Project Design Study on the Renewable Energy Development for Off-Grid Power Supply in Rural Regions of Kenya
Project no. 30979

Final Report

November 2014

Submitted to KfW Development Bank by:

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Executive summary

Background and introduction

German Development Cooperation, through KfW (Financial Cooperation) and GIZ (Technical Cooperation), intends to assist Government of Kenya in promoting the development of new medium-sized hybrid mini-grids (PV-/Wind-Diesel) focused on nascent small and medium-sized growth centres. To assist in identifying and preparing this project, KfW Development Bank contracted Economic Consulting Associates (ECA) of the UK, in conjunction with Trama Tecno Ambiental (TTA) of Spain and Access Energy of Kenya to undertake the *Project Design Study on the Renewable Energy Development for Off-Grid Power Supply in Rural Regions of Kenya*.

The work is divided into 4 main tasks – policy and regulatory framework, minigrid lessons from SSA and Kenya, design of mini-grid interventions, project implementation and next steps.

Task 1: Policy and regulatory framework for mini-grid development in Kenya

Policy, regulatory and institutional framework

Kenya's energy policy and law are currently being reviewed (a sixth draft of energy bill is currently in circulation) to reflect the adoption of the Kenya Vision 2030 and the promulgation of the Constitution of Kenya 2010. Although the details are yet to be formalised, the policy direction is clear in respect of accelerating universal access to electricity, both through grid extensions and through isolated mini-grids.

It is intended that renewable energy will play an increasingly important role in mini-grids. The development of hybrid mini-grids is one of Kenya's important projects within the Scaling-Up Renewable Energy Program (SREP).

Institutional responsibility for rural electrification has been allocated to the **Rural Electrification Authority (REA)**. Reflecting increasing importance being given to renewables as well as the progressive delegation of the implementation of rural electrification to the county governments, the Government of Kenya (GoK) proposes that REA will be replaced by an institution with a broader mandate, the **National Electrification and Renewable Energy Authority (NERA).**

REA works closely with the national distribution company **Kenya Power** (more commonly referred to as KPLC). Other key institutions involved are the **Energy Regulatory Commission (ERC)** and the **County Governments.** For the future development of mini-grids, technical support and capacity-building are particularly needed by the County Governments, covering technical aspects, administration and financial management. Streamlined regulatory procedures need also to be developed.

Existing mini-grids

At present, there is provision for different types of mini-grids in Kenya, the predominant type being the first category:

- ❑ ***Public mini-grids*** – these are developed by REA which owns the assets; KPLC operates the systems on exclusive concessions; uniform national tariffs.

- ❑ ***Private mini-grid concessions*** – generally full private concessions, but O&M agreements are possible; scheme-specific tariffs. This model is allowed but there is no precedent of private mini-grid concessions in Kenya.

- ❑ ***Off-grid feed-in tariffs (FiTs) and power purchase agreements (PPAs)*** – FiT framework is in place but no PPA projects as yet.

- ❑ ***Community mini-grids*** – new policy to promote community schemes; at present only a few micro-grid community schemes operating with NGO-support

New policy directions are for the public mini-grids to be privatised and for Counties to develop schemes which can later be transferred to operators other than KPLC (private or county government).

The policy and regulatory framework is evolving in Kenya, broadly towards good practice that is evident from regional and international experience. Key elements needed include having a clearly articulated strategy for mini-grid development, light handed regulation, and one-off capital rather than recurrent subsidies.

Licensing and permitting of mini-grid operators

The agencies involved in providing licenses and permits are the ERC and the County Governments (also NEMA – this is dealt with in the environmental section). At present, there are no procedures which are specific to mini-grids. Electricity generation, distribution and supply licences, and power purchase agreements have been designed for large power projects.

The current licensing and permitting procedures are thus not suitable for small mini-grid projects. A lengthy process is involved (typically 3 years) with high transaction costs. Many micro-grid sites are currently operating without a permit due to this.

There is no programmatic approach for firms interested in developing multiple sites, and no provisions for connection of mini-grids when extension of the national grid reach the site. Light-handed regulation for mini-grids is needed – some specific aspects are covered under financial and economic analysis below.

Task 2: Lessons learned and best practice analysis in SSA and Kenya

Experience in Sub-Sahara Africa

Three case study countries have been analysed, providing examples of various innovative features and a variety of experience of different technologies and delivery models.

Country	Case study	Business/ management model	Innovative/ noteworthy features
Cape Verde	Santo Antâo island solar PV hybrid mini-grid	Public Private Partnership	❑ Innovative energy management technology (energy dispensing meters) ❑ Community ownership (municipality) with private participation in O&M ❑ Community participation in civil works and community training.
Mali	Yeelen Kura solar hybrid mini-grids	Private concessions	❑ Yeelen Kura has installed 9 solar mini-grids ranging in size from 50kWp to 150kWp ❑ Good example to illustrate pros and cons of mini-grid concessions.
Somalia	Private diesel mini-grids	Private sector driven, unregulated	❑ More than a hundred unregulated IPPs running diesel mini-grids. ❑ Several IPPs considering investment in renewables to reduce costs.

A number of lessons emerge for Lessons learned applicable to Kenya from the SSA case studies:

- Technical – the concept of Energy Daily Allowance in Cape Verde is an effective load management tool. Smart metering and time-of-use tariffs can also assist. Where consumption levels per customer are very low (Mali and Somaliland), flat rates or load limited supplies may well be good options.
- Regulation – the benefits of light handed regulation of mini-grids are demonstrated in Somaliland and Mali. Performance monitoring needs to be carefully designed to avoid introducing perverse incentives (Mali).
- Private sector involvement has been beneficial in various ways, including leveraging parallel financing (Somaliland) and improving O&M of schemes (Mali)
- Community involvement in mini-grid development from an early stage has proved valuable in all countries.

Experience in Kenya

The categories of existing mini-grids have been described above, the predominant model being the public KPLC-operated systems. Private involvement in mini-grid development is only recent yet some important lessons transpire for the future development of mini-grids:

- ❑ Site selection: largest off-grid sites in Kenya have already been electrified. Opportunities for mini-grid development are in the small-scale (<100 kW).
- ❑ Technical aspects: The historic energy consumption patterns of KPLC mini-grids is a valuable benchmark for the design of future mini-grids, especially in regards to sizing. Hybridisation with renewables has had positive impacts in reducing generation costs. Research indicates that northern Kenya is attractive for mini-grids with a large penetration of solar energy (>85%). The use of pre-paid meters, smart meters and remote monitoring, has positively impacted performance of mini-grid operations.
- ❑ Light-handed regulation: existing unlicensed mini-grids have been able to charge cost-reflective tariffs and develop a tariff scheme more suited to the market (low upfront connection fees). This model could be self-regulating.
- ❑ Community involvement: there are clear advantages of interacting with the demand side, especially in relation to the promotion of productive use of electricity.

Task 3: Design of pilot mini-grid interventions

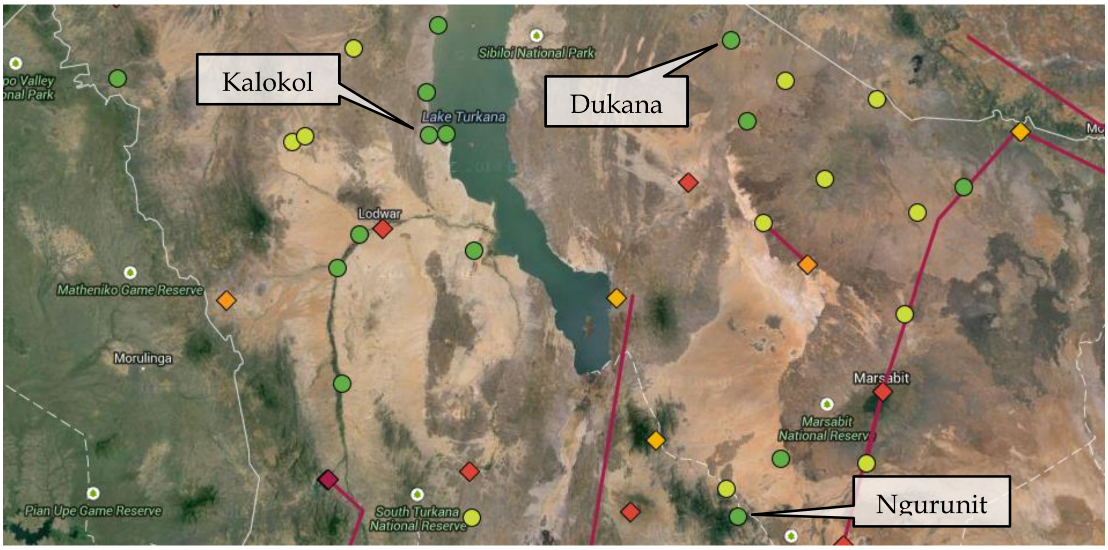
Selection of sites

The three pilot sites were selected from a list of 64 recommended greenfield sites, which was compiled from studies undertaken by various government energy programs and recommendations of GIZ and the Ministry of Energy. A shortlist of the best 10 sites were chosen on the basis of absence from the national grid, sufficient demand for electricity, population, economic activity, hybrid PV-diesel opportunities and potential for expansion and synergies.

After further desk research, field visits were conducted at 6 sites. The final choice was made through scoring additional criteria which covered local dynamics, demographics, geography, economics, potential for productive activities, ability and willingness to pay, accessibility, availability of land and security.

Based on the scoring results, **Kalokol**, **Dukana**, and **Ngurunit** were selected to be retained as the three pilot sites. They are logistically and technically feasible, and meet broad requirements for size / scope, community organization and support, economic growth, and potential impact. Ngurunit is the smallest of the three sites chosen, but is the best suited of the remaining sites to fit within the desired mini-grid size range. The report identified various options for future mini-grid programme expansions.

Location of selected pilot sites (Turkana and Marsabit counties)



Technical feasibility assessment

The three pilot sites are in the north west of Kenya, in Turkana and Marsabit Counties. They have significantly different characteristics:

- ***Kalokol*** has a population of 11,500. It is a big town on the western shore of Lake Turkana, at a point that is 200 km from the national grid. Fishing is the main industry. There is extensive use of solar home systems and diesel generators to support existing economic activities. There are also public service customers for electricity. The town has good access and land is available for mini-grid installations.

- ***Dukana*** has a population of 18,000. It is a big town close to the Ethiopian border, very remote from the national grid (300 km). Livestock trade is the main economic driver. There are government institutions and strong demand for cooling and water pumping services. The town is isolated. Communal land would be available for the mini-grid installations.

- ***Ngurunit*** has a population of 11,000. It lies between the Marsabit National Reserve and Namunyak Conservation Trust and is a smaller town than the other two. Livestock trade is again the main economic activity, together with tourism. There are a number of public institutions which would buy electricity. There is an airstrip which facilitates access. Communal land would be available for the mini-grid installations.

All three sites are located in northern Kenya, in drought-affected areas that raise concerns over the sustainability of existing economic activities and livelihoods. A number of organisations are actively supporting economic development in the region (specifically GIZ is active in both Turkana and Marsabit counties in the field of water management and the promotion of productive value chains). Synergies between electrification and these programmes are strongly encouraged.

For each of the centres, energy demand is estimated from our assessment of the customer base in 3 categories: commercial and industrial, public services and residential use. Load profiles have been developed and the system designed to meet the associated capacity and energy demand, with Homer being used to test alternative PV-diesel hybrid combinations. The demand level, key design parameters and costs are summarised in the following table.

Item	Units	Kalokol	Dukana	Ngurunit
Daily load demand	kWh/day	1,461	701	544
AAG (first 5 years)	% pa	4%	4%	4%
Renewable fraction	%	93%	95%	95%
PV generator	kWp	370	180	140
Battery capacity	kWh	2,164	1,133	991
Genset capacity	kW	200	100	100
LV distribution distance	m	10,000	6,000	6,000
Number of poles	#	334	200	200
Total cost	**EUR**	**2,530,974**	**1,274,981**	**1,132,777**
Cost Generation Plant	*EUR*	*1,903,236*	*977,627*	*841,887*
Cost Distribution Line	*EUR*	*627,738*	*297,353*	*290,889*
Unit cost Generation Plant	*EUR/kWp*	*5,143*	*5,431*	*6,013*
Unit cost Distribution Line	*EUR/user*	*1,778*	*1,327*	*2,203*

The results demonstrate the benefits of economies of scale, with the larger system in Kalokol, designed to meet an initial daily demand that is roughly twice that of Dukana and three times that of Ngurunit, being less costly per unit (by 3% to 15%) than the smaller systems in the other two towns.

Delivery case models

Five models have been considered. Key features are laid out in the table below.

Model	Generation	Distribution	Retail	Relevant situational factors	Financial model elements	Reference case studies (Task 2)
Fully public (Kenya model thus far)	Ownership of assets by REA, Kengen or KPLC O&M&M by KPLC			Kenya model thus far	Public funds "Uniform National Tariff" Cross-subsidies	Existing government mini-grids in Kenya
Fully private	Ownership of assets and O&M&M by vertically integrated private firm or two or more private firms.			Potentially in line with Privatisation Act	Private investment Cost-reflective tariffs or subsidy	Experience in Mali and Somalia

Model	Generation	Distribution	Retail	Relevant situational factors	Financial model elements	Reference case studies (Task 2)
"Mixed Model 1"	REA / KPLC builds and owns, operation outsourced to private sector either through concession or a management contract based on fee			Potentially in line with Privatisation Act	No initial capital investment Operating costs versus contractual fees	Similar to companies contracted to maintain power infrastructure for mobile telecom sites
"Mixed Model 2" or "PPA model"	Private sector builds and owns the generation part and sells power under PPA.	KPLC owns and operates the distribution element and retail of electricity		Existing policy/ regulatory framework (FiT for off-grid stations)	Private investment FiT/PPA	Experience of existing PPAs or PPAs under development
"Community -based / Cooperative Model"	Community / cooperative / municipal utility builds, owns and operates the mini-grid			Model encouraged by policy, potentially easier licensing procedures	Private investment Subsidies Electricity tariffs	Case study of Cape Verde and existing micro-grids in Kenya

The main advantages and disadvantages of the different models are as follows:

- ***Public model*** – highly reliant on cross-subsidies, no role for private sector; customers have low tariffs.
- ***Private model*** - less reliant on subsidies, but high revenue risk (from negotiation of tariffs and non-payment) and high transaction costs, so limited interest to date.
- ***Mixed Model 1*** – possible conflicts over long-term regarding responsibility on re-investments; lack of precedents
- ***Mixed Model 2*** *(PPA model)* - clear division of responsibilities; requires recurrent subsidies, but customers have low tariffs.
- ***Community*** – community buy-in but serious concerns regarding technical and managerial capacity in remote rural areas.

The main purpose of the financial and economic analysis summarised below is a quantitative assessment of the alternative delivery models which are presented in a qualitative way above.

Financial and economic analysis

Low income households are presently paying $11.40 per month on kerosene, dry cell batteries and phone charging. These end uses could be replaced by 7.5 kWh/month of mini-grid electricity at an ability to pay of at most $1.52/kWh, but more likely some lower rate down to $0.76/kWh. This is the figure adopted in the report for household willingness to pay (WTP), the assumed upper limit of household tariffs. Based on a similar analysis for commercial consumers, the centre-wide WTP is assumed to be $0.55/kWh.

Mini-grid electricity is expensive: indeed, the very high costs of the mini-grids make calculated EIRRs negative. The economic justification of the projects lies in wider economic and environmental benefits. To keep the tariffs within the bounds of what consumers will be willing to pay requires substantial capital subsidies to be provided in *all* of the delivery models. In those involving the distribution being done by KPLC, the uniform national tariff is assumed to apply, and recurrent subsidies will then have to be given, in addition to the capital subsidies. The figures for two of the delivery models are summarised in the table below.

	Kalokol		Dukana		Ngurunit	
Variable	**Private**	**PPA model**	**Private**	**PPA Model**	**Private**	**PPA Model**
LCOE (unsubsidised, USD/kWh)	0.82	0.74	0.92	0.79	1.00	0.91
Average retail tariff & tariff subsidy (USD/kWh)	0.54 -	0.21 0.31	0.54 -	0.21 0.33	0.52 -	0.22 0.36
PPA tariff (USD/kWh)	n.a.	0.41	n.a.	0.43	n.a.	0.47
Capex subsidy (% initial capex)	84%	84%	89%	89%	92%	92%
Present value of all subsidies (USDmillion)	2.8	4.2	1.5	2.2	1.4	2.0

Choice of delivery model

The assessment of the delivery models is not a purely technocratic matter which can be left to outsiders. There are some embedded policy issues relating particularly to the current policy of a uniform national electricity tariff, which imply that the delivery model decision is ultimately one for the Government of Kenya to make.

The consultant recommendation for the KfW project is the **Private Model** (developer having responsibility for generation and distribution), principally because this maximises the role of the private sector and involves the lowest level of subsidy. We also allow that if private operators do not wish to undertake distribution, the fall-back would be the **PPA model** (Mixed Model 2, in which the developer generates power which is sold to KPLC for distribution to final end-users).

The private model would free up resources to be used to accelerate the attainment of the national goal of universal access to electricity, but it was clearly stated at the dissemination workshop that Kenyan stakeholders would favour instead the PPA model. This is because the general view of the workshop participants was that uniform national tariffs should continue to prevail.

The Ministers of Energy from the Counties spoke out strongly in favour of KPLC remaining responsible for distribution and the uniform national tariff being applied. They are concerned about control of something as socially significant as electricity and perceive KPLC as a known entity that can be influenced, with channels for recourse if necessary. Whether higher mini-grid tariffs would really result in more rapid national electrification could be disputed, and in any event there would be no guarantee that the unelectrified centres in their particular counties would be the beneficiaries.

Phasing of projects and provisions for the arrival of the main grid

Another possible way to improve the financial performance of the projects and reduce the level of subsidy would be a phased investment strategy. Our model shows that the most cost-effective option is to install 2/3 of capacity initially and the remaining 1/3 in year 6. The capital subsidy requirement goes down by 13% with minimal impact on solar PV penetration.

The arrival of the main grid poses a risk to a private investor considering investing in a mini-grid project. How this eventuality is to be dealt with needs to be agreed in advance. The situation would be different for the two chosen delivery models:

- **Private Model** – either the operator should stop generating and become purely a distributor of electricity or, if grid supplies are unreliable, the generation equipment could be retained for use as back-up or for sale of power into the grid.
- **PPA Model (MM2)** – for solar-PV based schemes, at prevailing feed-in tariffs ($0.12/kWh) selling to the national grid would not be attractive for a private operator, and purchase of the generator would not be attractive for KPLC.

For both models, the risks associated with the arrival of the main grid can best be mitigated by the generation plant being designed to be easily removed and transferred to other locations.

Environmental and Social Impact Analysis

The law of Kenya requires that greenfield mini-grid projects, regardless of their size, obtain approval of the Environmental Impact Assessment by the National Environment Management Authority (NEMA). Based on the KfW Sustainability Guideline (Technical Note no. FI059), for the KfW project this requirement determines the need to conduct in-depth environmental impact assessment.

As regards overall impact assessment, the project is classified as ***Category C – minor impact***. During construction and normal operation, the project is expected to have either positive or minimal negative impact on land use, water use and CO_2 emissions. The relatively minor use of diesel (5%-7%) is noted in this regard.

An analysis of CO_2 emissions indicates the following net savings will be made over the assumed 20 year life of the projects. The levels of savings in the three schemes are insufficient to warrant applying for Certified Emission Reduction credits under the Programmatic Clean Development Mechanism (pCDM).

Item	Units	Kalokol	Dukana	Ngurunit
Total Current Emissions	tonnes CO2/year	123	206	315
Total CO2 savings (20 years)	tonnes CO2	2,263	5,567	8,921

Task 4: Design of project implementation and identification of next steps

Implementation recommendations

The scope of the proposed KfW project is to support the investments identified for the pilot mini-grids in Kalokol, Dukana and Ngurunit.

The main objective of the project is to contribute to the cost-effective, reliable and sustainable power supply in rural growth centres and thus to foster efficient and sustainable use of power. Productive use of electricity for agro-processing, storage, cooling, transportation/handling of goods to be sold, is a central aspect of achieving sustainability.

Expected results of the project

- ***Contribution to access to electricity***: a total of 700 electricity connections by year 5. This includes 500 households, 100 productive applications and the connection of schools, health centres, and other public services that are to improve socio-economic standards of the selected towns.

- ***Contribution to the improvement of the economic framework condition in Kenya***: 1.0 GWh/year (by year 5) of electricity, of which 60% is to be used in commercial and industrial activities and 20% in public services.

- ***Contribution to mitigation of climate change***: 1.0 GWh/year (by year 5) of electricity, of which >90% is generated from solar. Emission reductions of 16,800 tonnes CO2 in the life cycle of the project.

- ***Establish a viable model for delivery of hybrid mini-grids with private sector leverage:*** licensing and operation of 3 off-grid private concessions (for generation, distribution and supply or generation only), helping streamline licensing procedures for other private developers.

Proposed implementation modalities

Our recommendation is that the primary delivery model should be the fully Private Model, but note that the views expressed by County Governments were strongly in favour of the alternative PPA model. Our general recommendations for the implementation of either of these models are the following:

Under the fully private model, the following implementation modalities are proposed:

- The private developer/operator would finance the scheme and receive a grant equal to between 84% and 92% of the capital cost. This amounts to $ 5.7 million (EUR 4.3 million)[1].
- The source of the capital for the pilots would be subject to discussion with GoK. What is proposed is that:
    - KfW to provide the 84-92% capex subsidy for the power generation. For the three pilots this is estimated at $ 4.4 million (EUR 3.4 million).
    - The GoK contributes the portion of the subsidy related to the distribution infrastructure of $ 1.2 million (EUR 1.0 million). This can be done through REA constructing the distribution network
    - The remaining part of the capital investment is for the private developer(s) and amounts to $ 0.8 million (EUR 0.6 million) for the total of three sites.
- The assets would be developed under a concession agreement and handed to GoK at the end of the concession period with compensation based on the non-depreciated value of the assets.
- Competitive bidding for the concession is recommended to achieve the best value for money. Bidders can compete to provide a fixed number of connections and specified minimum service levels[2] on the basis of the smallest subsidy they would need to achieve the targets. Competitive bidding can be done through REA. Technical and financial assistance should be provided for this process.
- The private operator would charge customers a tariff calculated according to their willingness-to-pay – currently estimated at 0.54 $/kWh in average. This could be self-regulating since the operator

[1] The level of subsidy requirement may vary in the proposals received at the competitive bidding stage. This level of subsidy has been calculated based on the designs and budgets proposed above, which may vary in the different proposals.

[2] This should include plant availability, energy sold, % of power generated from renewables, etc.

is constrained from charging higher tariffs because of affordability. Tariffs would need to be monitored rather than regulated[3].

Changes may be necessary to the regulatory framework to allow a simplified approach to smaller licensees. Technical assistance to the MoEP and ERC is proposed to streamline licensing procedures for small private operators.

Under the PPA model, the following implementation modalities are proposed:

- The private developer/operator would finance the power generation plant and receive a grant equal to between 84% and 92% of the capital cost[4]. The construction, operation and financing of the distribution infrastructure would be responsibility of the GoK, through REA in construction and KPLC in operation.

- The source of the capital for the pilots would be subject to discussion with GoK. What is proposed is that:

  - KfW provides the 84-92% capex subsidy for the power generation. For the three pilots this is estimated at $ 4.4 million (EUR 3.4 million).

  - The GoK through REA develops the distribution network as public contribution to the capex. For the 3 pilots this is estimated at $ 1.4 million (EUR 1.1 million).

  - The remaining part of the capital investment is for the private developer(s) and amounts to $ 0.6 million (EUR 0.5 million) for the total of three sites.

- The power generation assets would be developed under a PPA agreement and handed to GoK at the end of the PPA period with compensation based on the non-depreciated value of the assets.

- Competitive bidding for the concession is recommended to achieve the best value for money. Bidders can compete on the basis of smallest subsidy required for a given PPA tariff and specified minimum service levels[5], or on the basis of the lowest tariff for a given level of subsidy. The latter option is preferred given its potential to minimise the requirement of on-going subsidies in favour of upfront capital subsidies. Competitive bidding can be done through REA. Technical and financial assistance should be provided for this process.

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[3] See "Five Reasons to Not Regulate the Retail Prices of Small, Isolated, Rural Mini-Grids" on p. 318-320 of Tenenbaum et, al (2014).

[4] The level of subsidy requirement may vary in the proposals received at the competitive bidding stage. This level of subsidy has been calculated based on the designs and budgets proposed above, which may vary in the different proposals.

[5] This should include plant availability, % of power generated from renewables, etc.

- The successful bidder would become the private operator of the power station and would receive the agreed tariff from KPLC.

- Changes will be necessary to the regulatory framework to simplify procedures and to provide specific conditions for off-grid PPAs (for example, a clear framework for renegotiation of tariffs based on significant variations in energy demand and for the situation where the mini-grid is connected to the main grid). Technical assistance to the MoEP and ERC is proposed for these tasks.

Implementation modalities should defined in detail after agreeing on the delivery model to be implemented (i.e. private model or PPA model). Our dissemination workshop recommended that a stronger policy direction should be laid out by the Central Government in consultation with the County Governments in order to define the model to be applied for these pilots.

For either delivery model, we recommend that technical assistance be provided to the government in technical, economic and legal aspects of concession agreements and PPAs, in managing the competitive bidding process and, finally, in streamlining licensing procedures.

LogFrame Matrix

A LogFrame is provided to systematically link the overall objective, project purpose, and project measures to outputs, verification indicators and risks. The main risks the project faces related to:

- Streamlining of licensing and PPA procedures

- Sufficient interest being expressed by private sector developers

- KPLC mobilising to operate distribution systems, if the PPA model is followed in some or all centres

- Demand growth occurring at least as fast as projected.

Organisation, management and administration

REA will take the lead in implementing the project, with support and assistance of consultants appointed by KfW. Key elements for REA include:

- Management of the bidding process

- Construction of the infrastructure that is GoK financed (the distribution networks)

The KfW consultants will work with MoEP and ERC to streamline the licensing and regulatory framework.

The private sector will be responsible for the construction of the remaining infrastructure. KPLC or a different regional distributor will be involved in managing the distribution if the private sector is only willing to bid for the generation component.

Monitoring and review, reporting and evaluation

Monitoring and review of the pilot projects is responsibility of REA and the consultants providing technical assistance. There will be quarterly reporting on technical assistance activities and semi-annual reporting on fund allocation to mini-grid developers. KfW guidelines will be followed.

Financial management and accountability

REA, supported by the KfW consultants, will manage disbursement of subsidies to selected developers. A specific project management unit may be formed within REA to facilitate this.

Funds will be disbursed from a ring-fenced account according to well defined procedures. Reporting and auditing requirements will be put in place.

Project budget and implementation plan

The estimated maximum total capex subsidies amount to EUR 4.3 million. The subsidy amount may well be lower in practice, because of the competitive bidding process.

Technical assistance to REA and MOE/ERC, project management and programme monitoring and evaluation are projected to add a further EUR 0.9 million.

The following cost sharing for the total budget is proposed:

- Total project cost of **EUR 5.2 million**
- KfW contribution **EUR 4.3 million** (subsidy corresponding to the power generation stations)
- Government contribution **EUR 0.9 million** (subsidy corresponding to the distribution networks)

As already mentioned, the detailed implementation plan for the project should be developed when the project concept has been accepted.

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Tables and Figures

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Acronyms

AAG	Average Annual Growth
AC	Alternating Current
ADO	Automotive Diesel Oil
AFD	French Development Agency
AMADER	Malian Agency for Household Energy and Rural Electrification
ASER	Senegalese Agency for Rural Electrification
ATP	Ability To Pay
CAPEX	CAPital EXpenditure
COSS	Cost of Service Study
DC	Direct Current
DFID	UK Department for International Development
DFR	Draft Final Report
DKTI	German Climate Technology Initiative
EDA	Energy Daily Allowance
ECA	Economic Consulting Associates
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EOI	Expression of Interest
ERC	Energy Regulatory Commission
ESCO	Energy Supply Company
ESIS	Environmental and Social Impact Studies
EUR	Euro
FCA	Fuel Cost Adjustment
FiT	Feed-in Tariff
FOREX	Foreign Exchange
FRES	Foundation for Rural Energy Services
GIC	Government Investment Corporation
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft fuer Internationale Zusammenarbeit
GoK	Government of Kenya
GPS	Geographic Positioning System
HCD	Human Capacity Development
HH	Household
HV	High Voltage
IDO	Industrial Diesel Oil
IFC	International Finance Corporation
INFLA	Inflation Adjustment
IPP	Independent Power Producer
IRR	Internal Rate of Return
KAM	Kenya Association of Manufacturers

KEREA	Kenya Renewable Energy Association
KES	Kenya Shilling
KfW	German Development Bank
KPLC	Kenya Power
LCOE	Levelised Cost of Energy
LV	Low Voltage
MFI	Micro-Finance Institution
MoEP	Ministry of Energy and Petroleum
MV	Medium Voltage
MW	Mega-Watt
NEMA	National Environmental Management Authority
NERC	National Energy Regulatory Commission
NERA	National Electrification and Renewable Energy Authority
NGO	Non-Governmental Organisation
NPV	Net Present Value
OBA	Output Based Aid
PC	Privatisation Commission
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PTPR	Presidential Task Force for Parastatals Reform
PV	PhotoVoltaic
RE	Renewable Energy
REA	Rural Electrification Authority
REMP	Rural Electrification Master Plan
SADC	Southern Africa Development Cooperation
SC	Small Commercial
SREP	Scaling Up Renewable Energy Programme
SSA	Sub-Saharan Africa
SWERA	Solar and Wind Energy Resource Assessment
TOR	Terms of Reference
TTA	Trama Tecno Ambiental
USD	US Dollars
VAT	Value-Added Tax
WB	World Bank
WTP	Willingness to Pay

Exchange rate

1 EUR = 1.31 USD = 116 KES (September 2014)

1 Introduction

In April 2014 the KfW Development Bank contracted Economic Consulting Associates (ECA) of the UK, in conjunction with Trama Tecno Ambiental (TTA) of Spain and Access Energy of Kenya to undertake the *Project Design Study on the Renewable Energy Development for Off-Grid Power Supply in Rural Regions of Kenya*.

1.1 Background

Currently, approximately 70% of Kenyan households do not have access to electricity. Government of Kenya is committed to significantly raising the access rate in the country. According to the Kenyan Rural Electrification Masterplan, access to power shall be improved through extensions, stand-alone systems, as well as isolated mini-grids. Renewable energy is supposed to be the main source of energy powering this access campaign.

At this stage, mini-grids are only playing a relatively minor role in supplying electricity to Kenyan households. Currently 21 mini-grid stations are in operation, yet another 10 are under construction. These mini-grids are mainly supplied through diesel-based generation and are operated by Kenya Power (KPLC), the electricity distribution company also responsible for managing the national grid. KPLC is majority government-owned (51%), Customers supplied through KPLC's mini-grid operations are charged the same tariff as customers served through the national grid, even though operating costs are significantly higher due to expensive diesel generation and other O&M costs. That means that electricity consumption in the existing mini-grid systems is heavily subsidized through the tariff structure (cross subsidies). The Kenyan Ministry of Energy and Petroleum (MoEP) plans to convert the existing mini-grids from diesel-based generation to hybrid generation (based on Solar PV and/or wind) to improve the cost efficiency of operations and to reduce carbon emissions. This activity is being supported by AFD. In addition, MoEP is planning to facilitate the installation of additional hybrid mini-grids, mainly in peri-urban areas and rural centres in Northern and Western Kenya.

German Development Cooperation, through KfW (Financial Cooperation) and GIZ (Technical Cooperation), intends to assist Government of Kenya in promoting the development of new medium-sized hybrid mini-grids (PV-/Wind-Diesel) focused on nascent small and medium-sized growth centres with an expected load of up to 1MW. In addition, as part of this project, institutional support to the Kenyan Rural Electrification Authority (REA) as the main official Kenyan institution responsible for rural electrification and to MoEP as well as to the Energy Regulatory Commission (ERC) will be provided. In addition, through the Project Technical Assistance will be made available to explore the viability of private sector engagement in rural electrification. The Project will be supported by German Development Cooperation, as part of the German Climate Technology Initiative (DKTI).

The main objective of the project is to contribute to the cost-effective, reliable and sustainable power supply in rural growth centres and thus to foster efficient and sustainable use of power ("productive use"; i.e. use of energy for agro-processing, storage, cooling, transportation/handling of goods to be sold).

1.2 Approach and methodology

For the organization of our work, we have divided the project into three stages.

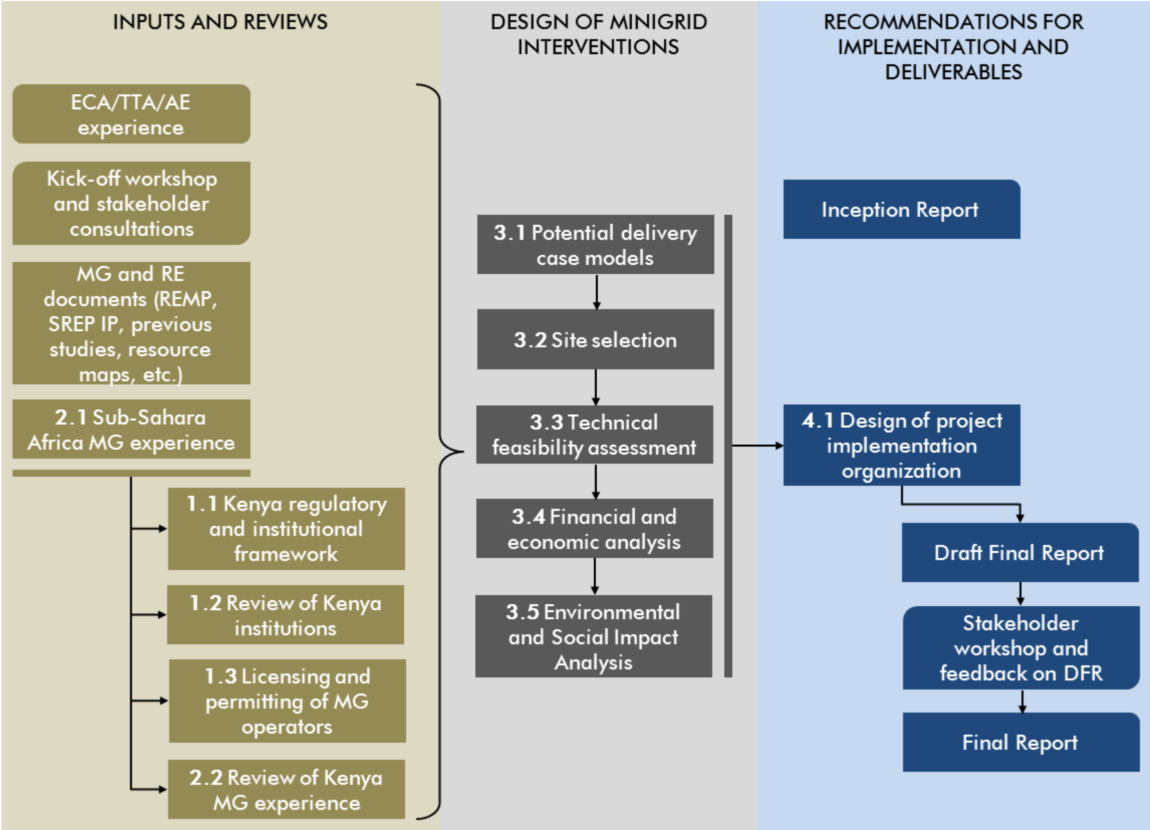
- ***Inputs and reviews:*** This stage of the project consisted in collecting and analysing information relevant to the design of KfW's mini-grid project. It included a review of policy, regulation and previous mini-grid experience in Sub-Saharan Africa and Kenya. To complement our literature review, we conducted extensive stakeholder consultations. In particular, an inception workshop with representatives from the government and private sector was organised to validate the scope and methodology of the study. *This stage covered tasks 1 and 2 of the TOR.*

- ***Design of mini-grid interventions:*** this stage consisted of selecting suitable sites for the mini-grid pilots, conducting a feasibility assessment including technical design, economic and financial analysis. Finally, suitable delivery models for the mini-grid pilots were proposed. The methodology followed for each of the sub-tasks is explained in detail in the corresponding sections of the report. *This stage covered Task 3 of the TOR, which represents the bulk of our work.*

- ***Recommendations for implementation:*** This stage provided our recommendations for the design of the implementation phase of the project. A dissemination workshop was conducted to discuss the project with stakeholders of the Government of Kenya. The outputs of this discussion have been integrated into this final report. *This stage covered Task 4 of the TOR.*

Figure 1 presents an overview of these stages, tasks and deliverables of the project as well as their interactions.

Figure 1 Overview of the project



1.3 Contents of this report

This report is structured according to the Terms of Reference of KfW, covering the four main tasks and sub-tasks in the same sequence.

- Task 1 (Assessment of policy and regulatory framework for development of mini-grids in Kenya) is covered in sections 2 to 4
- Task 2 (Assessment of best practices and lessons learned in mini-grid development and operation) is covered in sections 5 and 6 of this report.
- Task 3 (Design for three pilot mini-grid interventions) is covered in sections 8 to 11
- Finally, Task 4 (Design of project implementation organization and identification of next steps) is covered in sections 12 to 17.

Task 1: Policy and regulatory framework for mini-grid development in Kenya

2 Review of regulatory and institutional framework

The energy policy and law are currently being reviewed (a sixth draft of energy bill is currently in circulation[6]) to reflect the adoption of the Kenya Vision 2030 and the promulgation of the Constitution of Kenya 2010. Additionally, the Presidential Taskforce on Parastatal Reforms has presented its recommendations in October 2013, which also have implications on energy sector institutions, such as REA and ERC. The institutional landscape of the energy sector is currently in a process of transformation. The timeline is linked to the approval of the energy bill, expected for the end of 2014 and the 3-year period of transition to a devolved government, ending in March 2016.

In completing Task 1 of this study, we have taken into consideration the latest drafts available as well as interviews with relevant stakeholders in order to provide the most up-to-date overview of the policy and regulatory environment for mini-grids.

This section provides a concise analysis of policy and regulation relevant to hybrid mini-grids, with a focus on private sector participation opportunities.

2.1 Overview of policy and regulatory framework

This part of our research analyses the policy and regulatory environment for mini-grids at different levels:

- ***Strategy level:*** national electrification strategy including decision on delivery models to apply (public, private, mixed, etc.). We analyse existing documents and plans for mini-grid development (e.g. REMP, SREP Investment Plan, etc.) and consider the progress of the privatisation programme for the power sector and the implications of the ongoing decentralisation of administration under the new constitution.

- ***Acts of parliament and institutions:*** laws, policies and government bodies involved in electrification (REA, ERC, KPLC)

- ***Specific regulation for mini-grids:*** we analyse the public model for mini-grid development applied in Kenya thus far, i.e. investment and operation by Government institutions, and the relevant regulatory environment for the development of mini-grids under different models, in particular private sector involvement. This includes power purchase agreements (PPA) and regulations on concessions and tariffs.

[6] Approval expected by December 2014

- ❑ ***Incentives and support:*** availability of CAPEX subsidies, connection subsidies, tax breaks, etc.
- ❑ ***General regulation:*** applicable licensing procedures, technical standards, import regulations, etc.

Table 1 summarises the key documents that have been analysed. The energy sector is currently guided the policy set out in Sessional Paper No. 4 of 2004 and governed by a number of statutes, principally the Energy Act, No. 12 of 2006. However, with adoption of the Kenya Vision 2030 and the promulgation of the Constitution of Kenya 2010, these documents are currently being reviewed. The timeline of these changes is linked to the 3-year period of transition to a devolved government, ending in March 2016.

Table 1 Policy and regulatory documents relevant to mini-grids

Level	Key documents	Relevant inputs / issues	Other important issues
Strategy/ Planning	Rural Electrification Master Plan (update 2009)	- Updates national rural electrification strategy for the period 2008-2018 - Identification of mini-grid sites - The REMP details suitable institutional capacity required to roll out the Master Plan. It is therefore a good benchmark for the capacity assessment of REA.	The REMP is currently being updated (to be completed in the short term (2014-2017) according to the Energy Policy draft). The SREP mini-grids project document of 2013 is a more suitable tool for identification of mini-grid sites. It builds on the recommendations of the REMP 2009.
	SREP mini-grids project document (2013)	- Identification of mini-grid sites (including 23 sites from REMP 2009) - Basic performance information for existing mini-grids - Preliminary assessment of investment requirements	Proposed sites need to be critically assessed: certain proposed greenfield sites are planned to be connected to the grid (Loyangalani and South Horr) and capacity requirements are possibly overstated.
Policy	National Energy Policy (draft 2014)	Relevant short-term (2014-2017) objectives of the new policy: - **Devolution:** development of framework to establish roles for the two levels of government (National-County) - **Transformation of institutions**, e.g. the current REA into the National Electrification and Renewable Energy Authority (NERA) - **Licensing policy:** open to new distribution companies (though only one distributor in a given area at any particular time). Licensing primarily undertaken	Important to check progress of Devolution activities: The newly created Counties will have a role in the management of electricity within county borders particularly in the planning and development of electricity reticulation. Important to check progress of Privatisation activities: There currently is no specific policy for concession of mini-grids.

Level	Key documents	Relevant inputs / issues	Other important issues
		by the National Government. - **Privatisation:** concession of government owned off-grid power stations - **Promotion of renewable energy:** targets for solar energy are 100MW by 2017, 200MW by 2022 and 500MW by 2030. - **Promotion of community based power generation**	To date, no specific policy for private mini-grids Approval of policy expected for the end of 2014.
	Feed-in tariffs policy (update 2012)	- Applicable for Renewable Energy Projects feeding into Isolated Grids.	Several mini-grid sites being developed under PPA framework, e.g. Wind for Prosperity (13 sites) and Soligenia East Africa (3 sites)
Law	Energy Bill (draft 2014)	Amends and consolidates the laws relating to - Establishment of National Energy Entities: National Energy Regulatory Commission (NERC), NERA, etc. - Renewable Energy Feed-in Tariff System and connection, purchase and distribution of renewable energy - Licensing provisions for generation, transmission, distribution and retail of electricity. - Electricity tariffs - Rights of way, wayleaves and use of land	The new energy act will open way for regional distributors and allow private sector to set up and operate mini-grids. Village cooperatives and village trust models potentially not subject to licensing and tariff regulations (need to check Cooperatives Act). No mention of Uniform National Tariff. Proposed tariffs have to be submitted to the licensing authority for approval. Energy bill expected approval in December 2014.
	Privatisation Act (under development)	- The Privatisation Commission (PC) of Kenya was developing a Public Private Partnership (PPP) framework for concession/privatisation of isolated power stations.	Policy draft proposes concession of GoK mini-grids in the short term (2014-2017). However, last report delivered to the PC in 2013 was inconclusive. PTPR recommends PC to be dissolved and functions taken over by a the proposed Government Investment Corporation (GIC). Decision on privatisation therefore likely to delayed and follow the transition timeline (March 2016).
	Other Acts	- Cooperatives Act, PPP Act, etc.	Relevant to the analysis of different delivery models

Level	Key documents	Relevant inputs / issues	Other important issues
Regulations	Various RE regulations (drafts)	- Feed-in tariffs, connection of RE generators to the grid (or isolated mini-grids), etc.	Energy bill expected approval in December 2014. Drafting of relevant regulations after this.
	Energy (Electricity Licensing) Regulations, 2012	- Sets requirements for a licence or permit to carry out activities of generation, transmission, distribution or supply of electrical energy.	Regulation also subject to updates after approval of energy bill.
	Kenya Electricity Grid Code, 2008	- The primary technical document of the electricity supply industry, collating the majority of the technical regulations covering the generation, transmission, distribution and supply of electrical energy.	Off-grid networks shall meet the national power grid standards for future inter-connection. Grid code currently being updated. New version includes provisions for the integration of renewables. Consultation with stakeholders expected by the end of 2014.
	Electrical safety standards	- Electrical safety standards for generation, distribution and end-user connections	
	NEMA regulations	- NEMA requires an Environmental Impact Assessment to be conducted at each project site prior to authorization of any project.	
	Schedule of tariffs (2013)	- Tariffs approved by ERC for KPLC for 2013 - 2015	The approved tariff structure is for KPLC alone. There is no mention of Uniform National Tariff. However, these tariffs would be used as a base for negotiation. There is however no precedent of private concession negotiating retail tariffs.
Other	Report of the Presidential Taskforce on Parastatal Reforms (October 2013)	- Task force mandated to design the most appropriate institutional arrangement for government-owned entities taking into account the new Constitution and particularly devolution - Recommends that REA be dissolved and functions devolved to counties.	No restructuring recommendations for KPLC (although recommended that the Government Investment Corporation should consider increased shareholding in KPLC) No restructuring recommendations for ERC

The national electrification target of the Government of Kenya as set out in the Vision 2030 is to achieve 100% connectivity by 2030 with an interim target of 65% by 2020. Currently, only 30% of the households are connected to electricity.

The Government undertook to accelerate the pace of rural electrification in 2006 through creation of the Rural Electrification Authority (established under the Energy Act No. 12 of 2006). REA's current strategic plan[7] is focused on the electrification of all major public facilities (trading centres, schools and health centres) and households through:

- **Grid expansion:** by the end of 2013 REA had connected 90% of public facilities (trading centres, secondary schools and health centres) to the grid. The number of new electricity consumers has increased by approximately 300,000 per year between 2011 and 2013. New policy targets are of 500,000 annually by 2016, expanding the distribution network to an additional 16,000 km of medium voltage and 50,000 km of low voltage lines.

- **Isolated off-grid stations (mini-grids):** there are 21 mini-grids in operation (most of them located in northern Kenya) and another 10 under construction by REA, bringing the total in the country to 31.

- **Stand-alone solar PV systems:** by June 2014, REA had installed 671 solar PV systems in various schools and health centres in off grid areas.

The development of mini-grids (specifically hybrid mini-grids) is one of Kenya's projects within the Scaling-Up Renewable Energy Program (SREP). Kenya developed an investment plan for the SREP mini-grids project which builds on the Rural Electrification Plan (REMP) of 2009 and is therefore the latest document establishing mini-grid-specific targets.

