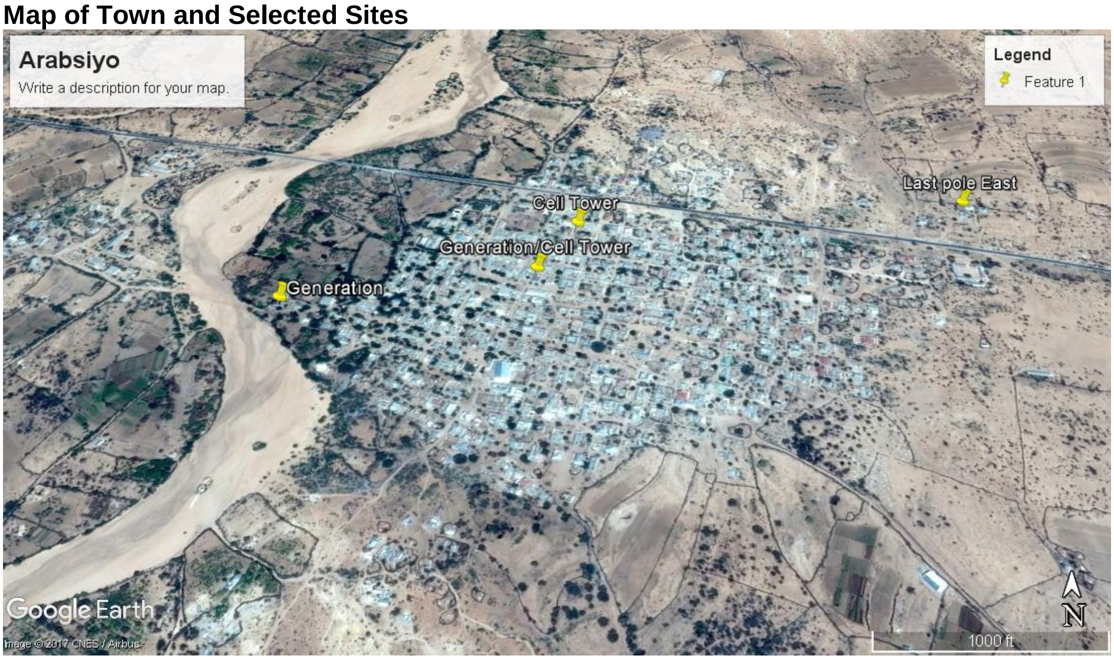
Annex 9: Village summary sheets

Aynabo

Reported and Estimated Customers in Aynabo

Customer Type/ Usage	Total	Grid	Own Generation
Household	12,000	429	
Shop			
Restaurant	7	7	
Hotel	2	1	1
School	4	1	1
MCH/Clinic	1	1	
Hospital	2	2	
Mosque	10	7	-
Cell Tower	1	1	
Fuel Station	2	2	
Water Pump	1	-	1