The SREP mini-grid project document identifies opportunities for retrofitting (hybridising) existing mini-grids and mini-grids currently under construction as diesel sites, proposing investment in 3.7MWp of solar PV and 1 MW of wind among 24 sites. The document also identifies 44 green-field sites (23 from the REMP and 21 from SREP-specific research). These 44 sites are to have an aggregate installed capacity of 18 MW (10 MW of diesel, 6 MW of solar and 2 MW of wind) and are to reach a population of almost 50,000 households (approximately 1% of the Kenya population).

Of these 44 green-field sites identified in the SREP document, three already have plans for electrification by the GoK (Loyangalani and South Horr will be connected to the national grid and a diesel mini-grid will be constructed in Kakuma). Additionally, a consortium of private developers known as Wind for Prosperity (WfP) has expressed

[7] REA's first strategic plan (2008/09-2012/13) adopted the target of connecting all the three main public facilities (trading centres, secondary schools and health centres) by the year 2012/13. It is estimated that 90% of these public facilities were electrified in this period. REA's second strategic plan (2013/14-2017/18) focuses on connectivity (driven by public facilities, now including primary schools, and households) and renewable energy.

interest in developing green-field sites (Kakuma and Liboi)[8]. The remaining 40 sites, along with new potential sites identified by the GoK (REA is currently constructing three new sites in Mandera county not identified in the SREP document) and other partners (e.g. GIZ has identified approximately 5 sites suitable for pilot projects), present opportunities for mini-grid development not only for the GoK but for private developers as well.

Thus far, the delivery of rural electrification projects (specifically mini-grids) has been driven by the GoK (through REA in construction and KPLC in operation and maintenance). Currently, the energy policy and the Act are being reviewed to align them with the Vision, the Constitution of Kenya (2010) and global trends. The policy text is clear in that the government seeks to accelerate access to modern energy services through public and private initiatives (such as the privatisation of mini-grids, involvement of county governments, power purchase agreements with privates, promotion of electric cooperatives, etc.). This will provide opportunities for collaboration with private sector in renewable energy development and national electrification. There is however no clearly articulated strategy for the development of mini-grids yet, i.e. no clear decision on the delivery model to apply and how they will be regulated.

Changes in the regulatory and institutional landscape of national electrification are to be expected after the approval of the energy law (expected December 2014) and within the transition [to a devolved government] timeline, ending in March 2016. There are currently no specific regulations for the development of mini-grids but rather for generation, transmission, distribution and retail activities, applicable to both grid and off-grid environments). The Energy Regulatory Commission acknowledges the need for mini-grid-specific regulations, but the development of these will require prior high level policy decisions, a clear framework for collaboration with county governments and demand from developers.

The following sections expand on regulatory and institutional aspects relevant to mini-grid development, considering both existing provisions in the current framework as well as trends indicated for the new framework.

2.2 Provisions for mini-grid development

Table 2 provides a summary of the policy and regulatory provisions for different types of mini-grid projects. Each of these models and the relevant policy and regulation aspects are further explained in the following sub-sections.

[8] WfP consortium is integrated by Vestas and local investment fund DI Frontier Market Energy & Carbon Fund. WfP seeks to hybridise mini-grids with wind power and has presented an expression of interest for 13 mini-grid sites (11 retrofit projects and 2 green-field sites).

Table 2 Regulatory provisions for mini-grid development

Type of mini-grid project	Details	Regulations	Precedents
Public mini-grids	REA implements projects and owns assets (generation and distribution) KPLC operates on behalf of GoK.	- KPLC granted exclusive concession for up to 50 years - Uniform tariff (for entire KPLC customer base) applies	All existing licensed mini-grids (except for Lamu and Garissa with generation in charge of KenGen) are under this framework
Private mini-grid concessions	Can include full private concessions (private owns assets and operates) or O&M agreements (private operates public infrastructure)	- Privates can apply for generation, distribution and retail licences - Privatisation of GoK mini-grids proposed in policy but advancement status unclear - Tariffs to be negotiated with regulator (based on costs and affordability)	Licences granted for captive generation, distribution and supply only. A few privates currently operate micro-grids without a licence.
Off-grid Feed-in Tariffs and PPAs	FiT framework includes solar energy feeding into off-grid networks Privates can also negotiate non-standardised PPAs for generation in mini-grids	- Existing FiT framework (FiT policy 2012) and PPA framework - Solar off-grid FiT of 0.20 $/kWh unattractive for off-grid projects	Several IPPs feeding into the national grid (both thermal and renewables) although none under FiT framework To date, no private generation in GoK mini-grids, although approved Expressions of Interest[9]
Community mini-grids	Electric cooperative model (under Cooperatives Act) or Village Trust (under Companies Act)	- New policy encourages community-based power generation - New bill proposes simpler licensing procedures (licensing by REA as opposed to ERC) - Potential concerns over cooperatives not being protected by a formal concession.	No precedent of licensed electric cooperatives running operating mini-grids. A few micro-grids operating without licences with NGO support

[9] Wind for Prosperity (13 sites) and Soligenia East Africa (3 sites)

2.2.1 Public mini-grids

Delivery model

The delivery of mini-grids in Kenya thus far has been through a public model, with the REA in charge of implementation of projects (construction of generation and distribution infrastructure) and hand-over to KPLC for operation and maintenance. REA and KPLC have signed a Service Level Agreement detailing this mode of operation. The generation and distribution assets remain property of the government (REA).

With the exception of the mini-grids in Lamu and Garissa (power generation by KenGen and scheduled to connect to the national grid due to their comparatively large size), all existing mini-grids as well as the 10 mini-grids currently under construction by REA (see section 6.1.1 for details) follow this institutional framework.

Licensing

KPLC is granted a license for distribution and supply to consumers in mini-grid sites. Since Kenya has a policy of having only one distributor in a given area at any particular time, this licence protects KPLC from competition during the licence's period. Some of these licences are granted for a period of 50 years[10].

Electricity tariffs and connection charges

KPLC's retail tariffs are regulated by the ERC and are uniform across KPLC's entire customer base. The schedule of tariffs is therefore sometimes referred to as "uniform national tariff". The regulated tariff responds to the costs of the entire utility (both grid and off-grid operations) and is therefore insufficient to cover the higher electricity costs of mini-grids.

Approved tariffs vary depending on the type of consumer (domestic, small commercial, commercial and industrial, etc.) and level of consumption (stepped tariffs for domestic consumers). Table 3 summarises the different components of the KPLC tariff structure.

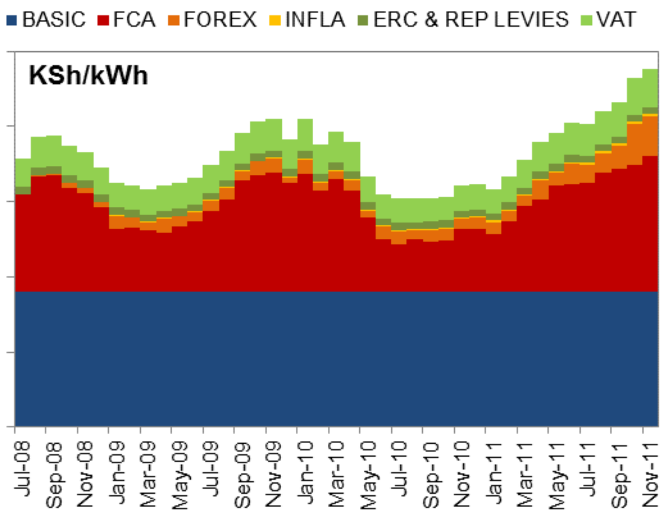
As will be further elaborated in section 6.1.1, the average selling price of electricity in mini-grids is of 0.19 $/kWh and the average cost (predominantly from diesel generation) is of 0.45 $/kWh. The operation of public mini-grids is therefore extremely reliant on cross-subsidies. One of the main instruments for cross-subsidising is the Fuel Cost Adjustment (FCA) in the electricity bill (see Table 3). 95.6% of power generation in mini-grids is from diesel and fuel costs are fully transferred to consumers.

[10] Register of licensed power-undertaking companies available online on ERC website: http://www.erc.go.ke/

Table 3 Tariff structure in Kenya

Tariff component	Description	Payable to
Basic tariff	Normative component of the tariff based on the cost of electricity of the system (excluding fuel costs). The basic tariff varies according to the type of consumer (domestic, small commercial, commercial/industrial, etc.) and includes: - Fixed charge per month - Energy charge per kW (stepped tariff for domestic consumers including a social baseline below 50 kWh/month) - Demand charge per kVA (only applicable to commercial / industrial consumers)	KPLC
Fuel cost adjustment (FCA, varies)	The cost of fuel used in power generation (by KenGen, IPPs and KPLC mini-grids) is fully transferred to consumers and varies with oil prices and amount of thermal generation every period. Can be a substantial portion of the electricity cost (see figure below).	Pass-through charge. Payable to Power Generators (KenGen & IPPs) and KPLC mini-grids.
Foreign exchange adjustment (FOREX, varies) and Inflation adjustment (INFLA, varies)	Electricity bills also contain adjustments for foreign exchange variations and inflation. These are however much smaller than the FCA.	KPLC & Power Generators
VAT	16% value added tax	GoK
ERC Levy	Collection on behalf of ERC (3 cents / kWh)	ERC
REP Levy	Collection on behalf of the REA to fund the rural electrification programme (5%)	REP

Figure:
Example of electricity price for small commercial consumer under the SC Method
Source: GIZ 2011



Connection charges are also regulated. Despite efforts to subsidise the cost of connection to between 200 and 500 USD, this amount is still beyond the reach of majority of rural consumers. Having identified this as a barrier to achieving a fast electrification pace, the new energy policy states that the GoK shall endeavour to eliminate connection charges.

This could be understood as reducing the upfront investment requirement, which is the main barrier for rural consumers. In this regard, KPLC has recently piloted a loan facility to help connect 300,000 customers[11].

Impacts of new framework

The new policy and regulatory framework for mini-grids proposes changes to the current public model for mini-grids. The most important developments are:

- **Privatisation of government-owned mini-grids:** The latest draft of the energy policy proposes private concessioning of GoK mini-grids in the short term (2014-2017). The status of the privatisation act is however unclear. The Privatisation Commission (PC) of Kenya was tasked with developing a Public Private Partnership (PPP) framework but their report of 2013 was inconclusive. The PTPR has recommended that Government Investment Corporation (GIC) [12] take over the issue of privatisation. This decision is therefore likely to be delayed and follow the transition timeline (ending March 2016).

- **Devolution to counties:** according to the new energy policy, county governments may plan and develop distribution networks and transfer them to distributor(s) duly licensed to operate and maintain them. This opens opportunities for regional distributors other than KPLC.

Section 6 of this report contains more detailed information on the experience with public mini-grids in Kenya.

2.2.2 Private mini-grid concessions

The new framework indicates that there will be support for Public Private Partnerships in the development, operation and maintenance of energy infrastructure and delivery systems. This creates opportunities for private sector participation in mini-grids. There is however no precedent of licensed private mini-grids in Kenya and the current licensing procedures have no provisions specific to this delivery model.

Delivery model

Private concessions can have different forms depending on the type of ownership:

- The private firm has ownership of assets and is responsible for O&M, referred to as "Full Private Model" later in this report

[11] "Stima Loan" is one of the initiatives spearheaded by KPLC in collaboration with the government, AFD and EU to ease the cost of power connections and help accelerate access to electricity. A 30 million Euro pilot started in July 2014 was to connect 300,000 households to the grid. Customers pay a 20% upfront deposit and repay their loan within a period of 24 months.

[12] PTPR recommends the incorporation of GIC as the holding company of the National Treasury, which is to have the shareholding role for commercial entities.

- ❑ REA builds and owns the infrastructure, but operation and maintenance are outsourced to a private firm through concession (or a management contract based on fee). This is referred to as "Mixed Model 1" later in this report.

Both models are permissible under the current framework as long as they do not conflict with existing KPLC concessions. Private firms interested in developing green-field can therefore apply for a licence for generation, distribution and retail of electricity.

The privatisation of government-owned mini-grids mentioned in the previous section would correspond to the "Mixed Model 1" but, as explained, the status of the Privatisation Act is currently unclear.

Licensing

Activities of generation, distribution and retail of electricity require a permit or licence from the ERC. The existing framework does not differentiate mini-grid operators from large-scale utilities (no differentiation in terms of size or number of customers).

While licences have been granted for captive power generation and distribution (this is the case for many tea factories[13] generating and distributing power within the boundaries of their property), there is no precedent of licensed private mini-grid operators.

ERC has noticed growing interest from the private sector in licensing mini-grid projects (based on a number of enquiries from local companies such as Powerhive and Powergen which currently operate micro-grids without a licence, see section 6.1.3). These discussions are however at a very early stage.

Specific licensing procedures and regulation for private mini-grids could be developed after the approval of the energy law provided there is demand from the industry. First movers are needed to pave the way.

Electricity tariffs and other regulatory issues

According to existing regulations, generation and distribution for more than 1 person requires negotiation of tariffs with the ERC. The tariffs approved for KPLC (sometimes referred to as "uniform national tariff") are not mandatory for new concessionaires but will normally be the benchmark for negotiation. As part of the licensing process, a tariff model based on costs and reasonable returns is to be submitted for discussion. The new policy states the government shall establish a pricing mechanism for energy services at the national level to make energy tariffs affordable[14], but there is no specific mention of uniform tariffs.

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[13] James Finlay (6.7 MW of hydro and thermal), Sotik Tea Company (1.5 MW of thermal), Sotik Highlands Tea Estate (1 MW of thermal), Unilever (4.7 MW of hydro and thermal) and Imenti Tea Factory (1 MW of hydro)

[14] "NERC shall ensure that during the energy contracting process, regulated asset base composition, return on equity for energy entities and the process of electricity tariff design is properly defined, scheduled,

While significant downward pressure on tariffs can be expected from the regulator (need for affordability of electricity tariffs is highlighted in the policy), there is currently no subsidy mechanism for private concessions that can place them in a levelled ground with KPLC.

One other major concern for private concessionaires is the lack of clarity regarding the arrival of the national grid. The GoK seeks to progressively connect off-grid systems to the national grid and regulations are needed to protect the interests of private developers of mini-grid sites.

Impacts of new framework

As mentioned above, the new policy and institutional framework suggests better opportunities for private sector participation:

- Although the advancement status is still unclear, the policy proposes the development of a framework for privatisation of mini-grids.
- The newly created counties will have an important role in the implementation of rural electrification projects[15], including the planning and development of electricity reticulation which could be transferred to regional distributors (other than KPLC) for operation
- Current licensing procedures allow for private concession of green-field mini-grid sites (where there is no conflict with existing KPLC concessions). First movers are encouraged to follow these procedures.

In order to attract private sector participation in mini-grids, significant improvements in the regulatory framework will be needed. Licensing procedures will need streamlining and conditions to protect the investors will have to be developed. In particular, clarity will be needed with regards to the approval of a tariff structure and the rights of concessionaires when the grid reaches the mini-grid concession. This discussion is resumed in section 2.3 and elaborated in more detail in the design of the pilots in sections 10 and 12.

2.2.3 Off-grid Feed-in Tariffs and PPAs

The latest revision of FiT Policy was approved in December 2012 and is applicable to renewable energy sources feeding into off-grid stations. For solar energy, there is a standardised tariff for off-grid stations of 0.20 $/kWh, but this is deemed unviable for commercial projects for the following reasons:

documented and provided for in regulations formulated under the Energy Act so as to also cater for the urban poor and marginalized groups."

[15] Framework of collaboration between the REA and the county governments is still being discussed. The timeline is linked to the transition period (March 2016).

- The tariff is for projects of installed capacity between 0.5 MW and 10 MW of solar. Existing mini-grids cannot accommodate this level of capacity with grid-tie/"fuel saver" technologies (i.e. solar energy feeding directly into the grid without storage) due to their comparatively low demand[16]. This level of capacity would require substantial investment in battery storage and control equipment making the 0.20 $/kWh tariff unviable.

- Hybrid systems with a high penetration of solar energy (>30%) require interaction with the diesel generator and control over the complete power generation system (both diesel and RE). The standardised agreement has no specific provisions regarding the ownership and management of shared control equipment.

- Finally, the standardised agreement does not contain take or pay purchase obligations from the off-taker (which in any case is not a good practice in off-grid stations where energy consumption is comparatively low) making the project especially attractive for private investors and lenders.

Based on the above arguments, it is recommended that privates willing to develop power generation projects in mini-grids opt for a negotiable PPA (as opposed to the FiT) for generation from both diesel and renewable sources).

Delivery model

In this model, the private sector builds and owns the power generation infrastructure and sells power under PPA to the distributor, presumably KPLC, who owns and operates the distribution element and retail of electricity.

Licensing and tariff negotiation

There are several Independent Power Producers (IPPs) with PPAs to sell power to KPLC (both thermal and renewable energy sold to the national grid). The procedures for applying for a PPA shall follow the Application and Implementation Guidelines, as published by the Government, the first step being the submission of an Expression of Interest (EOI). These procedures are explained in more detail in section 4 of this report.

The policy draft states that guidelines on PPA negotiations are currently unclear which results in lengthy negotiations. This has also been raised by private sector developers, in particular Wind for Prosperity Project Kenya[17] (WfP), who are developing a project to feed wind energy under a PPA into 13 mini-grid sites[18]. Based on their experience, WfP are of the opinion that it is not expedient to negotiate PPA for small mini-grid projects (their projects are below 0.5 MW) and would prefer a standardised approach.

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[16] Largest mini-grids (Lodwar, Wajir and Mandera) have registered peak demand of 1 to 1.5 MW (in the evening).

[17] Consortium of Vestas and Frontier Investment (local partner)

[18] At the time of writing, WfP was finalising negotiations of the PPA with KPLC. They were expecting to begin construction of in the first five sites before the end of 2014.

Impacts of new framework

The new policy clearly states the intention of having more involvement from the private sector in rural electrification and renewable energy and also acknowledges the need for improvements in the PPA framework.

The new framework (specifically the Devolution) is not expected to have major impacts in the implementation of PPAs in the short term:

- Regulation and licensing of power generation and distribution activities will still be undertaken by the national government (the ERC), although there will be more involvement of county governments through consultations.

- KPLC is likely to remain as the off-taker in the short term. Some of the existing mini-grid sites have 50 year concessions and the establishment of regional distributors in the counties is bound to take a few years as the counties develop institutional strength.

- Similarly to regulatory aspects of private concessions, improvements will be needed in the framework for PPAs in off-grid environments. Important issues to address are agreement of load forecasts, extent of purchase obligations, rights of investors when mini-grids are connected to the grid, etc.

2.2.4 Community mini-grids

Delivery model

Community mini-grids refer to projects where a community or municipality builds, owns and operates the mini-grid. The community organisation can take different forms, such as an electric cooperative (regulated by the Co-operative Societies Act) or a Village Trust (regulated by the Companies Act).

The financing is typically highly grant-based with some community contributions (financial or in-kind). The planning, procurement of equipment, installation and commissioning is often done by third parties, as local communities rarely have the technical and economic expertise to develop and implement mini-grids. Experience in Sub-Saharan Africa shows that a fundamental weakness of this model resides in the lack of capacity in remote rural towns to properly maintain the infrastructure and manage the business, with many projects resulting in failure. It is therefore considered a good practice to have some level of private sector involvement, such as shareholding in a trust or through O&M agreements.

Larger community-driven cooperative models running generation in the multi MW scale are more formalised and depend less on local structures.

Licensing and tariff negotiation

To date, there are no licensed community-operated mini-grids in Kenya. There are indications[19] that electric cooperatives might have simpler licensing procedures. In particular, having the community buy-in, tariff negotiations with the GoK might be avoided.

There are on the other hand concerns that cooperatives are not be protected by the law as a formal concession, not having exclusive rights to supply electricity.

Impacts of new framework

The new policy has the objective to promote community-based power generation in the medium term (2014-2022) and the draft of the bill also adds that:

- Licensing and supervision of cooperatives would be undertaken by the "National Electrification and Renewable Energy Authority" (NERA, the transformation of REA) as opposed to the ERC, which could potentially imply light-handed regulation
- The NERA is also to provide financial, institutional and technical support to electric cooperatives

2.3 Comparison with international good practices

This section provides a concise review of international good practices in mini-grid development and regulation in contrast with the current framework in Kenya.

The recommendations in this section are supported by the detailed, multi-country analysis in the recent publication of Bernard Tenenbaum, Chris Greacen and Tilak Siyambalapitiya *"From the Bottom Up: How Small Power Producers Can Deliver Electrification and Renewable Energy in Africa"*, a recent study produced by Economic Consulting Associates and Practical Action on behalf of the Regional Electricity Regulators' Association of Southern Africa (RERA) to establish a framework for attracting increased investment in mini-grids employing renewable and hybrid generation in the countries of the Southern African Development Community (SADC), and finally the recent "Minigrid Policy Toolkit" launched by EUEI-PDF.

The purpose of regulation of mini-grids is to protect consumers while providing confidence for investors, the main focus therefore being on licensing operators and tariffs. However, before this discussion it is important to highlight that higher level policy, planning and role clarity is fundamental.

[19] Opinions from experts rather than specific references in licensing regulations

Clear strategy for mini-grid development

Policy makers need to define clear objectives, strategies and plans and allocate resources and provide incentives for mini-grid development. In the current situation of Kenya, with the country transitioning to a devolved government and the institutional landscape being transformed accordingly, this strategy is unclear.

As explained in the previous section, the country's model for mini-grid development has thus far been a public one but, according to the new policy, there is willingness to have more private sector involvement. There is an on-going debate about privatisation of mini-grids and existing licensing procedures indicate private firms can apply for mini-grid concessions (as long as there is only one licensee in a given area at any particular time). However, there are no clear mechanisms or guidance for tariff negotiations. The new policy stresses the importance of guaranteeing affordable tariffs for all Kenyans but neglects to define affordability (e.g. whether this implies alignment with grid electricity tariffs or whether tariffs can be set at lowest of cost-reflective or ability to pay) or establish mechanisms to subsidise private concessions similarly as KPLC mini-grids.

After defining a clear strategy for the delivery of mini-grids, regulators must facilitate the implementation of the policy objectives through consistent procedures and regulatory compliance requirements.

Considering the policy trend in Kenya (expressed in the latest policy draft) of further involving the private sector in rural electrification and mini-grid development, international good practice on this suggests that regulation should be as light-handed as possible.

Light-handed regulation

The recommended regulatory provisions for mini-grids from the previously mentioned publication of Tenenbaum et al. can be summarised in six actions:

Six Recommended Actions for mini-grid regulation (Bernard Tenenbaum)
1. Exempt small system operators from licensing and prior tariff approvals. 2. If prior tariff approval is required, do not mandate that the operator must charge the same tariff as the national or state utility. 3. Allow operators to cross-subsidize between customer classes (usually, but not always, by charging businesses more than households). 4. Allow operators to sign power sales contracts with businesses without requiring prior regulatory approval of contract terms. 5. Specify what rights the operators have "when the big grid connects to the little grid." 6. Allow operators to make loans to potential and actual customers to connect and to buy appliances and machinery.

The main themes behind these recommendations is that mini-grid customers need electricity much more than they need low tariffs. Regulation should therefore be as light-handed as possible; in particular tariffs for small mini-grids should not be directly regulated. It may be seen as unfair for mini-grid customers to pay more per kWh for power than main-grid customers, but the real unfairness is for people in remote centres not to have electricity at all.

The key elements of the arguments made in Chapter 9 of Tenebaum's book are:

- In order for SPPs that operate isolated mini-grids to exist as commercially viable entities, they must be allowed to charge tariffs that are higher than the uniform national tariff (pg 275)

- Rural household customers can afford cost reflective tariffs if they are allowed to pay for the initial connection cost in small monthly payments over time. Once they get over the connection cost hurdle, they can afford to pay electricity tariffs that will produce monthly expenditures equal to or less than their prior expenditures on non-electricity energy sources (kerosene, candles, batteries). Electricity has the added benefit of producing better energy services: higher quality lighting, better access to information, and health benefits (pg 278)

While all mini-grids should have to show compliance with safety and technical standards, licensing procedures (and tariff negotiation) should be streamlined and simplified for small[20] mini-grid projects in order to reduce transaction costs and promote private investment. Light-handed regulation also reduces the burden for the regulator as illustrated in example of Mali below.

Senegal and Mali are examples of countries aggressively pursuing rural electrification through private concessions. Both countries have dedicated agencies for rural electrification, ASER and AMADER respectively, which by the end of 2010 had to supervise almost 100 concessions each[21]. In the specific case of Mali, which has been researched for this study, the tariffs negotiated between the operators and AMADER are different for each concession. While there is no policy of a uniform tariff, there is still significant pressure to keep electricity prices low and substantial subsidies are granted to private operators to overcome the gap between the cost-reflective tariff and the approved tariff. AMADER established a rural electrification fund (REF) which provides mini-grid operators with an 80% investment subsidy to electrify concession zones[22]. Despite the large level of subsidies, the tariff model relies on periodic revision by the AMADER. Due to their limited capacity to oversee so many concessions, tariff schedules usually become outdated requiring concessionaires to negotiate ad-hoc fuel subsidies with the entity.

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[20] The threshold can and should be subject to review as mini-grid experience is gained by the regulator.

[21] By 2010, AMADER (Malian Agency for Household Energy and Rural Electrification) was in charge of supervision of 82 concessions. 59,000 connections had been achieved, bringing the rural electrification rate to 14.9%. Similarly for the ASER (Senegalese Agency for Rural Electrification), the first phase of their Renewable Energy for Senegal (ERSEN) project (implemented jointly by GIZ) brought electricity to 74 villages by the end of 2009.

[22] The situation is similar in Senegal, where 80% of the mini-grid investment cost is financed by a donor (GIZ is supporting the ERSEN project), with 10% financed by customers, and 10% by a private operator.

In countries such as Kenya where (although not explicitly stated in the policy) significant pressure from the regulator can be expected to reduce tariffs to levels similar to the grid, then an adequate subsidy scheme will be needed to attract private investment.

Mini-grids and the arrival of the national grid

Connecting mini-grids to the main utility grid is a desired end for the customers. As a rule, central grid tariffs are lower than mini-grid tariffs because of economies of scale (in generation, transmission, and distribution of power) and because of regulatory interventions and cross-subsidisation (subsidising rural consumers by charging higher tariffs from urban and industrial consumers).

The risk of an uncompensated 'takeover' by an expanding grid is a significant deterrent to investors. However, in a positive policy environment, grid connection can instead provide opportunities for both the investor and the national utility. Tenenbaum et al. identify the following possible options for grid connection of private mini-grids:

- SPP (small power producer) stops generating and becomes a SPD (small power distributor)
- SPP stops distributing and sells power to KPLC
- SPP operates as combined SPP-SPD (grid main source of electricity, existing generation backup and/or sale at FiT)
- KPLC buys the SPP
- Abandonment

The preferred option needs to be specified in advance to reduce risk for private operator.

For a mini-grid to qualify for grid connection, the technical requirements of the main utility need to be met. These include overall network safety needs, frequency and voltage regulation, the integration of the distribution system into the utility system, whether the mini-grid system is able to "island" in the event of grid failure, and whether it is used as a "dispatchable" asset of the grid.

Additionally, financial issues need to be resolved before the utility enters the area. If the mini-grid operator has been charging a higher tariff than the utility (and the utility is "taking over" the concession) the new tariff has to be agreed and any obligations due to the mini-grid operator to enable it to "close out" its operations have to be met. If the mini-grid operator will continue to operate the site, then new tariff, generation and distribution agreements and Feed in Tariffs may have to be negotiated or regulated.

Funding of mini-grids and subsidy policy

To ensure the most efficient and equitable use of resources available for subsidies, it is important for subsidy policies for mini-grids to be developed and clearly enunciated. Recommendations on subsidy policy for mini-grids are:

- **Capital not recurrent subsidies:** Subsidies should be limited to one-off capital subsidies for viable projects[23], as this will enable many more mini-grid users to benefit than concentrating providing recurrent subsidies to those few mini-grid beneficiaries lucky enough to already have access to electricity.

- **Subsidies to catalyse complementary financing:** Subsidies from public and concessional resources should as far as possible leverage capital contributions from beneficiaries and project promoters, thereby allowing as many mini-grid projects as possible to be supported. Where a private project promoter is seeking a commercial bank loan as part of the project financing, it may be necessary or expedient for the public subsidy-granting entity to provide a partial risk guarantee for the project.

- **Require recipients to compete for the subsidy:** Essentially there are two main approaches:

  - Offer a fixed subsidy for a mini-grid and ask bidders to compete on the number of connections and the level of service which they will provide.

  - Set a fixed number of connections and specified minimum service levels and ask bidders to compete on the basis of the smallest subsidy they would need to achieve the targets.

- **Performance-based subsidies:** Whenever possible, subsidy provision is to have in-built performance incentives. This is the 'output based aid' (OBA) approach whereby the recipient only receives the subsidy on proof of a tangible output being achieved. OBA subsidies can be applied to the initial project development, but the classic use of OBA is to provide incentives for operators to increases the number of customers connected to the mini-grid. A fixed subsidy amount is provided for each new customer who is connected and purchases electricity, the subsidy only being paid when the connection and its use has been verified. The main problem with OBA subsidies is that the investments have to be financed up-front by the developer, with the subsidy being paid only when there is evidence of the investment being out to use.

[23] 'Viable projects' are those which can generate sufficient revenue to cover operation, maintenance and replacement costs so that the projects are sustainable without further subsidies. Providing capital and on-going subsidies for non-viable projects would disproportionately benefit the community involved, at the expense of other mini-grid projects requiring an initial capital subsidy to get started.

3 Review of Kenya institutions

As mentioned in the previous section, the institutional landscape in the energy sector is currently facing transformation based on the adoption of the Kenya Vision 2030 and the promulgation of the Constitution of Kenya 2010. This is reflected in the new energy policy and law as well as the recommendation of the Presidential Taskforce on Parastatal Reforms (PTPR).

This section includes:

- An overview of the existing institutions and the proposed institutional changes.
- A concise review of existing capacities and shortfalls at REA, KPLC and ERC in relation to mini-grid development. Considering the newly created counties will also have a role in the planning and implementation of rural electrification, they should also be considered for capacity building projects.

3.1 Overview of institutions

The Kenyan institutions most relevant to rural electrification and the development of mini-grids are the Ministry of Energy (MoE), the Rural Electrification Authority (REA), the Energy Regulatory Commission (ERC), Kenya Power (KPLC) and the newly created County governments (which have a department dedicated to energy).

The Ministry of Energy (MoE) is responsible for formulation and articulation of energy policies to create an enabling environment for efficient operation and growth of the sector. In the field of mini-grids, the ministry is responsible for the definition of a clear strategy for development to guide the bodies in charge of implementing rural electrification projects and the regulator.

Table 4 provides an overview of the institutions involved including their role and the proposed institutional reforms. The timeline for these reforms is linked to the approval of the new energy bill (expected before the end of 2014) which establishes the new institutions. In the particular case of REA, which performs devolved functions, the precise framework for collaboration and division of responsibilities with the county governments is still being discussed. The timeline for these transition activities ends in March 2016.

Table 4 Relevant energy sector institutions and proposed reforms

Institution	Current role	Institutional reforms under new energy policy	Recommendations of PTPR
Rural Electrification Authority (REA)	Extending electricity supply to rural areas, managing the rural electrification fund, mobilizing resources for rural electrification and promoting the development and use of renewable energy. REA is in charge of the construction of GoK mini-grids and hand-over to KPLC for operation.	Establishment of the **National Electrification and Renewable Energy Authority (NERA).** Functions include planning, implementation and promotion of electrification and renewable energy. NERA is to establish a **framework for collaboration with County Governments** in the discharge of its mandate.	It is recommended that **REA be dissolved** and the rural electrification levy be transformed to electricity fund at the national level for allocation to counties based on their rural electrification needs.
Energy Regulatory Commission (ERC)	Integrated energy planning (including elaboration of the Least Cost Development Plan), regulation of energy activities (electrical, renewables, petroleum, etc.) including licensing, enforcement and compliance and tariff setting.	No major reforms proposed. Licensing of power generation, transmission, distribution and retail remains with the national government. Tariff setting and approval of PPAs will also be primarily undertaken by the ERC.	No restructuring recommendations for the ERC.
Kenya Power (KPLC)	KPLC is currently the only off-taker in the power market purchasing bulk power from all power generators on the basis of negotiated PPAs for onward transmission, distribution and retail to customers. KPLC operates mini-grids on behalf of the GoK.	Distributors other than KPLC can be provided with regional licences to operate distribution networks in the different counties as well as mini-grids.	No restructuring recommendations for KPLC (although recommended that the GIC should consider increased shareholding in KPLC)
County governments	County governments have been newly created with the new constitution. Most county governments have departments dedicated to energy issues.	The policy states that the newly created counties will have a role in the planning and development of electricity reticulation which could be transferred to regional distributors (other than KPLC) for operation. A framework for collaboration with REA is under way.	No recommendations on the structuring of county governments.

Rural Electrification Authority (REA)

REA was created, under section 66 of the Energy Act of 2006 as a body corporate with the principal mandate of extending electricity supply to rural areas, managing the rural electrification fund, mobilizing resources for rural electrification and promoting the development and use of renewable energy. REA is financed by Rural Electrification Levy charged on electricity consumers on the national grid.

According to the PTPR, rural electrification activities could be viewed as a component of county planning and development under the new constitution, which allocates electricity and gas reticulation and energy regulation to the county level of government. In consideration of this, it is recommended that REA be dissolved and the rural electrification levy be transformed to electricity fund at the national level for allocation to counties based on their rural electrification needs.

The recommendation of the PTPR is not inconsistent with the new energy bill, which states that the Government shall transform the Rural Electrification Authority into the National Electrification and Renewable Energy Authority (NERA) to be the lead agency for development of renewable energy resources other than geothermal and large hydros. With regards to rural electrification, REA is supposed to develop their own devolution schedule and framework to work with county governments. This process is to occur within the transition period ending in March 2016.

Energy Regulatory Commission (ERC)

Energy Regulatory Commission is established under the Energy Act, 2006. The functions of the ERC which are relevant to this study are the technical and economic regulation of generation, transmission, distribution, supply and use of electrical energy. This includes the licensing of power undertaking companies and the negotiation of tariffs.

The new policy framework does not propose major reforms of the ERC. Licensing activities (including tariff setting and approval of PPAs) will be primarily undertaken by the ERC. Regulatory activities that might be devolved to the counties include the licensing of electrical contractors.

Kenya Power (KPLC)

KPLC is a State Corporation with GoK shareholding of 50.1% and private shareholding of 49.9% as at December 2011. It purchases electrical energy in bulk from KenGen and other power producers and carries out transmission, distribution, supply and retail of electric power.

KPLC is currently the only off-taker in the power market and the only licensed distributor and retailer of electricity. The new framework however presents opportunities for competition for concession areas (the policy is to have only one distributor in any given geographic area at any given time), including both grid and off-grid concessions. In the short-term, this would only apply to new developments since the current distribution and supply licences of KPLC are for 50 years.

KPLC's function is regarded as critical in ensuring Kenya has adequate affordable electricity to drive industrialization and economic development. For this reason, the PTPR has recommended that the Government Investment Corporation should consider increased shareholding in KPLC in a manner supportive of the national development goals.

County Governments

According to the new constitution, the National Government will be responsible for energy policy while the County Governments will be responsible for planning and development within their jurisdictions. These functions include electricity and gas reticulation and energy regulation. Counties have energy departments and electricity officers.

- With regards to planning and implementation of electricity reticulation, REA is to formulate cooperation arrangements with County Governments for the discharge of its functions.
- With regards, to energy regulation, the bill proposes that regulation will primarily be undertaken by the national government (the ERC). The counties will have a role in some licensing activities (such as the licensing of electrical contractors).

Despite the fact that the Constitution provides for the various roles of the two levels of the government, there is a possibility of operational uncertainty as to the extent of responsibility between the two levels of governments. A framework on the functional devolution of roles between the two levels of government is being developed by the different institutions to guarantee the continuity of services and avoid the uncertainty/overlap of responsibilities.

3.2 Review of existing capacities and shortfalls

This section provides a concise review of existing capacities and shortfalls at REA, KPLC and ERC regarding planning, financing, operation and monitoring of off-grid rural electrifications systems.

The GIZ ProSolar team has recently undertaken a 'Human Capacity Development' mission in April 2014. This mission was to assess the human capacity needs of ERC, KPLC, MoEP and REA as well as private sector actors and KEREA, which also extends to the communities or intended beneficiaries. As part of the scope of this project, a training structure will be developed, under which the training needs of each institution or player will be clearly stipulated and measures put in place meet the need.

Based on a discussion with the HCD team and our own assessment of needs (especially in line with the implementation of this pilot), we briefly present the possible areas for institutional support in the sections below.

Rural Electrification Authority (REA)

Areas	Challenges	Possible areas for institutional support
Planning	Update of REMP to be produced in the short term (2014-2017) Planning of rural electrification to involve both levels of government (national and counties) Lack of coordination and overlap of responsibilities is a concern NERA to become a one-stop shop for developers of renewable energy projects	Conducting energy surveys to feed into the master planning process Renewable energy resource assessments GIS mapping Trainings on policy development/ incentives Producing development process guidelines for mini-grid projects Coordination of two levels of government
Financing	Devolution involves allocation of rural electrification fund to counties based on their rural electrification needs Privatisation of GoK mini-grids and establishment of private mini-grid concessions would have REA (or the counties) channelling funds and subsidies	Investments framework for PPP's. Use of energy funds for mini-grid investment support. Administration of financial and other incentive schemes for mini-grids. Financial management in relation to devolution and allocation of subsidies.
Operation	REA currently developing a framework for collaboration and division of responsibilities with counties Lack of synergy and overlap of mandates is a serious concern NERA to become a one-stop shop for developers of renewable energy projects	Assist REA to develop capacity building services for counties and for project developers Managing the mini-grid project approval process Procurement processes and documents for competitive bidding (of services, mini-grid projects, renewable energy) Technical training in hybrid mini-grids: design skills, feasibility studies, etc.
Monitoring	Privatisation of GoK mini-grids and establishment of private mini-grid concessions will require REA (or the counties) to monitor performance	Monitoring and evaluation skills, especially regarding technical and financial performance of mini-grids

Energy Regulatory Commission (ERC)

Areas	Challenges	Possible areas for institutional support
Planning	More complexity in integrated planning tasks given the involvement of the counties in energy planning	

Areas	Challenges	Possible areas for institutional support
Financing	Funding requirements of increased workload relating to privatisation and devolution	
Operation	Growing demand from private sector for project licensing Devolution will require licensing counties to create regional distributors Currently no specific or streamlined procedures for licensing mini-grid projects. Need for reduction of transaction costs for developers. Trend of hybridisation of mini-grids	Technical regulation of hybrid mini-grids. Develop [simplified] standards and norms of mini-grids. Development of streamlined mini-grid licensing procedures and standardised licence templates. Development of other relevant regulations, e.g. procedures for grid connection of private mini-grids
Monitoring	Monitoring, enforcement and compliance (and potentially negotiation of tariffs) with an increasing number of power generation and distribution licensees	Monitoring and evaluation with a focus on private concessions

Kenya Power (KPLC)

Areas	Challenges	Possible areas for institutional support
Planning	More complexity in planning tasks given the involvement of the counties in energy planning and development of distribution networks	
Financing	KPLC as off-taker of IPPs in hybrid mini-grids. Added complexity in negotiation of PPAs.	Negotiation of PPAs for hybrid mini-grids
Operation	Integration of renewable energy into mini-grids. Added technical complexity to increase share of renewables (energy storage, control equipment for hybridisation, etc.) Metering technologies	Technical training in renewable energy and hybrid mini-grids, energy storage and control Production of feasibility studies Managing the operation and maintenance tasks in hybrid mini-grids Smart metering technologies, including time of use tariffs possibilities
Monitoring	Remote monitoring of hybrid mini-grid sites	Remote monitoring

3.3 Recommendations for institutional support

Based on the previous assessment, we recommend the following areas for institutional support and technical assistance. These are important in relation to the involvement of the private sector and the county governments in the development of hybrid mini-grids.

- **Technical aspects:**
  - Technical training in renewable energy and hybrid mini-grids, including energy storage and control equipment. Technical feasibility and operation and maintenance of hybrid systems.
  - Load management, smart metering technologies and remote monitoring
- **Administration and financial management:**
  - Producing development process guidelines for mini-grid projects
  - Assist REA to develop capacity building services for counties and for project developers
  - Investments framework for PPP's in the development of hybrid mini-grids. Use of energy funds for mini-grid investment support. Administration of financial and other incentive schemes for mini-grids.
  - Procurement processes and documents for competitive bidding (of services, mini-grid projects, renewable energy)
  - Financial management in relation to devolution and allocation of subsidies to private concessions.
- **Regulation:**
  - Technical regulation of hybrid mini-grids. Develop simplified standards and norms of mini-grids.
  - Development of streamlined mini-grid licensing procedures and standardised licence templates.
  - Development of other relevant regulations, e.g. procedures for grid connection of private mini-grids
  - Monitoring and evaluation regarding technical and financial performance of mini-grids

4 Review of licensing and permitting of mini-grid operators

The latest drafts for the new energy policy and law indicate that licensing activities will be primarily undertaken by the national government (the ERC). Although certain licensing functions will be devolved to county governments (see table below), these are not relevant to the development of mini-grids.

Table 5 Licensing activities and devolution to counties

Area	Licensing by the national government (ERC)	Licensing by the county government
Electricity	Licensing of: - Electric power generation, transmission and distribution - Retail of electrical energy (by KPLC, counties or other) - Examination of electricians - Electric power import and export - Appoint, register and oversee the operations of electricity service providers	- Issuance of licences for electrical contractors
Renewable energy	- Licensing of generation of electricity from solar and wind - Registration of energy auditors and keeping an updated register of the same	Licensing of: - solar water heater and PV contractors - Solar system installation technicians

It is important to highlight that to date there are **no licensing and permitting procedures specific to mini-grid development** and that there is no precedent in Kenya of licenced private mini-grids. The existing licensing procedures for RE generation are related to the PPA and FiT framework and the existing licensing procedures for distribution and retail are for utilities, i.e. the same framework applicable to KPLC.

4.1 Overview of applicable licences and permits

The Energy policy and existing legislation support the development of private mini-grids. All mini-grid projects must comply with:

- The Energy Act, 2006 (check Energy Act 2006 versus Draft Energy Bill) – in particular sections 27 to 31 on licensing of electrical energy activities.
- Energy (electricity) licensing regulations of 2012
- Environmental Management and Coordination Act 1999
- Kenya Electricity Code – in order to have mini-grids to grid-connection standards

Table 6 presents an overview of applicable licences and permits for different types of mini-grid projects. All mini-grid projects regardless of size require a licence or permit to operate. The only electricity undertakings exempted from such requirement are power generation projects of capacity below 1MW for own consumption.

Table 6 Overview of applicable licences and permits for mini-grid projects

Type of project (ownership)	Licence requirements	Precedents
Private mini-grid concessions	Electric Power Generation, Distribution and Supply Licence	Licences granted to tea factories for captive supply. No precedent for retail supply.
Power Purchase Agreement	Electric Power Generation Licence (>3MW) or permit (<3MW)	IPPs supplying to grid and captive power producers.
Community mini-grids (Electric cooperative or village trust)[24]	Electric Power Generation, Distribution and Supply Licence	No precedents

The new bill states specifies the minimum duration of licences for electricity undertakings as follows:

- fifteen years for electricity generation;
- thirty years for electricity transmission or distribution;
- five years for retail supply of electricity.

There is no specific mention to the case of vertically-integrated mini-grids, which encompass all of these activities.

4.2 Licensing and permitting process

As previously explained, there are currently no standardised procedures for licensing mini-grid projects. Based on the current licensing regulations (2012) as well as the guidelines for licensing renewable energy projects (the latter, developed within the framework of feed-in tariffs, are the clearest and most developed guidelines for IPPs[25]), the following table provides an indication of the steps and clearances needed for these type of projects.

[24] Community-based mini-grids (either electric cooperatives (regulated by the Cooperative Societies Act) or village trusts (regulated by the Companies Act) could be given different regulatory treatment than private mini-grid concessions. The new bill proposes that oversight of cooperatives be undertaken by NERA as opposed to the ERC. Licensing could be treated as captive supply thus avoiding the requirement of tariff negotiations with the regulator.

[25] Guidelines and additional information can be found in Kenya's Renewable Energy Portal: http://renewableenergy.go.ke/

Table 7 Indicative licensing and permitting process

Steps	Responsibility	Timeline	Details
Identification of project and prefeasibility assessment	Applicant	N/A	The Feed-in-Tariff Application and Implementation Guidelines can be used as a reference for the requirements to prepare for the Expression of Interest.
Submission of Expression of Interest (EOI) to the MoE	Applicant	N/A	Applicant must previously communicate interest to local authority (county government) Before making any application for a licence, the applicant shall give 15 days notice by public advertisement in at least two national newspapers
Approval of EOI	MoE	3 months	The EOI may be approved for three-year exclusivity period or rejected.
Project full feasibility study and acquisition of clearances	Applicant	24 months	This stage includes the following clearances: - Acquisition of land and wayleaves - Environmental Impact Assessment (NEMA, 2-4 months) - Approval of change of user (control of land use and development) (County government, 2 months) - Development Permit (Safety of buildings, planning control) (County government, 2-3 months)
Review of feasibility study	MoE	3 months	
Negotiation of PPA with off-taker	Applicant and off-taker	6 months	**Applicable to PPA projects only**
Approval of PPA by national regulator	ERC	1 month	**Applicable to PPA projects only**
Negotiation of retail tariffs with regulator	ERC	6-8 months? (no precedents)	**Applicable to private concession projects** Community-based projects might not need to negotiate tariff if there is community support.
Issuance of licence for power generation (and distribution and retail if relevant)	ERC	3 months	Compliance with Energy Act and Electricity Licensing Regulations 2010
Total duration of process		**Approx. 3 years**	

Note: The Commission may, through a fair, open and competitive process in accordance with procedures prescribed by the Cabinet Secretary by regulations, invite applications for a licence.