Map of Town and Selected Sites

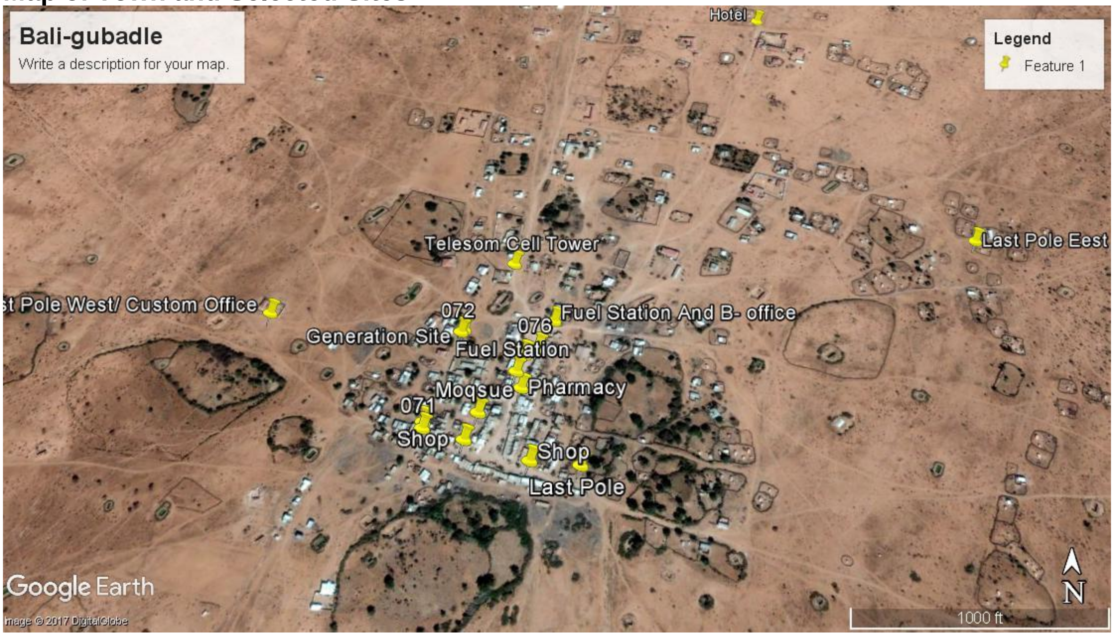


Bali Gubadle

Reported and Estimated Customers in Bali Gubadle

Customer Type/ Usage	Total	Grid	Own Generation
Household	3,000		
Shop	200	80	-
Restaurant	6	6	
Hotel	3	3	
School	4	4	
MCH/Clinic	1	-	1
Hospital	2	1	1
Mosque	8	7	
Cell Tower	2	1	1
Fuel Station	2	1	1
Water Pump	-	-	

Map of Town and Selected Sites

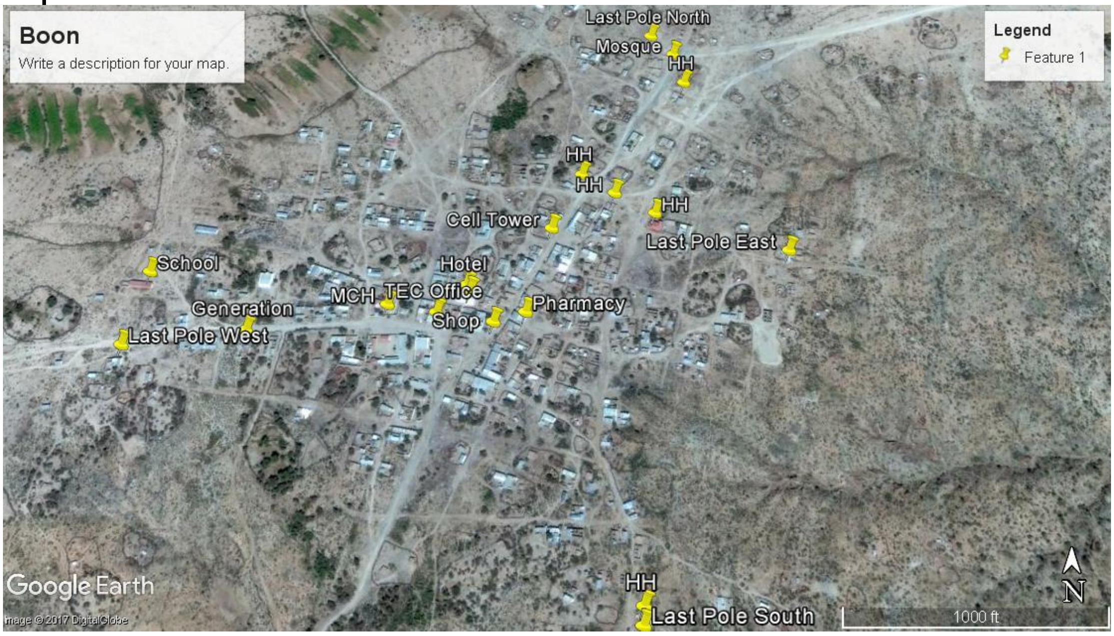


Boon

Reported and Estimated Customers in Boon

Customer Type/ Usage	Total	Grid	Own Generation
Household	1,500	183	
Shop		26	
Restaurant	10	10	
Hotel	2	1	1
School	3	3	
MCH/Clinic	1	1	
Hospital	-		
Mosque	4	3	1
Cell Tower	2	1	1
Fuel Station	-		
Water Pump	-		