Current issues faced by developers of mini-grids that could be addressed by regulation and licensing procedures are:

- Procedures currently not suitable for small projects. Lengthy process and high transaction costs. Many micro-grid sites are currently operating without a permit due to this.
- There is currently no programmatic approach for firms interested in developing multiple sites
- Light-handed regulation for mini-grids under a certain size (e.g. below 0.5MW) and standardisation of procedures recommended to reduce transaction cost.
- Existing unlicensed micro-grids rely on smart metering technology. Procedures for approval of non-standard metering technology might be required.
- Finally, as discussed in section 2.3 with regards to good practices, it is important to define a framework for the grid connection of private mini-grids still unclear.

Task 2: Lessons learned and best practice analysis in SSA and Kenya

5 Experience in Sub-Sahara Africa

The future electrification will rely on mini-grids to a large extent; the International Energy Agency (IEA) anticipates that more than 50% of the rural population currently without energy access are best supplied with electricity via mini-grids.

Putting in place the right policy for mini-grid deployment, and thus accelerating its uptake, requires considerable effort but can yield significant improvements in access to electricity, as examples from Senegal, Mali, Tanzania, Kenya and other countries show. Mini-grids can be operated by utilities, dedicated private companies, community-based organisations or some combination of these. The preferred choice of model is not merely a technocratic decision but rather depends on national, social and political circumstances as well as on the size and structure of the mini-grids. Today, more and more governments are trying to attract private financiers and private mini-grid operators in view of constrained public budgets[26].

The presentation of case studies in this section and section 6 seeks to cover different electrification models adopted in Sub-Saharan Africa in order to draw lessons from each. This includes public-sector-led models such as in Kenya and Tanzania, private concessions models such as in Mali and Senegal, community-led models such as the case study of Cape Verde, and finally, the case of unregulated private markets such as Somalia.

Table 8 presents the international case studies selected for this study. Each of these case studies has innovative features and/or lessons learned (related to technology, management models or other aspects) of value to this project. Section 6 will cover the utility-led approach of Kenya.

A brief presentation of each case study follows.

Table 8 Proposed SSA case studies

Country	Case study	Business/ management model	Innovative/ noteworthy features
Cape Verde	Santo Antâo island solar PV hybrid mini-grid	Public Private Partnership	❏ Innovative energy management technology (energy dispensing meters) ❏ Community ownership (municipality) with private participation in O&M ❏ Good example to illustrate pros and cons of

[26] From "Mini-grid Policy Toolkit" (RECP, EUEI-PDF, ARE and REN21)

Country	Case study	Business/ management model	Innovative/ noteworthy features
			mixed models
Mali	Yeelen Kura solar hybrid mini-grids	Private concessions	❑ Yeelen Kura has installed 9 solar mini-grids ranging in size from 50kWp to 150kWp ❑ Good example to illustrate pros and cons of mini-grid concessions.
Somalia	Private diesel mini-grids	Private sector driven, unregulated	❑ More than a hundred unregulated IPPs running diesel mini-grids. ❑ Several IPPs considering investment in renewables to reduce costs.

5.1 Cape Verde - Santo Antâo island solar PV hybrid mini-grid

Table 9 Santo Antâo island solar PV hybrid mini-grid

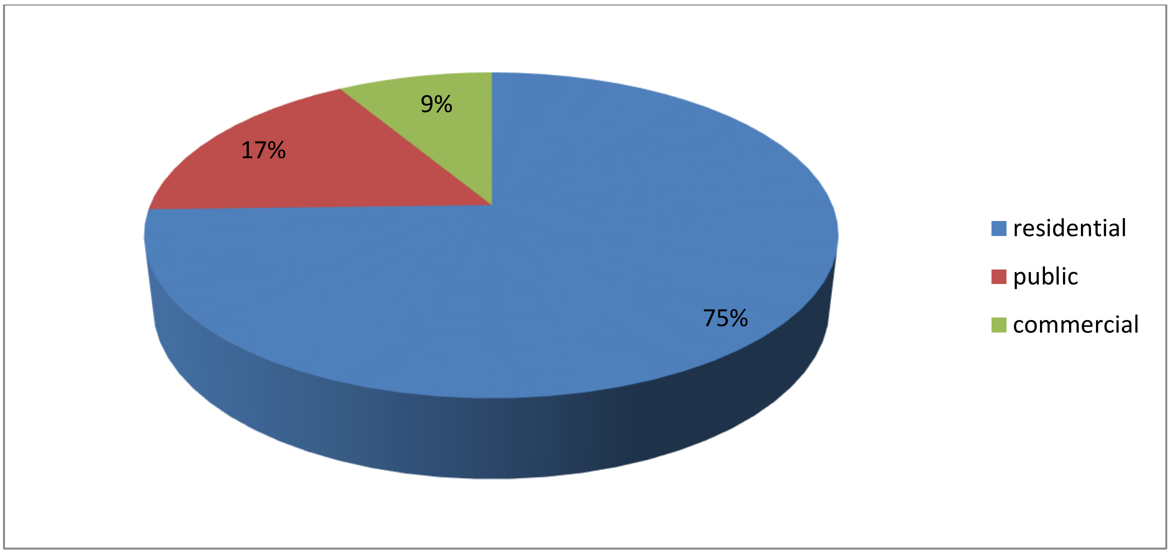
Location	Monte Trigo, Santo Antao Island, Cap Verde
Start date	2012
Technology	Hybrid solar/diesel, LV distribution, energy dispensing meters
Installed capacity	27.3 kWp (first phase) and 11.7 kWp (second phase), 20 kVA diesel genset
Number of people served	60 households in the first phase, addition of 15 in the second phase.
Other energy uses	Productive use (ice production for fish preservation), public lighting
Project cost	
Delivery model and private sector role	Ownership: Government (municipality) Management (generation, distribution, retail, O&M): public-private company
Organisations involved	❑ ACP-EU Energy Facility (funding) ❑ Aguas de Porto Novo (APN) (public-private entity managing the mini-grid)
Innovative/ noteworthy features	❑ Innovative energy management technology (energy dispensing meters) ❑ Community participation in civil works and community training.

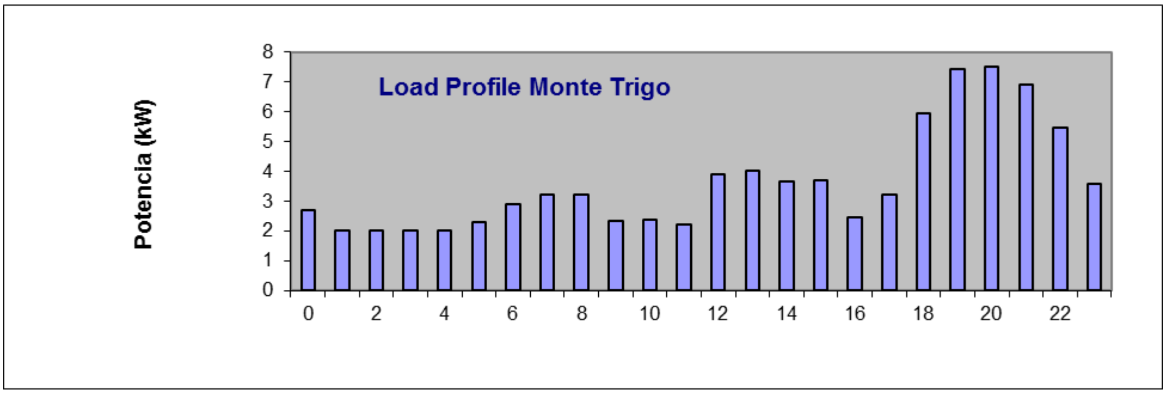
Technical description

The needs of the village are supplied with standard electricity of 230V, 50Hz AC delivered through an 800m aerial distribution line to households (75), one school, a church, a kinder garden, a health centre, a satellite TV dish, three general stores and 22 street lights. Power is available 24 hours per day. Productive use of energy includes production of ice to preserve fish.

The following figures illustrate the share of power consumption according to user and the load profile.

Figure 2 Power consumption by user category and daily load curve





The PV hybrid micro power plant can produce an average of 109 kWh per day. This energy is partially consumed during the daytime and part is stored in batteries with a capacity of about 370 kWh for night time consumption. The system´s main technical characteristics are summarised in the table below.

Table 10 Technical specifications of Monte Trigo mini-grid

MSG MONTE TRIGO	
GENERAL SPECIFICATIONS	
Owner	Municipality of Santo Antâo
Operator	APP
Quality of the service	24 h/day, 230 VAC single phase
Number of connections (initial/planned)	61 / 80
Type of Tariff	Energy Daily Allowance (EDA)
Aggregate contracted de EDA (kWh/day)	90
Rated RE Production (kWh/day – $H_{p)}$	85 at 5,2
INDIVIDUAL LOADS (ENERGY DAILY ALLOWANCE)	
Households (EDA=825 Wh/day)	20

Households (EDA=1 100 Wh/day)	18
Households/Shops (EDA=1 650 Wh/day)	14
Households/Shops (2 200 Wh/day)	6
School (EDA=1 650 Wh/day)	1
ICE maker machine (~ 4.200 Wh/day)- deferrable	1
PV GENERATOR	
Photovoltaic Capacity (STC)	27 300 W
Module Type	ATERSA 130 W_{STC}, 36 cells silicone mono crystalline
Number of modules	210
Inclination / orientation	15º / +20º S
BATTERY CHARGE CONTROLLER	
Rated power	12 x 2 000 W
Converter type	Maximum power point tracker (MPPT)
Recharge algorithm	3 stage with adaptative voltage
BACK UP GENSET	
Rated Capacity	20 kVA 3 phase
Fuel	Gasoil
BATTERY	
Technology	Lead-acid vented deep discharge cycle
Number of cells (voltage)	2 batteries of 24 cells (2V ea.) (48V)
Model	Exide OPzS Solar 3 850 Ah
Total capacity (C_{100}) (kWh)	370
Autonomy	4 days at rated demand
INVERTER	
Model	Studer Innotech XTH 8000
Voltage in/out	48 V_{CC} / 230 V_{AC} single phase
Rated Power (30')	2 X 8 000 W
Harmonic Distortion	< 2,5%
DATA LOGGING	
Type of data	Energy, voltage, temperature, solar radiation, etc.
ELECTRICITY DISPENSER METER	
Voltage	230 V_{AC} 50 Hz
Model	CIRCUTOR Electricity Dispenser BII
Cut off power	Setting according to tariff at (500 W,1000 W, etc)
Algorithm	Energy Daily Allowance (EDA) configurable
DISTRIBUTION and STREET LIGHTS FEEDER	
Length (m)	800
Number of lamps	20
Type	70 W hps / 2 level electronic ballast
Total Power – High (W)	1 400
Total Power – Low (W)	840

The diesel generator is used only for back-up. 99% of the energy is generated by the PV plant. As it can be seen the system has been sized in order to use the old 20 kVA genset only as a backup.

During the initial phase of the project, the team of Trama TecnoAmbiental (TTA) interviewed users to assess their energy needs and their willingness to pay for the 24 hour service. Then the concept of Energy Daily Allowance (EDA) was introduced.

The EDA makes the demand management more intelligent and flexible by capping the power and energy available to each user to an agreed maximum. This assures that the plant operates within its rated design and there will be no black outs nor unforeseen increases in operating costs because of higher back up diesel fuel consumption. This limit is, nevertheless, flexible according to the plant's condition and on very sunny days users' are encouraged to make use of the surplus generation at no extra cost. The community felt involved and each family chose to contract the EDA monthly fee they wanted from 5 possible options (see table).

Table 11 EDA levels for Monte Trigo

Energy demand type	Energy Daily Allowance [Wh/day]	Power limit [kW]
Very Low	825	0,55
Low	1 100	0,55
Medium	1 650	1,10
High	2 200	1,10
Very High	3 300	1,65

In order to implement the EDA concept, a smart meter, the Energy Dispenser, has been developed. This device limits both power and energy at programmed EDA levels according to the needs of the users. The following table shows the operating modes available offering additional features to the users in function of the state of charge of the battery.

Table 12 Operating mode of the dispenser

Mode	Description	"Price" of energy	Power plant's status
Bonus	Incentive to consume energy	2 energy unit consumed = 1 unit	Battery is full and equalized
Restriction	Incentive to reduce energy	1 energy unit consumed = 2 unit	Battery SoC is low

A monitoring and data logging system has been implemented in order to register technical data on the operation of the grid at the "generation plan" level giving information of PV generation, level of charge of the battery, yields and performance ratios, load profile, etc. It also monitors the quality of the services (quality of the electricity, interruption occurrence, etc). The figures 4 and 5 show the type of monitoring realized.

At the users' level, the energy dispenser is gathering information regarding energy consumption. The user satisfaction and the service quality are subjective matters and should be quantified through questionnaires, which has not been done so far. However, the increase of the consumption and the extention of the PV plant are positive signal proving that the population is using the systems and benefit from it.

This monitoring based on technical indicators gives an accurate idea of the quality of the electricity service given to the users. Nevertheless a social study coupled with an economic study is necessary to assess the impact of the project in the community.

So far the quality of the service is excellent. There is no problem in maintenance, no interruption of the service (the genset has been turned on once only), etc.

The system expansion is motivated by two main factors: the increase of the consumption in each household and the will of the local fisherman's to have more ice production. In fact in the original idea the ice machines could only be used during energy exciding level within the system. They insist a lot for system expansion so, as there were also 20 families who were waiting to be connected, it was decided to implement 12 kWp more PV capacity. A part on that the operation was always excellent and the diesel genset was only turned one once, during local village celebration when many villagers from the villages nearby and the overall energy consumption reached extremely high level for one week continuously.

Organisation and stakeholders

Before the implementation of the project, a diesel generator supplied the users only 4 hours per day. The Operation and Maintenance were assured by the public service of the municipality of Porto Novo of which this community depends. The municipality owned the generator and the grid, paid the fuel and replacement and charged a flat tariff based on the regulated national tariff.

Aguas de Ponta Preta, implementing private entity of the project and specialised in water treatment, has created with the Municipality of Porto Novo a private-public partnership to create a mix company called Aguas de Porto Novo (APN) in charge of water treatment in the area and which became the operator of the electricity service in Monte Trigo.

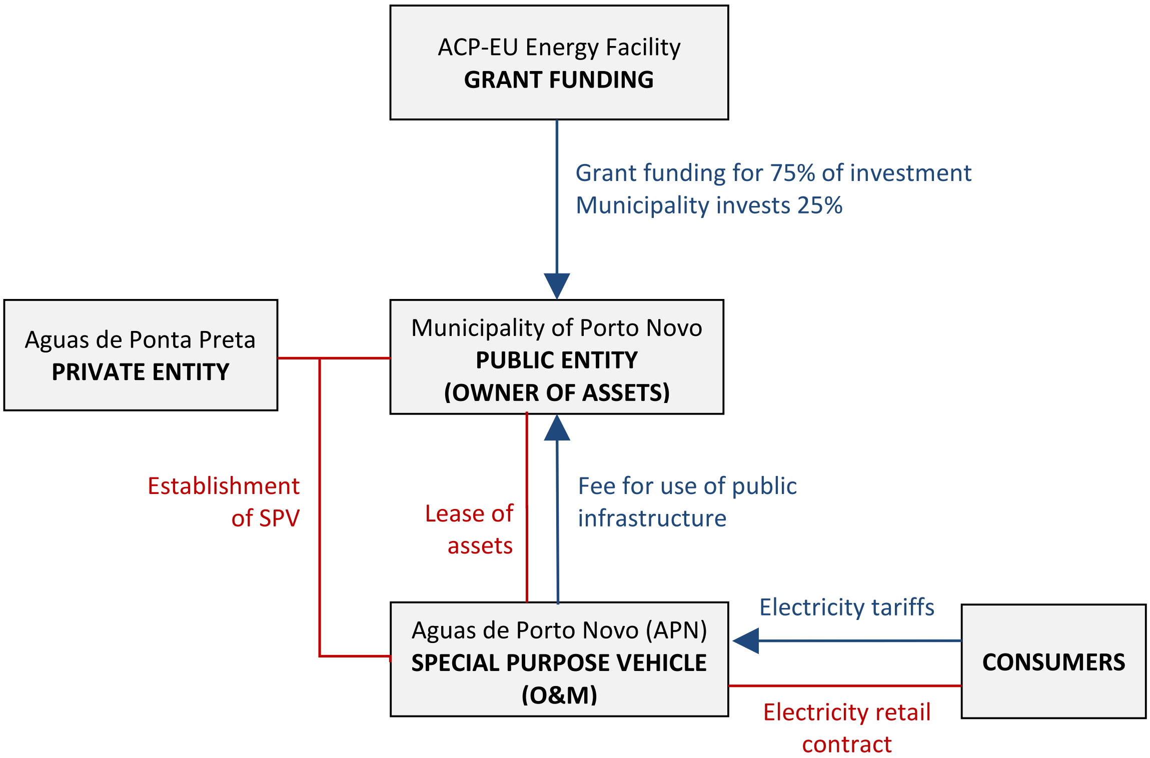
The new assets (PV array, battery, etc) purchased in the framework of the project belong totally (100%) to the Municipality as well as the distribution grid. APN ensures the O&M, pays a fee to the municipality for the use of the public infrastructure and charges a tariff to the users.

The experiences of APP / APN in service providing was essential in administrative and organizational activities for electricity service providing. Also it gives a trustable impression to final users and relevant actors of the project.

If we include the local village O&M basic maintainer, APN is currently dedicating 4 people for the utility management.

Up to date this service management model is completely successful even though it has not been tested yet in serious fails and reinvestments needs which, certainly is the more critical moment of every model.

Figure 3 Delivery model for Monte Trigo mini-grid



Financing and Tariff scheme

The table below summarises the capital requirements of the Monte Trigo mini-grid project.

Table 13 Investment cost of Monte Trigo mini-grid

Item	Cost (EUR)
Ice machines	12.000
PV generator	86.500
Batteries	36.979
Electronic devices and cabling	70.000
Diesel genset (only protections, cabling, accessories, etc)	5.440
Public lighting (renew of existing system)	5.440
Dispenser and wiring connections	9.960
Internal installation and distribution line (renew of existing system)	14.640
Civil works	15.000
Final users connections	8.400
Shipping	28.000
Electrical installation and commissioning	28.000
TOTAL CAPITAL	**320.359**

75% of the Capital Costs of the PV project were financed by the EU within the framework of a EuropeAid project. The other 25% were financed by the municipality as public investment for infrastructure. APP as the other partners participated to the project with the 25% of their direct dedicated budget, which was mainly contribution in human resources. While the local community was involved during all the installation phase (discharging materials, small works etc).The tariff definition is based on a financial analysis of the LCOE (Life Cycle Cost of Energy) at a 20 years horizon. The average cost of the kWh is around 0.25 EUR/kWh.

The first group of costs related to O&M service is related to the personnel dedicated to these activities. For these reason we assumed:

- One Administrative manager
- One technical specialist
- Two basic technicians

Regarding replacement of parts, the assumptions have been the following:

- Batteries (after 9 years possible considering EDA concept implemented)
- Diesel generator (after 8 years with 95% of solar fraction considered)
- Electronic devices, Dispenser meters and communication system (10 years)

Tariff collection is based on fixed monthly fees related to the contracted EDA and sustains operation and maintenance activities (O&M), which includes replacements of all the required devices to be repairs/substitute within the 20 years of life-cycle, and also pay back of part of the capital costs. Users were very happy with this scheme because it allows them to have an energy budget cost that they can count on.

Table 14 EDA tariff

Category	EDA [Wh]	Power Limit [kW]	Max. "store" Capacity (EDA)	Recommended Monthly Fee [€]
T0301	825	0,55	6	11,52
T0401	1.100	0,55	6	14,58
T0602	1.650	1,1	6	21,12
T0802	2.200	1,1	6	27,64
T1203	3.300	1,65	6	40,30

The tariff fee presented in the table above is composed by energy fraction (fix monthly fee related to EDA contracted) plus a fix fee related to the power max limit contracted (average of 1,33/500W) plus 0,40 euro / dispenser rental fee. The price for new connection is around 2 euro /connection.

This figure represent the real cost since there is no cross-subsidy or feed-in tariff. The initial investment, or at least 75% of it, is not taken into account since this was a donation from the EU. The tariffs cover the remaining 25% of the investment, the O&M and replacement costs, and the commercial margin of the operator.

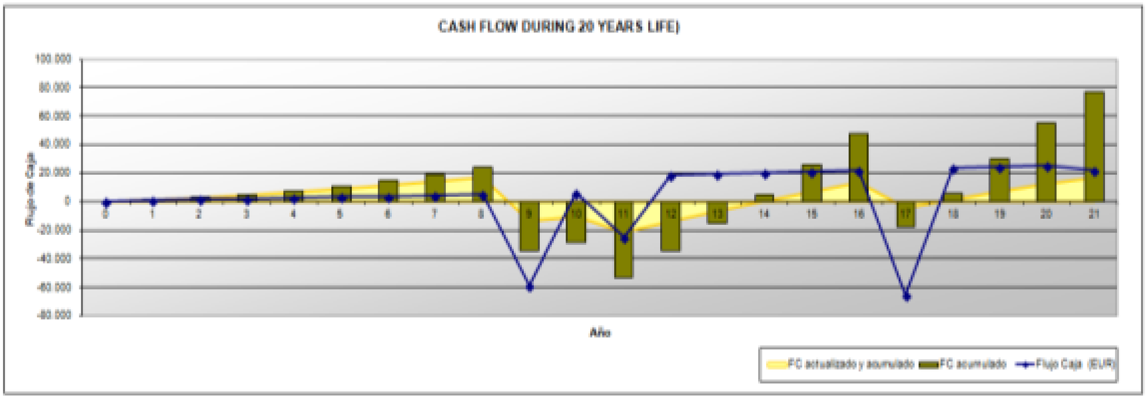
We remind that all the tariff fees presented are recommended, not yet approved by the national regulator.

It is difficult to compare with the former system since the service is totally different. The user used to have only 4 hours of electricity service per day. Now they have 24/24h.

The financial performance expected from the project has been shaped in order to recover 25% of the initial capital costs made by the local government, a part from having a positive NPV.

In the graph below it can be seen the economic trend of the main indicators and in particular the aggregate cash flow (brown bars).

Figure 4 Economic Results considering recommended tariffs (TTA)



NPV 16.795 EUR SUSTAINABLE PROJECT

Lessons learned

1: COMMUNITY INVOLVEMENT AND CAPACITY BUILDING

The participation of the community from an early stage in the project definition, project execution and during the operation has helped realizing a design matching the current demands, and has made the final users more involved in term of responsibility and up keeping the installations. On top of that, during the following stages, the community has been involved in simple O&M tasks.

2: TARIFF SCHEME BASED ON FLAT RATES

Flat rates based on Energy Daily Allowance have proven to make the operation easier and cost-efficient, without the need to carry out meter-reading to invoice the users. Flat rates has reduced the risk of users or failing with their payments, allowing a sound cash-flow to ensure sustainability.

3: SMART ENERGY CONTROL SYSTEM BASED ON THE DISPENSER METER

Electricity dispensers-meters have been fundamental in load management, in consequence the battery operation is safely kept within their design limits, therefore ensuring the expected lifetime of the installation.
Electricity dispending meters also serve as an incentive to consume energy during the day, which is fundamental in solar energy systems.

4: POSITIVE PERFORMANCE EFFECTS

Also the productive use of the energy, promoted especially with the two ice machines capable of up to 500 kg/day using peak and solar surplus generation had improve the commercial activities on which the village sustains its economy. Other activities have included welding machines, refrigerators, etc.

5: WEAKNESSES

One weakness of this model could be the mix between private and public entities in the ownership and the operation. There could be a conflict since the interests may be different. For instance, in the case of Monte Trigo, it exist some conflicts because the municipality does not pay back so far the agreed amount from the tariffs to the operator.

5.2 Mali - Yeelen Kura solar hybrid mini-grid concessions

Mali has adopted a concession model to rural electrification. In 2010, 82 concessions were in operation and 59,000 connections had been achieved, bringing the rural electrification rate to 14.9%, which exceeded the original targets. Most of the concessions in place operate diesel mini-grids but the government has started to actively support the use of renewables with funding from bi-lateral and multi-lateral donors and development banks.

One of the concessionaires, Yeelen Kura, currently operates 9 mini-grids located in the cotton-growing region in southern Mali since 2001 company. It is one of five companies supported by FRES (Foundation Rural Energy Services) of the Netherlands.

Table 15 Yeelen Kura (Mali) solar hybrid mini-grid concessions

Location	9 concession sites in Mali (Sikasso and Ségou provinces)
Start date	Start of operations in 2001. First solar mini-grids in 2007
Technology	Medium size solar mini-grids, ranging from 50 to 150 kWp (total installed capacity of 622 kWp of solar), diesel back-up, MV and LV distribution
Installed capacity	Ranging from 50 to 150 kWp of solar PV per site
Number of people served	6,000 connections considering all sites
Other energy uses	Low commercial and industrial use (only 15% of consumption)
Project cost	between USD 0.5 and USD 1.5 million per site

Delivery model and private sector role	Ownership: Private (Yeelen Kura) Management (generation, distribution, retail, O&M): Private (Yeelen Kura)
Organisations involved	❑ Funders: Government of Mali and FRES ❑ Utility/concessionaire: Yeelen Kura
Innovative/ noteworthy features	Concession model to accelerate pace of rural electrification through private sector leverage

Technical description

Yeelen Kura owns and operates 9 solar hybrid mini-grids. Many of these sites started operations as diesel mini-grids which were later converted to hybrids. The total installed capacity of solar PV is of 622 kWp (capacity in each site ranges from 50kWp to 150kWp).

Yéelen Kura produces approximately 750 MWh of energy annually to cover the needs of approximately 5,000 mini-grid customers. Production is almost exclusively from solar PV with the diesel gensets being used as back-up.

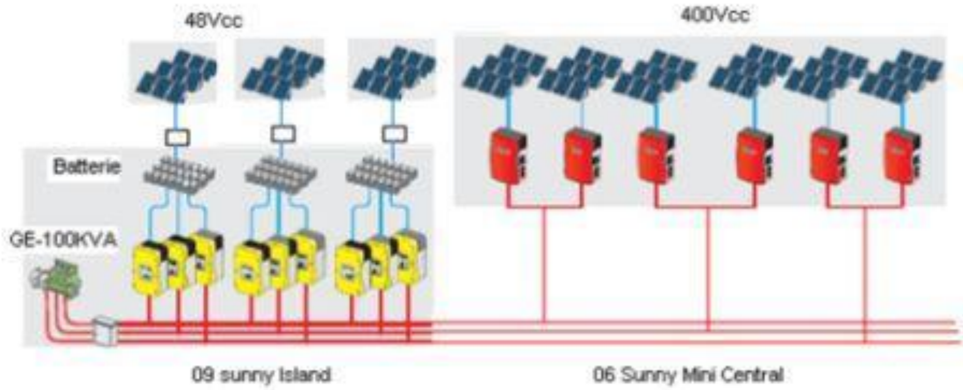
The profile of energy consumers is 80% residential, 15% commercial and 5% public. Power consumption per user is low (12.5 kWh/month per customer) and mini-grids usually supply power in the afternoon and evening, making the integration of batteries (1 to 2 days of autonomy) fundamental.

Although minigrids should have the capacity of supplying energy on demand at whatever hour, technical limitations as well as requests arising from communities restrict operating hours in order to avoid high electricity bills for consumers. For example, the schedule in Kimparana is from 4pm to 1am. The schedule for Bla is from 9am to 2pm and 6pm to 1am.

Distribution is usually in low voltage and customers are equipped with meters or load limiters depending on the tariff scheme chosen.

The solar minigrid at Kimparana is 72 kWp was designed and installed by Dutch firm Tss4U. Technologies used include Ubbink modules, SMA grid inverters and sunny island systems and batteries.

Figure 5 Configuration of solar mini-grid (Kimparana, Mali)



The new solar PV plants at Kolondieba (50 kWp) and Ourikela (51 kWp) have been designed and installed by German system integrator Asantys Systems GmbH. They are also based on sunny island technology and have a hybrid configuration with diesel genset.

Organisation and stakeholders

The approach to rural electrification in Mali is a concession model (concessions granted for 12 or 15 years depending on the installed capacity). These concessions are managed and regulated by AMADER (Malian Agency for Household Energy and Rural Electrification).

AMADER established a rural electrification fund (REF) which provides mini-grid operators with an 80% investment subsidy (with a ceiling of USD 500,000) to electrify concession zones. The original REF endowment was of USD 25 million and the main objective was to provide access to electricity to 10% of the rural population in 2010 and 55% in 2015 (from 5% in 2007).

Energy supply company Yeelen Kura is one of the private concessionaires that started incorporating solar energy into their projects. It currently operates 9 solar hybrid mini-grids. Funding for investment capital comes from the Government grants (the stated 80% investment subsidy) and other donor funds sourced through Dutch mother company FRES. The strategy of FRES is to help set up rural electrification concessions with a planned exit after the companies are deemed self-sustainable.

Yeelen Kura is a vertically integrated energy supply company operating on a fee-for-service model. The fees are proposed by Yeelen Kura based on the costs of operation and balancing the clients' ability to pay. These tariffs require negotiation and approval by AMADER and are therefore not entirely cost-reflective. Currently, operating expenses and profits are covered by the fees charged to users but investment cost is not entirely recovered.

Yeelen Kura has encouraged the formation of energy committees in communities to represent in negotiations with the utility. For example, the committees agree the number of hours and specific schedules of operation with the utility.

Financing and Tariff scheme

Financing of mini-grids has been through FRES (20%) and the Government of Mali through AMADER (80% capital subsidy). Funders of mini-grid projects set performance targets based on number of connections.

Tariffs are regulated by AMADER for each concession and take into consideration power generation costs. There are flat tariffs (for consumers with load limiters (50W or 100W) or tariffs for metered costumers (either for single phase or 3-phase supply). Average tariff for Yeelen Kura is approximately 0.50 $/kWh.

Capacity constraints at AMADER and the growing number of concessions requiring oversight (82 concessions in 2010) limits their ability to update tariff agreements and tariff schedules sometimes are outdated triggering ad-hoc subsidies, such as fuel subsidies.

Lessons learned

A private concession model has allowed Mali to leverage limited public resources for rural electrification. Yeelen Kura has been an excellent example of technological innovation (first concessionaire to integrate renewables).

The main challenges faced by energy service companies and the AMADER are:

- Low energy consumption in rural populations. Electricity use remains at a basic level (lighting, basic appliances, etc.) and the benefits of electricity for value added purposes (commercial and industrial) have not been fully exploited. In the particular case of Yeelen Kura this has been linked to operating in provinces whose economy was dominated by cotton, an economy which collapsed due to falling commodity prices. Also, performance targets strongly linked to number of connections have generated ill incentives (one of the mini-grids decided not to connect large consumers such as a textile factory or a telecom tower) in favour of achieving more low energy consuming connections.

- The tariffs negotiated between the operators and AMADER are different for each concession and normally well above the kWh price paid by grid-connected customers. The demand from the rural population for uniform tariffs remains a concern for the AMADER and causes significant downward pressure in the negotiation of fees with the operators.

- The capacity of small local players to manage an energy company effectively with a fee-for-service model has been raised as a concern by AMADER.

- ❑ The income of the mini-grids currently do not allow initial expenses to be earned back, and expansion of the business is thus dependent on government subsidy schemes (80% of equipment costs) remaining available. These conditions may be uncertain in the medium to longer term, given limited budgets and alternative (possibly lower cost) options that governments have to promote rural electrification.

5.3 Somaliland - Private unregulated diesel mini-grids

Since the declaration of independence in 1991, Somaliland's electricity system was rebuilt and is now operated almost entirely by independent power producers (IPPs) each supplying areas in its neighbourhood. There is no central grid in Somaliland, so the system could be regarded as a conglomeration of mini-grids, both in urban and rural settings.

Technology

IPPs have fully vertically-integrated systems; they have built and maintained infrastructure to generate, transmit and distribute electricity in the areas in which they operate. In urban environments, it is common for different IPPs to compete for the same geographic area and have overlapping distribution networks.

At present, all Somaliland power producers rely exclusively on imported diesel fuel as the source of energy to generate electricity. Cost of fuel can vary between 0.30 – 0.80 USD/kWh depending on the size and efficiency of the generator, the maintenance conditions and the technical losses.

The cost implication of transmission and distribution losses is not negligible. Distribution losses are estimated by different at IPPs to range between 10% to more than 30%. A relatively low density of energy demand and distribution in low voltage over long distances help explain the high level of technical loss.

A few private companies are planning investments in renewables (both solar and wind) to hybridise their power systems and reduce costs.

Organisation and stakeholders

While over 20 IPPs operate in Somaliland, there has been significant consolidation of IPPs in recent years with many IPPs coming together to form one large company in order to deal with duplication and inefficiencies. This is a trend that is emerging in Hargeisa, Somaliland's capital, as well as other cities.

There are a few public electricity suppliers in Somaliland, although the largest and most successful electricity suppliers are private companies (with the exception of Berbera where only the government operates). The table below shows the power supply situation in the main cities in Somaliland.

Table 16 Power supply in main towns in Somaliland

City	Installed capacity (MW)	Number of connections	Penetration in their areas	Power suppliers	Examples and updates
Hargeisa	7.5	100,000	65%	IPPs, Government	KAAH is the largest IPP in Hargeisa, with approximately 30,000 customers. (approx. 60% of households in Hargeisa). Public supplier SEA has about 8,500 active connections.
Burao	5.5	15,000	70%	IPP and Industry	
Berbera	3.5	2,400	20%	Local government and port	Berbera Electric Authority has 3,300 active connections and approximately 4,000 blocked connections
Erigavo	3.3	13,000	35%	IPP only	
Borama	0.6	4,000	25%	IPP and local government	Aloog is the largest IPP with approx. 11,000 customers (about 70% of the market). Borama Power (20% of market) and Telesom (10%).
Las Anood	0.6	3,000	85%	IPP only	
Sheikh	0.6	1,000	40%	IPP only	
Togwajaale	0.6	1,800	60%	IPP only	
Total	**22.2**	**140,200**	**61%**		

The sector is largely unregulated. In June 2013 however, the Ministry of Energy and Minerals (MEM) submitted to Parliament Somaliland's first Electrical Energy Act. This act focuses on the creation of an Energy Commission to regulate the power sector. The expected date of approval of this law is uncertain and the MEM indicated having no resources to implement and enforce this law at the moment.

Financing and tariff scheme

The price of electricity in Somaliland is high at 0.80 to 1.50 USD/kWh. This is attributed to absence of subsidies, to electricity being derived almost exclusively from diesel generators (many of them in poor condition), inefficient transmission and distribution of electricity (high technical losses) and a considerable number of consumers not paying for electricity (high non-technical losses).

Existing IPPs have an opportunity to add solar power to their existing grids, lowering their per-kWh cost. Grid connected solar PV systems can be used to reduce fuel consumption and work in parallel with the diesel generator.

Investment in IPPs is mainly exclusively driven by private equity due to the absence of a mature banking sector in Somaliland. Raising funds to buy new equipment is a major challenge. This is a barrier for the development of capital intensive renewable energy projects.

A WB-supported grant facility for business development, the Somaliland Business Fund, has created new opportunities for the development of the RE sector, the ceiling of 150,000 USD of their grants is however low. Examples of renewable energy projects currently under development are:

- ***Aloog (largest IPP in Boroma):*** Aloog is constructing 300 kW of wind power plant to connect to its grid (which has an estimated load of 1 MW, on average). The project has been funded through private capital (50%) and the Somaliland Business Fund (SBF) grants (50%). The engineering department will be trained in their operation. The addition of wind power to the grid is expected to allow for price reductions to consumers (e.g. from 1 USD/kWh to 0.80 USD/kWh)

- **LESCO (IPP in Las Anod):** another recipient of SBF grants, IPP LESCO in Las Anod is investing in solar power to hybridize its grid.

Mini-grids in rural environments

In the case of smaller villages (population below 5,000), installed capacity is low (below 100 kVA) and power is available during a limited number of hours per day, usually in the late afternoon and evening. The electricity price charged to consumers is based on the appliances used, typically charging 0.50 USD/day for an 18W bulb. This fee is equivalent to 3.4 USD/kWh, which is extremely high.

5.4 Lessons learned applicable to Kenya

Technical aspects

The concept of Energy Daily Allowance in Cape Verde has been an excellent load management tool, which is crucial for solar energy mini-grids with a limited output. Also, the incentives provided to consume electricity during daylight hours is fundamental for solar mini-grids in order to minimise the investment of batteries and significantly reduce costs. Smart metering technology and the use of time-of-use tariff schemes can help in this regard.

In the case of Mali and Somaliland, for consumers with very low levels of consumption, such as low-income households, and given the high costs of metering, the operators have chosen to charge customers flat rates per appliance or based on load limiters.

About the role of regulation

Positive aspects of light-handed regulation are well illustrated in the cases of Somaliland (unregulated market) and Mali (regulated concessions). Somaliland is an example of an electricity sector developed with minimal oversight or funding from public bodies. The sector is purely private-sector driven and competitive, tariffs are cost-reflective and electrification rates are high. In the case of Mali, the public body in charge or rural electrification grants private concessions (based on competitive bids), dispenses capital subsidies and regulates tariffs. While this model has seen a rapid growth of mini-grid concessions, the ability of the agency to supervise each concession (>100 concessions in the country) is limited causing inefficiencies in the system, such as delays in reviewing tariff schedules which trigger ad-hoc subsidies.

Another example of a negative effect of regulation (in Mali) has been to measure performance of concessionaires solely on the base of number of connections achieved, which has generated perverse incentives (e.g. one of the solar mini-grid concessions decided not to connect large consumers such as a textile factory or a telecom tower) given that their level of consumption was equivalent to a hundred or more households.

About the role of the private sector

The involvement of the private sector in all three case studies has had favourable effects. In Mali, private concessions have been a successful model in leveraging public funds. In Somaliland, the sector is purely private sector and self-regulating. In the case of Cape Verde, a private operator has been involved in an otherwise community model to avoid failures related to poor O&M.

One weakness of this model could be the mix between private and public entities in the ownership and the operation. There could be a conflict since the interests may be different. For instance, in the case of Monte Trigo, it exist some conflicts because the municipality does not pay back so far the agreed amount from the tariffs to the operator. Community involvement in the

About community involvement

The participation of the community from an early stage in the project definition (example of Cape Verde) has helped in designing a system that properly matches the energy demands. The role of community organisations in Mali has also been important in the operation of mini-grids, with the committees created to discuss energy matters with the mini-grid operator (preferences on operating hours, maintenance of electrical installations in households, etc.).

6 Experience in Kenya

6.1 Mini-grid developments in Kenya

This section provides a review of existing mini-grids and mini-grid projects under development in Kenya. Table 17 provides a summary of the type of mini-grids/ off-grid projects that are relevant to this study and what aspects have been assessed.

Table 17 Assessment of Kenya mini-grid experience

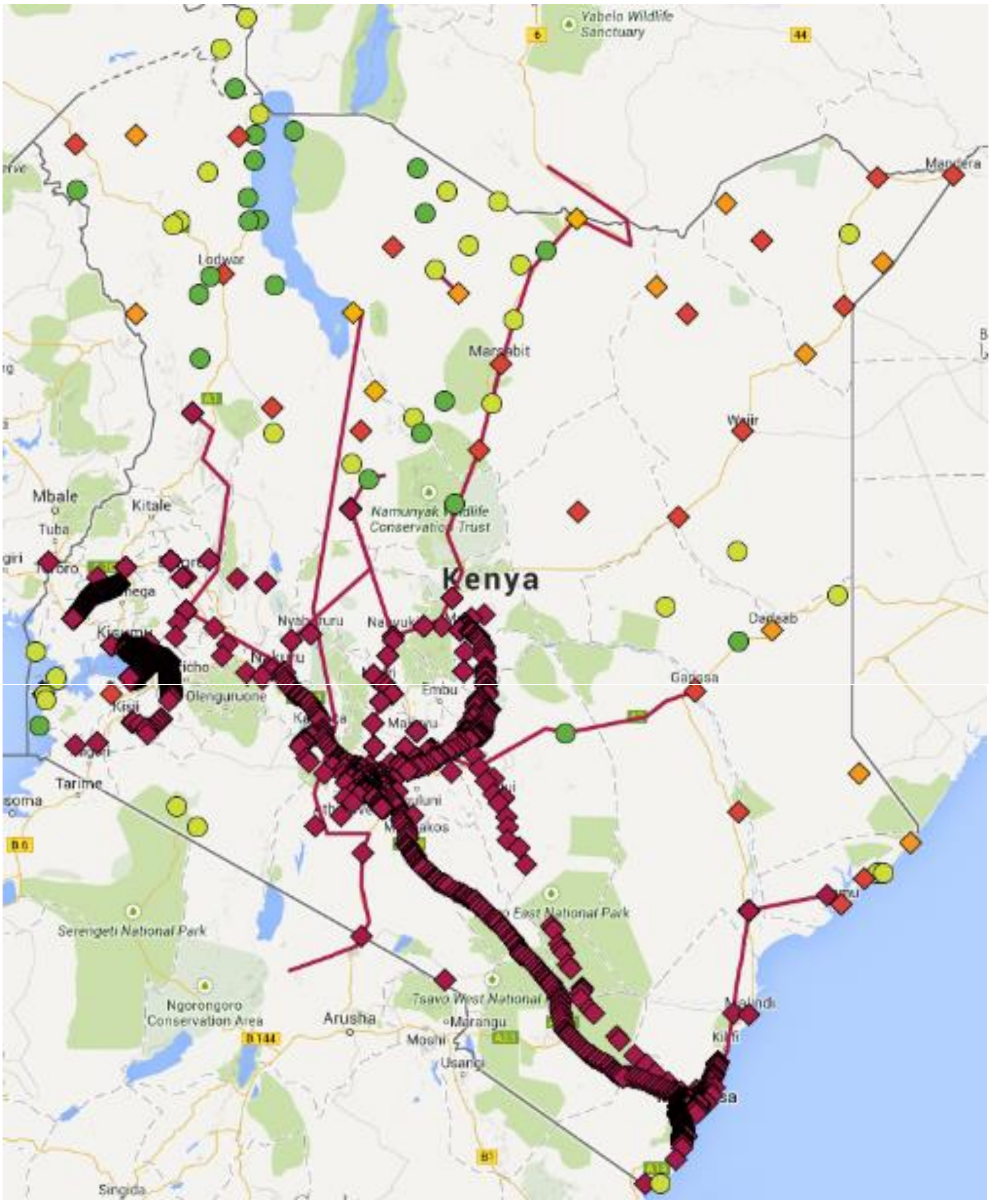
Type of mini-grid	Description	Technology assessment	Business and financing models assessment	Examples (and case studies)
Existing government mini-grids	Mini-grids operated by KPLC and mini-grids under construction by REA (including hybrid mini-grids)	❑ Energy source, installed capacity, nr. of customers, distance to the national grid, etc. ❑ Performance: load factor, O&M, fuel consumption, etc.	❑ Institutional arrangement ❑ Financing structure ❑ Financial performance ❑ Impact of privatisation act	❑ KPLC and KenGen mini-grids ❑ Retrofit RE programme
New mini-grid concessions	Mini-grid projects by private sector, including IPPs feeding into diesel mini-grids and developing greenfield sites	❑ Information from pre-feasibility or feasibility assessments	❑ Information from pre-feasibility or feasibility assessments	Example of developers: ❑ WfP Energy ❑ Soligenia East Africa
Privately run micro-grids	Existing hybrid micro-grids managed by private sector, community groups, NGOs, etc.	❑ Information on energy source, installed capacity, number of customers, distance to the national grid, etc. ❑ Performance: load factor, O&M, fuel consumption, etc.	❑ Institutional arrangement ❑ Financing structure ❑ Financial performance	Example of developers: ❑ Powerhive ❑ PowerGen ❑ Access Energy

The following sub-sections provide more details on the different types of mini-grids.

6.1.1 GoK mini-grids

There are 21 mini-grids in operation (19 operated by KPLC and 2 operated by Kengen) and 10 under construction in different stages of development. These sites are mapped in Figure 6 and listed in Table 18 and Table 19 below.

Figure 6 GoK mini-grids



KPLC Stations	GIS information of existing substations (source: KPLC)
All items (2008)	Purple lines represent existing and planned transmission nerwork. They have been reproduced from map “National Electricity Transmission Grid Network (showing additional proposed lines)” (KPLC 2008) – this map is out of date but gives a good overview of grid expansion plans.
Existing stations (24)	Existing KPLC mini-grids
Stations under construction	Mini-grids under construction by REA
Planned Connection (3)	Sites with planned grid connection
Greenfield (Filtered) (40)	Possible greenfield sites (see section 7) that have been filtered (considered not viable) for the KfW project due to low population (<200 buildings), existence of other energy projects or lack of data.
Greenfield (Viable) (22)	Possible greenfield sites (see section 7) that have been evaluated for the KfW project

Table 18 Existing GoK mini-grids

	Site and county	**Year comm-issioned**	**Number of customers** (SREP 2013)	**Installed capacity** (kW)	**Proposed retrofit and other projects**
1	**Lodwar** (Turkana)	2007	1,610	Diesel 1,440 Solar 60 (2012)	Solar 250 (SREP) EOI from SEA for 550 solar (2012)[27] EOI Maara Energy for wind project (2012)[28]
2	**Hola** (Tana River)	2007	1,300	Diesel 800 Solar 60 (2012)	Solar 100 (SREP) Studies from Frankfurt School for commercial hybridisation and piloting on-going
3	**Marsabit** (Marsabit)	2011	2,194	Diesel 800 Wind 500 (2011)	
4	**Mandera** (Mandera)	2007	3,270	Diesel 1,600 Solar 330 (2012)	Solar 200 (SREP) EOI from SEA for 650 solar (2012) EOI Maara Energy for wind project (2012) Site within AFD retrofit programme, studies on-going

[27] EOI from Soligenia East Africa Ltd approved by MoEP in January 2012. Pre-feasibility studies conducted but no developments since then.

[28] EOI from Maara Energy approved by MoEP in November 2012 for wind power projects (Wind for Prosperity project from Vestas). Feasibility studies conducted. Tariff negotiations on-going.

	Site and county	Year comm-issioned	Number of customers (SREP 2013)	Installed capacity (kW)	Proposed retrofit and other projects
5	**Wajir** (Wajir)	1988	3,360	Diesel 1,746	Solar 800, Wind 300 (SREP) EOI from SEA for 850 solar (2012) EOI Maara Energy for wind project (2012) Site within AFD retrofit programme, studies on-going
6	**Merti** (Isiolo)	2007	287	Diesel 128 Solar 10 (2011)	Solar 100, Wind 100 (SREP) Site within AFD retrofit programme, studies on-going
7	**Habaswein** (Wajir)	2010	779	Diesel 640 Wind 50 (2012) Solar 30 (2012)	Solar 100, Wind 100 (SREP) Site within AFD retrofit programme, studies on-going
8	**Elwak** (Mandera)	2009	535	Diesel 360 Solar 50 (2012)	Solar 100 (SREP) EOI Maara Energy for wind project (2012) Site within AFD retrofit programme, studies on-going
9	**Baragoi** (Turkana)	2009	199	Diesel 128	Solar 100, Wind 100 (SREP) EOI Maara Energy for wind project (2012) Site within AFD retrofit programme, studies on-going
10	**Mfangano** (Homa Bay)	2011	101	Diesel 584 Solar 11 (2013)	Solar 100 (SREP) Site within AFD retrofit programme, studies on-going
11	**Garissa** (Garissa) (Kengen)	1996	Not available	Diesel 6,700	To connect to national grid (SREP)
12	**Lamu** (Lamu) (Kengen)	1989	Not available	Diesel 2,900	To connect to national grid (SREP)
13	**Rhamu** (Mandera)	2012	210 (1,770 potential)*	Diesel 184	Solar 150 (SREP) REA installing 50 kW solar Site within AFD retrofit programme, studies on-going
14	**Eldas** (Mandera)	2012	80 (1,370 potential)*	Diesel 184	Solar 150 (SREP) REA installing 30 kW solar Site within AFD retrofit programme, studies on-going
15	**Takaba** (Mandera)	2012	153 (2,526 potential)*	Diesel 184	Solar 150 (SREP) REA installing 50 kW solar Site within AFD retrofit programme, studies on-going
16	**Lokichoggio** (Turkana)	2012	(10,980 potential)*	Diesel 640	Solar 150 (SREP) EOI Maara Energy for wind project (2012) Site within AFD retrofit programme, studies on-going

	Site and county	Year comm-issioned	Number of customers (SREP 2013)	Installed capacity (kW)	Proposed retrofit and other projects
17	**Lokori** (Turkana)	2014	8,261*	Diesel 184	Solar 150 (SREP)
18	**Faza** (Lamu)	2014	1,681*	Diesel 380	Solar 100, Wind 100 (SREP)
19	**Laisamis** (Marsabit)	2014	1,456*	Diesel 184	Solar 150 (SREP)
20	**North Horr** (Marsabit)	2014	1,883*	Diesel 184	Solar 100, Wind 100 (SREP)
21	**Lokitaung** (Turkana)	2014	7,239*	Diesel 184	Solar 150 (SREP)

**Potential number of customers based on number of households.*

Table 19 Mini-grid stations under construction

	Site and county	Number of HH (SREP 2013)	Proposed capacity (kW) (SREP)	Status of development (REA)	Proposed RE additions (SREP)
22	Kiunga (Lamu)	762	184	Installation of genset in progress. Completion September 2014	Solar 150
23	Hulugho (Garissa)	759	184	Installation of genset in progress. Completion September 2014	Solar 150
24	Dadaab (Garissa)	10,064	640	Civil works and reticulation complete. Gensets to be installed December 2014	Solar 100 Wind 100
25	Maikona (Marsabit)	1,208	640	Civil works in progress and gensets tender under evaluation. Completion Dec-2014	Solar 100 Wind 100
26	Lokiriama (Turkana)	482	380	Civil works in progress and gensets tender under evaluation. Completion Dec-2014	Solar 150
27	Banisa (Mandera)	3,217	184	Civil & mechanical works complete. Genset to be installed July 2014	Solar 100 Wind 100
28	Kamoliriban (Mandera)	Not available	Not available	Civil works in progress and gensets tender under evaluation. Completion December 2014	No specific plans for renewable energy

	Site and county	Number of HH (SREP 2013)	Proposed capacity (kW) (SREP)	Status of development (REA)	Proposed RE additions (SREP)
29	Kotulo (Mandera)	Not available	Not available	Civil works in progress and gensets tender under evaluation. Completion December 2014	No specific plans for renewable energy
30	Khorondile (Wajir)	Not available	Not available	Civil works in progress and gensets tender under evaluation. Completion December 2014	No specific plans for renewable energy
31	Kakuma (Turkana)	Not available	Not available	Procurement of EIA, civil and mechanical works and gensets starting July 2014. Project to be commissioned June 2015.	EOI WfP 600kW wind

Technical aspects

Technical information has been made available by KPLC for 14 existing mini-grid sites (the KPLC sites commissioned before 2014) including energy generated by source, fuel consumption and cost, impact of integration of renewable energy, etc.

In the 12 months from July 2103 to June 2014, energy generation from these sites totalled 29.3 GWh, of which 95.6% was generated from diesel, 2.9% from solar and 1.5% from wind. Most mini-grids have already integrated renewables or have planned investments to reduce fuel consumption. The exceptions are the sites operated by Kengen (Lamu and Garissa) which are expected to connect to the national grid. Up to now, all RE additions have used "fuel-saver" technology (grid-tie technology without batteries) to displace a minor portion of fuel (usually under 10% of generation).

Table 20 Power generation and fuel cost for existing mini-grids

Site	Installed capacity (kW)	Peak demand (kW)	Power generation (MWh/a[29])	Fuel cost ($/kWh)	% RE	Solar LCOE ($/kWh)
Lodwar	Diesel 1,440 Solar 60 (2012)	1011	5,078	0.40	2.1%	0.29
Wajir	Diesel 1,746	1412	6,955	0.37	0.0%	

[29] 12 months from July 2013 to June 2014

Site	Installed capacity (kW)	Peak demand (kW)	Power generation (MWh/a[29])	Fuel cost ($/kWh)	% RE	Solar LCOE ($/kWh)
Mandera	Diesel 1,600 Solar 330 (2012)	1340	6,351	0.44	8.0%	0.42
Marsabit	Diesel 800 Wind 500 (2011)	930	4,105	0.39	10.3%	
Hola	Diesel 800 Solar 60 (2012)	601	2,838	0.38	2.7%	0.42
Merti	Diesel 128 Solar 10 (2011)	60	238	0.80	8.9%	0.72
Habaswein	Diesel 640 Wind 50 (2012) Solar 30 (2012)	211	1,106	0.48	5.4%	0.47
Elwak	Diesel 360 Solar 50 (2012)	153	697	0.45	13.1%	0.43
Baragoi	Diesel 128	77	217	0.65	0.0%	
Mfangano	Diesel 584 Solar 11 (2013)	70	236	0.56	2.3%	
Lokichoggio	Diesel 640	292	835	0.55	0.0%	
Takaba	Diesel 184	95	255	0.74	0.0%	
Eldas	Diesel 184	80	181	0.57	0.0%	
Rhamu	Diesel 184	131	186	0.84	0.0%	
Total / Avg			**29,279**	**0.42**	**4.4%**	

Fuel costs in KPLC mini-grids average 0.42 $/kWh resulting from an average diesel price of 1.33$/L. Procurement of fuel is done through competitive tenders for supply on-site (i.e. includes transportation cost) for a 2-year period. Fuel price is indexed based on an agreed formula considering the international fuel price.

Very low load factors, and consequently inefficient genset operation and high fuel costs is a concern for several mini-grids, especially relevant in the new sites. In the case of Mfangano Island, the smallest genset is of 150kVA for a load of 20-30 kW during most of the day and a peak of 55 kW in the evenings. The fuel cost for Mfangano is therefore above the average at 0.56 $/kWh.

KPLC statistics regarding energy consumption per user, daily load profiles, seasonality of demand and energy demand growth over the years are a very useful benchmark for the development of new mini-grids. As shown in the following tables and graphs:

- Average energy consumption per customer ranges from 57 kWh/month to 216 kWh/month, averaging 138 kWh/month. Demand per customer (coincident) averages 505 W (Table 21)

- Typical load profiles show high levels of consumption during the day and a peak in the evening (Figure 7 and Figure 8)

- Energy consumption from month to month over the past two years does not show obvious seasonal variations (Figure 9)

- Growth of energy demand is fast during the first few years of operation (Figure 10), averaging 30% p.a. A similar analysis for the older more established mini-grids (e.g. Lodwar, Wajir, Mandera) shows a continuing growing trend averaging 10% p.a.

- Finally, mini-grids Lokichogio (Turkana), Takaba and Rhamu (Mandera) and Eldas (Wajir), all commissioned recently (2012) and located in Northern Kenya, show relatively low penetration rates (in terms of number of connections versus household population) between 4% and 12% (averaging 7%)

These statistics are used as a benchmark for the design of the mini-grid pilots later in this report.

Table 21 KPLC mini-grids - units sold and demand per customer

STATION	No. of customers (2013)	Units generated (2013-14)	Units sold (est., 2013-14)[30]	Units sold per customer per month	Peak demand, kW (2013-14)	Demand per customer (W, coincident)
LODWAR	1610	5078131	4164067	216	1011	628
WAJIR	3360	6955092	5703175	141	1412	420
MANDERA	3270	6351205	5207988	133	1340	410
MARSABIT	2194	4105128	3366205	128	930	424
HOLA	1300	2837944	2327114	149	601	462
MERTI	287	238204	195327	57	60	209
HABASWEIN	779	1106495	907326	97	211	271
ELWAK	535	696698	571292	89	153	286
BARAGOI	199	217221	178121	75	77	387
MFANGANO	101	235916	193451	160	70	693
Lokichogio	460	835241	684898	124	292	635
Takaba	153	255461	209478	114	95	621
Eldas	80	180995	148416	155	80	1000
Rhamu	210	185537	152140	60	131	624
TOTAL / AVG	**14538**		**24009000**	**138**		**505**

[30] Based on average network losses of 18%.

Figure 7 Typical load profile (Lodwar)

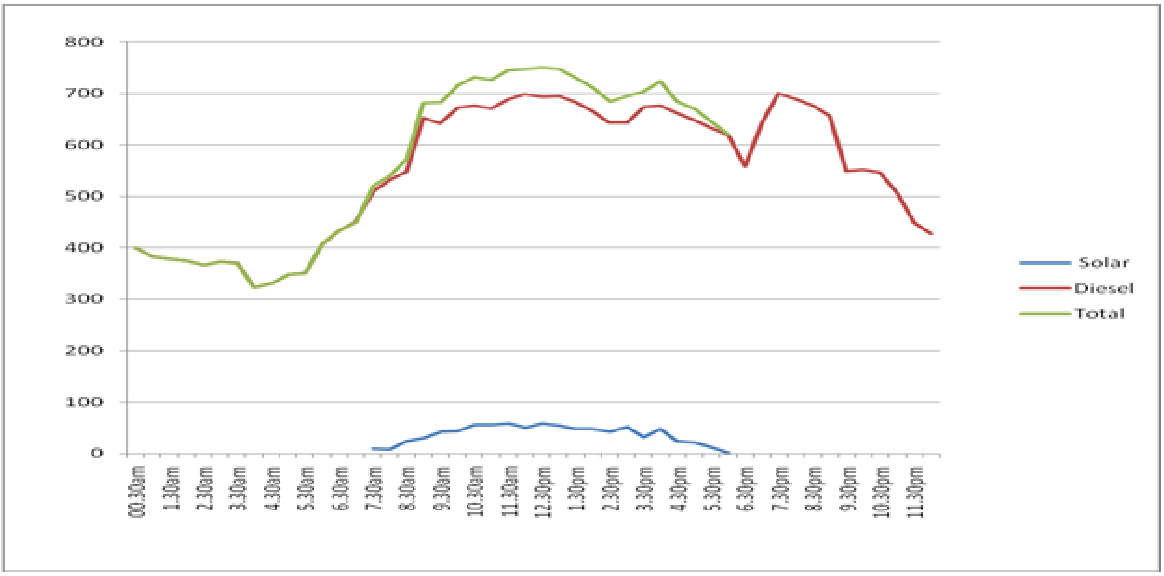


Figure 8 Typical load profile (Wajir)

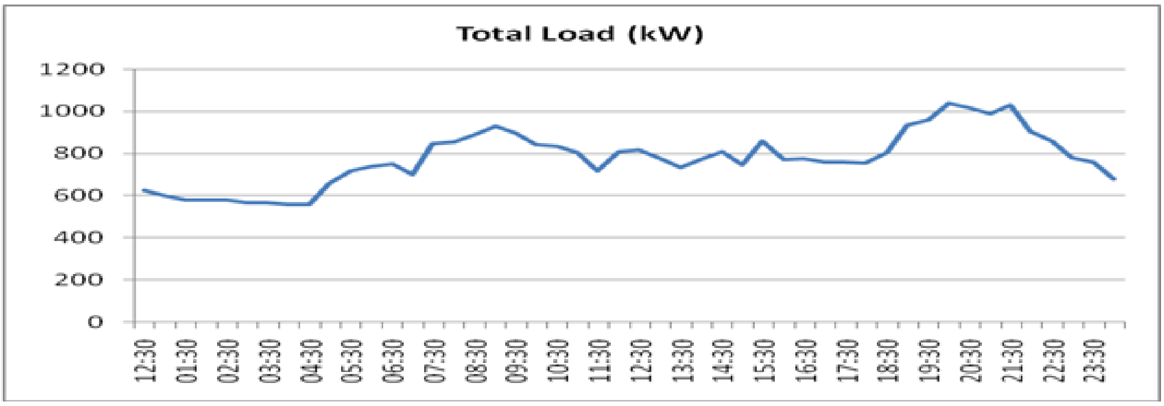


Figure 9 Energy consumption per month in KPLC mini-grids

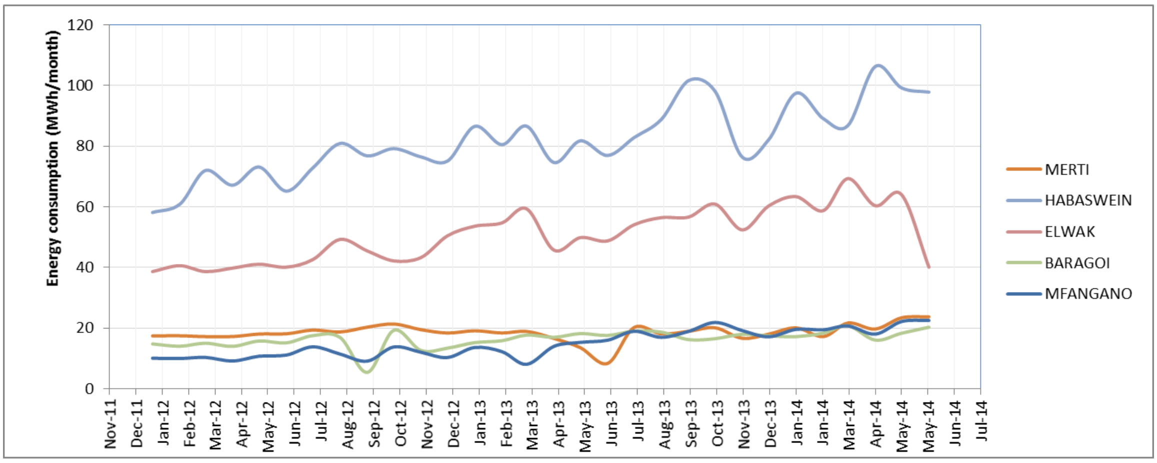
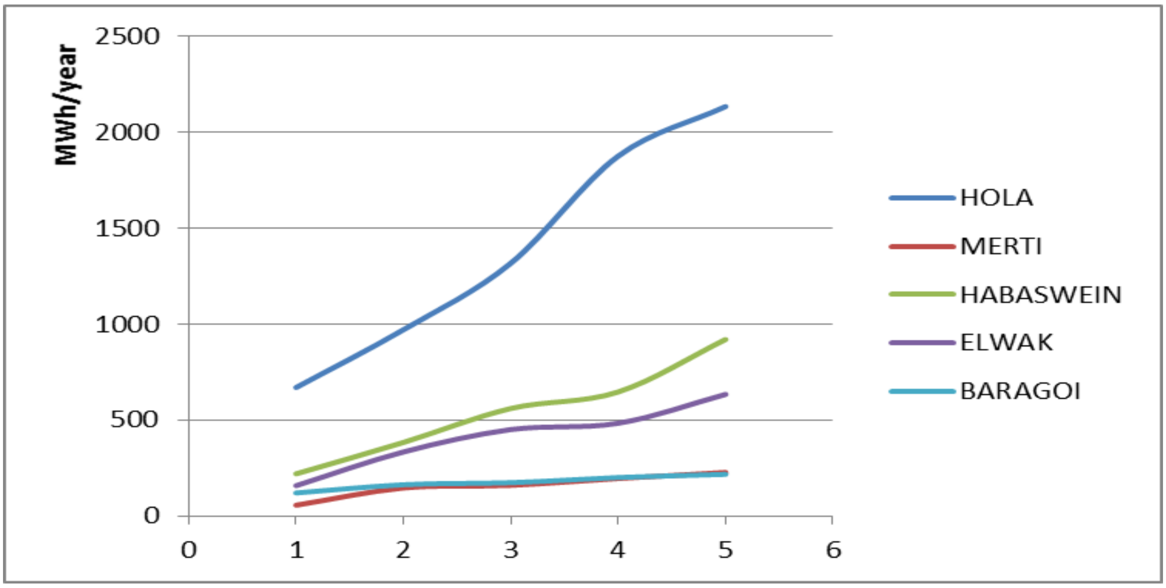


Figure 10 Growth of demand versus number of years in operation



Financing and tariff scheme

KPLC tariffs are approved by the ERC and are uniform across KPLC's entire customer base, it is therefore sometimes referred to as "uniform national tariff". Approved tariffs vary depending on the type of consumer (domestic, small commercial, commercial and industrial, etc.) and level of consumption (stepped tariffs for domestic consumers).

No detailed customer profiles or revenue information have been provided for the existing mini-grids. As a reference, according the KPLC Annual Report (year ended June 30) virtually all (99.8%) customers of the Rural Electrification Programme are in categories DC and SC (80.9% and 18.8% respectively).

Current schedule of tariffs for these categories are:

Table 22 Average electricity tariffs for mini-grid customers

Billing method	Current schedule of tariffs (As of July 2014)[31]	Average level of consumption[32]	Average tariff[33]
DC (Domestic)	**Fixed charge**: 150 KES/month Stepped **basic consumption** (per kWh) charges as follows: - Units 0-50: 2.5 KES/kWh - Units 51-1500: 13.68 KES/kWh - Units >1,500: 21.57 KES/kWh **Fuel cost adjustment (FCA)**: 5.19 KES/kWh[34]	Units 0-50: 18 kWh/month Units 51-1500: 172 kWh/month	Units 0-50: 0.18 $/kWh Units 51-1,500: 0.19 $/kWh

[31] Including fixed charge, basic consumption tariff and fuel cost adjustment. Excluding levies and taxes.

[32] COSS 2013

[33] Including fixed charge, energy charge and FCA

Billing method	Current schedule of tariffs (As of July 2014)[31]	Average level of consumption[32]	Average tariff[33]
SC (Small Commercial)	**Fixed charge**: 150 KES/month **Energy charge:** 14 KES/kWh **Fuel cost adjustment (FCA):** 5.19 KES/kWh	508 kWh/month	0.22 $/kWh

With electricity tariffs between 0.18 – 0.22 $/kWh and fuel costs ranging from 0.37 to 0.78 $/kWh (averaging 0.42 $/kWh), it is clear that the operation of mini-grids under a uniform tariff is highly subsidised.

As mentioned in section 2.2.1, subsidies are implemented in the following manner:

- The investment in mini-grid infrastructure is done by the GoK and does not make part of the revenue requirements of the operator KPLC
- The cost of fuel used in power generation is fully transferred to all KPLC customers through the Fuel Cost Adjustment, in practice a cross-subsidy mechanism

6.1.2 New mini-grid concessions

There are no utility-scale mini-grids currently operating under private concessions. There is however growing interest from the private sector and from donors promoting private sector interventions. At the time of writing, interviews with the ERC revealed that at 5 private sector developers had started discussions about licensing mini- or micro-grid projects. In particular:

- One developer (Wind for Prosperity) got approval from the MoE for their Expression of Interest to develop mini-grid projects. This developer is interested in a PPA model to supply electricity (wind energy) to 13 mini-grid sites (2 of which are greenfield sites: Kakuma and Liboi).
- Developers such as Powerhive, Powergen and Access Energy currently operate over a dozen unlicensed vertically integrated micro-grids (see section below for details). Many of these have also enquired about the procedures for acquiring a permit from ERC.
- Finally, both the World Bank and DfID are intending on promoting mini-grid development with private sector participation(see section 6.4 for details)

6.1.3 Privately run (unlicensed) micro-grids

Companies such as Powergen, Access Energy (full case studies presented in annex A1) and Powerhive are running renewable energy micro-grids in small but densely populated centres. These developers are in the early (pilot) stage of their businesses, having installed approximately 10-15 micro-grid sites (size ranging between 2 and 15

[34] Average for 2013/2014

kWp) to supply fewer than 1,000 households (total for all projects) through low voltage distribution networks. They however have ambitious targets of rolling out in the order of hundreds of sites.

The micro-grid model substantially differs from the utility-scale approach of KPLC in that plants are small and relatively mobile. They can operate in proximity to the national grid due to their flexibility to:

- Charge cost-reflective (unregulated) tariffs and tariff structures suited to their markets. This has also allowed for the reduction (or elimination) of high connection charges (KPLC connection charges are one of the main barriers for electrification).

- Electricity tariffs are high (1 to 5 $/kWh depending on customer category and energy consumption) to guarantee fast payback. Being unprotected without a concession, fast payback is fundamental.

These companies have approached ERC in order to discuss permitting procedures but regulatory requirements are currently too burdensome (and expensive) for micro-grids in relation to their small size.

Annex A1 presents case studies for Access Energy and PowerGen with more details on their technology, operating model and finances.

6.2 Comparative performance of KPLC mini-grid projects

Based on the information made available by KPLC, the performance of the activities of generation, distribution and retail has been assessed for the existing KPLC mini-grids. Table 23 and Table 24 below present the results of the assessment.

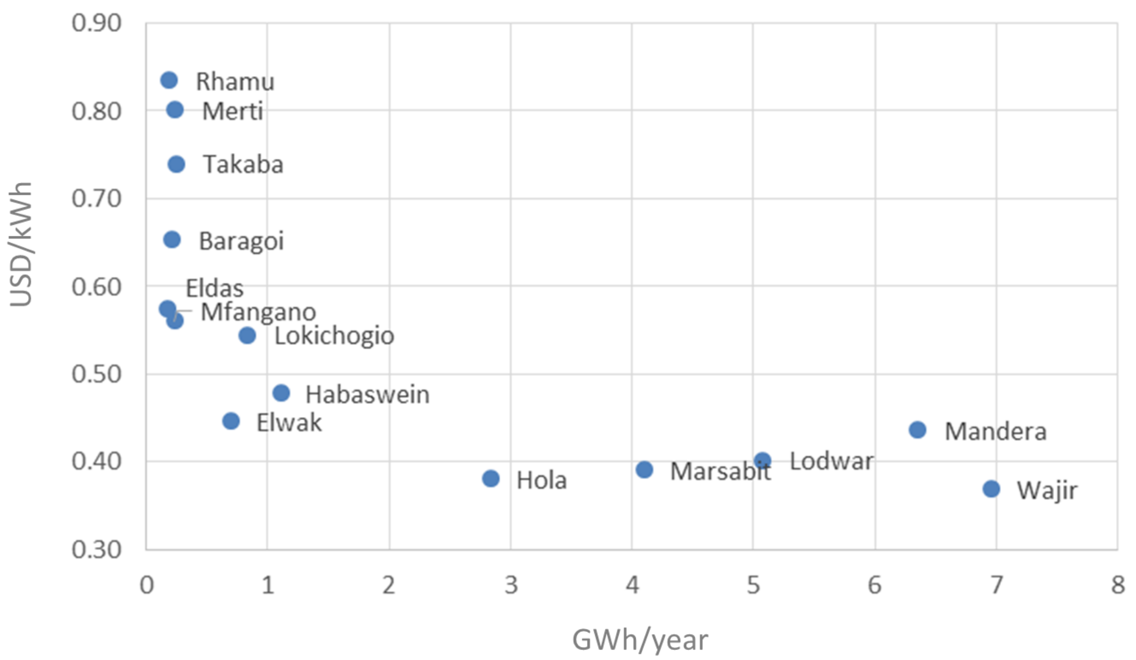
Performance in power generation has been assessed in terms of cost of power generation:

- As shown in Table 20, investment in renewable energy has so far been limited (total penetration of 4.4% of energy generation) and the main cost component in power generation is fuel cost. The least performing sites tend to be the newer mini-grids, where demand is low in relation to installed capacity and generators work under very low load factors. Figure 11 shows a clear inverse relation between fuel cost and the size (measured through total energy generation) for KPLC mini-grids.

- A simplified LCOE has been calculated for solar plants based on the total investment cost, expected lifetime output, lifetime of 25 years and a 10% discount rate. O&M costs, residual value and fiscal benefits have been ignored. A simplified IRR was calculated as well based on the avoided cost of fuel (assuming a fuel escalation rate of 5%). In all cases, PV investments have been favourable with IRRs between 13 and 20%.

- The integration of wind power in Marsabit and Habaswein has not yielded favourable results so far. Based on current output, a simplified LCOE calculation (same assumptions as above) would be of 0.66 and 2.35 $/kWh respectively. In the case of Marsabit (500 kW), this is the result of low energy demand and mismatch between demand and supply, causing limited uptake. KPLC will invest in a flywheel system to improve penetration of wind energy. In the case of Habaswein, problems have included lower wind speed than originally expected and technical faults of the wind turbines.

Figure 11 Fuel cost versus size for KPLC mini-grids



Regarding distribution and retail, no information has been made available regarding network losses or revenues (or customer profiles) for each mini-grid. The following assumptions have therefore been made:

- A comparison of the length of the MV lines (11 and 33kV) and the installed capacity for each mini-grid gives an idea of the density of energy consumption and network losses. Certain mini-grids such as Wajir, Marsabit, Hola and Habaswein have extended their networks to nearby towns up to 50km away from the power station, thus increasing network losses.

- Units sold[35] per customer per month serve as a proxy for the level of revenue. A large part of sales are for customers in the domestic category (with a stepped tariff with an especially low social tariff for the first 50 kWh/month). Therefore, the lower the energy consumption per user the lower the revenues.

[35] Estimated as total energy generation minus 18% network losses

Based on the results shown in Table 23 and Table 24, comparative performance of KPLC mini-grids based on estimations of cost and revenue indicate that:

- The best performing sites are **Lodwar, Wajir and Hola**. All three have been operating for several years and have an established energy demand and low energy costs.

- The worst performing sites are **Merti** (with extremely high energy costs, both for diesel and solar and the lowest energy demand per customer even though the site was commissioned in 2008) and those recently commissioned such as **Takaba** and **Rhamu** (handed over to KPLC in September 2012) which might improve as demand (and load factor of gensets) grows. In the particular case of Merti, the main reasons for the comparatively higher operation cost are related to overcapacity (128 kW installed capacity for a maximum peak of 60 kW) and accessibility (diesel price is 15% higher than the average due to higher transportation costs).

Table 23 Performance in Generation

Station	Diesel installed capacity (kW)	Fuel type	Renewable energy (kW), year installed	RE investment details	CAPEX in RE ($ '000)	CAPEX per unit ($/kW)	Peak demand, kW (2013-14)	Fuel cost ($/kWh) (avg 2013-2014)	RE (%)	Performance in generation
Lodwar	1,440	AGO	Solar 60 (2012)	Fuel saver (grid-tie PV, no batteries)	306	5,103	1,011	0.40	2.1%	Solar LCOE 0.30 $/kWh, IRR 20%
Wajir	1,746	IDO/ AGO					1,412	0.37		
Mandera	1,600	AGO	Solar 300 (2012)	Fuel saver connected to 11kV	2,134	7,114	1,340	0.44	8.0%	Solar LCOE 0.44 $/kWh, IRR 15%
Marsabit	800	IDO/ AGO	Wind 500 (2011)	2x250kW turbines connected to 11kV	2,527	5,054	930	0.39	10.3%	Very low output of wind turbines (38% of estimated output)
Hola	800	AGO	Solar 60 (2012)	Fuel saver	405	6,750	601	0.38	2.7%	Solar LCOE 0.49 $/kWh, IRR 13%
Merti	128	AGO	Solar 10 (2011)	Fuel saver	136	13,575	60	0.80	8.9%	High fuel cost (low utilisation) Solar LCOE 0.71 $/kWh, IRR 17%
Habaswein	640	AGO	Wind 50 (2012) Solar 30 (2012)	3x20kW turbines with batteries PV fuel saver	493 (wind) 248 (solar)	9,856 (wind) 8,263 (solar)	211	0.48	5.4%	Low output of turbines (13% of estimated) Solar LCOE 0.61 $/kWh, IRR 13%
Elwak	360	AGO	Solar 50 (2012)	Fuel saver	367	7,343	153	0.45	13.1%	Solar LCOE 0.44 $/kWh, IRR 16%
Baragoi	128	AGO					77	0.65		High fuel cost (low utilisation)
Mfangano	584	AGO	Solar 11 (2013)	Fuel saver			70	0.56	2.3%	High fuel cost (low utilisation)

Station	Diesel installed capacity (kW)	Fuel type	Renewable energy (kW), year installed	RE investment details	CAPEX in RE ($ '000)	CAPEX per unit ($/kW)	Peak demand, kW (2013-14)	Fuel cost ($/kWh) (avg 2013-2014)	RE (%)	Performance in generation
Lokichogio	640	AGO					292	0.55		
Takaba	184	AGO					95	0.74		High fuel cost (low utilisation)
Eldas	184	AGO					80	0.57		High fuel cost (low utilisation)
Rhamu	184	AGO					131	0.84		High fuel cost (low utilisation)
Total	**9,418**		**1,071**					**0.42**	**4.4%**	

Reference: green highlight shows best performance while orange poorest performance

Table 24 Performance in distribution and retail

Station	Length of MV lines (km)	Length of MV lines / Installed capacity (km/kW)	No. of customers (2013)	Units sold (MWh/a) (est., 2013-14)	Units sold per customer per month (kWh)
Lodwar	35	0.02	1,610	4,164	216
Wajir	186	0.11	3,360	5,703	141
Mandera	86	0.05	3,270	5,208	133
Marsabit	123	0.15	2,194	3,366	128
Hola	175	0.22	1,300	2,327	149
Merti	6.85	0.05	287	195	57
Habaswein	105	0.16	779	907	97
Elwak	25	0.07	535	571	89
Baragoi	7	0.05	199	178	75
Mfangano	42	0.07	101	193	160
Lokichogio	19.5	0.03	460 (est.)	685	124 (est.)
Takaba	66	0.36	153	209	114
Eldas	66	0.36	80	148	155
Rhamu	58	0.32	210	152	60
Total	**1000**	**0.11**	**14,538**	**24,009**	**138**

Reference: green highlight shows best performance while orange poorest performance

6.3 Lessons learned for future mini-grid developments

Mini-grid development in Kenya for the past 3 decades has been through a public model. A recent trend is the development of micro-grids by private firms, which rely on light infrastructure (i.e. small plants with movable generation assets and distribution in low voltage) and a more flexible business model. These micro-grids have not been in operation for long but lessons can still be drawn. Table 25 below provides a brief comparison between these two schemes. A list of lessons learned from both models follows.

Table 25 Comparison of mini-grid schemes in Kenya

	Public model	Micro-grid model
Site selection	Based on national plan and sometimes political motives. Sites should be further than 50km from the grid. Priority given to large population centres.	Focused on smaller centres (usually fewer than 100 households). Site selection has been more tolerant of the proximity of the grid (some sites are only a few kilometres from the grid). This is because of the higher tariffs guaranteeing a fast payback and the small size of plants which allows to move assets if needed.
Technical aspects	Medium-scale (0.1 to 2 MW) with generation predominantly from diesel Rapid growth (30% p.a. in the first 5 years) Relatively low seasonality in medium-scale mini-grids (>100 kW) Rolling out pre-paid meters to all domestic consumers	Very small scale (1 to 20 kW) with generation predominantly from solar energy. Remote operations technology is crucial to keep costs low and is crucial for a mini-grid business model which could attract private-sector investment.
Regulation	Subject to technical and economic regulation. In particular, uniform tariff regulation.	Currently no framework for the legal operation of these entities.
Operating model and private sector involvement	Public model with private sector participating only in EPC works.	Fully private, vertically integrated micro-grids. Fee-for-service model.
Financing	Public funding and uniform tariffs well below the cost of electricity (0.44 $/kWh average cost[36] and 0.19 $/kWh average tariff) making the model extremely reliant on subsidies. Rolling out pre-paid meters.	Private funding and cost-reflective tariffs. Usually low connection tariffs[37] and high electricity charges (>1 $/kWh). Due to the high risk of operations (namely, no legal protection in the form of a concession), fast payback (2-3 years) required. Pre-paid metering technology used to secure revenues. Meters allow for variable tariffs depending on pre-paid amount.

[36] Operating cost, excludes capital cost

[37] For example, Powerhive charges connection fees of 2,500 KES versus the 35,000 KES of KPLC. This is a major advantage in attracting consumers.

	Public model	Micro-grid model
Community involvement and promotion of productive use	Little involvement with the demand side (only promotion of energy efficiency and a few activities from REA such as supply to public facilities, trading centres and water pumps).	Different approaches to community involvement. The operators mentioned above have interacted with communities in issues of land and wayleaves to proposing community shareholding. In the case of Powerhive, productive use has been encouraged through granting loans for income-generating activities.

Private involvement in mini-grid development is only recent and the micro-grid model is not directly comparable to larger mini-grids, however, some important lessons can be drawn for the future development of mini-grids:

- **Site selection:** the largest off-grid sites have been selected for development by REA through a public model. Remaining green-field sites identified in the SREP document or other surveys are much smaller and suited for small mini-grids (<100 kW).

- **Technical aspects:**

  - Hybridisation with renewables has had positive impacts in reducing generation costs. The penetration of renewables in KPLC mini-grids has thus far been very low (>5%) but there is potential for increasing the share. The technology chosen by the existing micro-grid operators is in fact based practically exclusively on solar PV with a diesel genset as back-up.

  - Fuel costs increase significantly if the power plant is oversized. The historic energy consumption per user, total consumption and growth of the different KPLC mini-grids are very valuable benchmarks for the design of future mini-grids.

  - The use of pre-paid meters has been fundamental in securing revenue from tariff collection as well as reducing administrative costs. In the case of micro-grids incorporating pre-paid meters and remote monitoring, this has positively impacted performance.

- **Light-handed regulation:** there are several reasons to encourage light handed regulation of mini-grid sites[38]. Specific to the Kenya examples cited above, unregulated mini-grids have been able to charge cost-reflective tariffs and develop a tariff scheme more suited to the market (i.e. low connection fees). This model could be self-regulating since the operator is constrained

[38] See "Five Reasons to Not Regulate the Retail Prices of Small, Isolated, Rural Mini-Grids" on p. 318-320 of Tenenbaum et, al (2014).

from charging higher tariffs because of affordability. Tariffs would need to be monitored rather than regulated. Small mini-grids could rely on easier permitting procedures (e.g. focused on safety aspects). The capacity threshold under which a light-handed approach is recommendable needs to come from experience.

- **Community involvement:** approach to community involvement is mixed. There are however clear advantages of interactive with the demand side, especially in relation to the promotion of productive use of electricity.

6.4 On-going mini-grid programmes

Other relevant mini-grid programmes currently under development by other organisations are presented below.

Table 26 Other on-going mini-grid promotion programs in Kenya

Organisation	Scope	Selection of sites	Other details
AFD	Retrofit 22 sites from existing mini-grid sites and sites currently under construction (those to be commissioned before Dec 2014).	Selection of 22 existing sites for retrofitting. Selection completed.	Unclear whether funds will be used in public procurement or for a PPA model. The study recommending investments is yet to be finished (expected November 2014).
DfID	Green Mini-Grids programme for East Africa	Sites to be proposed by private developers.	60 million GBP fund for Kenya and Tanzania. Funds channelled through AFD and Kenya Association of Manufacturers (KAM) for subsidies and/or concessionary financing for private developers. Currently defining the logical framework and implementation modalities for the programme.
WB/IFC	Study aimed at unlocking private sector participation in mini-grid development	Not applicable	Different studies (not yet commissioned) covering: Barriers assessment: policy and regulation, skills, financing, information, infrastructure, etc. Nation-wide market analysis (demand and supply): energy demand, ability and willingness to pay, capacity of local players, etc. Financing requirements of mini-grid projects Regulatory analysis and drafting of regulations (late 2015)

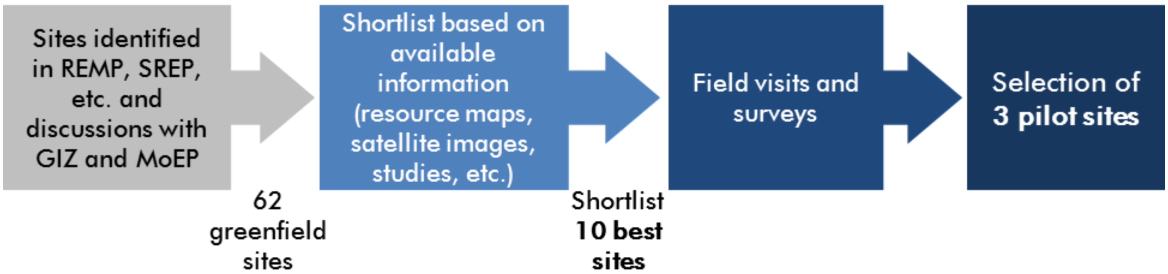
Organisation	Scope	Selection of sites	Other details
	WB mini-grids project	Procurement notice for selection of sites in October 2014	10 million USD available to support the development of mini-grid sites under private sector models (specifically looking at private concessions and PPA model). Procurement of consultancy services for design of programme on-going.. Pre-feasibility assessment will be conducted in 30 sites and 3-5 sites (depending on subsidy requirements) will finally be chosen for investment.
Frankfurt School	Research on feasibility of private models for hybridisation of mini-grids for IRENA/UNEP	1 site for retrofit: Hola	1 pilot project planned (mini-grid in Hola) for hybridisation.

Task 3: Design of pilot mini-grid interventions

7 Selection of sites

Our proposed methodology for the selection of sites is summarized in the figure below.

Figure 12 Selection of pilot sites



- **Step 1 - Initial list of sites:** We developed a database of potential greenfield sites for the KfW project based on sites identified in the REMP of 2009 and additional sites identified since then (greenfield sites proposed in the SREP document and recommendations from REA and GIZ. This is explained in section 7.1.

- **Step 2 – Shortlist of sites:** the sites identified in the previous stage were evaluated and ranked based on readily available information (proximity to the grid, satellite images, census information, etc.). This process is explained in section 7.2.

- **Step 3 – Field visits and final selection:** we conducted visits and surveys in the sites shortlisted in the previous stage. The information collected allowed for the final selection of the three most suitable sites for this pilot project. This process is explained in sections 7.3 and 7.4.

7.1 Initial list of sites

The proposed pilot sites have been selected from a list of 62 greenfield sites, which has been compiled from studies undertaken by various government energy programs (REMP 2009, SREP) as well as the recommendations from GIZ and the MoEP. The map below shows the geographic location of these sites.

Table 27 Potential greenfield sites for mini-grid pilots

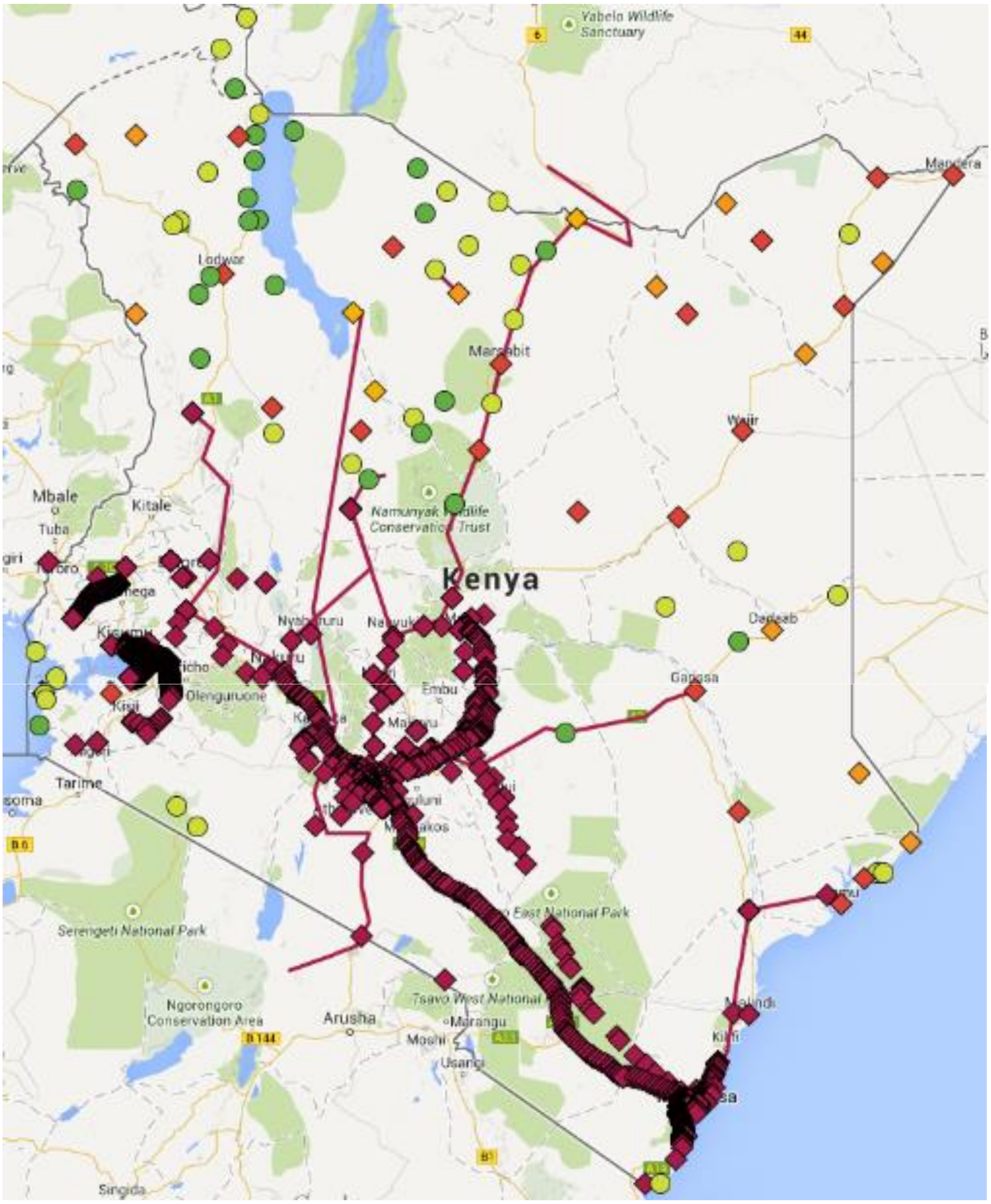


Table 28 Map key

KPLC Stations	GIS information of existing substations (source: KPLC)
◆ All items (2008)	Purple lines represent existing and planned transmission nerwork. They have been reproduced from map "National Electricity Transmission Grid Network (showing additional proposed lines)" (KPLC 2008) – this map is out of date but gives a good overview of grid expansion plans.
◆ Existing stations (24)	Existing KPLC mini-grids
◆ Stations under construction	Mini-grids under construction by REA
◆ Planned Connection (3)	Sites with planned grid connection
● Greenfield (Filtered) (40)	Possible greenfield sites (see section 7) that have been filtered (considered not viable) for the KfW project due to low population (<200 buildings), existence of other energy projects or lack of data.
● Greenfield (Viable) (22)	Possible greenfield sites (see section 7) that have been evaluated for the KfW project

A database containing information on each of these sites as well as an online version of the above map can be found in the following locations.

Table 29 Links for site database and map location

Database of mini-grid sites	- https://docs.google.com/a/accessenergy.org/spreadsheets/d/12WafeJwzsA1rxrDtXzcvU63EGAiX9843UJ5vfuOgas8/edit?usp=sharing - Attached excel document – KfW Sites database
Map of existing and planned rural electrification projects	- https://mapsengine.google.com/map/edit?mid=zmPSZv6aF8KE.krdKNSVSmt2U

7.2 Shortlist of sites

Criteria considered during the shortlisting stage is summarised in the table below. The annexed site database contains all information used in the selection process as well as the results of the shortlisting stage and final selection.

Table 30 Site shortlisting criteria	
Criteria	**Comments**
Absence of national grid	Site should ideally not be expected to connect to the national grid within 10 years. Distance to the grid and other geographic features (e.g. island location) serve as a proxy for this[39]. Sites ranked based on **"geography score"**. This score is determined based on distance to grid, distance to KPLC off-grid station and whether location is an island.
Sufficient demand for electricity	Estimated through number of buildings (counted based on satellite images) which provides a more relevant indicator than census information on number of households (the latter includes population in center of town as well as population scattered in the in the administrative area which would not be reached by the mini-grid). Sites ranked based on **"demography score".**
Population density	Number of buildings per square km. Counted based on satellite imagery. Sites ranked based on **"demography score".**
Economic activity	Preliminary ranking based on percentage of buildings which are tin-roofed (as opposed to more precarious constructions such as "manyattas"(counted based on satellite images). Sites ranked based on **"economics score".**
Hybrid PV-diesel potential	We have assumed that hybridisation with solar energy is technically and economically viable in the entire country (see annex A2) and have therefore NOT used this as part of the selection criteria, rather focusing on other aspects such as distance to grid, energy demand, economics, etc.
Expansion potential	Existence of sufficient settlements nearby for a reasonable scale-up of the system if successful. Parameter not considered for site selection (no sites in database closer than 10km from one another) but information present in site profiles.
Potential of synergies	Potential of synergies with ongoing projects of Kenyan-German Technical and Financial Cooperation have not been used as selection criterion but are explored in the selected sites profiles.