Map of Town and Selected Sites

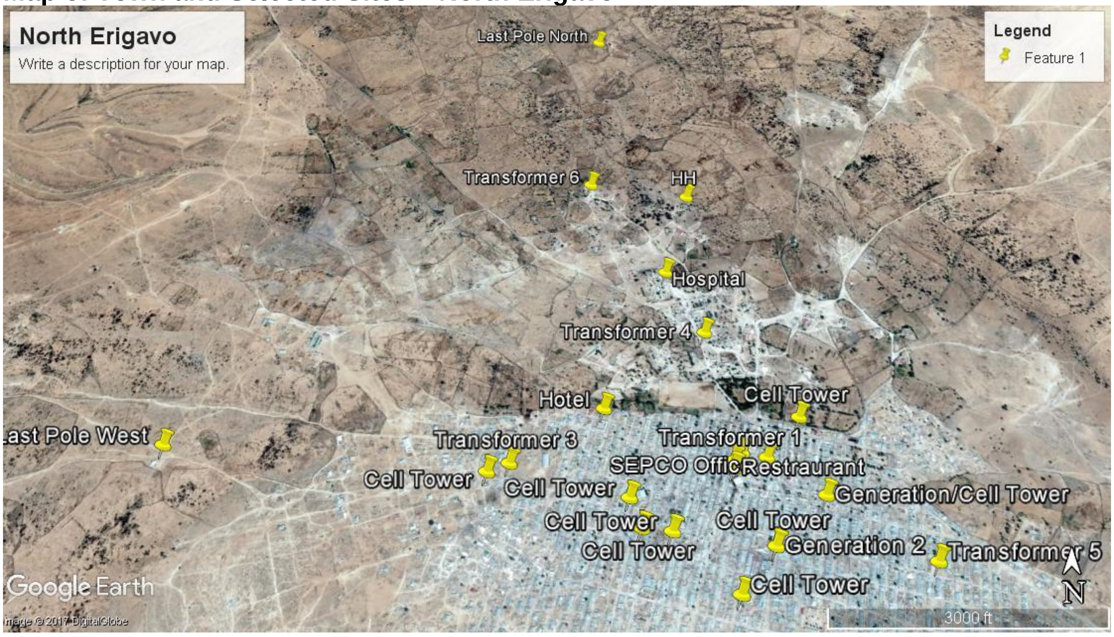


Erigavo

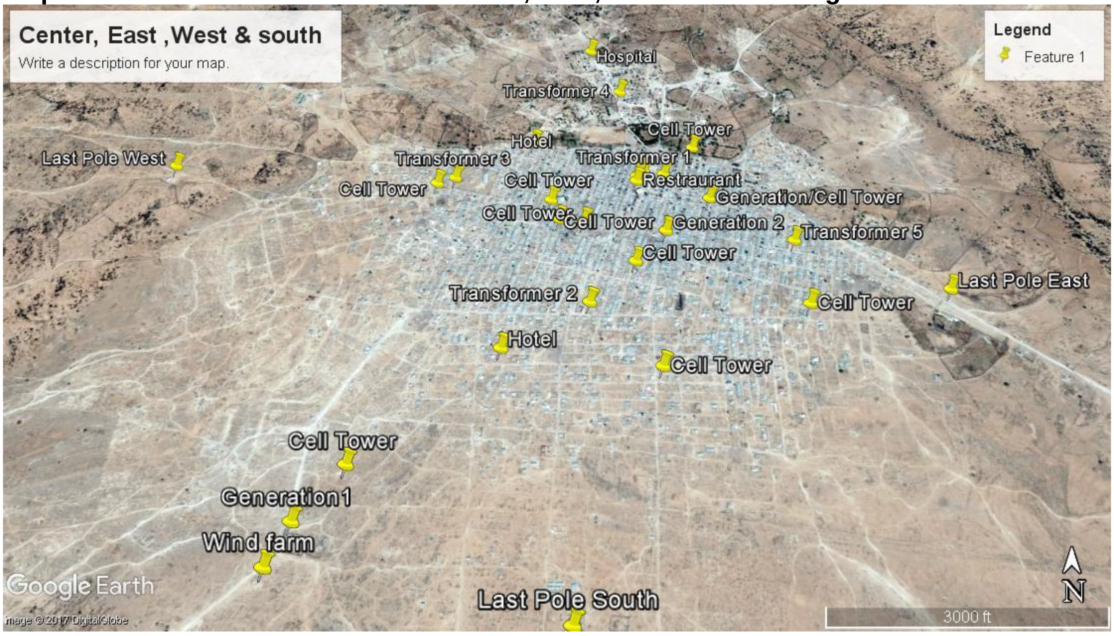
Reported and Estimated Customers in Erigavo