Table 31 below presents the sites that were shortlisted and surveyed following a rapid rural appraisal methodology.

[39] We have only been able to obtain maps for the transmission electricity network (incl. proposed lines) down to 33kV. Reliable maps for 11kV lines have to date not been made available.

Table 31 Shortlisted sites

No	Site Name	County	Geography score	Demography score	Economics score	Total score	Comments
54	Kiwa	Homa Bay	0.92	0.2	0.9	0.66	Island town - distance from grid is not large but isolation factor is high
71	Naduat	Turkana	0.62	0.82	0.3	0.59	Nearby towns Gold/ Makutano and Lolupe (10km)
64	Korr	Marsabit	0.67	0.15	0.9	0.56	
66	South Horr	Marsabit	0.54	0.15	0.9	0.51	
69	Logologo	Marsabit	0.49	0.51	0.5	0.5	
30	Dukana	Marsabit	0.71	0.34	0.4	0.49	Some concerns about accessibility and security
37	Kokuro	Turkana	0.54	0.78	0.05	0.48	Security concerns (border with South Sudan)
76	Kalacha	Marsabit	0.56	0.28	0.6	0.48	Lower-quality satellite imagery
32	Illeret	Marsabit	0.96	0.36	0.05	0.47	Security concerns (border with Ethiopia)
47	Kalokol	Turkana	0.6	0.52	0.25	0.47	Proximity to Longech
84	Longech island	Turkana	0.62	0.66	0.05	0.47	Proximity to Kalokol
41	Oropoi	Turkana	0.88	0.36	0.1	0.46	
72	Kataboi	Turkana	0.70	0.32	0.25	0.43	
70	Ngurunit	Marsabit	0.70	0.21	0.35	0.42	Proximity to Illaut Lower-quality satellite imagery
44	Lowarangak	Turkana	0.32	0.78	0.10	0.42	

7.3 Field surveys

Before and during the field surveys a number of the sites from the above shortlist were found to be unsuitable:

- South Horr, Logologo and Kalacha already have electrification plans which were not known until the field survey stage through interviews with local authorities.
- Kokuro and Illeret are located in the proximity of borders with South Sudan and Ethiopia respectively and based on satellite imagery they appear too small to fit within the desired scope of this project.
- Longech island is in the close proximity of Kalokol and would not merit a separate project but rather future integration into the same mini-grid
- Oropoi and Kataboi are currently being surveyed by GIZ for mini-grid projects and were thus not considered.

Based on the above, the following sites were shortlisted for field surveys:

- Kiwa island (Homa Bay)
- Naduat (Turkana)
- Korr (Marsabit)
- Dukana (Marsabit)
- Kalokol (Turkana)
- Ngurunit (Marsabit)

A brief presentation of each of the surveyed sites is given in the following sub-sections.

7.3.1 Kiwa island (pop. 3,500, Homa Bay County)

Criteria	Comments
Location	A small but well-populated island in Lake Victoria off the coast of Western Kenya, located 2 km from nearest national grid point on the mainland
Energy demand and productivity	The economic activity is mainly based in the relatively stable fishing industry, with some agriculture, and retail of goods/services. Although the population is small and space is limited, there is good business activity and access to tourism on the lake. This economic activity in turn supports a variety of local businesses and services related to fishing storage and processing. There is a high percentage of alternative energy use which could be replaced by a mini-grid, including small petrol generators and kerosene lamps.
Public services	Health facilities, primary and secondary school, community centre, church
Payment for utility services	Some selling of generator power for services by genset owners (e.g. phone charging services)
Organisational, Legal and Political aspects	Good community organization, fishing coop present; some land is available for the project but it is limited
Accessibility	The town can be accessed only by boat; roads up to the boat launch are in fair condition
Security	Location is deemed secure (good community cohesion, competent leaders).
Possible mini-grid options	Energy demand justifies only a small mini-grid (approx. 50kW installed capacity); high island fuel prices means solar energy could be successful

7.3.2 Kalokol (pop. 11,500; Turkana County)

Criteria	Comments
Location	Big town, located on the western shore of Lake Turkana, 200km from the national grid (and 55km from the Lodwar off-grid station).
Energy demand and productivity	Fishing is the main industry (fish are trucked on a daily basis to Nairobi and DRC). Heavy use of solar home systems and small petrol generators for commercial activities (refrigeration, pumping, milling, etc.); current installed capacity can be estimated at 200 kVA.
Public services	Water supply, police station, primary and secondary school, health facilities, churches, mosque, etc.
Payment for utility services	Petrol pump in place (people buy petrol to run gensets), a few solar energy products retailers, payment for water supply.
Organisational, Legal and Political aspects	There is communal land available for the project.
Accessibility	The town can be accessed by road from Lodwar (tarmac, although not in good condition)
Security	Location is deemed secure (good community cohesion, competent leaders).
Possible mini-grid options	Energy demand in Kalokol justifies a medium-sized mini-grid (300-400 kW) powered by solar and diesel. Wind resource should be considered (there is a telecom mast powered by a wind generator) but the lack of wind speed measurements (to be confirmed with MoE) would justify investing in solar as a first step. Delivery model could be a private concession or a mixed model with an IPP in generation and KPLC in distribution and retail.

7.3.3 Naduat (pop. 8,500; Turkana County)

Criteria	Comments
Location	In Turkana county west of Lake Turkana, roughly 200 km from the national grid (and 70 km from Lodwar off-grid station)
Energy demand and productivity	The main economic activity is the nearby gold mining operations, which in turn create a small market for goods / services. There is also a significant portion of the community which participates in the livestock trade, but the town is relatively small and isolated which limits its scope and capacity to promote economic activity. The local businesses are therefore fewer, and generally more limited in their applications of energy, tending to use it just for lighting, phone charging, etc.
Public services	Health facilities, primary and secondary school, church
Payment for utility services	Some indirect selling of generator power for services by genset owners (e.g. phone charging services, video halls)
Organisational, Legal and Political aspects	There are no formal community organizations, however there is strong local leadership
Accessibility	The town can be accessed by road from Lodwar (tarmac in passable condition)
Security	Location is deemed secure (good community cohesion, competent leaders).
Possible mini-grid options	Energy demand in Naduat would only justify a small mini-grid (<50kW). Nearby towns Gold/Makutano could be integrated into the same mini-grid to justify a larger project. The lower economic potential in the community makes a private-ownership model less attractive; it would be possible to set up a mixed model with an IPP in generation and KPLC in distribution and retail

7.3.4 Dukana (pop. 18,000; Marsabit County)

Criteria	Comments
Location	Big town, located in the far northern section of Marsabit county, about 20 km south of the Ethiopian border. The nearest off-grid station is North Horr, almost 100 km away, and the nearest national grid point is over 300 km away.
Energy demand and productivity	Livestock trade is the main economic driver in the community. Despite its isolation, the community hosts a number of public institutions which in turn drives local business. Particularly of note is the district government office which is an administrative hub for the area. Because of the hot, dry climate, there is also a strong demand for refrigeration and water-pumping services, and there is an existing water-pumping business in town which is currently limited by the availability of solar power and generator fuel. The government and several development partners (specifically GIZ) are supporting Marsabit in sustainable water management and the promotion of productive value chains.
Public services	Police station, local govenrment office, primary and secondary school, health facilities, churches, mosque, etc.
Payment for utility services	There is some private retail of generator and solar power, payment for water supply
Organisational, Legal and Political aspects	There is communal land available for the project; there are community organizations based around the livestock trade for producing goods such as skins/hides; many public institutions
Accessibility	The town can be accessed by road from North Horr, but it is extremely isolated and the roads are rocky.
Security	Location is generally secure, though there has been conflict nearby due to the proximity to the Ethiopian border.
Possible mini-grid options	Energy demand in Dukana could justify a mini-grid of 100-200kW installed capacity. Due to isolated location, maximising solar energy penetration is important.

7.3.5 Korr (pop. 6,100; Marsabit County)

Criteria	Comments
Location	Located in the southern area of Marsabit county, west of the Marsabit National Reserve and Marsabit National Park, Korr is 170 km from the nearest grid connection in Marsabit town and 70 km from the nearest off-grid station in Laisamis.
Energy demand and productivity	The livestock trade is the primary driver of economic activity in the community, however the community is isolated and so the best markets for such trade are long distances away. As such, there is limited private business activity in the community compared to other sites, which includes the standard shops, bars, and posho mills.
Public services	Local telecom tower, local government office, schools, health facilities, churches, mosque, etc.
Payment for utility services	There is some private retail of indirect energy services such as phone charging, video halls, and posho mills.
Organisational, Legal and Political aspects	There is communal land available for the project.
Accessibility	The community is accessible by roads from the nearby towns, but these roads can become muddy in the rainy season.
Security	Location is deemed secure.
Possible mini-grid options	Due to lower economic activity, this site merits only a small mini-grid.

7.3.6 Ngurunit (pop. 11,000; Marsabit County)


Criteria	Comments
Location	Fairly large town, in Marsabit county between the Marsabit National Reserve and Namunyak Conservation Trust; located 70 km west of the nearest off-grid station at Laisamis
Energy demand and productivity	Livestock trade is the main economic activity in the community, which in turn creates economic opportunities for small businesses and services. There is also access to tourism due to the community's proximity to parks and reserves, and Kenya Wildlife Service has recently opened a post in town which promises to promote even more economic opportunities, particularly for lodging and other tourism-related service providers.
Public services	Health services, primary and secondary schools, local government office, police force, church, KWS (Kenya Wildlife Service) administration post
Payment for utility services	Some private retail for energy services (phone charging, etc), payment for water services
Organisational, Legal and Political aspects	There is communal land available for the project. The community is highly organized, with a farmers cooperative and charcoal reduction program.
Accessibility	There is a nearby airstrip that makes transport convenient, though the roads from the airstrip to the community are very poor quality.
Security	Location is deemed secure; runoff into the valley has potential to cause minor flooding, but according to the residents this does not pose a problem
Possible mini-grid options	The size of the town merits only a small-scale mini-grid, though the community is growing.

7.4 Three selected pilot sites

This section presents the final selection criteria for the pilot sites as well as the results of the process.

7.4.1 Selection criteria

Table 32 Selection criteria for pilot sites

Criteria	Comments
Local dynamics	Ensure there is a local chief who has been contacted and is supportive of potential efforts to establish a mini-grid in the community
Demographics	Factor in the population, number of buildings (households and businesses), and type/quality of the buildings (quantified as the percent of brick, cement, or mabati buildings)
Geography	Since all the selected sites were completely isolated from the national grid, this rating only examines population density of the community
Economics and potential for productive activities	Weight type(s) of trade, presence of market(s) in the area, presence of community activities (such as coops), natural resources, water access, and number and type of businesses in the community
Ability and willingness to pay	Calculate a typical person's monthly energy expenditure from disposable batteries, kerosene, and petrol for generators; factor in other relevant observations such as a vocalized willingness/unwillingess to pay energy tariffs
Accessibility, availability of land and security	Consider whether the site: is accessible by all-weather roads, is far from Nairobi or another easily-accessible point, has relevant resources such as technical rooms and available land, has any security concerns

7.4.2 Selection of sites

Table 33 below presents a summary of the evaluation of sites according to the above criteria. Because all sites had been deemed viable through the initial screening process, the scores for each site in the specified areas was done via a relative ranking system. The table presents the rankings for each of the criteria--with a rank of 1 indicating the most desirable site for that criteria and 6 indicating the least desirable site.

A more detailed explanation of the evaluation process can be found in annex A4 and in the annexed site database.

Table 33 Ranking of shortlisted sites

No	Site Name	County	Demography (Rank)	Geography (Rank)	Economics (Rank)	Tariff Feasibility (Rank)	Accessibility / Logistics (Rank)	Total (Avg) Rank
47	Kalokol	Turkana	1	4	1	2	1	**1.8****
54	Kiwa	Homa Bay	5	3	4	5	5	**4.4**
30	Dukana	Marsabit	2	1	2	4	2	**2.2****
70	Ngurunit	Marsabit	4	5	3	1	3	**3.2****
71	Naduat	Turkana	6	2	6	6	6	**5.2**
64	Korr	Marsabit	3	6	5	3	4	**4.2**

** Chosen in the final selection of pilot sites

Based on these results, **Kalokol**, **Dukana**, and **Ngurunit** were selected to be retained as the three pilot sites. They are logistically and technically feasible, and meet broad requirements for size / scope, community organization and support, economic growth, and potential impact. Ngurunit is the smallest of the three sites chosen, but based on recent growth and expansion of public services, we believe that it is the best suited of the remaining sites to fit within the desired mini-grid size range.

Full profile of selected sites in annex A6.

7.5 Mini-grid site options for future programme expansion

Other potential sites for expansion of KfW's hybrid mini-grid programme include:

- Shortlisted sites that were not selected for the pilot stage, e.g. Kiwa Island and Korr
- Sites that were originally filtered due to small size (<200 buildings) but would still be feasible for mini-grid electrification, e.g. Shimoni Island, Ndau, Kiwayuu, etc.
- Sites currently under construction by REA that could be retrofitted to include renewables (and are not included in AFD's retrofit programme) such as Kamor Liban, Kotulo and Khorondile.

8 Technical feasibility assessment

This section presents an overview of the technical aspects of the three mini-grid systems.

8.1 General technical recommendations

Energy systems have been designed taking into consideration:

- State of the art PV hybrid architecture: based on a centralised power station with PV and thermal generation, lead acid batteries and an AC distribution grid[40]
- Scalability: systems will allow future expansions to accommodate growing level of supply over time.
- Prioritisation of renewable energy: the stations are sized to maximise the penetration of renewable energy

8.2 Kalokol

8.2.1 Energy demand

Energy demand in Kalokol has been estimated taking into consideration existing commercial and industrial activities, public services and residential users as well as future likely applications once a reliable and cheaper source of electricity is available.

Data collection was done following a "rapid rural appraisal" methodology as opposed to classic quantitative survey techniques. This implies having fewer but better qualified surveyors and a smaller statistical sample but better qualitative data. Our activities in the field included:

- **Observation, familiarization ("walk-around") in the village**, this included taking photographs and GPS coordinates of important energy consumers (businesses, industry, institutions, telecom base stations, etc.). Supporting information can be found in annex A6.
- **A focus group and interviews with key informants** led by the village chief in order to collect general information on energy demand, potential productive uses of energy, cost of energy as well as ability and willingness to pay. The contact details of the village chief leading the focus group as well as the results of these meetings are recorded in the annexed site database.

[40] Other technology options may be considered in the future implementation stage but for the study a conservative reference has been considered

- **Questionnaires for selected households, businesses and institutions** to confirm/complement the findings of the focus group. The forms used for these questionnaires can be found in annex A3. Interviews in Kalokol included 27 medium/large energy consumers (public institutions, businesses and middle/high income households) (see annex A6 for details). The energy use of the more numerous low income households were determined through the focus groups.

A summary of the findings broken down by category of consumers follows:

- **Commercial and industrial activities:** related to fish processing and trade (main commercial activity), water pumping and irrigation and a wide variety of small businesses (restaurants, grain mills, barber shops and salons, etc.)

  There exist concerns regarding the sustainability of the fishing industry in Lake Turkana due to the receding level of water, caused by drought and which could be aggravated by the construction of dams upstream in Ethiopia[41,42]. Kenya organisations active in Kalokol to mitigate this include the Kenya Wildlife Society (KWS) and the Beach Management Unit (BMU), a fishermen's cooperative dealing with fisheries in the lake.

  There also on-going efforts from the GoK and development partners (e.g. EU and GIZ among others have programs in the region) for diversification of the economy in Arid and Semi-Arid Lands (ASAL). These includes water management, development of livestock and agricultural supply chains including dairy products, etc. irrigation, etc. Oil exploration activities in Turkana could also bring employment and CSR projects to the area.

  While it is difficult to predict the future of the economy of Kalokol in the long term, Kalokol is one of the greenflied sites with highest economic activity at present. There are also on-going efforts to preserve and diversify activities which would benefit from availability of electricity. Finally, both levels of Government (national and county) have identified Kalokol as a site suitable for the development of infrastructure and services, as is evident in their electrification priorities and the number of public institutions operating in the area.

- **Public services:** the town includes a variety of amenities and institutions, including generator-pumped borehole water, health and school facilities, a local government office, BMU (Beach Management Unit), and religious organizations. There is also a local police force.

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41 AfDB, Socio-Economic Analysis and Public Consultation of Lake Turkana Communities regarding the Gibe III Hydro-electric Dam in Ethiopia, 2009

42 Sean Avery, What Future for Lake Turkana?, University of Oxford, December 2013

- **Residential use:** we have estimated that approximately 200 low income households (basic energy use: lighting, radio, phone charging) and 50 medium/high income households (higher energy consumption including TV, fans and fridge) could be connected to the mini-grid.

The load demand in Kalokol has been calculated based on interviews with businesses and institutions in the field, focus groups and benchmarking with KPLC mini-grids.

As mentioned above, most high energy consuming users were visited and interviewed with regards to their current energy consumption and energy priorities in case a reliable electricity supply was made available. In most cases, our field staff physically confirmed the existing appliances and power sources. The summarized results of this exercise (which included 27 users) is presented in annex A6.

Table 34 presents a summary of the calculated energy demand broken down by consumer category. The details on specific loads, time of use, number of future users, etc. that led to these results can be found in the annexed sizing tool (excel file).

Table 34 Energy consumption in Kalokol

Users	Consumption per user (Wh/day)	Number of users	Total consumption (Wh/day)	% of total
Commercial and industrial				
Wholesales	5925	6	35550	3%
Retails Shops	1681	30	50430	4%
Water Pumps	60000	3	180000	16%
Garage / Repairshop	21291	3	63873	6%
Lodges	11320	2	22640	2%
Wholesales	5925	6	35550	3%
Fish industry	106924	1	106924	9%
Restaurants	4306	10	43060	4%
Beach Management Unit	8832	1	8832	1%
Kenya Wildlife Services	18517	1	18517	2%
Fisheries Association and Kenya Marine	23610	1	23610	2%
Cinema	3835	7	26845	2%
Telecom Tower	58696	2	117392	10%
Public uses				
Primary School	8695	9	78255	7%
Secondary School	43579	1	43579	4%
Health Center	25022	1	25022	2%
Catholic Missions	6760	5	33800	3%
Mosque	3686	1	3686	0%
Police Station	18349	1	18349	2%
Administrative Police Station (API)	6428	1	6428	1%

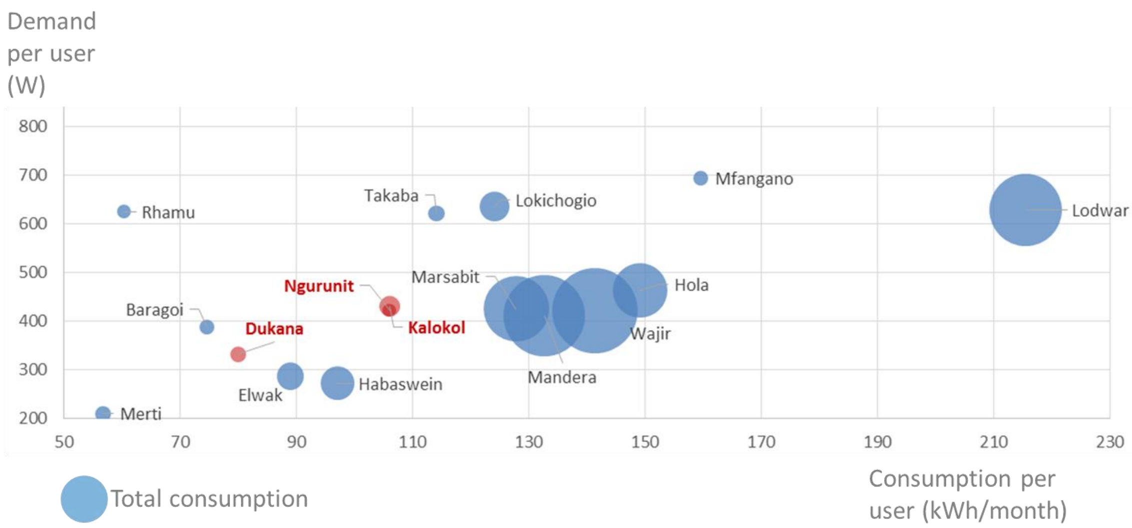
Users	Consumption per user (Wh/day)	Number of users	Total consumption (Wh/day)	% of total
Street Lights	396	16	6336	1%
Chief Office	4306	1	4306	0%
Residential				
Big Housesolds	3358	50	167900	15%
Small Households	249	200	49800	4%
Totals		**353**	**1,135,134**	

The total daily consumption without transmission losses has been estimated at 1,135 kWh/day. Considering 10% grid losses, the electrical energy produced from the power plant should be **1,248 kWh/day**. The estimated **total power demand is 151 kW**[43].

The above figures equate to an average monthly energy consumption of 106 kWh/month per user and an average demand of 430 W/user.

As a reference, the same averages for existing KPLC mini-grids are 121 kWh/month per user and 495 W/user (coincident demand) (see section 6.1 and figure below). It is reasonable to have lower averages for Kalokol considering the different stage of development of the new site in relation to existing mini-grid sites.

Figure 13 Sizing benchmark – demand and consumption per user (KPLC mini-grids)



Source: ECA analysis based on information supplied by KPLC

8.2.2 Load profile and seasonality

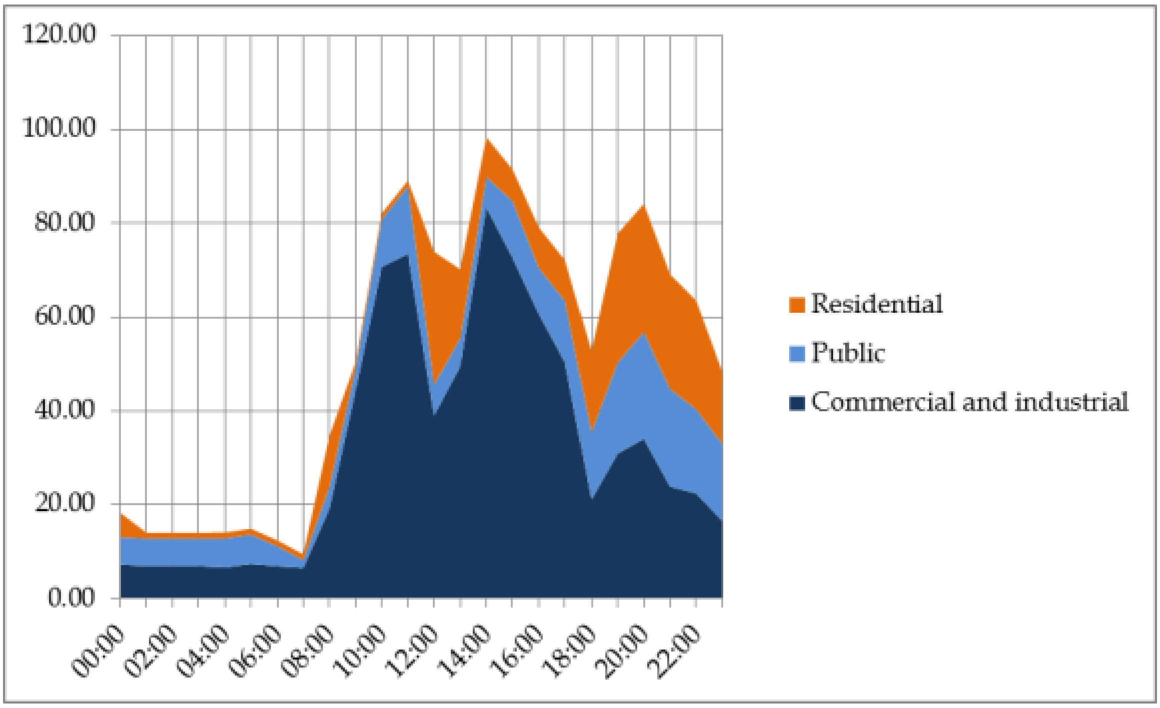
Figure 14 shows the estimated load profile for Kalokol which is based on the individual load profiles of the users presented in the table above. The peak during the day is

[43] Total contracted peak demand: sum of power demand (non-coincident) of all energy consumers

dominated by commercial activities (of which fish processing and refrigeration, water pumping and telecom BTS represent a large part) and the evening peak is dominated by residential use. The 100 kW peak shown in the figure is for an average day but higher peaks could potentially occur. The 151 kW demand mentioned above corresponds to the maximum peak demand (contracted peak demand).

For solar PV plants, energy use during the daytime is to be encouraged to reduce the duty cycle of the battery. A smart pricing mechanism based on time-of-use is useful in providing this incentive to customers.

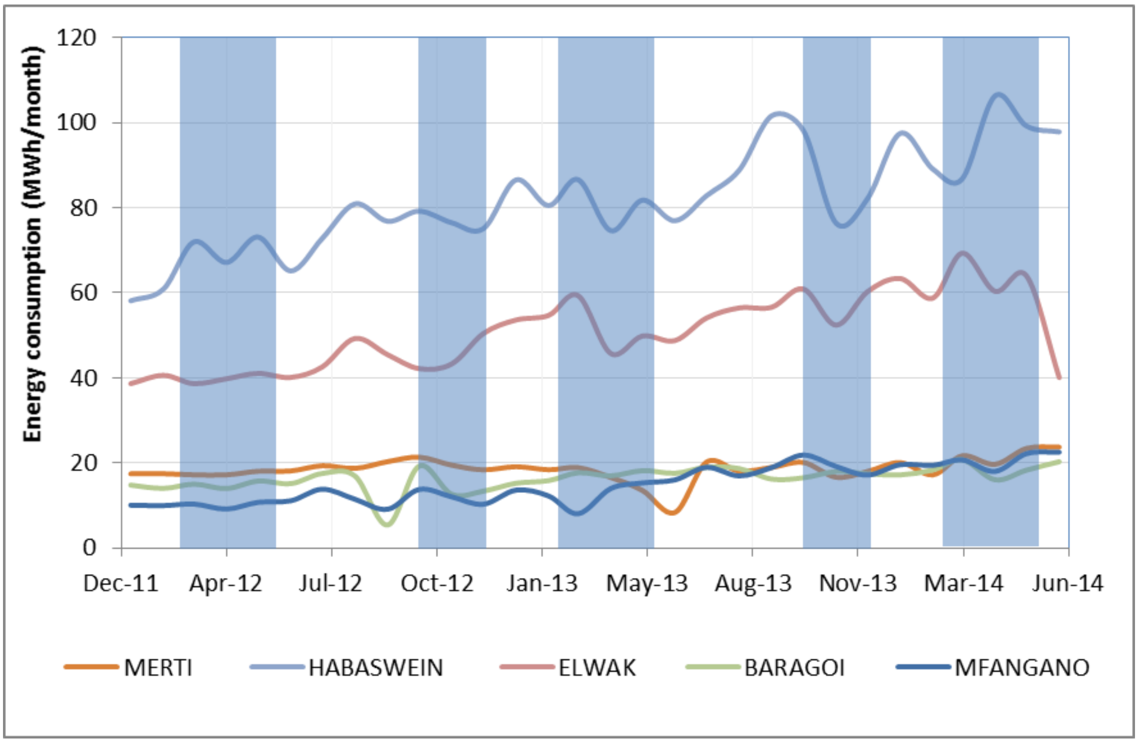
Figure 14 Estimated average daily load profile in Kalokol (kW)



With regards to seasonality, no significant energy demand variations are expected. Due to the location in the proximity of the equator no significant variations in temperature and daylight hours occur which would cause variations in energy demand for lighting and cooling. With regards to commercial activities, the rainy seasons should be expected to affect fishing patterns as well as the price of livestock and agricultural activities. The precise impact of this could however not be determined based on discussions with local authorities.

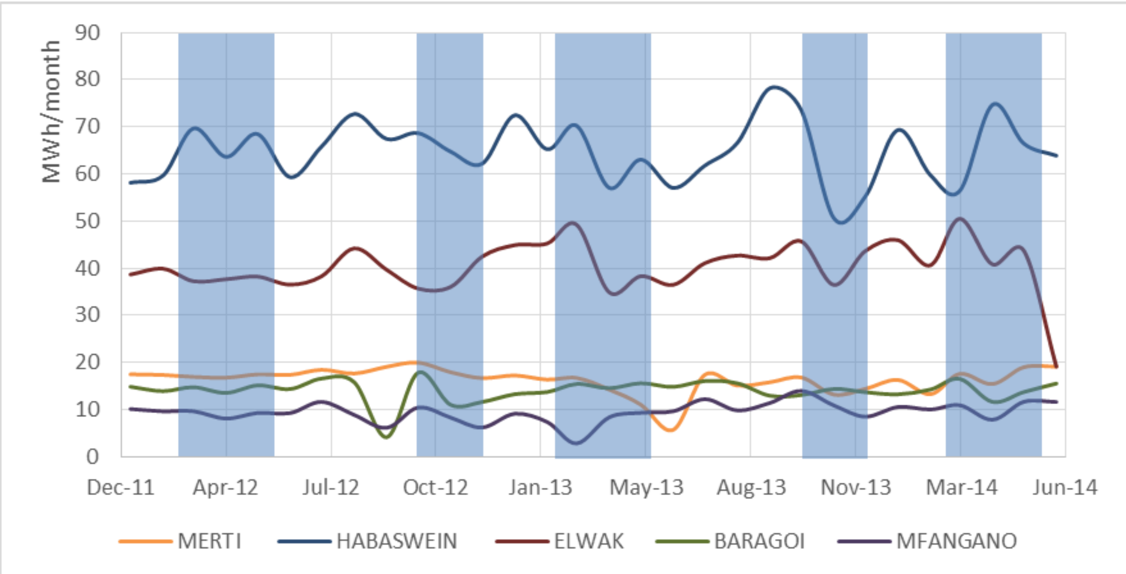
Energy demand patterns of comparable mini-grids (similar size and similar location in northern Kenya) show limited seasonal variations (Figure 9 from section 6.1 is reproduced below for convenience). A linear regression analysis was done in order to isolate monthly variations from growth patterns (see Figure 15). Based on this analysis, variations in consumption levels were calculated at +/- 17% in average (after eliminating outliers). Such variations are within the operational range of these type of stations. The generation plant has therefore been sized according to annual energy consumption. Electricity supply is also expected to help diversify the economy thus mitigating the town's economic cycles.

Figure 9 Energy consumption per month in KPLC mini-grids



Usual bi-modal rainy season periods marked in blue

Figure 15 Monthly variations in energy consumption (values normalised to consumption at beginning of period)



8.2.3 Demand growth projections

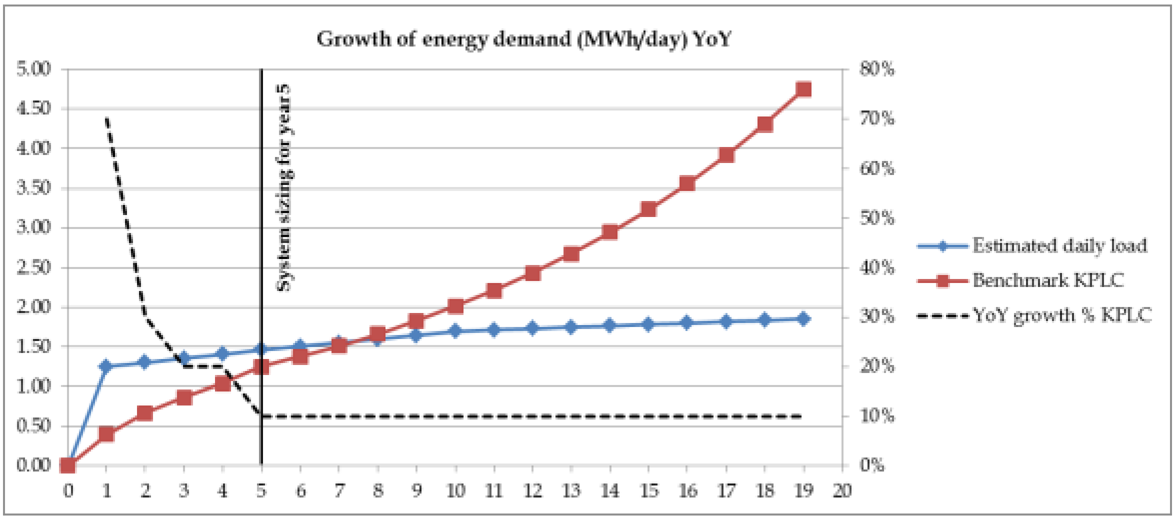
Based on the analysis of existing mini-grids run by KPLC, growth is fast during the first five years and then stabilizes at a growth rate of approximately 10% p.a. This decreasing growth rate is shown with a dotted line in Figure 16.

Additionally, a comparison of number of connections and number of households[44] for existing mini-grids suggests that 15% of connections is achievable by year 5. For Kalokol, the estimated 353 connections among 2311 households (i.e. 0.15 connections/HH) also suggest that the calculated energy demand of Table 34 corresponds to the expected demand of year 5.

Based on the above comparisons with KPLC mini-grids, energy consumption growth is represented by the red line in Figure 16.

An alternative growth curve based on the experience of TTA in similar projects suggests a faster connection of customers during the first year and a slower growth rate during the following years (4% p.a. until year 5, 3% until year 10 and 1% onwards) (blue line).

Figure 16 Growth of the daily demand in Kalokol (MWh/day)



Given the uncertainty of consumption growth, it is proposed that the power station is sized for year 5, which has similar results for both projections. System will be designed to be easily scalable to adapt to growth thereafter.

The financial analysis in section **Error! Reference source not found.** presents the benefits of a staged investment strategy (i.e. capacity expansion after year 5). From the technical perspective, the system is designed to be modular and the precise requirements for expansion and/or replacement of equipment (batteries) can be determined at this second instance.

8.2.4 Resource assessment

The average solar radiation on the Horizontal Plane in Kalokol is 6,540 Wh/m²/d. The values have been taken from the website PVGIS website: re.jrc.ec.europa.eu/pvgis/. PVGIS data are based on calculations from satellite images performed by CM-SAF

[44] Based on available number of connections (KPLC data) and number of households (SREP document) for Lokichogio, Takaba, Eldas and Rhamu

(Climate Monitoring – Satellite Application Facility). The monthly solar irradiation in Kalokol is shown in the table below.

Table 35 Solar resource in Kalokol (Source PVGIS)

Month	H_h	$H(10)$
Jan	6520	7040
Feb	6780	7090
Mar	6650	6680
Apr	6170	5960
May	6330	5890
Jun	6410	5850
Jul	6460	5940
Aug	6830	6470
Sep	6980	6890
Oct	6600	6790
Nov	6400	6820
Dec	6320	6870
Year	6540	6520

H_h: Irradiation on horizontal plane ($Wh/m^2/day$)

$H(10)$: Irradiation on plane at angle: 10deg. ($Wh/m^2/day$)

8.2.5 PV hybrid mini-grid sizing

As explained in the previous section, the power system has been sized based on the energy requirements (energy consumption and contracted peak demand) of year 5. This equates to:

- Energy consumption of 1.46 MWh/day (projection for year 5)
- Peak demand of 177 kW (projection for year 5)

The system will be modular, so that it can be upgraded easily to meet future needs.

The power plant will be configured as AC coupled due to the significant portion of daytime loads that can be fed directly from the solar generator without intermediate battery storage. This will include:

- PV modules with PV inverters
- Wind technology could also be considered but no reliable wind speed measurements have been made available to date. It is proposed that wind power is considered as an alternative to expansion of the mini-grid.
- Diesel thermal genset

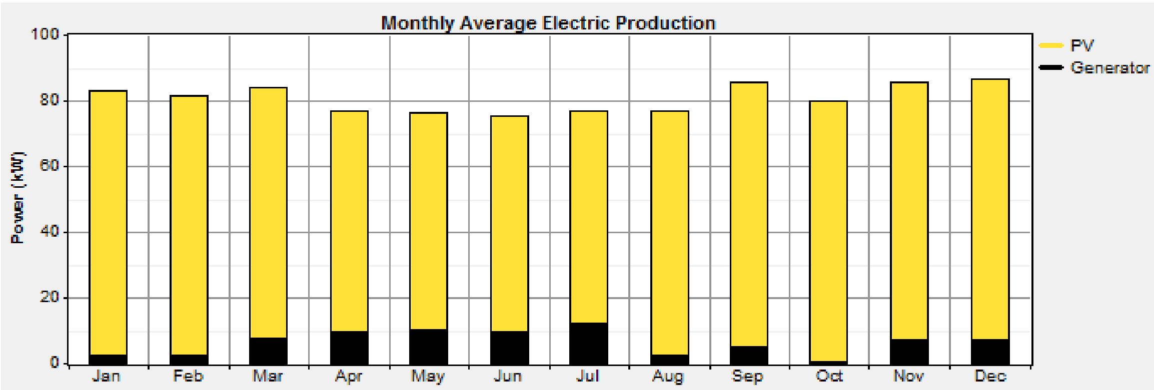
- Deep-cycle lead-acid electrochemical batteries with liquid electrolyte (largely used in off-grid applications thanks to its well proven technology at baseline costs compared with other types of batteries)

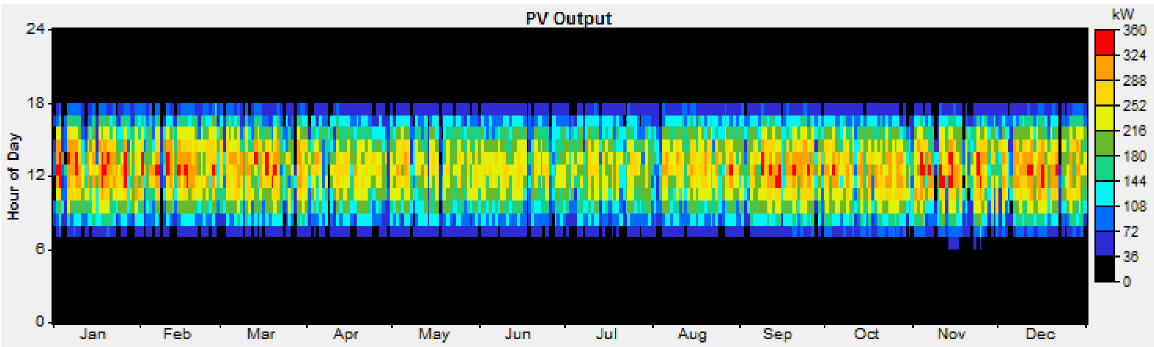
Sizing scenarios

Different sizing scenarios were tested using the software HOMER[45] in order to maximise penetration of solar energy while keeping a low cost of energy. Main variables were the capacity of the PV generator and the size of the battery.

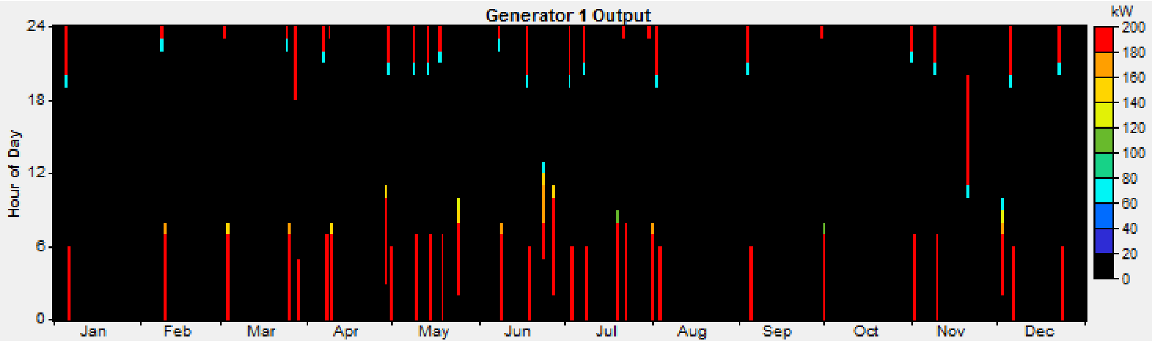
The preferred option is for a **370 kWp PV solar energy station** with a **2.16 MWh battery**. This solution achieves a 93% penetration of solar energy in year 5 as shown in the figures below:

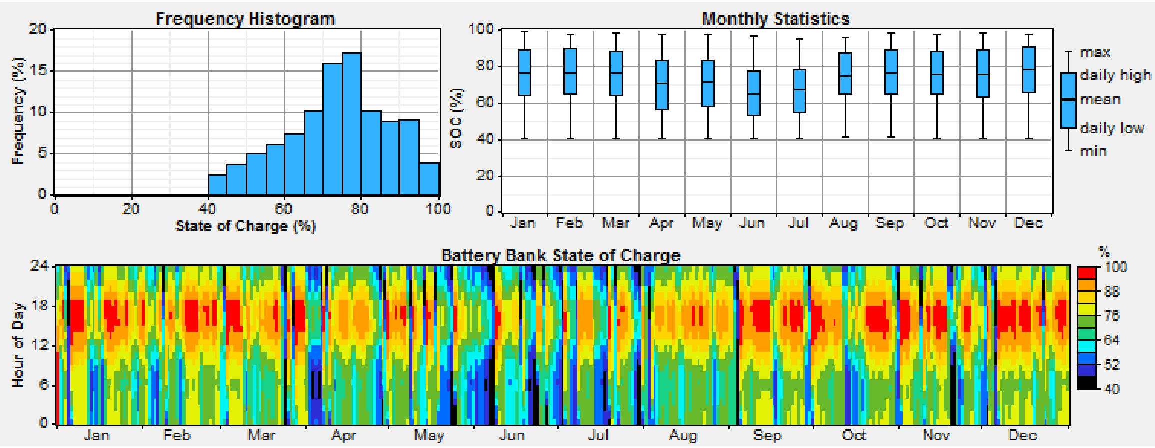
Table 36 Kalokol power plant outputs (source: Homer)





[45] Optimisation software for hybrid renewable energy systems, www.homerenergy.com





Architecture and basic design specifications

As a reference for this study, the architecture of the Mini-Grid is based on a centralized Photovoltaic Plant connected to a Three Phase AC Bus, where the Battery Multi-mode Inverter and the Diesel Genset are also connected. The configuration follows an AC-Coupling model, where the Battery Multi-mode Inverter act as voltage source and the PV grid-dependent inverter act as current source, following the 50 Hz frequency of the battery inverter. Whenever the Diesel Genset is on, the Battery Inverter changes its modality to act as a current source, following the 50 Hz frequency from the Genset.

The electricity distribution to the consumers should be by means of a Medium Voltage line at 11 kV. This line starts at the centralized PV station with a MV Transformer and following the main street in Kalokol. At specific points, the line has branches with Transformers to a low voltage to lines.

The daily load demand used to size the Solar Mini-grid was the demand at year 5, 1461 kWh/day.

The PV plant and the Battery capacity have been sized accordingly to the daily demand and the solar resources. The PV plant capacity (370 kWp) is sized with 5 Peak Sun Hours at the worst month and taking into account a Performance Ratio of 0.8 for the worst month of radiation.

The water pumps considered for the load demand analysis will consume a high percentage of the daily energy consumption. This kind of load can be used as storage of energy as it pumps water to a reservoirs and it can be switched on and off at any time during the day, depending on the load demand, solar radiation and battery State of Charge. Thus, this consumption has not been considered to size the battery, having a smaller battery capacity. The daily demand without the pump consumption at year 5 is 1250 kWh. The consumption with one day of autonomy, Depth of Discharge of 60% and 5% of losses gives a battery capacity of 2193 kWh.

The Renewable Generation Plant will also have a Diesel Genset, which will be used normally as back-up. The size of the Genset is 200 kW, in order to have the sufficient power capacity at year 5. The Genset should only be switched on whenever the Battery State of Charge is under a certain limit which will be defined at commissioning stage. The Diesel Genset is sized to load the Battery at C10 rates, so that the Genset is operating at its optimum power rate.

PV Generator

The PV generator consists of Silicon Crystalline Photovoltaic modules of capacity at STC of 240 Wp or more. The PV modules should comply with the norms IEC 61215 and IEC 61730. The outside junction box with the positive and negative terminals shall incorporate bypass diodes that have the function of preventing any possibility of the electrical circuit inside the module being broken due to the partial shading of a cell and shall be at least IP 65 and UV resistant.

The module support structure shall be ground-mounted on arid soil. The support shall have a tilt angle between 10° - 15° from the horizontal. No soil test has been performed but from the site inspection, ramming or screw foundations could be used. The support frame shall be of either light weight aluminium or galvanized steel and it shall be easy for installation, maintenance and disassembly at the end of life cycle.

Cables used within the PV generator shall have a voltage rating of at least 1,2 V_{OC} ; have a temperature rating higher than 40 °C above ambient temperature; be UV-resistant; water resistant and it is recommended that they be flexible (multithreaded) to allow for thermal/wind movement of modules.

The PV inverter shall be of type current source grid-tied to convert DC to an AC Sinusoidal current. String inverters shall be installed indoors or outdoors with a cover and suitable for desert conditions with high ambient temperatures and dust. Only 3-Phase Inverters Transformer-less and with Maximum and European Efficiency higher than 95% shall be considered. The PV inverters should comply with the international norm IEC 61727.

The PV generator will have all electrical protections necessary at DC and AC side, an earth connection of all modules, the electronic equipment and the structure and surge protection devices type I+II.

Multi-mode Inverter

The multi-mode inverter (or inverter set) for this application is a 200 kW (nominal) bidirectional sinusoidal inverter. It can operate in autonomous mode as well as grid-tied mode. The efficiency curve shall be always above 80% in all cases, adjusting it at the load demand curve (base load, partial load or maximum load).

A priority function of the Multi-mode Inverter is to adjust the instantaneous power consumed from the source according to the battery voltage. The operation of the solar priority function shall be done with an automatic adjustment algorithm of the input limit current. The input limit current is decreased, if there is enough energy available at the DC side, from the initial value.

Battery

The battery considered is lead-acid, deep discharge type with a permissible repeated deep discharge without damage. Automotive or starting type batteries are not acceptable. It shall be of the open "vented" OPzS type with recombination caps and transparent enclosure for easy inspection of electrolyte level. The batteries must be manufactured according DIN 40736-1: "Stationary batteries with tubular positive plates. Capacities, measurements and weights".

Battery rating

The battery nominal voltage does not need to be established at this stage and different technology providers may offer different solutions on this issue. Nevertheless it must be noted that the voltage class, either ELV or LV, will determine the electrical isolation and accesibility requirements of the battery room. The battery shall have at least the rated capacity of 2.16MWh at the C_{10} discharge rate according to DIN 43539-9.

Battery performance

The battery shall have a self-discharge when new of less than 5% per month (at 25^{o}C and fully charged) of its rated capacity and shall have a Coulombic efficiency of at least 85% and energy conversion efficiency of at least 85% when new and charged to more than 50% of capacity.

The battery cycle life for discharge/charge regular cycles down to 80% DOD shall be more than 1500 cycles (According to IEC 896-1).

Lifetime

The design lifetime of the batteries shall be of at least 8 years without losing more than 10% of the rated C_{10} capacity.

Battery cabling and protections

The battery connection point shall be as close as possible to the Multi-mode Inverter. Cables used to connect the battery shall have a temperature rating higher than 20 °C above ambient temperature[46]. It is recommended that they be flexible (multithreaded) to allow for easy installation and maintenance.

Fuses in cables that connect components to the battery shall be rated for d.c. use, be installed separately as close as possible to the battery terminals and rated to interrupt high fault currents from the battery. The battery tray to contain any electrolyte spills shall be constructed of impact and acid resistant material.

Diesel Genset

The Diesel Generator Set shall have a capacity of 250 kVA (200 kW) with an output of 400 V / 230 V @ 50 Hz and 1500 r.p.m. The rated consumption will follow a 0.25 L/h/kW curve at stand-by power. It should include a highly corrosion resistant enclosure, control panel and monitoring, fuel tank and circuit breaker protections.

The Diesel Genset shall be suitable for indoor or outdoor installation and shall perform accordingly with Multi-mode Inverter and the mentioned architecture model. The Diesel Genset shall be working in a fully automatic manner with the above stated components.

Distribution Line and Energy Meters

The electricity distribution from the generation plant to the end consumers will be done by means of a distribution line formed by a main Medium Voltage (MV) line at 11 kV and Low Voltages (LV) lines at 3-phase 400 V or 1-phase 230 V towards the consumers. All lines shall be over-head mounted on wood or concrete poles.

The main transformer will be installed at the generation plant with all necessary protections at LV and MV. The transformer will have a power capacity of 250 kVA, primary voltage of 11 kV and secondary of 420 V, connection Dyn11. Maximum losses ±15%. Meet standards of the IEEE C57.12.

At each branch, it will be installed distribution pole-mounted transformers of 50 kVA and 25 kVA. All Transfomers will have surge protection devices and circuit breakers for protection. Meet requirements and regulations of KPLC.

All Distribution Line cables will be of Aluminium multithreaded with the neutral made of steel. The distribution lines protection and cross-sections shall be sized accordingly with regulations of REA, KPLC and ERC, in particular the Kenya Electricity Grid Code. Mini-grids are required to be to comply with grid connection standards.

An energy meter for each consumer shall be considered. The energy meter shall be one or three phase multifunction meter which can read the active and reactive energy. Energy meters shall comply with the European Regulation EN 50470-1 and EN 50470-3, class B for active and reactive measurements.

[46] Consider ambient temperature of 40C.

Pre-paid meters[47] or electricity dispensers[48] (also on a pre-payment basis) are preferred due their advantages in securing revenue and reduced administrative costs. The billing scheme could be based on a consumed energy basis but often advanced service based tariffs are better adapted to low consumers in mini-grids. A comparison of different pre-paid meter options available in the market is provided in annex A7. The final decision on metering technology is closely linked to choice of delivery model (models discussed in the following section) and the regulatory requirements (not yet specified for mini-grids). We are therefore not prescribing a specific type of meter at this stage.

Electrical Protections

The system will include all necessary electrical protection to ensure the safety of persons and goods. At the LV distribution boards, thermomagnetic circuit breakers with C trip curve shall be included meeting IEC 60947-2 requirements. It shall also be included differential residual current circuit breaker for the person protection.

It is also important to include lighting protection system, ensuring the coverage of the whole PV plant, Power House and Diesel Genset. The standards to be followed are IEC 61643 and IEC 62305.

Power House

The Battery, Multi-mode inverter and all monitoring equipment will be installed indoors with air ventilation accordingly to the manufacturer's recommendations. Thus, a power house or a containerized solution, taking into account the equipment manufacturer's recommendations shall be installed. All electrical boards and LV protections will also be installed indoors. The batteries will be installed in the power house in a separate room, specifically for their use and meeting the electrical safety requirements according to its voltage class.

The PV inverters, Transformer and the Diesel Genset could be installed indoors or outdoors. For the PV inverters if installed outdoors, they will be covered so that no direct solar radiation affects the inverter performance.

The Power House will also be equipped with safety and protective elements required for operations, maintenance and emergencies. This will include fire extinguisher, water reservoirs for rinsing off acid splashes, baking soda (bicarbonate) for neutralising acid spills, protective goggles and clothing, etc.

The table below summarises the basic technical specification of the Mini-grid:

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[47] Pre-paid kWh-meters, such as meters currently being rolled out by KPLC

[48] The electricity dispenser can manage the user demand based on a Daily Demand Allowance (EDA) which is contracted by every user and saved it in an RFID card. The dispensers allow for better load management, which is important for mini-grids powered predominantly be renewable energy, i.e. resource availability is variable and the plant's output is limited. More information on the advantages of energy dispensers can be found in section 5.1 (Cape Verde case study).

Table 37 Technical specs for power plant in Kalokol

General Specifications	
Daily load demand	1.461 kWh/day
Coordinates	3.518N, 35.848E
Annual demand growth factor for first 5 years	4%
Renewable Fraction	93%
PV generator	
PV generator	370 kWp
Type of modules	Crystalline
Module Nominal Power	> 240W
Grid-Tied Inverter Type	String inverter
Battery Inverter	
Power demand	177 kW
Inverter type	Multi-mode
Inverter Continuous Power Rating	200 kW
Wave form type	Sinusoidal
Power output	Low Voltage 3-phase
Battery	
Autonomy (days)	1
Night load demand factor	53%
Battery voltage	≥ 48 Vdc
Battery Depth Of Discharge	60%
Battery capacity (C10)	2.164 MWh
Battery type	Lead Acid
Genset	
Number of gensets	1
Rated power	200 kW
Genset type	Low Voltage 3-phase
Distribution line	
Ditribution type	Medium Voltage 11kV
MV Distribution line distance	8.000 mts
LV Distribution line distance	2.000 mts
Number of poles	334
Number of transformers	9
MV Transformer 250kVA	1
LV Transformer 50kVA	4
LV Transformer 25kVA	4
Monitoring system	
Battery Supervisory control	1
Monitoring software for local and remote	1
GPRS/GSM Modem	1
Metereological Sensors	1

Technical annexes include:

- System sizing tool (Excel)
- Reference layout drawings for the distribution grid

8.2.6 Provisions on system O&M

- Maintenance costs for the solar power plant have been estimated at 1.5% of installed of capex (not including replacement of equipment).
- Batteries have been estimated to require replacement every 6 years. Inverters to require replacement at year 12.

8.2.7 System costing

Table 38 Power station cost for Kalokol

System components	Capacity	Units	Unit cost (EUR)	Total cost (EUR)	Comments
PV generation	370	kWp	1,500	555,000	Includes modules, grid inverters, cabling, mounting structure
Battery	2164	kWh	300	649,200	Battery, cabling, protections
Converters	200	kW	800	160,000	Battery inverter
Monitoring	1	lumpsum	25,000	25,000	Communications, sensors, etc.
Distribution Line	10000	mts	20.00	200,000	8000 mts MV, 2000 mts LV 3-phase
Distribution Poles	334	poles	350	116,900	
Diesel Genset	200	kW	150	30,000	
Transformers	9	units	10,000	90,000	4 x 12kVA, 4 x 50KVA, 1 x 250kVA (11kV/400V)
Civil and electrical Works	1	lumpsum	182,610	182,610	
Logistics	1	lumpsum	127,827	127,827	
Engineering and Consultancy Services	1	lumpsum	164,349	164,349	
			Total	**2,300,886**	
		Contingency	10%	230,088	
			Grand Total	**2,530,974**	
Cost Generation Plant				*1,903,236*	
Cost Distribution Grid				*627,738*	
Unit cost Generation Plant			*EUR/kWp*	*5,143*	
Unit Cost Distribution Line			*EUR/user*	*1,778*	

8.3 Dukana

8.3.1 Energy demand

Dukana is a large town of 15,000 people. The community is home to approximately 2400 households and 80 businesses. The local economy is based around the livestock trade, with private businesses providing goods and services ranging from phone charging to barber shops and video halls. Energy demand has been calculated based on existing energy use as well as likely potential activities after a reliable and cheaper supply of electricity is available. Energy demand comes from commercial/industrial activities, public services and residential use:

- **Commercial and industrial activities:** Dukana's economy is pastoralist and revolves around cattle and camels. Related economic activities that can benefit from power include meat processing and refrigeration of dairy products. Water pumping is also essential for drinking water, for cattle and for irrigation. Finally, electricity can enable a broad variety of small businesses (retail shops, lodges, ICT, etc.).

  Similarly to our arguments regarding the sustainability of economic activities in Kalokol in the previous section, Dukana is also located in a drought-affected area in northern Kenya and the pastoralist economy is linked to the availability of water resources. The future of water resources has not been included within the scope of our work but we are aware of Government programs actively working in the field of water management in northern Kenya. GIZ in particular is collaborating in the field of water management and economic value chains (livestock, agriculture, etc.) in both Marsabit and Turkana counties. It is proposed to collaborate and create synergies between this electrification project and their efforts on economic development.

- **Public services:** the town includes a variety of amenities and institutions, including a generator- and solar-pumped borehole for drinking water, health and school facilities, the district government office, religious organizations, and a local police force.

- **Residential use:** we have estimated that approximately 150 low income households (basic energy use: lighting, radio, phone charging) and 20 medium/high income households (higher energy consumption including TV, fans and fridge) could be connected to the mini-grid. 170 households represent about 10% of the population[49].

The energy demand in Dukana has been calculated based on interviews with businesses and institutions in the field, focus groups and benchmarking with KPLC mini-grids. Table 39 presents a summary of the calculated energy demand broken down by

[49] Population of Dukana is of 1,594 households according to the SREP document.

consumer category. The details on specific loads, time of use, number of future users, etc. that led to these results can be found in the annexed sizing tool (excel file).

Table 39 Energy demand in Dukana

Users	Consumption per user (Wh/day)	Number of users	Total consumption (Wh/day)	% of total
Commercial and industrial				
Wholesales	3,813	4	15,252	3%
Retails Shops	1,681	15	25,215	5%
Water Pumps	63,000	2	126,000	23%
Garage / Repairshop	20,941	1	20,941	4%
Lodges	6,260	2	12,520	2%
Meat industry	63,624	1	63,624	12%
Public uses				
Girls Primary School	31,693	1	31,693	6%
Boys Primary School	19,315	1	19,315	4%
Secondary School	59,101	1	59,101	11%
Health Center	18,157	1	18,157	3%
Catholic Church	15,690	1	15,690	3%
Mosque	3,686	1	3,686	1%
Police Station	10,265	1	10,265	2%
Administrative Police Station (API)	6,428	1	6,428	1%
Street Lights	396	20	7,920	1%
Chief Office	4,306	1	4,306	1%
Residential				
Big Housesolds	3,358	20	67,160	12%
Small Households	249	150	37,350	7%
Totals		**224**	**544,623**	

The total daily consumption without network losses has been estimated at 545 kWh/day. Considering 10% grid losses, the electrical energy produced from the power plant should be **599 kWh/day**. The estimated contracted peak power is 74 kW.

The above figures equate to an average monthly energy consumption of 80 kWh/month per user and an average peak demand of 330 W/user.

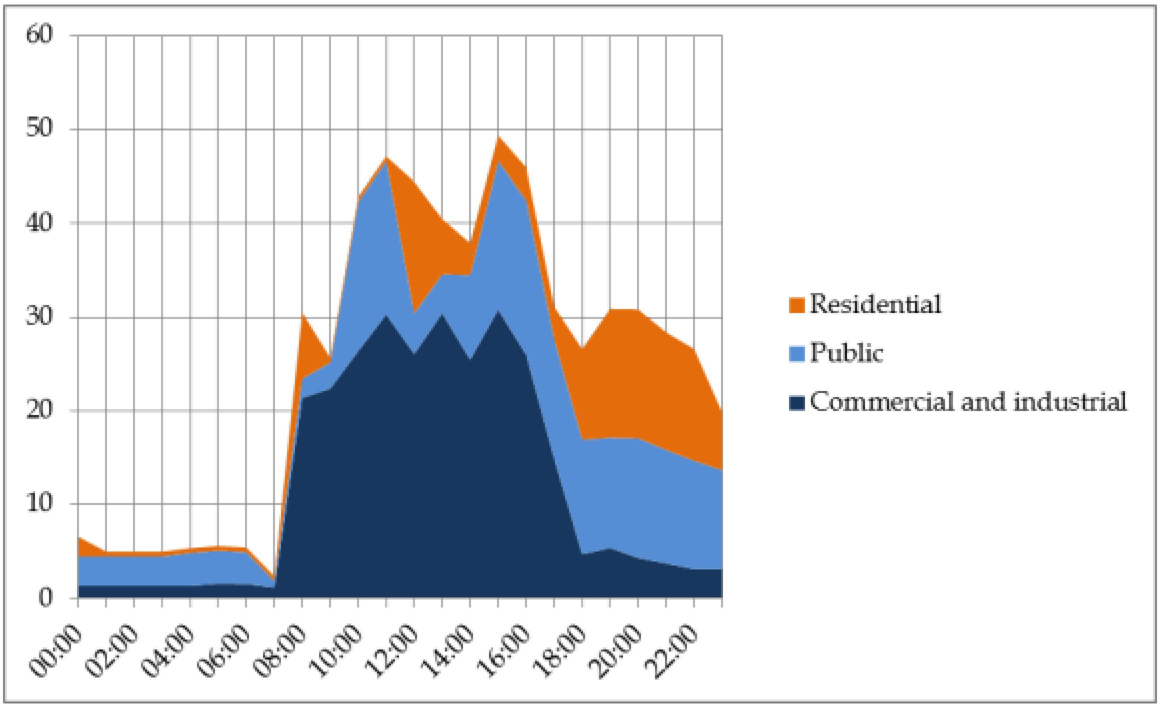
As a reference, the same averages for existing KPLC mini-grids are 121 kWh/month per user and 495 W/user (coincident demand). It is reasonable to have lower averages for Dukana considering the different stage of development of the new site in relation to existing mini-grid sites.

8.3.2 Load profile and seasonality

Table 40 shows the estimated load profile for Dukana, which is based on the individual load profiles of the users presented in the table above. The peak during the day is dominated by commercial activities (of which meat and dairy industries and water pumping represent the largest part) and the evening peak is dominated by residential consumption.

For solar PV plants, energy use during the daytime is to be encouraged to reduce the duty cycle of the battery. A smart pricing mechanism based on time-of-use is useful in providing this incentive to customers.

Table 40 Average daily load profile in Dukana (kW)



With regards to seasonality, the arguments presented in the previous section for Kalokol are also valid for Dukana. We expect limited energy demand variations due to relatively temperature and daylight hours patterns. With regards to commercial activities, the rainy seasons should be expected to affect the trade of livestock and agricultural activities but the precise impact of this on electricity could not be determined. Similarly to what was presented in the analysis for Kalokol, KPLC mini-grids of comparable size located in northern Kenya show monthly variations in energy consumption of +/- 17%. Such variations are within the operational parameters of this type of mini-grids.

8.3.3 Demand growth projections

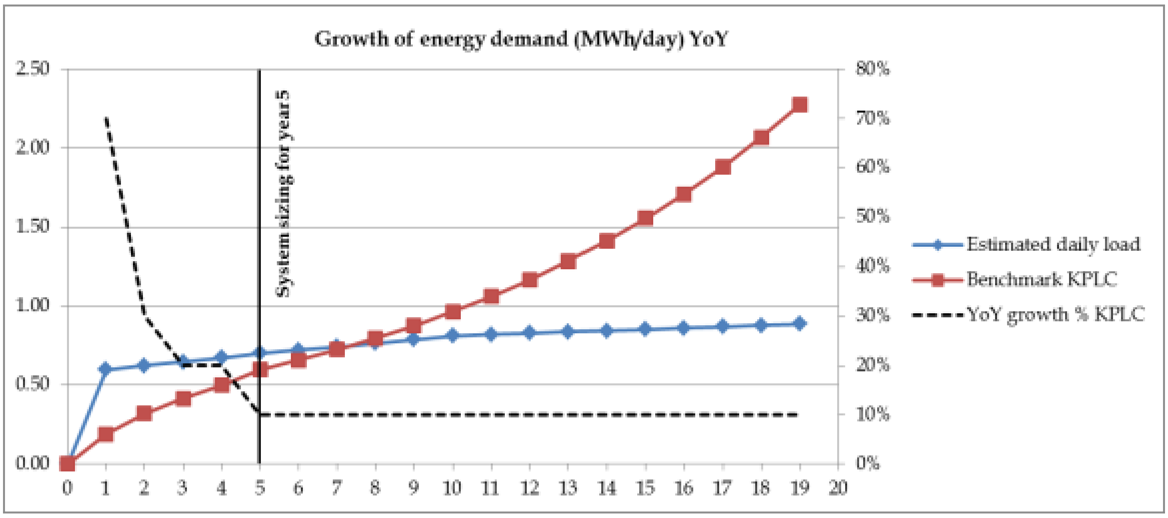
Based on the analysis of existing mini-grids run by KPLC, growth is fast during the first five years and then stabilizes at a growth rate of approximately 10% p.a. This decreasing growth rate is shown with a dotted line in Table 41.

Additionally, a comparison of number of connections and number of households[50] for existing mini-grids suggests that 15% of connections is achievable by year 5. For Dukana, the estimated 224 connections among 1,594 households (i.e. 0.14 connections/HH) also suggest that the calculated energy demand of Table 39 corresponds to the expected demand of year 5.

Based on the above comparisons with KPLC mini-grids, energy consumption growth is represented by the red line in Table 41.

An alternative growth curve based on the experience of TTA in similar projects suggests a faster connection of customers during the first year and a slower growth rate during the following years (4% p.a. until year 5, 3% until year 10 and 1% onwards) (blue line).

Table 41 Growth of the daily demand in Dukana (MWh/day)



Given the uncertainty of consumption growth, it is proposed that the power station is sized for year 5, which has similar results for both projections. System will be designed to be easily scalable to adapt to growth thereafter.

8.3.4 Resource assessment

The average solar radiation on the Horizontal Plane in Dukana is 6,160 Wh/m²/d. The values have been taken from the website PVGIS website: re.jrc.ec.europa.eu/pvgis/. The table below shows the monthly solar irradiation in Dukana.

[50] Based on available number of connections (KPLC data) and number of households (SREP document) for Lokichogio, Takaba, Eldas and Rhamu

Table 42 Solar resource in Dukana (Source PVGIS)

Month	H_h	$H(10)$
Jan	6380	6880
Feb	6650	6950
Mar	6380	6410
Apr	5670	5480
May	5870	5490
Jun	5870	5400
Jul	5930	5490
Aug	6300	6000
Sep	6580	6510
Oct	6140	6310
Nov	6090	6490
Dec	6160	6700
Year	6160	6170

H_h: Irradiation on horizontal plane ($Wh/m^2/day$)

$H(10)$: Irradiation on plane at angle: 10deg. ($Wh/m^2/day$)

8.3.5 PV hybrid mini-grid sizing

As explained in the previous section, the power has been sized based on the energy requirements (energy consumption and contracted peak demand) of year 5. This equates to:

- Energy consumption of 700 kWh/day
- Peak demand of 87 kW

The system will be modular, so that it can be upgraded easily to meet future needs.

The power plant will be configured as AC coupled due to the significant portion of daytime loads that can be fed directly from the solar generator without intermediate battery storage. This will include:

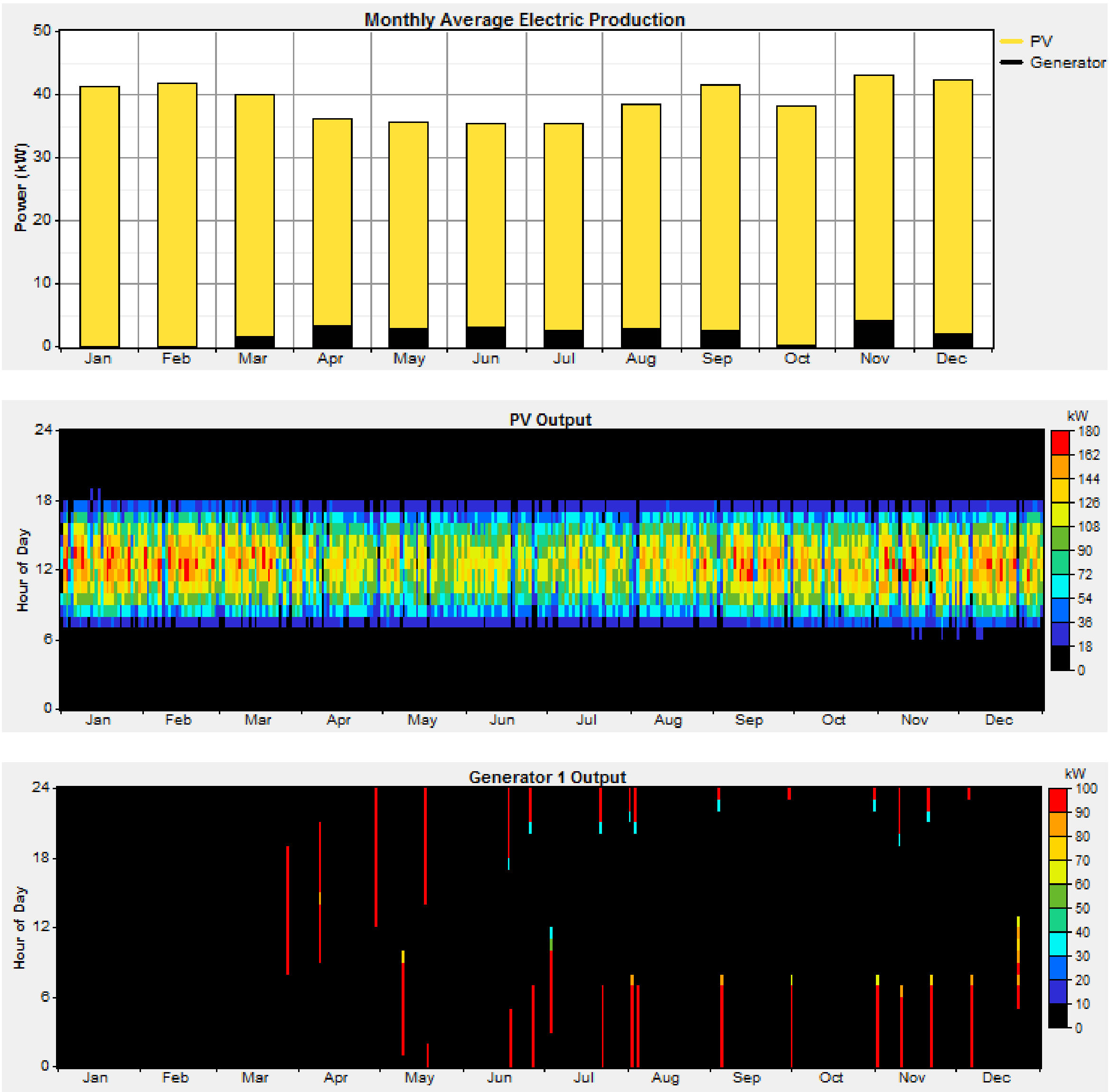
- PV modules with PV inverters
- Wind technology could also be considered but no reliable wind speed measurements have been made available to date. It is proposed that wind power is considered as an alternative to expansion of the mini-grid.
- Diesel thermal genset
- Deep-cycle lead-acid electrochemical batteries with liquid electrolyte (largely used in off-grid applications thanks to its well proven technology at baseline costs compared with other types of batteries)

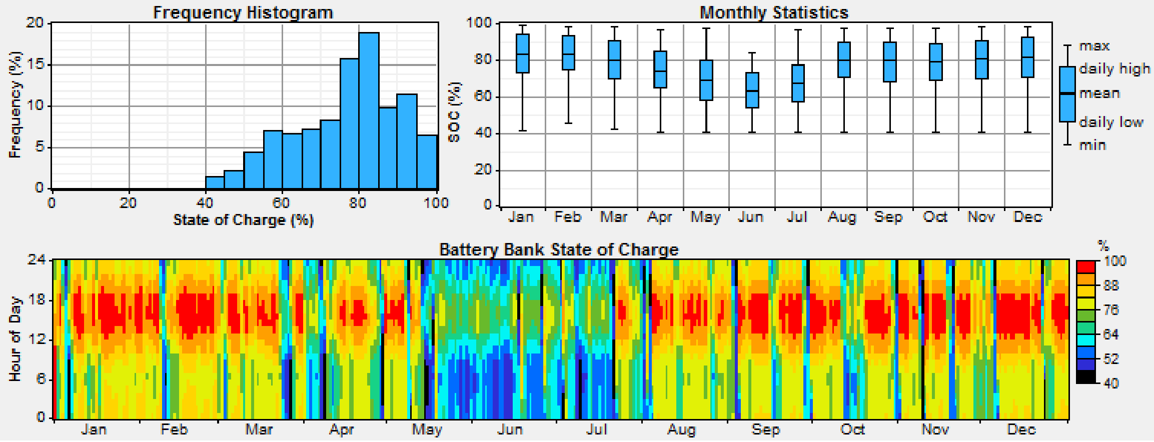
Sizing scenarios

Different sizing scenarios were tested using the software HOMER in order to maximize penetration of solar energy while keeping a low cost of energy. Main variables were the capacity of the PV generator and the capacity of the battery.

The preferred option is for a **180 kWp PV solar energy station** with a **1.13 MWh battery**. This solution achieves a 95% penetration of solar energy in year 5 as shown in the figures below.

Table 43 Output of proposed power plant in Dukana





Architecture and basic design specifications

As reference for this study, the architecture of the Mini-Grid is based on a centralized Photovoltaic Plant connected to a Three-Phase AC Bus, where the Battery Multi-mode Inverter and the Diesel Genset are also connected. The configuration follows an AC-Coupling model, where the Battery Multi-mode Inverter act as voltage source and the PV grid independent inverters act as current source, following the 50 Hz frequency of the battery inverter. Whenever the Diesel Genset is on, the Battery Inverter changes its modality to act as a current source, following the 50 Hz frequency from the Genset.

The electricity distribution to the consumers should be by means of a Low Voltage line 3-Phase. This line starts at the centralized PV Station and follows the main street in Dukana.

The daily load demand which is used to size the Solar Mini-grid has been the demand at year 5, 701 kWh/day.

The PV plant and the Battery capacity have been sized accordingly to the daily demand and the solar resources. The PV plant capacity (180 kWp) is sized with 5 Peak Sun Hours at the worst month and taking into account a Performance Ration of 0.8 for the worst month of radiation.

The battery capacity shall have a capacity of 1133 kWh, taking into consideration the daily load demand, one day of autonomy, Depth of Discharge of 60% and 5% of losses.

The Renewable Generation Plant will also have a Diesel Genset, which will be used normally as back-up. The size of the Genset is 100 kW, in order to have the sufficient power capacity at year 5. The Genset should only be switched on whenever the Battery State of Charge is under a certain limit which will be defined at commissioning stage.

PV Generator

The PV generator shall consist on Silicon Crystalline Photovoltaic modules of capacity at STC of 240 Wp or more. The PV modules should comply with the norms IEC 61215 and IEC 61730. The outside junction box with the positive and negative terminals shall incorporate bypass diodes that have the function of preventing any possibility of the electrical circuit inside the module being broken due to the partial shading of a cell and shall be at least IP 65 and UV resistant.

The module support structure shall be ground-mounted on arid and rocky soil. The support shall have a tilt angle between 10° - 15° from the horizontal with an azimuth of 0° South. No soil test has been performed but from the site inspection, no ramming or screw foundations might be used, therefore it is recommendable to use concrete block as foundation. The support frame shall be of either light weight aluminium or galvanized steel and it shall be easy for installation, maintenance and disassembly at the end of the life cycle.

Cables used within the PV generator shall have a voltage rating of at least 1,2 V_{OC} ; have a temperature rating higher than 40 °C above ambient temperature; be UV-resistant; water resistant and it is recommended that they be flexible (multithreaded) to allow for thermal/wind movement of modules.

The PV inverter shall be of type current source grid-tied to convert DC to an AC Sinusoidal current. String inverters shall be installed indoors or outdoors with a cover and suitable for desert conditions with high ambient temperatures and dust. Only 3-Phase Inverters Transformer-less and with Maximum and European Efficiency higher than 95% shall be considered. The PV inverters should comply with the international norm IEC 61727.

The PV generator will have all electrical protections necessary at DC and AC side, an earth connection of all modules, the electronic equipment and the structure and surge protection devices type I+II.

Multi-mode Inverter

The multi-mode inverter (or inverter set) for this application is a 100 kW (nominal) bidirectional sinusoidal inverter. It can operate in autonomous mode as well as grid-tied mode. The efficiency curve shall be always above 80% in all cases, adjusting it at the load demand curve (base load, partial load or maximum load). One-phase or 3-phase Multi-mode Inverters can be considered, but only 3-phase connection to the AC-bus is allowed.

Battery

The battery considered is lead-acid, deep discharge type with a permissible repeated deep discharge without damage. Automotive or starting type batteries are not acceptable. It shall be of the open “vented” OPzS type with recombination caps and transparent enclosure for easy inspection of electrolyte level .The batteries must be manufactured according DIN 40736-1: “Stationary batteries with tubular positive plates. Capacities, measurements and weights”.

Battery rating

The battery nominal voltage does not need to be established at this stage and different technology providers may offer different solutions on this issue. Nevertheless it must be noted that the voltage class, either ELV or LV, will determine the electrical isolation and accesibilty requirements of the battery room. The battery shall have at least the rated capacity of 1.13MWh at the C_{10} discharge rate according to DIN 43539-9

Battery performance

The battery shall have a self-discharge when new of less than 5% per month (at 25ºC and fully charged) of its rated capacity and shall have a Coulombic efficiency of at least 85% and energy conversion efficiency of at least 85% when new and charged to more than 50% of capacity.

The battery cycle life for discharge/charge regular cycles down to 80% DOD shall be more than 1500 cycles (According to IEC 896-1).

Lifetime

The design lifetime of the batteries shall be of at least 8 years without losing more than 10% of the rated C_{10} capacity.

Battery cabling and protections

The battery connexion point shall be as close as possible to the Multi-mode Inverter. Cables used to connect the battery shall have a temperature rating higher than 20 °C above ambient temperature. It is recommended that they be flexible (multithreaded) to allow for easy installation and maintenance.

Fuses in cables that connect components to the battery shall be rated for d.c. use, be installed separately as close as possible to the battery terminals and rated to interrupt high fault currents from the battery. The battery tray to contain any electrolyte spills shall be constructed of impact and acid resistant material.

Diesel Genset

The Diesel Generator Set shall have a capacity of 125 kVA (100 kW) with an output of 400 V / 230 V @ 50 Hz and 1500 r.p.m. The rated consumption will follow a 0.25 L/h/kW curve at stand-by power. It should include a highly corrosion resistant enclosure, control panel and monitoring, fuel tank and circuit breaker protections.

The Diesel Genset shall be suitable for indoor or outdoor installation and shall perform accordingly with Multi-mode Inverter and the mentioned architecture model. The Diesel Genset shall be working in a fully automatic manner with the above stated components.

Distribution Line and Energy Meters

The electricity distribution from the generation plant to the end consumers will be done by means of a distribution line formed by several branches at Low Voltage (LV) 3-phase 400 V or 1-phase 230 V towards the consumers. All lines shall be over-head mounted on wood or concrete poles.

The distribution lines protection and cross-sections shall be sized accordingly with regulations of REA, KPLC and the Energy Regulatory Commission.

The discussion on energy metering from the previous section (design for Kalokol) is also applicable to Dukana.

Electrical Protections and Power House

The requirements for electrical protections and the power house were stated in the section for Kalokol and are applicable to Dukana.

The table below summarizes the basic technical specification of the Mini-grid:

Table 44 Technical specs for proposed power plant in Dukana

General Specifications	
Daily load demand	701 kWh/day
Coordinates	4.003N, 37.273E
Annual demand growth factor for first 5 years	4%
Renewable Fraction	95%
PV generator	
PV generator	180 kWp
Type of modules	Crystalline
Nominal Module Power	> 240W
Grid-Tie Inverter Type	String inverter
Battery Inverter	
Power demand	87 kW
Inverter type	Multi-mode
Inverter Continuous Power Rating	100 kW
Wave form type	Sinudoidal
Power output	Low Voltage 3-phase
Battery	
Autonomy (days)	1
Night load demand factor	47%
Battery voltage	≥ 48 Vdc
Battery Depth Of Discharge	60%
Battery capacity	1.133 MWh
Battery type	Lead Acid
Distribution line	
Ditribution type	Low Voltage
LV Distribution line distance	6.000 mts
Number of poles	200
Genset	
Number of gensets	1
Rated power	100 kW
Genset type	3 phase
Monitoring system	
Battery Supervisory control	1
Monitoring software	1
GPRS/GSM Modem	1
Metereological Sensors	1

Technical annexes related to the system design include:

- System sizing tool (Excel sheet)
- Reference Layout drawings of distribution grid

8.3.6 Provisions on system O&M

- Maintenance costs for the solar power plant have been estimated at 1.5% of installed of capex (not including replacement of equipment.
- Batteries have been estimated to require replacement every 6 years. Inverters to require replacement at year 12.

8.3.7 System costing

System components	Capacity	Unit	Unit cost (EUR)	Total cost (EUR)	Comments
PV generation	180	kWp	1,500	270,000	Modules, wiring, PV inverters, mounting structure
Battery	1133	kWh	300	339,900	Battery, wiring, protection
Converters	100	kW	800	80,000	Battery inverter, protections
Monitoring	1	lumpsum	25,000	25,000	Communications, sensors, etc.
Distribution Line	6000	mts	20	120,000	6000 mts LV 3-phase
Distribution Poles	200	poles	350	70,000	
Diesel Genset	100	kW	150	15,000	
Services					
Civil and electrical Works	1	lumpsum	91,990	91,990	
Logistics	1	lumpsum	64,393	64,393	
Engineering and Consultancy Services	1	lumpsum	82,791	82,791	
			Total	**1,159,074**	
		Contingency	10%	115,907	
			Grand Total	**1,274,981**	
Cost Generation Plant				*977,627*	
Cost Distribution Line				*297,353*	
Unit cost Generation Plant			***EUR/kWp***	***5,431***	
Unit Cost Distribution Line			***EUR/user***	***1,327***	

8.4 Ngurunit

8.4.1 Energy demand

Ngurunit is a moderately-sized but rapidly growing town of 11,000 people. The community is home to approximately 2,500 households and 150 businesses. The local economy is based around tourism and the livestock trade, and Kenya Wildlife Service (KWS) recently opened an outpost in the community. Private businesses provide goods and services ranging from phone charging to bars and lodges. Energy demand has been estimated based on existing and potential commercial activities, public services and residential use.

- **Commercial activities:** the economy is based off the livestock trade as well as tourism. Opportunities for productive use of electricity include livestock related activities, including meat processing and dairy refrigeration, and tourism services, including improved electricity supply in tented camps as well as KWS offices. Water pumping and irrigation are also estimated to be a major driver of electricity demand. Finally, there is a wide variety of small businesses that will benefit from power.

  Similarly to our arguments regarding the sustainability of economic activities in Dukana in the previous section, Ngurunit is also located in a drought-prone area in northern Kenya and the pastoralist economy is linked to the availability of water resources. The future of water resources has not been included within the scope of our work but we are aware of Government programs actively working in the field of water management in northern Kenya. GIZ in particular is collaborating in the field of water management and economic value chains (livestock, agriculture, etc.) in both Marsbit and Turkana counties. It is proposed to collaborate and create synergies between this electrification project and their efforts on economic development.

- **Public services:** the town includes a variety of amenities and institutions, including generator-pumped borehole water, health and school facilities, a local government office, churches, and a local police force.

- **Residential use:** we have estimated that approximately 80 low income households (basic energy use: lighting, radio, phone charging) and 10 medium/high income households (higher energy consumption including TV, fans and fridge) could be connected to the mini-grid. These 90 households represent about 10% of the population[51] in the proximity to Ngurunit's town centre.

[51] According to interviews with local representatives, Ngurunit is home to 2,500 households. Previous GIZ surveys (October 2013) however indicate a population of 800 households. The latter figure is used as a better representation of the households in the proximity to the town centre.

The energy demand in Ngurunit has been calculated based on interviews with businesses and institutions in the field, focus groups and benchmarking with KPLC mini-grids. The table below presents a summary of the calculated energy demand broken down by consumer category. The details on specific loads, time of use, number of future users, etc. that led to these results can be found in the annexed sizing tool (excel file).

Table 45 Estimated energy consumption in Ngurunit

Users	Consumption per user (Wh/day)	Number of users	Total consumption (Wh/day)	% of total
Commercial and industrial				
Wholesales	5925	3	17775	4%
Retails Shops	1681	10	16810	4%
Water Pumps	60000	1	60000	14%
Garage / Repair shop	28779	1	28779	7%
Lodges	11320	4	45280	11%
Restaurants	4306	2	8612	2%
Kenya Wildlife Services	18517	1	18517	4%
Cinema	3835	1	3835	1%
Telecom Tower	58696	1	58696	14%
Public uses				
Primary School	8695	2	17390	4%
Secondary School	43579	1	43579	10%
Health Center	25022	1	25022	6%
Catholic Missions	6760	1	6760	2%
Mosque	3686	1	3686	1%
Administrative Police Station	6428	1	6428	2%
Street Lights	396	10	3960	1%
Chief Office	4306	1	4306	1%
Residential				
Big Housesolds	3358	10	33580	8%
Small Households	249	80	19920	5%
Totals		**132**	**422,935**	

The total daily consumption without network losses has been estimated at 423 kWh/day. Considering 10% grid losses, the electrical energy produced from the power plant should be **465 kWh/day**. The estimated contracted peak power is 55kW.

The above figures equate to an average monthly energy consumption of 106 kWh/month per user and an average peak demand of 420 W/user.

As a reference, the same averages for existing KPLC mini-grids are 121 kWh/month per user and 495 W/user (coincident demand). It is reasonable to have lower averages for

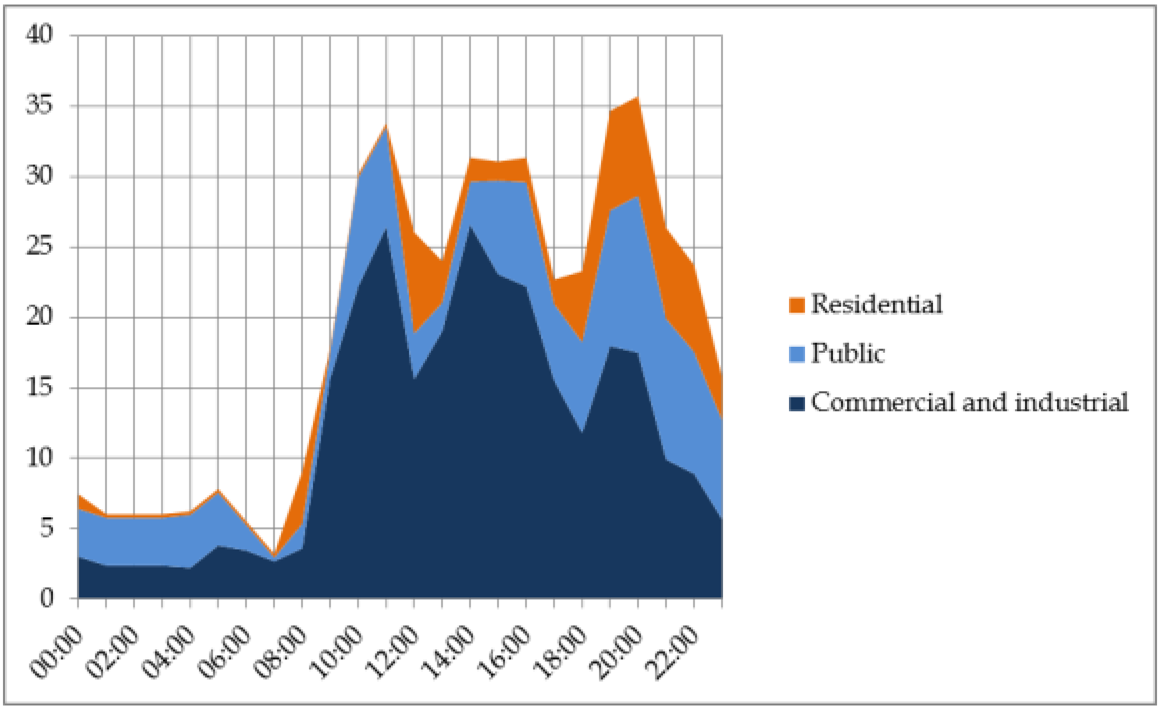
Ngurunit considering the different stage of development of the new site in relation to existing mini-grid sites.

8.4.2 Load profile and seasonality

Table 46 shows the estimated load profile for Ngurunit, which is based on the individual load profiles of the users presented in the table above. The peak during the day is dominated by commercial activities (of which tourism, water pumping and telecom towers represent the largest part). Residential consumption peaks in the evening as it is normally found in a rural context.

For solar PV plants, energy use during the daytime is to be encouraged to reduce the duty cycle of the battery. A smart pricing mechanism based on time-of-use is useful in providing this incentive to customers.

Table 46 Average daily load profile in Ngurunit (kW)

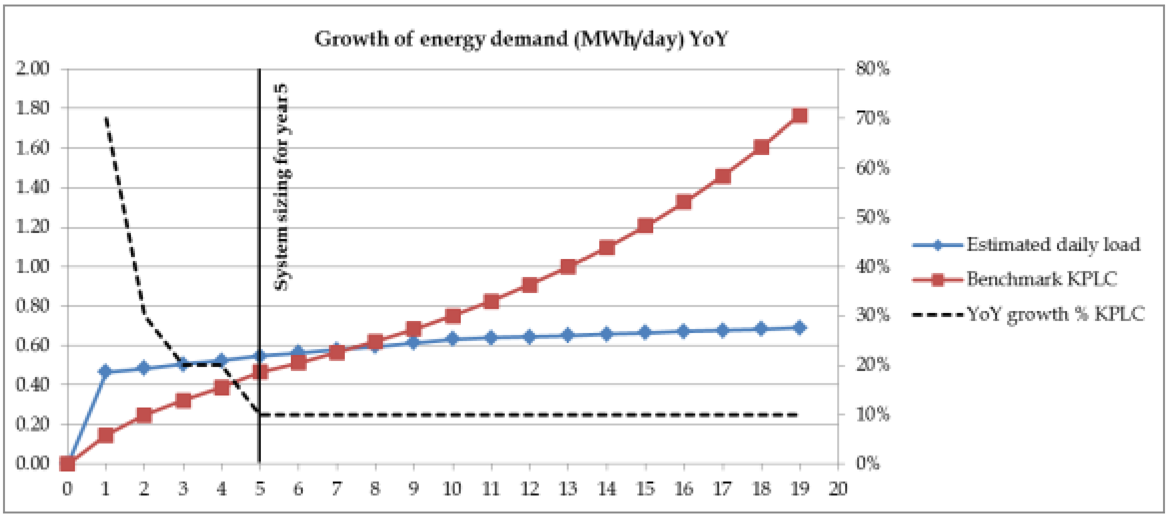


With regards to seasonality, the arguments presented in the previous sections for Kalokol and Dukana are also valid for Ngurunit. We expect no significant energy demand variations due to relatively temperature and daylight hours patterns. With regards to commercial activities, the rainy seasons should be expected to affect the trade of livestock and agricultural activities but the precise impact of this on electricity could not be determined. Similarly to what was presented in the analysis for Kalokol, KPLC mini-grids of comparable size located in northern Kenya show monthly variations in energy consumption of +/- 17%. Such variations are within the operational parameters of this type of mini-grids.

8.4.3 Demand growth projections

Similarly to the demand growth projections for Kalokol and Dukana, alternative growth scenarios have been done based on comparison with existing KPLC mini-grids (red line) and previous experience of TTA in mini-grid projects (blue line).

Table 47 Growth of the daily demand in Ngurunit (MWh/day)



Given the uncertainty of consumption growth, it is proposed that the power station is sized for year 5, which has similar results for both projections. System will be designed to be easily scalable to adapt to growth thereafter.

8.4.4 Resource assessment

The average solar radiation on the Horizontal Plane in Ngurunit is 6,250 Wh/m²/d. The values have been taken from the website PVGIS website: re.jrc.ec.europa.eu/pvgis/. The table below shows the Monthly Solar Irradiation in Ngurunit.

Table 48 Solar resource in Ngurunit (Source PVGIS)

Month	H_h	$H(10)$
Jan	6210	6630
Feb	6810	7070
Mar	6530	6520
Apr	5900	5680
May	6170	5720
Jun	6010	5470
Jul	5930	5440
Aug	6440	6080
Sep	6860	6750
Oct	6490	6640
Nov	5800	6120
Dec	5860	6300
Year	6250	6200

H_h: Irradiation on horizontal plane (Wh/m^2/day)

$H(10)$: Irradiation on plane at angle: 10deg. (Wh/m^2/day)

8.4.5 PV hybrid mini-grid

As explained in the previous section, the power system has been designed based on the energy requirements (energy consumption and contracted peak demand) of year 5. This equates to:

- Energy consumption of 544 kWh/day
- Peak demand of 65 kW

The system will in any case be modular, so that it can be upgraded easily to meet future needs.