Customer Type/ Usage	Total	Grid	Own Generation
Household	10,000	6,000	
Shop			
Restaurant	15	15	
Hotel	10	10	
School	15	13	
MCH/Clinic	2	2	
Hospital	2	2	
Mosque	50	50	
Cell Tower	12	12	
Fuel Station	9	9	
Water Pump	8	2	

Map of Town and Selected Sites – North Erigavo



Map of Town and Selected Sites – Center, East, West & South Erigavo



Gar-Adag

Reported and Estimated Customers in Gar-Adag

Customer Type/ Usage	Total	Grid	Own Generation
Household	???	85	
Shop	250	250	
Restaurant	5	5	
Hotel	1	1	
School	2	0	
MCH/Clinic	1	0	
Hospital	1	0	
Mosque	5	3	
Cell Tower			
Fuel Station			
Water Pump			

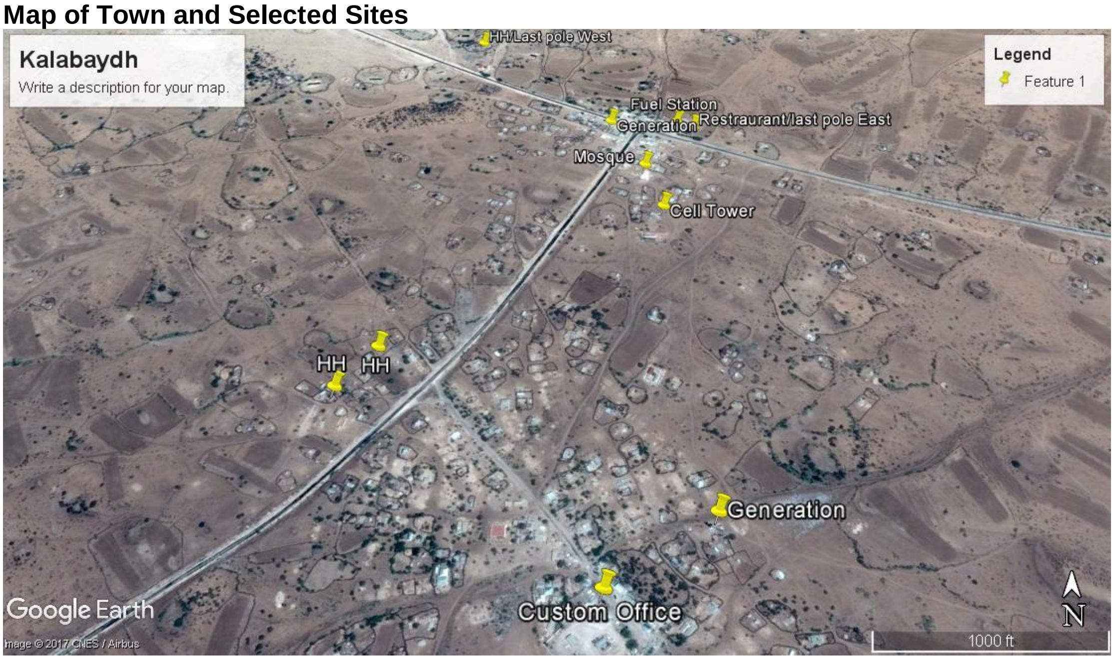
Map of Town and Selected Sites

Kalabaydh

Reported and Estimated Customers in Kalabaydh

Type/ Usage	Total	Grid	Own Generation
Household		45	
Shop		108	
Restaurant			
Hotel	2		
School	2		
MCH/Clinic	1		
Hospital	1		
Mosque	5	2	
Cell Tower	3		
Fuel Station	1		1
Water Pump	0		