The power plant will be configured as AC coupled due to the significant portion of daytime loads that can be fed directly from the solar generator without intermediate battery storage. This will include:

- PV modules with PV inverters
- Wind technology could also be considered but no reliable wind speed measurements have been made available to date. It is proposed that wind power is considered as an alternative to expansion of the mini-grid.
- Diesel thermal genset

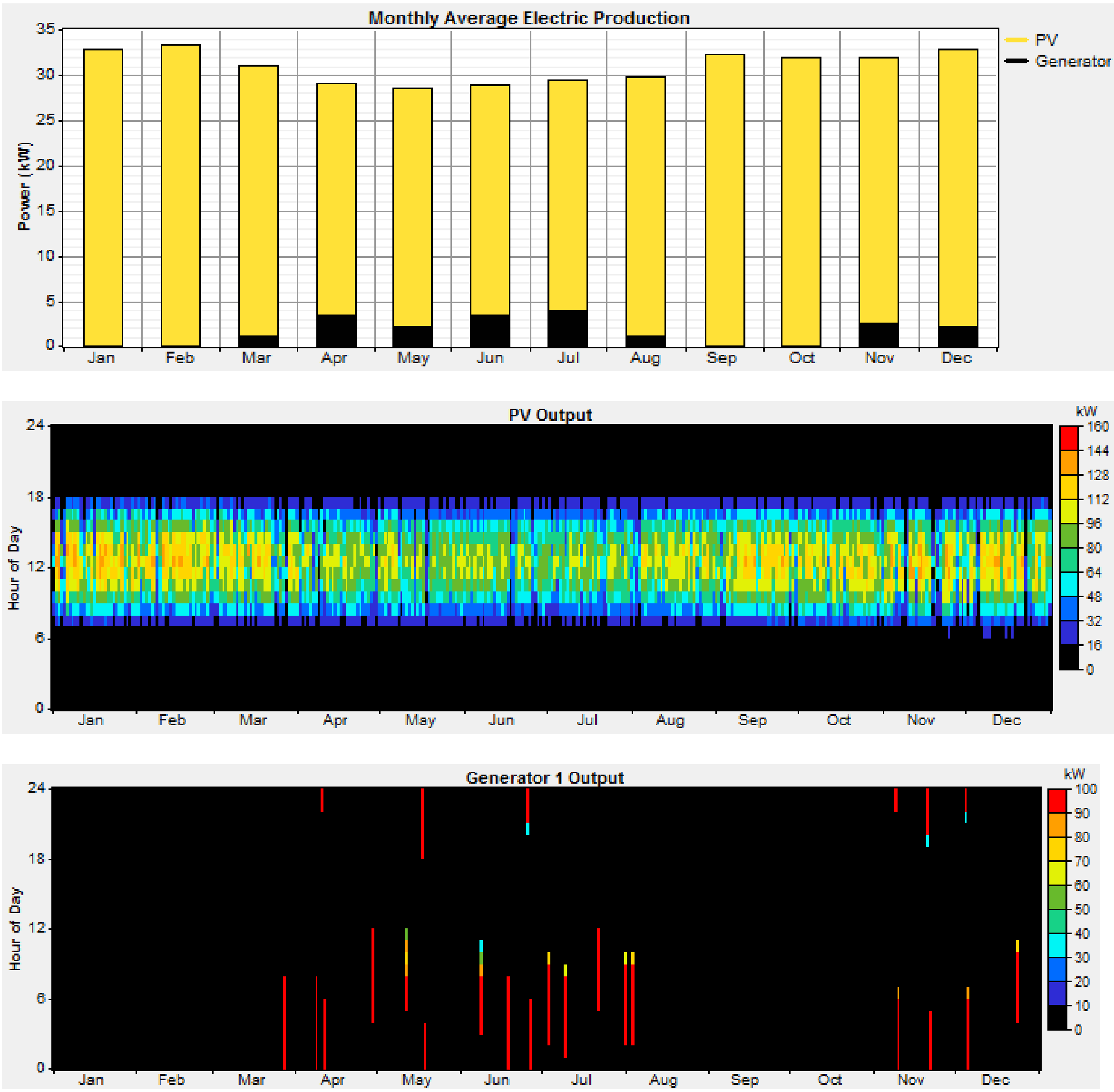
- ❑ Deep-cycle lead-acid electrochemical batteries with liquid electrolyte (largely used in off-grid applications thanks to its well proven technology at baseline costs compared with other types of batteries)

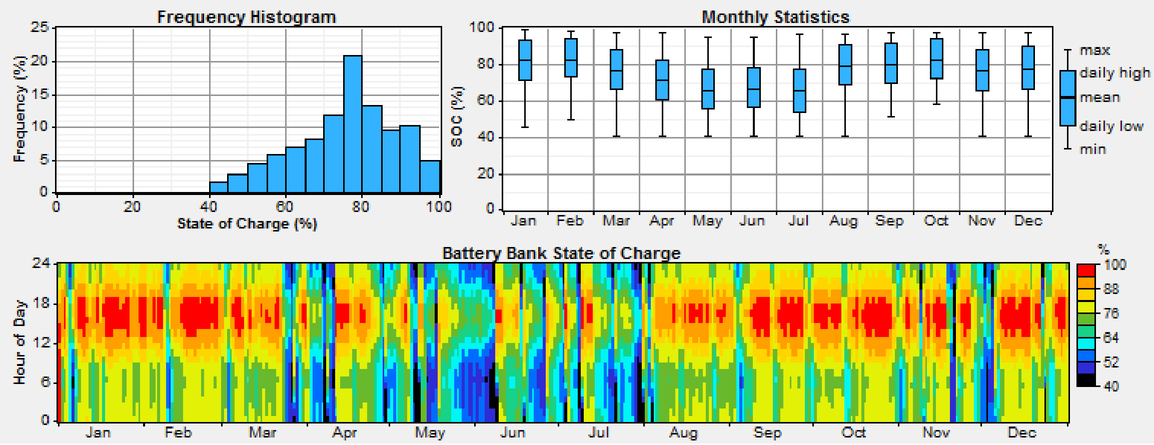
Sizing scenarios

Different sizing scenarios were tested using the Homer software in order to maximize penetration of solar energy while keeping a low cost of energy. Main variables were the capacity of the PV generator and the capacity of the battery.

The preferred option is for a **140 kWp PV solar energy station** with a **0.99 MWh battery**. This solution achieves a 95% penetration of solar energy in year 5 as shown in the figures below.

Table 49 Output of power plant proposed for Ngurunit (source: Homer)





Architecture and basic design specifications

As a reference for this study, the architecture of the Mini-Grid is based on a centralized Photovoltaic Plant connected to a Three-Phase AC Bus, where the Battery Multi-mode Inverter and the Diesel Genset are also connected. The configuration follows an AC-Coupling model, where the Battery Multi-mode Inverter acts as voltage source and the PV grid-dependent inverters act as current source, following the 50 Hz frequency of the Inverter. Whenever the Diesel Genset is on, the Battery Inverter changes its modality to act as a current source, following the 50 Hz frequency from the Genset.

The electricity distribution to the consumers should be by means of a Low Voltage line 3-Phase. This line starts at the centralized PV Station and follows the main street in Ngurunit.

The daily load demand which is used to size the Solar Mini-grid has been the demand at year 5th, 544 kWh/day.

The PV plant and the Battery capacity have been sized accordingly to the daily demand and the solar resources. The PV plant capacity (140 kWp) is sized with 5 Peak Sun Hours at the worst month and taking into account a Performance Ration of 0,8 for the worst month of radiation.

The battery capacity shall have a capacity of 991 kWh, taking into consideration the daily load demand, one day of autonomy, Depth of Discharge of 60% and 5% of losses.

The Renewable Generation Plant will also have a Diesel Genset, which will be used normally as back-up. The size of the Genset is 100 kW, in order to have the sufficient power capacity at year 5. The Genset should only be switched on whenever the Battery State of Charge is under a certain limit which will be defined at commissioning stage.

PV Generator

The PV generator consists of Silicon Crystalline Photovoltaic modules of capacity at STC of 240 Wp or more. The PV modules should comply with the norms IEC 61215 and IEC 61730. The outside junction box with the positive and negative terminals shall incorporate bypass diodes that have the function of preventing any possibility of the electrical circuit inside the module being broken due to the partial shading of a cell and shall be at least IP 65 and UV resistant.

The module support structure shall be ground-mounted on arid and rocky soil. The support shall have a tilt angle between 10° - 15° from the horizontal with an azimuth of 0° South. No soil test has been performed but from the site inspection, no ramming or screw foundations might be used, therefore it is recommendable to use concrete block as foundation. The support frame shall be of either light-weight aluminium or galvanized steel and it shall be easy for installation, maintenance and disassembly at the end of the life cycle.

Cables used within the PV generator shall have a voltage rating of at least 1,2 V_{OC} ; have a temperature rating higher than 40 °C above ambient temperature; be UV-resistant; water resistant and it is recommended that they be flexible (multithreaded) to allow for thermal/wind movement of modules.

The PV inverter shall be of type current source grid-tied to convert DC to an AC Sinusoidal current. String inverters shall be installed indoors or outdoors with a cover and suitable for desert conditions with high ambient temperatures and dust. Only 3-Phase Inverters Transformer-less and with Maximum and European Efficiencies higher than 95% shall be considered. The PV inverters should comply with the international norm IEC 61727.

The PV generator will have all electrical protections necessary at DC and AC side, an earth connection of all modules, the electronic equipment and the structure and surge protection devices type I+II.

Multi-mode Inverter

The multi-mode inverter (or inverter set) for this application is a 100 kW (nominal) bidirectional sinusoidal inverter. It can operate in autonomous mode as well as grid-tied mode. The efficiency curve shall be always above 80% in all cases, adjusting it at the load demand curve (base load, partial load or maximum load). One-phase or 3-phase Multi-mode Inverters can be considered, but only 3-phase connection to the AC-bus is allowed.

Battery

The battery considered is lead-acid, deep discharge type with a permissible repeated deep discharge without damage. Automotive or starting type batteries are not acceptable. It shall be of the open "vented" OPzS type with recombination caps and transparent enclosure for easy inspection of electrolyte level .The batteries must be manufactured according DIN 40736-1: "Stationary batteries with tubular positive plates. Capacities, measurements and weights".

Battery rating

The battery nominal voltage does not need to be established at this stage and different technology providers may offer different solutions on this issue. Nevertheless it must be noted that the voltage class, either ELV or LV, will determine the electrical isolation and accesibilty requirements of the battery room. The battery shall have at least the rated capacity of 2.16MWh at the C_{10} discharge rate according to DIN 43539-9

Battery performance

The battery shall have a self-discharge when new of less than 5% per month (at 25°C and fully charged) of its rated capacity and shall have a Coulombic efficiency of at least 85% and energy conversion efficiency of at least 85% when new and charged to more than 50% of capacity.

The battery cycle life for discharge/charge regular cycles down to 80% DOD shall be more than 1500 cycles (According to IEC 896-1).

Lifetime

The design lifetime of the batteries shall be of at least 8 years without losing more than 10% of the rated C_{100} capacity.

Battery cabling and protections

The battery connexion point shall be as close as possible to the Multi-mode Inverter. Cables used to connect the battery shall have a temperature rating higher than 20 °C above ambient temperature. It is recommended that they be flexible (multithreaded) to allow for easy installation and maintenance.

Fuses in cables that connect components to the battery shall be rated for d.c. use, be installed separately as close as possible to the battery terminals and rated to interrupt high fault currents from the battery. The battery tray to contain any electrolyte spills shall be constructed of impact and acid resistant material.

Diesel Genset

The Diesel Generator Set shall have a capacity of 125 kVA (100 kW) with an output of 400 V / 230 V @ 50 Hz and 1500 r.p.m. The rated consumption will follow a 0.25 L/h/kW curve at stand-by power. It should include a highly corrosion resistant enclosure, control panel and monitoring, fuel tank and circuit breaker protections.

The Diesel Genset shall be suitable for indoor or outdoor installation and shall perform accordingly with Multi-mode Inverter and the mentioned architecture model. The Diesel Genset shall be working in a fully automatic manner with the above stated components.

Distribution Line and Energy Meters

The electricity distribution from the generation plant to the end consumers will be done by means of a distribution line formed by several branches at Low Voltage (LV) 3-phase 400 V or 1-phase 230 V towards the consumers. All lines shall be over-head mounted on wood or concrete poles.

The distribution lines protection and cross-sections shall be sized accordingly with regulations of REA, KPLC and ERC.

The discussion on energy metering from the previous section (design for Kalokol) is also applicable to Ngurunit.

Electrical Protections and Power House

The requirements for electrical protections and the power house were stated in the section for Kalokol and are applicable to Ngurunit.

The table below summarises the basic technical specification of the Mini-grid:

Table 50 Technical specs for power plant in Ngurunit

General Specifications	
Daily load demand	544 kWh/day
Coordinates	1.741N, 37.323E
Annual demand growth factor for first 5 years	4%
Renewable Fraction	95%
PV generator	
PV generator	140 kWp
Type of modules	Crystalline
Nominal Module Power	> 240W
Grid-Tied Inverter Type	String inverter
Battery Inverter	
Power demand	65 kW
Inverter type	Multi-mode
Inverter Continuous Power Rating	100 kW
Wave form type	Sinudoidal
Power output	Low Voltage 3-phase
Genset	
Number of gensets	1
Rated power	100 kW
Genset type	3 phase
Battery	
Autonomy (days)	1
Night load demand factor	56%
Battery voltage	≥ 48 Vdc
Battery Depth Of Discharge	60%
Battery capacity	991 KWh
Battery type	Lead Acid
Distribution line	
Ditribution type	Low Voltage
LV Distribution line distance	6.000 mts
Number of poles	200
Monitoring system	
Battery Supervisory controller	1
SCADA software	1
GPRS/GSM Modem	1
Metereological Sensors	1

Technical annexes related to the system design include:

- System sizing tool (Excel sheets)
- Reference Layout for distribution grid

8.4.6 Provisions on system O&M

- Maintenance costs for the solar power plant have been estimated at 1.5% of installed of capex (not including replacement of equipment.
- Batteries have been estimated to require replacement every 6 years. Inverters to require replacement at year 12.

8.4.7 System costing

Table 51 Cost of power plant in Ngurunit

System component	Capacity	Unit	Unit cost (EUR)	Total cost (EUR)	Comments
PV generation	140.00	kWp	1,500	210,000	Solar modules, PV inverters, mounting structure
Battery	991.00	kWh	300	297,300	Battery, wiring, protections
Converters	100	kW	800	80,000	Battery inverter, protections
Monitoring	1	lumpsum	25,000	25,000	Communications, sensors, etc.
Distribution Line	6000	mts	20	120,000	6000 mts LV 3-phase
Distribution Poles	200.00	poles	350	70,000	
Diesel Genset	100	kW	150	15,000	
Services					
Civil and electrical Works	1	lumpsum	81,730	81,730	
Logistics	1	lumpsum	57,211	57,211	
Engineering and Consultancy Services	1	lumpsum	73,557	73,557	
			Total	**1,029,798**	
		Contingency	10%	102,979	
			Grand Total	**1,132,777**	
Cost generation Plant			***EUR***	*841,887*	
Cost Distribution Line			***EUR***	*290,889*	
Unit Cost Generation Plant			***EUR/kWp***	***6,013***	
Unit Cost Distribution Line			***EUR / user***	***2,203***	

9 Potential delivery case models

This section of the report presents the different delivery models that have been analysed in relation to their potential for implementation in Kenya and the opportunities for private sector participation.

9.1 Potential delivery models

The following sub-sections summarise the main features (and feasibility) of different mini-grid delivery models in Kenya. These are then compared in section 9.2.

9.1.1 Public model

Delivery model	Generation	Distribution	Retail supply
Construction	REA		
Ownership of assets	REA / MoEP (GoK)		
O&M	KPLC on behalf of GoK		
Situational factors	- Kenya model thus far. 21 mini-grids in operation (19 operated by KPLC and 2 operated by Kengen) and 10 under construction in different stages of development. Most of these mini-grids have already integrated renewables (solar and wind). Integration of RE (hybrididisation) in mini-grids has been thus far conducted by the GoK. - The Privatisation Commission of Kenya was developing a Public Private Partnership (PPP) framework for concession/privatisation of isolated power stations. The results of their study of 2013 on privatisation were however inconclusive. Privatisation now being revised in the current process of streamlining parastatals (recommendations of the PTPR) and devolution to counties and therefore linked to the transition timeline. - The new constitution allocates responsibility over the planning and implementation of electricity reticulation to counties. This opens possibilities for regional distributors.		
Financial model	- Public funds are used to construct mini-grids - Consumers charged the "Uniform National Tariff", sale price of electricity averaging 0.20 $/kWh[52] - Power generation costs are high (average of 0.44 $/kWh) and account for approximately 90% of total operation cost of mini grids. In 2013, 95% of power generated was from diesel. Fuel costs account for approximately 80% of the generation costs. - Cross-subsidies: the model is extremely reliant on cross-subsidies		

[52] Including fixed charge, energy charge and fuel cost adjustment, excluding levies and taxes

	(65% of the kWh cost is subsidised). Fuel cost is passed on to the entire KPLC consumer base though the Fuel Cost Adjustment in the electricity bill. - Despite very high investment costs for solar energy equipment (5,100 to 13,600 $/kWp of grid-tie PV in previous KPLC projects), hybridisation has allowed for cost reductions with IRR for solar investments ranging from 13% to 20% (based on the displacement of fuel costs). As discussed before, only 4.4% of power generation is currently from renewables.
Measures for securing financial income	- KPLC is rolling out pre-paid meters for all consumers in DC (domestic) category. - There are no other significant interventions from KPLC on the demand side (i.e. encouragement of productive, income generating, use of energy by consumers)
Lessons learned	- Fast energy consumption growth rates (averaging 30% p.a. in the first 5 years and then stabilising in 10% p.a.) - Model is extremely reliant on cross subsidies. The development of more sites under a public model inevitably implies an increase of electricity tariffs of KPLC for the entire customer base (higher fuel cost adjustments). There is significant pressure on KPLC to reduce electricity prices, therefore privatisation of mini-grids (at least the generation side) is attractive. - Government procurement of renewable energy (grid-tie) to displace fuel in mini-grids is economically attractive.

9.1.2 Private model

Delivery model	Generation	Distribution	Retail supply
Construction	Private		
Ownership of assets	Private		
O&M	Private		
Situational factors	- Licensing of Electric Power Generation, Distribution and Supply is possible in areas where there is no existing (conflicting) concession. There is however no precedent of such licences granted to supply communities (i.e. more than one person). Similar licences have been granted to tea factories for captive power generation, distribution and supply (i.e. not subject to price regulation) for 15-25 years. Other smaller micro-grid projects currently in operation are not licensed. - Regulatory and licensing framework for distribution of electric power is not tailored to small mini-grid projects. There are no simplified procedures for mini-grids. Based on current procedures to license IPPs, it is estimated that licensing a private mini-grid operator would be a long process (3 years). - G&D for more than 1 person requires submission of tariffs for approval by ERC. KPLC tariffs will normally be the benchmark but		

	tariffs can be negotiated if a reasonable pricing model is presented. - Framework is unclear with respect to arrival of the grid to a mini-grid concession. - There is growing interest from private companies to license mini-grid operations.
Financial model	- Private investment (higher cost of capital than public model) - Cost-reflective tariffs or subsidy needed. Cost-reflective tariffs are higher than KPLC tariffs (due to absence to cross-subsidies as well as higher capital costs). - Experience in Kenya and elsewhere in Africa indicates ability and willingness to pay higher tariffs in rural populations but restrictions might come from price regulation. - There are no standard subsidies from the GoK for private mini-grid developers.
Measures for securing financial income	- Technological options include pre-paid meters - Other options include collaboration with other organisations to encourage productive (income generating) use of energy by consumers
Lessons learned	- Ability to pay to pay high prices: concessions in Mali 0.50 $/kWh, Somalia 1 $/kWh and > 1$/kWh in unlicensed micro-grids in Kenya. - Regulation of electricity tariffs adds inflexibility to changes, sometimes indexation of tariffs not adequate (e.g. in Mali, the negotiated tariff structure with concessionaires was insufficient to cover the costs of operating diesel mini-grids which triggered ad hoc fuel subsidies) - Downward price pressure (from population and regulators) toward national utility tariffs

9.1.3 Mixed Model 1

Delivery model	Generation	Distribution	Retail supply
Construction	REA		
Ownership of assets	REA / MoEP (GoK)		
O&M	Private - operation outsourced to private sector either through concession or a management contract based on fee		
Situational factors	- Similarly to the private model, there is no precedent of private licences granted to supply communities (more than 1 person). - As explained in the previous section, the status of the privatisation act (concessions for operation of GoK mini-grids) is unclear. - Potentially easier model for donor support. Funds allocated to the development of public infrastructure while involving the private sector in operation and maintenance.		

Financial model	- No significant capital expenditure for private party (avoids issue of higher cost of capital of private sector) - Cost-reflective tariffs can either be set to cover operating expenses of the concessionaire (lower than for full private concession) or both opex and capex (similarly to full private concession) - Experience in Kenya and elsewhere in Africa indicates ability and willingness to pay higher tariffs in rural populations but restrictions might come from price regulation.
Measures for securing financial income	- Technological options include pre-paid meters - Other options include collaboration with other organisations to encourage productive (income generating) use of energy by consumers
Lessons learned	- Not much experience in SSA with this type of PPP arrangement for mini-grids. Case study of Cap Verde has similar arrangement (the operator pays a fee for the use of the government's infrastructure) but the project is too recent to draw lessons. - Possible conflicts over responsibility for large maintenance works, re-investments and upgrades. This is especially relevant for systems with large battery banks, which can represent as much as 30% of capex and lifetime is very sensitive to O&M conditions. Similar conflicts might arise from expansion works required to cope with demand growth. - In case of concessions with cost-reflective tariffs, and similarly to full private concessions, downward price pressure can be expected from the population and the regulator.

9.1.4 Mixed Model 2

Delivery model	Generation	Distribution	Retail supply
Construction	Private	REA	
Ownership of assets	Private	REA / MoEP (GoK)	
O&M	Private	KPLC	
Situational factors	- Regulatory and legal framework already exists for IPPs and PPAs (several IPPs, both thermal and renewable energy) selling power to KPLC. - There is also a FiT for solar energy connected to off-grid stations. This FiT of 0.20 $/kWh is however for capacity above 500kWp and too low for solar systems including batteries and control equipment. - For technical, regulatory and financial reasons, a negotiable PPA for the entire power generation (diesel and RE) is preferred than a standardised FiT for the solar energy component only. - There is no precedent of PPAs to be the sole supplier of a mini-grid. Legal provisions regarding quality of supply, adaptation to growing		

	demand, etc. will need to be developed.
Financial model	- Responsibility of the private sector for CAPEX of power generation. - PPA to be negotiated with the GoK to cover costs of hybrid power generation. - Model provides incentive for generator to optimise power plant design and minimise cost
Measures for securing financial income	- PPAs reduce revenue risk in comparison to concessions with responsibility over collection of tariffs. However, generator shares risk of low energy demand in mini-grids (demand being lower than generation capacity of RE system). Take or pay clauses are not usual for mini-grids. It is fundamental the generator size energy system .
Lessons learned from similar experience	- Negotiation of PPAs for grid connected projects is a lengthy process (up to three years). - With no precedents of PPAs for sole suppliers in mini-grids, the process for first movers also expected to be long and costly. This is a big barrier for firms developing small-scale projects (>1MW) where transaction costs need to be minimised.

9.1.5 Community-based / Cooperative Model

Delivery model	Generation	Distribution	Retail supply
Construction	Community / cooperative / Village trust		
Ownership of assets	Community / cooperative / Village trust		
O&M	Community or Private		
Situational factors	- Model encouraged by new policy. Potentially easier licensing procedures (oversight by REA instead of ERC, negotiation of tariffs with regulator potentially not needed (treatment as captive supply)). - Electrical cooperatives without formal licenses to operate might be vulnerable to competition (from other mini-grid projects or the grid). - Existing community projects in Kenya are not licensed to operate.		
Financial model	Financial model elements are similar to those of a private concession with a few differences. - Marginally lower investment cost (community involved in construction works against sweat equity) - Typically lower tariffs and higher subsidies.		
Measures for securing financial income	- Community models usually rely on the community's social structure to guarantee payments. Informal cross-subsidisation is also common.		
Lessons learned from similar experience	- International experience of community models in remote rural sites shows many projects fail due to technical and managerial capacity problems. Involvement of the private sector in the model (through O&M agreements or shareholding) is a good practice. - Similarly to mixed model 1, the involvement of the private sector in		

	O&M would not come without risks: potential conflicts over the responsibility of major maintenance works or replacement of equipment especially critical with hybrid technology.

9.2 Summary of delivery model features

Error! Reference source not found. below summarises pros and cons of each model from the perspective of different stakeholders.

Table 52 Comparison of mini-grid delivery models

Delivery models	Utility / GoK	Private sector	Population	Other comments
Public model	Model highly reliant on cross subsidies, increasing electricity prices for all KPLC customers. GoK considering privatisation and regional distributors.	No significant role for private sector, only EPC	Benefit of cheaper electricity (grid prices)	Business as usual. Not attractive for a pilot project (except for showcasing innovative hybrid generation technologies, smart metering, etc.)
Private model	Cost reflective tariffs ease pressure on public funds or cross subsidy schemes GoK however highlights importance of affordability of tariffs	First movers needed (no precedent of private concessions in Kenya) Revenue collection risk, bankability is a concern Burdensome, unclear licensing procedures Unclear mechanisms for allocation of subsidies	More expensive electricity (but better than no electricity) Private sector concession can be more involved in encouraging opportunities for productive use of electricity	No precedent of licensed operators, but highly relevant to current policy and market trends in Kenya. Attractive for pilot project.
Mixed model 1	If case of concession for operation, there is an opportunity for cost reflective tariffs, thus reducing burden on cross-subsidy schemes.	Private exposed to revenue risk from collection of tariffs but does not need to recover capital investment.	Same as private model above. Tariffs potentially lower due to GoK developing and owning infrastructure.	Possible conflicts over large maintenance works, re-investments and upgrades (especially relevant for capital-intensive hybrid systems).

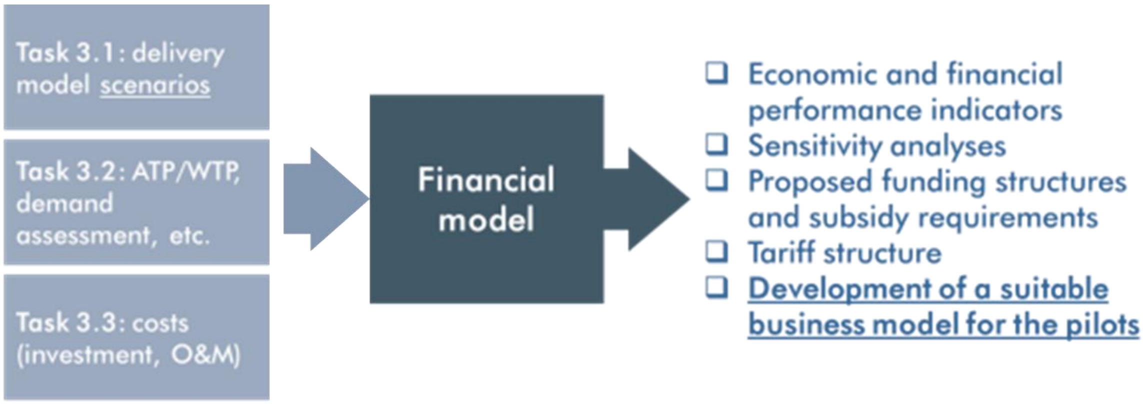
Delivery models	Utility / GoK	Private sector	Population	Other comments
Mixed model 2	Payment of PPA while charging national tariff to consumers will require subsidies from the GoK. On the other, private generation potentially more efficient (and cheaper) due to incentive of fixed PPA tariff. Private sector leverage in rural electrification.	PPA reduces revenue risk Bankable "Comparatively easier" permitting and licensing procedures. Still lengthy process requiring specific PPA clauses for off-grid suppliers.	Similar to public model. Limited interaction of private with demand side.	No precedent of PPAs for suppliers to mini-grids yet relevant to current policy and market trends. Suitable for pilot project.
Community-based / Cooperative Model	Cost reflective tariffs could ease pressure on public funds but community models known to be highly subsidised.	Private sector can play role in shareholding or O&M. Potentially easier licensing procedures	Community involvement in project	Sustainability is a concern (technical and managerial capacity, tendency to charge too low tariffs)

Before making a recommendation on the preferred delivery model (in section 10.4), the above qualitative analysis is complemented with quantitative analysis of the implications on consumer tariffs and required capital and recurrent subsidies (section 9).

10 Financial and economic analysis

The main purpose of the financial and economic analysis is a quantitative assessment of the alternative delivery models which were discussed in a qualitative way in section 9. The results presented in this section are based on the outputs of previous tasks, in particular the mini-grid delivery model scenarios (from task 3.1), willingness and ability to pay findings (task 3.2) and costs associated with investment, operation and maintenance of hybrid mini-grids (task 3.3).

Figure 17 Financial and economic analysis



As will be seen from the discussion below, the assessment of the delivery models is not a purely technocratic matter which can be left to outsiders. There are some embedded policy issues, which imply that the delivery model decision is ultimately one for the Government of Kenya to make.

To give a preview of the arguments which will be presented in more detail below, the national electricity sector policy that is of central importance for mini-grids relates to the uniform national tariff. Mini-grid electricity is expensive[53] – it turns out that to keep the tariffs within the bounds of what consumers will be willing to pay requires substantial capital subsidies to be provided in all of the delivery models. In those involving the distribution being done by KPLC, the uniform national tariff is assumed to apply, and recurrent subsidies will then have to be given, in addition to the capital subsidies.

An alternative would be to allow tariffs in mini-grids where distribution is carried out by the private sector to be above the uniform national level. If the resources thus saved were to be used to accelerate the attainment of universal access to electricity, then the abandonment of the uniform national tariff policy would result in many more Kenyans having electricity sooner than would otherwise be the case.

[53] The model developed and described below provides analyses in both economic and financial terms. No economic internal rates of return (EIRR) are reported here. In general, unless account is taken of the external benefits of electrification (health, education, local economic development), the EIRRs of the mini-grid projects would be negative. The subsidies are justified on the basis of external benefits, but the magnitude of such benefits is the subject of debate in the economics literature and quantitative economic assessment would be contentious.

The key questions to be answered to inform policy-making are:

- ❑ Do people in remote centres need electricity more than they need low tariffs?
- ❑ Is it better for Kenya to accelerate universal access, or for a few communities to have access to electricity at low tariffs?

The analysis in this section is intended to inform the policy debate around these questions.

10.1 Ability and willingness to pay

Ability to pay for modern energy in the selected sites has been estimated based on current expenditure in energy (kerosene, batteries, diesel, etc.) following the methodology explained in annex A5. Results are displayed in the table below and have been found to be similar across the different locations. Low income households are presently paying $11.40 per month on kerosene, dry cell batteries and phone charging. These end uses could be replaced by 7.5 kWh/month of mini-grid electricity at an ability to pay of at most $1.52/kWh, but more likely some lower rate down to $0.76/kWh.

The maximum is based on the assumption that the complete current energy expenditure is available for payment of modern electricity while the minimum assumes that only 50%[54] of current expenditure is displaced by electricity (i.e. households continue to use kerosene, dry-cells, etc. during part of the day). This more conservative calculation reduces the electricity budget (and ability to pay per kWh) by half.

Table 53 Ability to pay based on current expenditure and increased energy use

Consumer category	Current expenditure ($/month)	Equivalent unit cost of energy ($/kWh)	Estimated consumption with modern energy (kWh/month)	Ability to pay, MAX ($/kWh)	Ability to pay, MIN ($/kWh)
Household	11.4 (kerosene, dry-cells and phone charging)	Kero (8.5-10.2) Dry-cells (3) Phone chrg (45)	7.5 (lights, radio, phone charging)	**1.52** (current expenditure divided by estimated consumption)	**0.76** (only 50% of traditional sources displaced)
Commercial	Variable, based on solar and gensets	Solar (0.75) Genset (1.34-1.43)	Variable depending on business	**1.04-1.09**	**0.52-0.55**

54 This 50% correction factor was introduced due to the impossibility of providing an accurate measure of Willingness to Pay. As discussed below, it is clear that users would be highly accepting of a tariff that offers noticeable savings over current energy expenditure. This 50% is our conservative estimate for the population's desired level of savings. We therefore propose this lower limit of ATP as a measure for their Willingness to Pay.

The "Willingness to Pay" (WTP) differs critically from the "Ability to Pay" in that it considers the much softer psychological features of the site's potential customer base.

- In Kalokol, users would likely be highly accepting of a tariff that offers noticeable savings over current energy expenditure. When interviewed and in focus group discussions, residents and business-owners in Kalokol indicated a lack of familiarity with KPLC's prices and services, and those who were familiar expressed dissatisfaction with their high connection fees. This response supports the overall conclusion that the Kalokol residents have a high willingness to pay for energy tariffs priced competitively with existing energy expenditures.

- In the case of Dukana, residents and business-owners indicated some knowledge of KPLC services and fees, but because of the isolated nature of the town they did not see this as a realistic option for their community. This attitude is a weaker indication of willingness to pay than was seen in Kalokol, but does not indicate any serious doubts about willingness to pay.

- Finally, in the case of Ngurunit, residents and business-owners indicated knowledge of KPLC services and fees, but expressed eagerness to get grid-type power from whatever source is most easily available. This attitude is a weaker indication of willingness to pay than was seen in Kalokol and Dukana. It suggests that tariffs should be structured more carefully, but does not raise any serious doubts about willingness to pay.

Based on the above, our recommendation for setting the WTP limit of electricity tariffs is to use the more conservative estimates of ability to pay (minimum ability to pay of Table 53) as a measure of willingness to pay. For households, WTP-based tariffs of $0.76/kWh would be substantially higher than KPLC tariffs ($0.21/kWh for domestic customers), they would nevertheless offer the population significant savings over the current expenditure.

Non-household energy users switching to mini-grid electricity have lower avoided costs, as indicated in the table above for commercial users. The maximum tariffs we use below are based on an assumed WTP of $0.76/kWh for households and an average of $0.55/kWh for the centre as a whole.

10.2 Economics of the different delivery models

There are aspects of the different delivery models that are more characteristic of the models than of the sites selected. Accordingly, we preface the specifics of the site analysis with discussion of the economics of the different delivery models.

Under each delivery model, the owner of the assets must be able to return their cost of capital to project financiers, after paying all expenses, but no more, as we expect tariffs to be regulated to prevent this.

Returns are received through tariffs charged to customers, offset by operating and capital costs. To ensure no more than appropriate cost-recovery, including the cost of capital, the lower limit on tariffs will be guided by the levelised cost of energy including the reasonable return on capital. The upper limit of the tariffs may be set either by conformity with the national tariff or the customers' willingness to pay. If the lower limit (set by cost) is greater than the upper limit (set by national tariff conformity or willingness to pay), then a payment external to the system is necessary to ensure cost recovery and electricity delivery. This external payment can be termed a 'subsidy'.

The subsidy may be of two kinds, both of which allow customers to pay tariffs which fall below cost recovery levels:

- ***Once-off capital subsidies***, which reduce the investment costs and hence the rate of return element of the tariffs. This type of subsidy mechanism is the one which is preferred by development partners.

- ***On-going recurrent subsidies***, which contribute to the operational costs and reduce the monthly revenue that is required to be collected from the customers. On-going subsidies could be provided through a specific central or county government budget allocation, but are more commonly provided through mechanisms that are internal to the electricity system. In Kenya, recurrent subsidies are regularly provided to the existing KPLC mini-grids through a cross-subsidy from the rest of KPLC's customers.

As will be shown in the analysis below, the economics of mini-grids in Kenya are such that capital subsidies are needed in all the delivery models. The level of subsidy is chosen so that the tariffs fall below the assumed WTP levels. In the case of delivery models where KPLC is responsible for distribution and the uniform national tariffs are assumed to apply, recurrent subsidies are also needed. It is presumed that these will continue to be provided through cross-subsidisation by KPLC consumers.

Inputs and outputs specific to the different delivery model scenarios are summarised in the table below.

Table 54 Financial modelling of different delivery models

Model	Description	Private participation	Public participation
Fully public	- Ownership of assets by GoK - O&M&M by KPLC	- Only EPC	- Public funds - "Uniform National Tariff" - Determination of subsidy (cross-subsidies) requirements
Full private concessions	- Assets developed privately as consession, and O&M&M by vertically integrated private firm (or two or more private firms).	- All private	- Grant of subsidies (if required)

Model	Description	Private participation	Public participation
Mixed Model 1	- Assets developed and owned by GoK; private O&M contract for grid.	- O&M of infrastructure - Electricity retail	- Development & ownership of distribution assets - Generation (KPLC)
Mixed Model 2	- Generation developed as IPP	- Generation	- Distribution and supply
Community-based / Cooperative Model	- Community based model	- All community based	- Grant of subsidies (if required) - None (unless community models classified as public)

We now discuss the economics of each of the first four models in turn. The fifth is broadly similar to the private concession and is therefore not analysed separately.

Fully public model

Under the fully public model, all assets are financed with public funds. Assets are constructed by REA and remain property of the Government of Kenya. Because of the Government funding, the mini-grid will have a lower cost of capital than for a private concessionaire. Administrative costs will be lower than for private concessions given economies of scale in KPLC's management. Based on KPLC's current administration expenses, we estimate this as $100/customer/year.

Connection costs charged to each customer include capital contribution charges for network reinforcement. Charges are of approximately KES 35,000 for single phase and KES 49,000 for three phase for customers within 600m of transformer (USD 398 and USD 557 respectively).

The schedule of tariffs approved for KPLC is the same for grid-connected consumers as mini-grids and sometimes referred to as "Uniform National Tariff". The tariff schedule sets different tariffs according to the type of consumer and amount of energy consumed. Most energy consumers of rural mini-grids are expected to be in categories Domestic Customer (DC) and Small Commercial (SC). Large commercial and industrial consumers (CI) consume above 15 MWh/month and are not relevant[55].

The tariff path will follow that of the national uniform tariff. Tariffs will be indexed based on power cost of the entire system (grid and off-grid) and therefore indexation of mini-grid tariffs is expected to be lower than the increase of mini-grid costs.

As noted earlier in this section, tariffs for public models are unable to cover the cost-recovery tariffs based on the levelised cost of energy. Therefore, to ensure KPLC can cover its cost of capital, it must either cross-subsidise the costs from other customers, or seek an external subsidy. This will generate positive project and equity NPVs and IRRs

[55] Largest consumers in the selected locations are expected to consume below 5 MWh/month, well below the lower threshold of CI consumers.

no lower than the WACC and cost of equity respectively. However, there will be a high economic return to customers who will be paying much less than they have been spending on alternative energy sources.

Full private concessions

Under the fully private concession, a private developer and operator will source all the finance for the development and retain ownership of the assets, as well as supplying electricity and charging for the service. Private financiers will have a higher cost of capital than public owners, and higher administration costs as they do not benefit from economies of scale in administration of sites, but otherwise costs are expected to be the same as for the public model.

Tariffs must be guided by the levelised cost of energy in order to recover all costs, including the costs of capital. If this level is higher than the customers' willingness to pay (for each category), then the private concessionaire must receive a subsidy in order to provide power. This subsidy could be given either through a capital subsidy, effectively reducing the amount of capital costs to recover through the tariff, or by covering the gap between the willingness to pay and the levelised cost. The source of the subsidy is not relevant to the returns of the project.

Tariffs can be indexed to real cost increases and inflation. These will include the cost of diesel as well as O&M and administrative costs. These costs are relatively small compared to others (particularly the recovery of capital costs), so tariffs are not expected to increase significantly from their initial levels.

With tariffs set to cost recovery levels, the project and equity NPVs will be positive and IRRs no less than the WACC and cost of equity (provided the signs of the cash flows allow for the IRR to be calculated). With customers paying higher tariffs than under the public model, there is a lower economic benefit to customers. If the tariff is under the willingness to pay, then customers still gain an economic return relative to their position without electricity. If the willingness to pay is below the tariff, then an external subsidy will be required to cover the difference in present value terms. This can be paid either as a capital sum up front (reducing the cost to serve), or as an ongoing amount to cover the difference between the willingness to pay and the cost-reflective tariff.

The private entity's financing structure will be determined based on the costs of equity and debt, and the risks concerning cashflows. As cashflows are not anticipated to be particularly stable, at least in the project's early years, financing should be provided through more flexible equity, or through debt with a grace period on interest and repayments.

A concern of the private model is the preference of the concessionaire to supply power to those customers most willing and able to pay, rather than to all customers who would be supplied under a public model. This issue should be addressed with appropriate incentives and contractual requirements.

Mixed Model 1 (MM1)

Under the first mixed model, the Government of Kenya finances and owns all the mini-grid assets, benefitting the project with its lower cost of capital. A private concessionaire will purchase power from the Government of Kenya / KPLC (at a cost-reflective tariff) and on-sell it, acting solely as distribution operator and supplier. The operating costs of the system will be similar to the other two models, except the administration cost will probably be lower than the private concession (as it does not have to manage the generation) but higher than the public operation (as it does not have the full benefit of economies of scale).

With a private supply of electricity, tariffs will be fully cost-reflective, at costs slightly below those for the fully private model. The discussion of who bears the costs and receives the economic benefit of this arrangement is per the discussion for the fully private model.

Under this model, the NPVs will be positive, with IRRs hopefully at least equal to the cost of capital for KPLC. We cannot calculate a return to the private concessionaire as there is no investment made against which to off-set the positive cash flows from administration of the mini-grid.

Mixed Model 2 (MM2)

In the second mixed model, a private generator sells power to KPLC, which distributes and supplies power to customers. The private generator develops the generation assets with private finance, at a cost of capital that is higher than would have been achieved by the public utility, but lower than it would have achieved for the whole mini-grid as it is not bearing the supply risk of customers, instead having KPLC as the sole counterparty to its PPA. KPLC's distribution assets will be funded by the Government of Kenya at its lower cost of capital.

The private concessionaire's administration costs will be lower than if it was managing the entire grid, as it will simply be running a generation plant without distribution costs. KPLC's administration costs will be lower than it would have been for a private supplier, and lower than its own costs for managing a whole mini-grid.

The private generator sells power to KPLC under a cost-reflective PPA, achieving cost recovery and no more. Therefore it achieves positive NPVs and IRRs at least equal to its WACC and cost of equity. We refer to this MM2 model elsewhere as the '**PPA model**'.

KPLC must sell power at its uniform national tariff, despite having purchased it at a higher cost, and incurred additional distribution expenses, including recovery of the capital cost of the distribution assets. Therefore, KPLC will make a loss on every unit of energy sold, which must be covered through some form of subsidy. An external subsidy may reduce the cost of the distribution assets, or a cross-subsidy (or external subsidy) can cover the margin loss between the national tariff and the costs to serve (including the cost of the PPA).

Community-based / Cooperative Model

The community-based / cooperative model essentially operates the same as the fully private model, with cost-reflective tariffs, but some adjustments to the cost inputs. In particular, its cost of capital may be higher than the fully private model, but it may also have lower administration costs. Similarly, it may have lower capital costs if the community is involved in its development, providing cheap labour through 'sweat equity', as is the case with community-based developments in other parts of the world.

10.3 Financial Model and Results

We have developed a financial model (accompanying this report) to allow detailed estimates of the costs to serve customers under the different delivery models, for each site. The model comprises:

- a cover page,
- a contents page outlining the structure of the model, with a key to colour coding and version history,
- an instructions page detailing how to use the model, and outlining the different scenarios and inputs that change under them,
- an inputs page covering all sites on a single sheet for the models 1-3 and a separate inputs sheet for model 4 (Mixed Model 2), and
- three calculation pages for each site for models 1-3, and three additional calculation sheets for each site for model 4.

A user should be able just to use the inputs sheets to find all relevant information. All relevant outputs are presented at the top of the inputs sheet so that the user can immediately see the impact of any changes to inputs on the relevant outputs. Inputs may be changed to reflect different delivery model scenarios (guided by the instructions sheet), or to test the sensitivity of the model to changes in the inputs.

Error! Reference source not found. presents a selection of the relevant assumptions used in the model across the sites that are constant regardless of the delivery model scenario chosen. Any of these inputs can be changed for sensitivity analysis, but changes would not be determined by the delivery model.

Table 55 Financial model assumptions across all sites and delivery models

Input	Kalokol	Dukana	Ngurunit
Initial energy demand (MWh/year)	456	219	170
Demand growth years 1-5, 6-10, 11-19 (% p.a.)	4%, 3%, 1%	4%, 3%, 1%	4%, 3%, 1%
PV system size (kWp)	370	180	140
Distribution network losses	10%	10%	10%
Number of customers	353	224	132

Input	Kalokol	Dukana	Ngurunit
Customer split (residential, commercial/industrial, public)	20% / 61% / 19%	19% / 48% / 32%	13% / 61% / 26%
Connection fee received (USD/customer)	500	500	500
Collection efficiency	100%	100%	100%
Diesel fuel costs (USD/kWh)	0.45	0.45	0.45
Real fuel cost increase (% p.a.)	0%	0%	0%
Diesel unit maintenance cost (% of diesel capex p.a.)	10%	10%	10%
Solar unit maintenance (% of diesel capex p.a.)	1.5%	1.5%	1.5%
Risk insurance (% of project costs p.a.)	0.1%	0.1%	0.1%
Depreciation rate (% of all assets, p.a., straight line)	4%	4%	4%
PV unit capex (USD/kWp)	1,971	1,971	1,971
Battery (USD)	852,646	446,418	390,468
Converters (USD)	210,141	105,070	105,070
Monitoring (USD)	32,835	32,835	32,835
Distribution Line (USD)	262,676	157,606	157,606
Distribution Poles (USD)	153,534	91,937	91,937
Diesel Genset (USD)	39,401	19,701	19,701
Transformers (USD)	118,204	-	-
Civil and electrical Works (USD)	239,836	120,818	107,343
Logistics (USD)	167,885	84,572	75,140
Engineering and Consultancy Services (USD)	215,853	108,736	96,608
Contingency (% of capex)	10%	10%	10%
Total capex	3,324,510	1,674,719	1,487,911
Loan term (years)	12	12	12
Inflation (% p.a.)	0%	0%	0%
Corporate tax rate (% of net profit before tax)	30%	30%	30%

The key input assumptions that vary by delivery model include:

Table 56 Key inputs to the four delivery models

Variable	Fully public	Fully private	Mixed Model 1	Mixed Model 2
Administration costs ($/customer)	100	130	120	90[56]
Gearing (debt/capex; also for generation only in MM2)	60%	60%	60%	70%
Distribution gearing (MM2 only)	n.a.	n.a.	n.a.	60%
Cost of debt (also for generation only in MM2)	8%	10%	8%	9%
Distribution cost of debt (MM2 only)	n.a.	n.a.	n.a.	8%
Cost of equity (also for generation only in MM2)	17%	20%	17%	18%
Distribution cost of equity (MM2 only)	n.a.	n.a.	n.a.	17%

[56] Administration cost of KPLC in distribution and retail. Additional administrative costs incurred by private power generator (see excel model).