Map of Town and Selected Sites



Quljeed

Reported and Estimated Customers in Quljeed

Customer Type/ Usage	Total	Grid	Own Generation
Household	670	150	
Shop		150	
Restaurant	20	20	
Hotel			
School			
MCH/Clinic	1	1	
Hospital			
Mosque	1	1	
Cell Tower			
Fuel Station			
Water Pump			

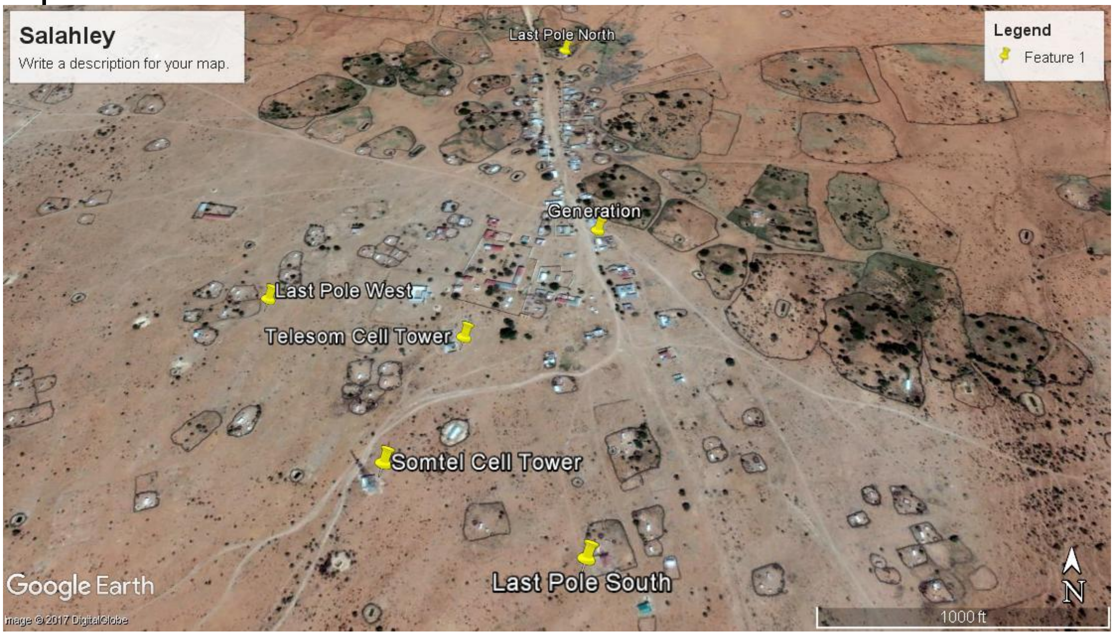
Map of Town and Selected Sites

Salahley

Reported and Estimated Customers in Salahley

Type/ Usage	Total	Grid	Own Generation
Household		40	
Shop		38	
Restaurant	2	2	
Hotel	1	1	
School	4	2	
MCH/Clinic	1	1	
Hospital	1	0	
Mosque	4	3	
Cell Tower	2	1	
Fuel Station	1	1	
Water Pump	0		

Map of Town and Selected Sites



Suuqsade

Reported and Estimated Customers in Suuqsade

Customer Type/ Usage	Total	Grid	Own Generation
Household	???	40	
Shop	???	60	
Restaurant			
Hotel			
School	2	-	???
MCH/Clinic	1	-	1
Hospital			
Mosque	1	-	1
Cell Tower			
Fuel Station			
Water Pump	1	-	1

Map of Town and Selected Sites