Following the discussion earlier in this section, the model's outputs focus on the level of capital subsidy that, given other assumptions on tariffs and other input variables, is necessary to allow the developer to earn a reasonable rate of return consistent with their cost of capital. We also provide a brief discussion on the sensitivity of the results to changes in some of the key inputs.

For each site and model, we calculate a combination of tariff levels across the customer categories that ensures cost recovery across the whole project. If this is higher than the national uniform tariff (for models administered by KPLC) or the willingness-to-pay (for privately-administered models), the difference is covered with subsidies, either through the tariff as a reduction per kWh, or through a percentage of the capex in the first five years. Where required, each subsidy is paid directly to the project to cover costs, so that the tariff received by the operator is equivalent to the sum of the tariff paid by the customer and the additional subsidy.

The key outputs of the analysis for each site are.

- The LCOE shows the levelised costs for the four delivery models without subsidies. These differ between delivery models only because of differences in the assumed cost of capital and economies of scale affecting administration costs. (These are, optimistically, calculated on the assumption that the full output of the plants will be used. This is not accurate because the plants are generally oversized relative to the potential load. In practice the schemes should be developed in stages to ensure a better match between demand and capacity so that this assumption will be more realistic).

- The assumed end-use tariffs for residential, commercial and public customers. These are the tariffs actually paid by end users. These are either the willingness-to-pay or the LCOE for privately developed schemes or the KPLC tariff for KPLC operated schemes. The subsidy element, shown in brackets in the Tables below, is that amount paid directly to suppliers as a top-up to the amount paid by customers. Note that the top-up is not the only source of subsidy provided to the schemes.

- The Capital expenditure subsidy necessary to allow the developer to earn a reasonable rate of return.

- The final row in each Table – the Present value of all subsidies – shows the total amount of subsidies and cross-subsidies applied in each of the models. This includes the direct tariff subsidies (from Government), capital subsidies (either from Government or from donors) and cross-subsidies between KPLC's other customers and the rural grids.

The financial model is useful in identifying subsidy requirements but not so useful in choosing between the delivery models.

10.3.1 Kalokol

The results of the financial analyses for Kalokol are shown below.

Table 57 Key inputs and outputs of Kalokol site under different delivery models

Variable	Fully public	Fully private	Mixed Model 1	Mixed Model 2
LCOE (unsubsidised, USD/kWh)[57]	0.74	0.82	0.75	0.74
Residential tariff (subsidy[58]; USD/kWh)	0.19 (0.51)	0.70	0.70	0.19 (0.41)
Commercial / industrial tariff (subsidy; USD/kWh)	0.22 (0.28)	0.50	0.50	0.22 (0.28)
Public tariff (subsidy; USD/kWh)	0.22 (0.28)	0.50	0.50	0.22 (0.28)
Capital expenditure subsidy (% of initial capex; also for generation only in MM2)	80%	84%	82%	84%
PPA tariff (USD/kWh)	n.a.	n.a.	n.a.	0.41
Distribution capex subsidy (MM2 only)	n.a.	n.a.	n.a.	84%
Present value of tariff subsidies (USD'000)	1,630	-	-	1,415
Present value of capex subsidies (USD'000)	2,655	2,802	2,732	2,802
Present value of all subsidies (USD'000)	4,284	2,802	2,732	4,216

The results show that the amount of subsidy required across the different models is reasonably similar at between 80% and 84% of the investment cost. The capital expenditure subsidy is lower in the first model because, arguably, it is assumed that publicly funded investment benefits from lower financing costs.

The total amount of subsidy in present value terms is shown to be highest for the two models with least private sector participation (Fully public and MM2). This is because customers of the mini-grids in these two models pay only the KPLC tariff whereas with the other two models the customers are assumed to pay according to their willingness-to-pay, which is much higher. There are therefore less overall subsidies required in the Fully private model and MM1.

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[57] The LCOE presented here is for all costs incurred before subsidies, and divided by energy transmitted at the point of generation. While these LCOE values might appear high, it is important to understand what cost components have been included in the calculation before comparing the figures with LCOE of other mini-grid projects. The annexed financial modelling tool (excel file) contains the calculation of LCOE, which includes all power generation costs, the cost of the distribution network, administrative costs and different cost of capital for each delivery model.

As an example of the sensitivity of LCOE values, the LCOE of 0.82 $/kWh for the fully private model will go down to 0.69 $/kWh if administrative costs are neglected and cost of capital is assumed to be 10% (as opposed to the 12.2% WACC assumed for the private model). These are assumptions often used in other projects. Furthermore, deducting the costs of distribution infrastructure would cause a reduction of LCOE to 0.57 $/kWh.

The above LCOE calculations are for a time horizon of 20 years and the terminal value of the assets has been neglected. While the distribution infrastructure could be considered to have a useful life of 50 years, the impact on the LCOE of adding the terminal value in year 20 is negligible (discount factor at year 20 for a WACC of 12.2% is 0.10).

[58] The subsidy is received directly by the supplier, as a 'top-up' to the tariff presented here

We tested the sensitivity of the average tariff (weighted by customer consumption) to changes in various key inputs. Having looked at changes in the cost of capital, administration, fuel, maintenance, growth in customer numbers and the capital expenditure subsidy, we determined that the only input that had a major impact on the weighted average tariff was the capital expenditure subsidy. This result was to be expected as the major cost for each of the models and each of the sites is the capital cost, which is very difficult to recover through reasonable tariffs, with other costs having very little impact on the tariff. This is a manually selected input rather than an exogenous output to the model and as such we do not feel any further attention needs to be paid to the effect of exogenous inputs.

10.3.2 Dukana

The results of the financial analyses for Dukana are shown below.

Table 58 Key inputs and outputs of Dukana site under different delivery models

Variable	Fully public	Fully private	Mixed Model 1	Mixed Model 2
LCOE (unsubsidised, USD/kWh)[59]	0.83	0.92	0.84	0.79
Residential tariff (subsidy; USD/kWh)	0.19 (0.51)	0.70	0.70	0.19 (0.54)
Commercial / industrial tariff (subsidy; USD/kWh)	0.22 (0.28)	0.50	0.50	0.22 (0.28)
Public tariff (subsidy; USD/kWh)	0.22 (0.28)	0.50	0.50	0.22 (0.28)
Capital expenditure subsidy (% of initial capex; also for generation only in MM2)	85%	89%	88%	89%
PPA tariff (USD/kWh)	n.a.	n.a.	n.a.	0.43
Distribution capex subsidy (MM2 only)	n.a.	n.a.	n.a.	89%
Present value of tariff subsidies (USD'000)	777	-	-	732
Present value of capex subsidies (USD'000)	1,431	1,494	1,474	1,494
Present value of all subsidies (USD'000)	2,209	1,494	1,474	2,226

The amount of capital expenditure subsidy is higher for Dukana (85-89%) because Dukana is a smaller scheme and the costs per kWh at Dukana are higher.

The present value of the subsidies over the life of the scheme is, as with Kalokol, higher for the Fully public model and for MM2 and lower for the other two. The level of subsidies is lower for Dukana than for Kalokol because Dukana is a smaller scheme.

As with Kalokol, the only input variable which, when changed, had a significant impact on the weighted average tariff, was the capital expenditure subsidy. This is discussed above for Kalokol.

[59] The LCOE presented here is for all costs incurred before subsidies, and divided by energy transmitted at the point of generation. That is, energy generated but not sold is not included

10.3.3 Ngurunit

The results of the financial analyses for Ngurunit are shown below. The costs per kWh of the scheme at Ngurunit are higher than the other two sites discussed above, as shown by the LCOE above. The capital subsidy necessary to make the schemes financially viable is also correspondingly higher. The site is financially viable with a subsidy of approximately 90% of the capital cost. The overall subsidy, in present value terms, is equal to $1.9 million in the Fully public model and $1.4 million in the Fully private model.

Table 59 Key inputs and outputs of Ngurunit site under different delivery models

Variable	Fully public	Fully private	Mixed Model 1	Mixed Model 2
LCOE (unsubsidised, USD/kWh)[60]	0.90	1.00	0.91	0.91
Residential tariff (subsidy; USD/kWh)	0.19 (0.51)	0.70	0.70	0.19 (0.93)
Commercial / industrial tariff (subsidy; USD/kWh)	0.22 (0.28)	0.50	0.50	0.22 (0.28)
Public tariff (subsidy; USD/kWh)	0.22 (0.28)	0.50	0.50	0.22 (0.28)
Capital expenditure subsidy (% of initial capex; also for generation only in MM2)	89%	92%	91%	92%
PPA tariff (USD/kWh)	n.a.	n.a.	n.a.	0.47
Distribution capex subsidy (MM2 only)	n.a.	n.a.	n.a.	92%
Present value of tariff subsidies (USD'000)	574	-	-	621
Present value of capex subsidies (USD'000)	1,328	1,363	1,354	1,363
Present value of all subsidies (USD'000)	1,901	1,363	1,354	1,984

As with Kalokol, the only input variable which, when changed, had a significant impact on the weighted average tariff, was the capital expenditure subsidy. This is discussed above for Kalokol.

10.4 Choice of delivery model

The financial and economic analysis discussed above revealed the level of subsidy and funding structures necessary for each of the four delivery models under consideration and estimated the amount of external subsidy, through capital expenditure subsidies and tariff subsidies, which are necessary to make the mini-grids financially viable.

The values are summarised in Table 60 below. This makes clear that the models which involve distribution by KPLC and customers being charged the uniform national tariffs have different implications to those where distribution is carried out by the private operator and subsidies are scaled so that tariffs can be set at WTP levels.

- Models involving KPLC distribution:

[60] The LCOE presented here is for all costs incurred before subsidies, and divided by energy transmitted at the point of generation. That is, energy generated but not sold is not included

- Require much higher levels of subsidy – for example, the total over the 3 centres for the PPA model is US$ 8.4 million, which is US$ 2.8 million more than for the private model

- Low income household customers reduce their monthly energy expenditure from $11.40 for energy sources prior to the mini-grid to $2.36[61] (or they might keep paying the same amount, but increase their consumption of energy, which would have social and economic benefits)

- Business customers (bulk of consumption) also have very low energy costs

- Opportunity cost for the country of higher subsidy outlays is slower electrification, delayed attainment of universal access

Table 60 Tariffs and subsidies summary for the different delivery models

Variable	Gen	Distri-bution	Cost $/kWh	Payment $/kWh	NPV capex subsidy $m	NPV total subsidy $m
Kalokol						
Public model	KPLC		0.74	0.21	2.7	4.3
PPA Model (MM2)	Private	KPLC	0.74	0.21	2.8	4.2
Private model	Private		0.82	0.54	2.8	2.8
Public assets (MM1)	Private O&M		0.75	0.54	2.7	2.7
Dukana						
Public model	KPLC		0.83	0.21	1.4	2.2
PPA Model (MM2)	Private	KPLC	0.79	0.21	1.5	2.2
Private model	Private		0.92	0.54	1.5	1.5
Public assets (MM1)	Private O&M		0.84	0.54	1.5	1.5
Ngurunit						
Public model	KPLC		0.90	0.21	1.3	1.9
PPA Model (MM2)	Private	KPLC	0.91	0.21	1.4	2.0
Private model	Private		1.00	0.54	1.4	1.4
Public assets (MM1)	Private O&M		0.91	0.54	1.4	1.4
Totals						
Private model	Private			0.54	5.7	5.7
PPA Model (MM2)	Private	KPLC		0.21	5.7	8.4
Difference					-	2.8

Note: Costs/kWh are levelised costs over the lifetime of the projects (capital and O&M costs)

- Models involving private distribution:

  - Have lower subsidy level - for example, the total over the 3 centres for the private model is US$ 5.7 million, which is US$ 2.8 million less than for the PPA model

[61] Consumption of 7.5 kWh/month billed at KPLC tariffs in 2013/2014. Includes fixed charge ($1.71), basic charge (social lifeline of 0.03 $/kWh) and fuel cost adjustment (0.06 $/kWh).

- Low income household customers reduce their monthly energy expenditure from $11.40 for energy sources prior to the mini-grid to $4.05[62] (or they might keep paying the same amount, but increase their consumption of energy somewhat, which would have social and economic benefits)
- Business customers (bulk of consumption) also have low energy costs relative to the situation before the mini-grid
- With subsidy cost being reduced by 33%, resources are freed up to accelerate national electrification
- Choosing the fully private model minimises the burden on the public sector.

The above analysis throws light on the policy questions which we raised at the start of Section 10.

- Do people in remote centres need electricity more than they need low tariffs?
  - Do low income households presently paying $11.40 per month need to be offered higher quality energy services at $2.36 per month?
  - Or would it be reasonable to ask them to pay $4.05 per month – this would still allow higher levels of energy consumption – similarly for businesses (which form the bulk of demand)
- Is it better for Kenya to accelerate universal access, or for a few communities to have access to electricity at low tariffs?
  - Offering KPLC tariffs to mini-grid customers roughly doubles the subsidy requirement
  - The pace of electricity access roll-out could be doubled by limiting the subsidy and requiring tariffs to be set at WTP level (which are still only half ability to pay level)

We assumed at the time of the Dissemination Workshop on 10 October 2014 that the arguments in favour of higher tariffs being paid by mini-grid customers would prevail and that the **Private Model** therefore should be chosen as the preferred delivery model. This would be

- consistent with GoK's policy of leveraging private sector finance and skills, minimising burden on public sector

[62] Consumption of 7.5 kWh/month at proposed weighted average tariff of 0.54 $/kWh

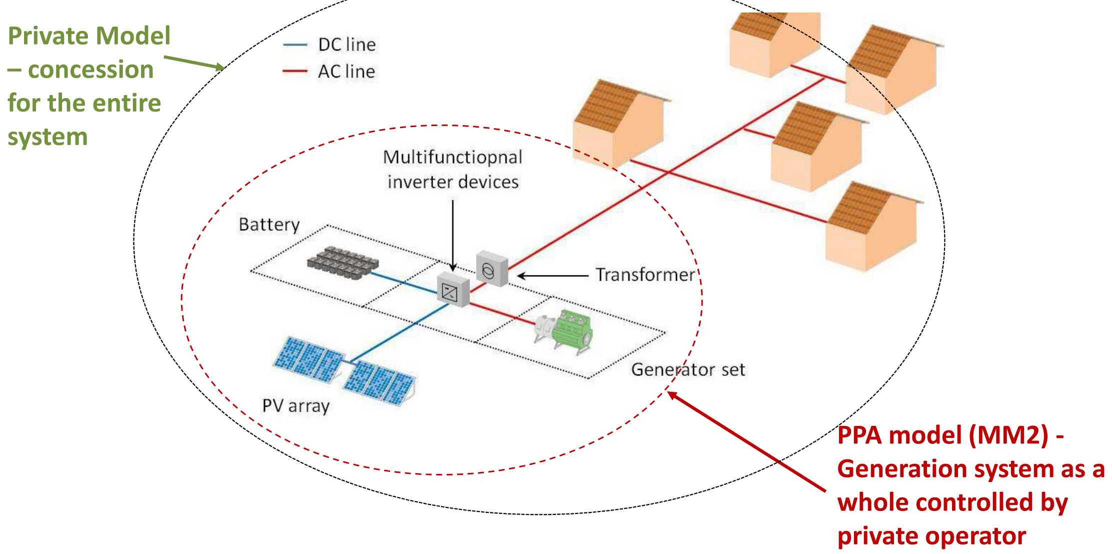
- ❑ the private model involves the lowest subsidy requirement and is therefore consistent with accelerating national electrification effort

However, we allowed for a situation in which private sector might be reluctant to take on distribution, in which case the recommended delivery model would be the Mixed Model 2, which is better characterised as the **PPA Model.** In this model:

- ❑ consumers would be better off in this model, as tariffs would be subsidised
- ❑ however, high level of subsidies would have an opportunity cost for national electrification.

While there we some differences of opinion expressed at the workshop, the general view of the participants was that uniform national tariffs should continue to prevail. The centres to be electrified via mini-grid installations are in some of the most deprived areas of the country and it would not be politically acceptable for these consumers to pay more for electricity than consumers elsewhere in Kenya, even if this implies far fewer such centres being electrified. If the policy is to be changed so as to accelerate electrification, then higher tariffs for mini-grids should apply to all centres, including the towns already benefitting from KPLC mini-grid operations.

Figure 18 Recommended delivery models – Private Model and PPA Model



The Ministers of Energy from the Counties spoke out strongly in favour of KPLC remaining responsible for distribution and the uniform national tariff being applied. They are concerned about control of something as socially significant as electricity and perceive KPLC as a known entity that can be influenced, with channels for recourse if necessary. Whether higher mini-grid tariffs would really result in more rapid national electrification could be disputed, and in any event there would be no guarantee that the unelectrified centres in their particular counties would be the beneficiaries.

In the remainder of this report, we maintain the recommendation that the primary delivery model should be the fully Private Model, but note that the views expressed were strongly in favour of the alternative PPA model. The workshop recommended that a stronger policy direction should be laid out by the Central Government in consultation with the County Governments.

10.5 Impact of a phased investment strategy

A possible way to improve the financial performance of the projects and reduce the level of subsidy required is to invest in power generation capacity in phases as opposed to investing in the total capacity in year 0.

As shown in **Error! Reference source not found.** below, the philosophy of design for year 5 will mean that the plant will initially be underutilised, and a scenario we explore is a phased investment strategy. This would both reduce the NPV of the capital costs and mitigate demand growth risk (Figure 19).

Figure 19 Power generation capacity versus energy demand (kW)

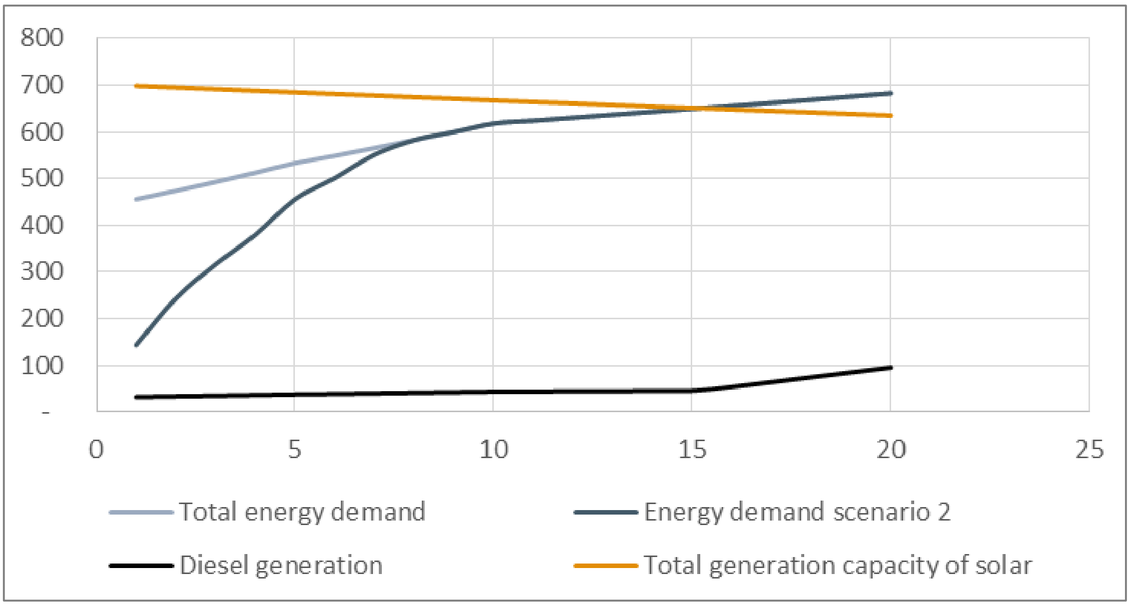
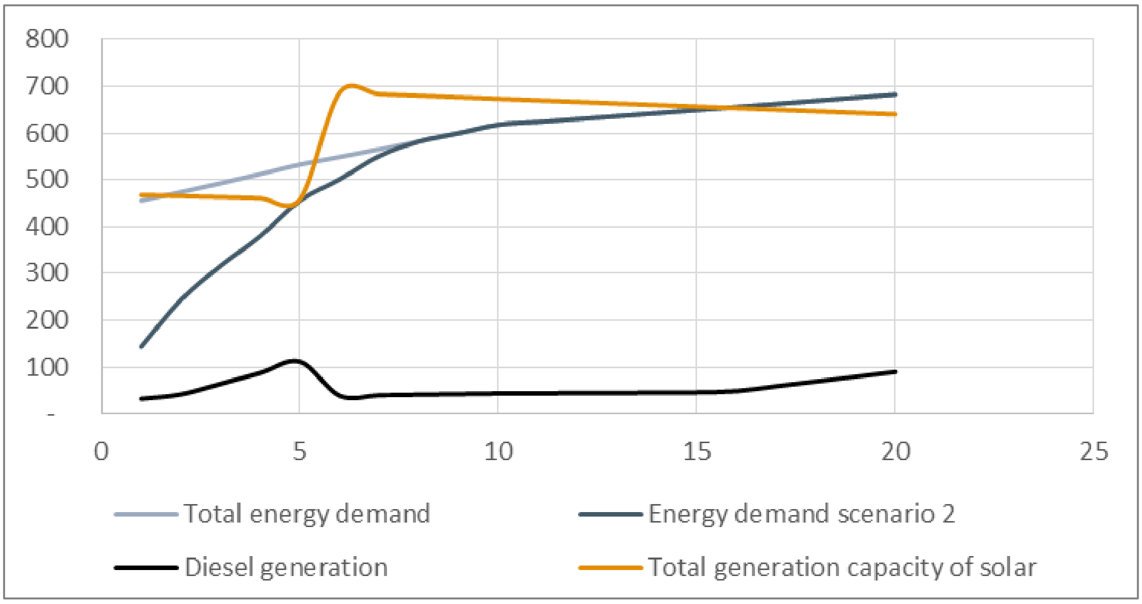


Figure 20 Staged investment in solar energy equipment



The results of this analysis, tested for the full private model, are:

- Most cost-effective option is to install 2/3 of capacity[63] initially and the remaining 1/3 in year 6
- Subsidy required goes down by 12% to 13% (total of USD 711,000). This is not only related to cost of capital. Phased investment would reduce deterioration of equipment (especially critical in batteries) and thus overall life-cycle investment. Additional benefits would come from falling solar equipment prices, but these have not been quantified.
- Disadvantages are that power generation from solar PV (life cycle, although not discounted) falls by 1% to 2% and the additional administrative cost for REA and KfW (which should be much lower than the savings)
- One of the main advantages of this strategy is the mitigation of low energy demand risk (see energy demand scenario 2 in the graphs)

Table 61 Staged investment results (private model)

Variable	Kalokol	Dukana	Ngurunit
Initial investment (as % of design capacity for year 5)	67%	67%	67%
Reduction in subsidy requirement (%)	13%	13%	12%
Reduction in subsidy requirement (Present value of subsidy, USD '000)	354	192	165
Impact in solar fraction (life-cycle, not discounted)	-1%	-2%	-2%

[63] This refers to the investment in generation equipment only (solar PV, batteries and converters)

Based on the above arguments, we recommend adopting this staged investment strategy.

10.6 Provisions for the arrival of the main grid

In designing the contractual arrangements either for a private concession or for the PPA model, it is important to consider what the arrival of the main grid would mean for the mini-grid project. This is a topic that has been explored in detail in the mini-grid manual referenced earlier[64], where 5 main options are identified:

- Option 1: SPP (small power producer) stops generating and becomes a SPD (small power distributor)
- Option 2: SPP stops distributing and sells power to KPLC. The SPP might need to be compensated for the non-depreciated value of assets that are made obsolete (i.e. batteries and battery inverters).
- Option 3: SPP operates as combined SPP-SPD (grid main source of electricity, existing generation backup and/or sale at prevailing feed in tariffs)
- Option 4: KPLC buys the SPP
- Option 5: Abandonment

In order to reduce the risk for private operators considering investing in mini-grid projects, which option is to apply needs to be specified in advance. For the two chosen delivery models:

- **Private Model** – either the operator should stop generating and become purely a distributor of electricity (Option 1) or, if grid supplies are unreliable, the generation equipment could be retained for use as back-up or for sale of power into the grid (Option 3).
- **PPA Model (MM2)** – for solar-PV based schemes, at prevailing feed-in tariffs ($0.12/kWh) selling to the national grid (Option 2) would not be attractive for a private operator, and purchase of the generator (Option 4) would not be attractive for KPLC.

The definition of the applicable option for a Private Model or PPA Model (and the details of what aspects are to be negotiated[65]) is a prerequisite for private investors. We

[64] See Chapter 10 of Bernard Tenenbaum, Chris Greacen and Tilak Siyambalapitiya "From the Bottom Up: How Small Power Producers Can Deliver Electrification and Renewable Energy in Africa", World Bank, 2013

[65] For example, the arrival of the grid will make certain assets obsolete (e.g. batteries and battery inverters). Investors will have to be compensated for the non-depreciated value of these at the time of arrival of the

are therefore recommending that this be an activity for the projects implementation (see section 12 – Technical assistance for the development of standardised concession or power purchase agreements).

grid. This could be done by either allowing the SPP or SPD to maintain higher tariffs to recover this value or by buying out these assets.

11 Environmental and Social Impact Analysis

The law of Kenya requires that greenfield mini-grid projects, regardless of their size, obtain approval of the Environmental Impact Assessment by the National Environment Management Authority (NEMA). Based on the KfW Sustainability Guideline (Technical Note no. FI059), this requirement determines the need to conduct in-depth environmental impact assessment. The TOR for such study can be found in annex A8.

This section presents an assessment of the environmental impacts of the project, the classification of the project based on the screening methodology of the KfW Sustainability Guideline, the relevant regulatory requirements and a CO2 emission analysis.

11.1 Impact Assessment

11.1.1 Classification of Project: Category B - potentially negative impact, can be mitigated

Our assessment covers only the direct social and environmental impacts potentially arising from the construction, generation, distribution and supply of power. We do not assess the impacts of the end-uses of power. Firstly, electricity use is considered an indirect, not a direct impact of the proposed project. Second, the exact uses of power, the parties responsible for those uses and the practices they pursue are unknown and unpredictable at this early stage and are not within the operator's power to control at any stage.

During normal operation, the project is expected to have minimal negative impact on land use, water use and CO2 emissions. The use of lead acid batteries and diesel fuel however pose a risk to the environment and justify the above project classification - Category B, requiring further in-depth Environmental and Social Impact Study (ESIS).

The table below summarises the preliminary appraisal (screening) of the project based on the Sustainability Guideline of KfW Development Bank (Technical Note no. FI059).

ENVIRONMENTAL ASSESSMENT	Y/N	Comments
Does the measure potentially have a substantial negative impact on one or more of the following subjects of protection? - Humans, including human health - Animals, plants and biological diversity - Soil, water, air and landscape - Cultural goods and other assets - Interdependencies between the above-mentioned protected resources	N	The use of lead acid batteries and diesel fuel pose a risk to the environment and to people operating the power plant. This is however not considered a **substantial** negative impact if properly managed and disposed of (see mitigation measures below).

Does the measure have considerable potential to improve environmental quality, resource protection or strengthen ecological sustainability?	N	
Is an environmental assessment required by the national law of the partner country?	Y	All project of this nature require approval by the National Environment Management Authority (NEMA). This is granted through an established licensing process which includes an environmental impact assessment
CLIMATE ADAPTATION ASSESSMENT (CLIMATE PROOFING)	**Y/N**	**Comments**
Are the intended developmental impacts of the measure substantially dependent on climatic parameters such as temperature, rainfall, wind, etc?	N	
Does the measure present the possibility of substantially increasing the adaptation capacity of the target groups or ecosystems?	N	This analysis does not consider indirect applications of the project, such as end uses of power, on the basis that they are impossible to predict, and therefore effects which may increase adaptation capacity (such as access to water pumping, etc) are not taken into account here.
CLIMATE CHANGE REDUCTION ASSESSMENT (EMISSION SAVING)		
Is the measure expected to make a substantial contribution to greenhouse gas emissions?	N	
Can it be assumed that the measure will have the potential to considerably reduce emissions of greenhouse gases or increase CO2 sequestration in soil?	Y	See CO2 analysis table in section 11.1.4

11.1.2 Environmental Assessment

The following section sets out terms of reference for an ESIS, the content of which should elaborate on the specific measures outlined below. The recommended measures are intended to ensure the project remains low impact (Category C) by operating within the parameters specified in other sections of this report, rather than to avoid impacts that are specifically countenanced within the normal development of the project.

CO2

- **Specification:** 93% solar, 7% diesel generator use. CO2 emissions are quantified in section 11.1.4 below.
- **Concerns:** accurate accounts of procurement, storage and use of fuel should be kept on a periodic basis (eg. monthly) to monitor fuel consumption of the diesel generator.

- **Success:** if these parameters are met, we expect a net saving in greenhouse gas emissions and a net positive impact on solid and liquid fuel use.
- **Failure:** fuel consumption, and therefore CO2 emissions, may be heavier than anticipated due to a) solar power system malfunction b) faults in the distribution system that increase the load on the system or c) under-specification of the solar capacity in relation to actual demand.
- **Mitigation measures:** 1) keep accurate and regularly-reviewed records of fuel purchase and/or generator runtimes; 2) regular monitoring of PV system generation performance

Land Use

- **Specification:** power plant footprint, including solar array area of approximately 0.5 ha[66]. Overhead distribution cabling of low or medium voltage.
- **Concerns**: fair acquisition of land; disruption of human or wildlife activity; loss of biodiversity due to site clearing
- **Success:** a distribution plan that does not disturb productive agriculture, human settlement, roads and wildlife corridors.
- **Failure:** power plant and / or distribution network that disrupts productive agriculture, human settlement, roads or wildlife corridors.
- **Mitigation measures:** 1) keep to specified voltages, distribution of electricity not to exceed a threshold length on any single power line whichwould require high voltage (and higher impact) transmission infrastructure; 2) coordinate with public planners to gain planning permission and private landowners to gain wayleaves; 3) full examination of siting alternatives to identify lowest-impact locations

Construction Related Impacts

- **Specification:** as in the technical section.
- **Concerns:** implementer follows best practices and national legal requirements for construction projects.
- **Success:** human health and safety; good solid waste management; minimal or very short term negative impacts on noise pollution, air pollution.

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[66] Assumes a standard 150 W / m2 panel efficiency, requiring approximately 2500 m2 of panels in tightly-packed arrays with space for maintenance pathways at regular intervals and adequate housing for the associated equipment

- **Failure:** danger to the implementer's staff and the general public; poor solid waste management; mid or long term negative impacts on noise pollution, air pollution; fire hazard.

- **Mitigation measures:** 1) appropriate disposal of construction waste; 2) provide appropriate training and personal protective equipment to those working in the solar station and its auxiliaries, and use only licensed professionals for equipment installation; 3) create awareness on safe driving amongst relevant personnel; 4) work closely with community leaders to plan and schedule construction activities; 5) provision of appropriate fire safety equipment and adherence to fire safety regulations.

Water Use

- **Specification:** cleaning of solar panels at least once per month.

- **Concerns:** water abstraction in drought affected areas

- **Success:** negligible water use for cleaning of solar panels.

- **Failure:** high levels of water use for cleaning solar panels OR solar underperformance leading to increased diesel fuel use and therefore increased CO2 emissions (see above).

- **Mitigation measures:** 1) keep records to monitor rainfall, efficient water use for cleaning only when rainfall is infrequent; 2) consider installation of rainwater collection system for solar panel runoff

Mini-grid Waste Impacts

- **Specification:** all batteries properly disposed at end-of-life

- **Concerns:** implementer follows best practices for disposal of decommissioned batteries

- **Success:** avoidance of any environmental contamination from battery waste

- **Failure:** local environmental contamination at site of improper battery disposal; potential subsequent health impacts

- **Mitigation measures:** 1) appropriate disposal of decommissioned batteries; 2) consider return programs for used batteries (usually via supplier)

11.1.3 Permitting / Regulatory Requirements

Kenyan law requires that greenfield mini-grid projects, regardless of their size, obtain approval of the Environmental Impact Assessment by the National Environment Management Authority (NEMA).

Once the application is submitted NEMA is required to respond within 90 working days. The application fee for Environment Impact Assessment (EIA) is 0.1% of the total project cost with a minimum of KES 10,000/= and no upper capping.[67]

The prerequisite for an (EIA) is approval of an Expression of Interest and a Detailed Feasibility Study by the Ministry of Energy and Petroleum. This can be obtained within 90 days.

Environmental Impact Assessment through NEMA

NEMA requires an Environmental Impact Assessment to be conducted at each project site prior to authorization of any project. A clear policy framework exists in Kenya for specification of an EIA, which can be carried out by the project developer or through one of several environmental consulting agencies. Several such agencies exist in Kenya who are able to handle drafting and submission of an EIA for a project such as this with only minimal input from the project developer.

An EIA report for a project of this type may address the following social and environmental impacts (a complete list is detailed in Appendix A11):

- ❑ Soil erosion due to runoff from impervious surfaces
- ❑ Loss of biodiversity due to clearing of vegetation and habitat destruction
- ❑ Solid waste, air, and/or noise pollution from construction activities
- ❑ Occupational hazards during construction and subsequent operations / maintenance activities
- ❑ Electrical fires
- ❑ Disposal of battery waste
- ❑ Spilling of diesel fuel
- ❑ Security of project site

The report contains the following sections, some of which require input from or cooperation with the project developer:

1. Project overview outlining:
   - involved parties
   - equipment to be installed
   - project location and scope
   - company / organization profile for each involved party

[67] Energy Regulatory Commission (http://www.renewableenergy.go.ke/)

  - GPS coordinates of key locations (i.e. point of power generation, distribution network where known)
  - total estimated project cost
2. Overview of energy demand in Kenya and analysis of baseline impacts for the various energy generation alternatives (no developer inputs required)
3. Overview of Kenyan policy, legal, and administrative framework for energy generation and distribution systems (no developer inputs required)
4. Social and environmental baselines in the project location, (requires engagement with community members and on site collection of social and environmental data)
   - local climate
   - biodiversity
   - hydrology and topology
   - geology
   - community demography and economic activity
   - community perceptions, recommendations and objections to the proposed project
   - existing use of land
   - existing access to and uses of energy
   - Detailed summary of project design
   - list of equipment to be installed including quantities, dimensions / specifications
   - total project footprint (land use area)
   - expected electricity output
   - expected end uses of electricity
5. Anticipated impacts and mitigation measures
   - the project developer must be ready to comply with any and all measures required by NEMA

Additional Regulatory Requirements

The following is a list of legislation / regulations that may potentially apply to a mini-grid project:

Policy and Legal Provisions

❑ National Environmental Action Plan (NEAP)

❑ National Policy on Water Resources Management and Development

Enacted Legislation

❑ The Environment Management and Coordination Act, 1999

❑ The Water Act, 2002

- The Public Health Act (Cap. 242)
- The Local Government Act (Cap. 265)
- The Physical Planning Act (Cap. 286)
- The Land Planning Act (Cap. 303)
- The Building Code, 2000
- The Penal Code (Cap. 63)
- The Occupational Safety and Health Act, 2007
- The Environmental Management and Co-ordination (Water Quality) Regulations, 2006
- The Environmental Management and Co-ordination (Waste Management) Regulations, 2006
- Noise and Excessive Vibration Pollution control Regulations, 2009

11.1.4 Emission Saving

CO2 Emissions Analysis and pCDM Assessment

The following CO2 emissions analysis establishes a baseline use of energy sources and thereby a baseline level of CO2 emissions for each pilot community prior to the installation of a mini-grid. The analysis uses the FGD-determined average values from survey data to establish a baseline for current energy use and associated CO2 emissions. These are extrapolated over a 20-year timeline to obtain an emissions baseline for each project site. These emissions are compared to the estimated emissions from project construction and contributions from diesel generation over the same project lifetime, taking into account anticipated demand growth.

The data from the community surveys showed that generator, kerosene, and wood fuel use were the CO2-emitting energy sources at all three pilot sites. We therefore took into account the total emissions from each of these sources, as indicated by the data, regardless of the other environmental and health effects of that source. For example, wood fuel, though its primary environmental impact is not CO2 emissions, is still a contributor to this calculation due to the high percentage of rural residents who use fires for cooking and lighting.

Sources are specified and assumptions explained in the footnotes. The footnotes also contain explanations of any potentially ambiguous calculations listed in the analysis.

Table 62 Constants for CO2 analysis

Fuel Efficiency: Diesel Generator	4.00[68]	kWh / litre
Fuel Efficiency: Kerosene Lamp	5.00E-01[69]	kWh / litre
CO2 density: Diesel fuel	2.60E-03[70]	tonnes CO2 / litre
CO2 density: Kerosene	2.54E-03	tonnes CO2 / litre
CO2 density: Petrol	2.32E-03	tonnes CO2 / litre
CO2 density: Wood fuel	2.32E-03	tonnes CO2 / kg
Emissions: Petrol	5.79E-01[71]	tonnes CO2 / MWh
Emissions: Kerosene	5.08E+00	tonnes CO2 / MWh
Emissions: Wood fuel	4.10E-01	tonnes CO2 / MWh
Typical Use of Wood Fuel	2.00[72]	kg / user / day
CO2 Emissions from PV Plant: Transportation and Installation	54.00[73]	tonnes / GWh
Demand Growth: Baseline Conditions	4.00[74]	%
Demand Growth: Y 0-5	4.00	%
Demand Growth: Y 6-10	3.00	%
Demand Growth: Y 11-19	1.00	%
Generator Use Scaling Factor[75]	20[76]	
Kerosene Use Scaling Factor	5	
Wood Use Scaling Factor	1	

Table 63 CO2 analysis variables and calculations

	Kalokol	Dukana	Ngurunit	Units
TECHNOLOGY / DEMAND VARIABLES				
Installed Capacity: Solar[77]	370.00	180.00	180.00	kW
Expected Generation Proportion: Solar	0.93	0.95	0.95	%

[68] Sections 17.2.5, 18.2.5, 19.2.5 ("System Design")
[69] Mills, Evan. "Technical and economic performance analysis of kerosene lamps and alternative approaches to illumination in developing countries." Lawrence Berkeley National Laboratory Report (2003).
[70] CO2 density values from: U.S. Energy Information Administration. "Environment: Carbon Dioxide Emissions Coefficients", February 14, 2013. http://www.eia.gov/environment/emissions/co2_vol_mass.cfm.
[71] Emissions values from: "Solid, gaseous, liquid and biomass fuels". Federal Register (2009) EPA; 40 CFR Parts 86, 87, 89 et al; Mandatory Reporting of Greenhouse Gases; Final Rule , 30Oct09, 261 pp. Tables C-1 and C-2 at FR pp. 56409-56410
[72] Based on relevant professional experience
[73] IPCC, 2011; IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change . Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp. (Chapter 7 & 9).
[74] Demand growth rate predictions taken from the financial model in Section 10
[75] Scaling factor represents magnitude of typical energy use from that source, relative to the baseline case of wood fuel
[76] Scaling factor values based on relevant professional experience
[77] All technology / demand variable values taken from report Sections 17.1.2, 18.1.2, 19.1.2 (System Costing) and 17.2.1, 18.2.1, 19.2.1 (Energy Demand)

	Kalokol	Dukana	Ngurunit	Units
Installed Capacity: Generator	200.00	100.00	100.00	kW
Expected Generation Proportion: Generator	0.07	0.05	0.05	%
Expected PV Plant Losses	20%	20%	20%	%
Expected Network Losses	10%	10%	10%	%
Estimated Demand: Year 0	1135.00	545.00	423.00	kWh / day
CURRENT USE VARIABLES				
Displaced Energy Use: Number of Residential Users[78]	250	170	90	connections
Displaced Energy Use: Number of Commercial / Institutional Users	103	54	42	connections
Proportion of Residential Consumers Using Kerosene[79]	10.00%	20.00%	90.00%	%
Proportion of Commercial Consumers Using Kerosene	0.00%	10.00%	10.00%	%
Proportion of Residential Consumers Using Generators	0.00%	0.00%	0.00%	%
Proportion of Commercial Consumers Using Generators	5.00%	5.00%	1.00%	%
Proportion of Residential Consumers Using Wood Fuel	5.00%	6.00%	4.00%	%
Proportion of Commercial Consumers Using Wood Fuel	0.00%	0.00%	0.00%	%
Typical Kerosene Use	3.47	5.00	3.89	L / user / day
Typical Generator Use	4.84	2.90	4.30	L / user / day
DEMAND CALCULATIONS				
Total Displaced Energy: Year 0	414.28	198.93	154.40	MWh
Estimated Demand: Year 6[80]	494.67	237.53	184.36	MWh
Estimated Demand: Year 11	541.01	259.78	201.63	MWh
Cumulative Demand Over Project Lifetime[81]	10442.58	5014.28	3891.82	MWh
Cumulative Energy Production Over Project	14503.59	6964.28	5405.30	MWh

[78] "Displaced Energy Use: Number of Users" taken from report Sections 17.2.1, 18.2.1, 19.2.1 (Energy Demand) in report

[79] All use proportion and typical use values taken from detailed site survey data

[80] Estimated demand at years beyond Y0 is calculated from the Y0 estimate, compounded annually at the corresponding growth rate specified in the Constants section

[81] Calculated by summing the demand totals of each year of operation, determined using the the formula specified in 15. Our estimates of current demand based on the site survey reports are considerably lower than these values; we anticipate that these figures will grow rapidly within the first few years of grid operation to eventually meet up with the report demand estimates by Y5

	Kalokol	Dukana	Ngurunit	Units
Lifetime[82]				
Total Diesel Consumption Over Project Lifetime[83]	253,812.76	87,053.46	67,566.27	L
CO_2 CALCULATIONS				
CO_2 Emissions from Project Implementation[84]	728.37	357.27	277.29	tonnes CO_2
Total Grid Emissions Over Project Lifetime[85]	1,388.28	583.61	452.96	tonnes CO_2
Annual Emissions from Residential Users: Kerosene[86]	80.35	157.61	292.04	tonnes CO_2 / year
Annual Emissions from Commercial Users: Kerosene	0.00	25.03	15.14	tonnes CO_2 / year
Annual Emissions from Residential Users: Generator[87]	0.00	0.00	0.00	tonnes CO_2 / year
Annual Emissions from Commercial Users: Generator	21.10	6.64	1.53	tonnes CO_2 / year
Annual Emissions from Residential Users: Wood Fuel	21.17	17.27	6.10	tonnes CO_2 / year
Annual Emissions from Commercial Users: Wood Fuel	0.00	0.00	0.00	tonnes CO_2 / year
Total Current Emissions[88]	122.62	206.55	314.81	tonnes CO_2 / year
Total CO_2 Savings[89]	2263.12	5567.09	8921.35	tonnes CO_2

We expect the projects at Kalokol, Dukana, and Ngurunit to save 2263 tonnes, 5567 tonnes, and 8921 tonnes of CO_2 respectively over a 20-year life cycle. Based on these figures, we conclude that application for pCDM involvement is impractical. Participation offers Certified Emission Reduction credits in recognition of tonnes of CO_2 displaced by carbon-saving technologies. Requirements for participation are:

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[82] Calculated by dividing the total demand by the system efficiency (1 - PV losses)*(1 - network losses)
[83] Calculated by multiplying total energy production with the proportion produced by the generator, the efficiency of the generator (litres of fuel / unit energy) and the CO_2 density of the fuel (tonnes / litre)
[84] Calculate the total PV generation by multiplying the total production and the percent of PV generation, then multiplied with the IPCC estimate of installation CO_2 emissions per GWh
[85] Sum of annual diesel emissions and emissions from project implementation
[86] All annual emissions estimates calculated from the following formula for a given user type (residential vs. commercial) and energy source (kerosene, generator, wood):
[Number of users * % of people utilizing the energy source * typical annual energy use from that energy source * CO_2 emissions per energy unit for the energy source]
[87] Assumes all current residential and commercial generator use is of smaller petrol generators
[88] Sum of annual emissions of all CO_2-emitting energy sources
[89] Lifetime CO_2 emissions of grid system subtracted from total projected emissions without the system (current annual emissions compounded annually over the project lifetime with the constant growth rate specified

- Programme of Activities Design Document setting a detailed framework for the implementation of the PoA and unambiguously defining a CDM programme activity (CPA) under the PoA
- CDM Programme Activity Design Document demonstrating how the associated project meets requirements with respect to:
  - demonstration of the additionality of the CPA;
  - calculations of baseline emissions and estimated emission reductions by sources or removal by sinks of greenhouse gases.
  - environmental analysis as per requirements of the CDM modalities and procedures
  - cooperative efforts with local stakeholders, including a summary of the comments received
- a detailed sampling plan for CO2 data with a description of the sampling approach, important assumptions, and justification for the selection of the chosen approach; approach must demonstrate ability to achieve 90/10 confidence/precision for small-scale project activities and 95/10 for large scale project activities

Currently, Certified Emission Reduction (CER) credits are valued at approximately USD 1 / tonne CO2, and have been consistently under USD 5 / tonne CO2 for the past 2 years[90]. Meanwhile administrative costs for CDM registration are estimated at USD 70,000 - 110,000 for small projects, with associated annual monitoring and verification costs of USD 3,000 - 15,000 per project per year[91]. These values combined with the predicted emissions savings make a profitable pCDM scenario virtually impossible with a PoA of 100 or fewer Component Project Activities (i.e. micro-grids) of the scale detailed in this report. This even considers the possibility that the added efficiency when multiple CPAs are undertaken simultaneously could reduce the annual project costs by 4 times. These estimates are likely conservative, since the UNDP CDM cost estimates do not specify project locations, and the necessarily isolated locations of these off-grid projects would certainly increase monitoring costs.

[90] Intercontinental Exchange: "ICE CER Emissions Futures", August 2014.

[91] UNDP: The Clean Development Mechanism: A User's Guide; "Chapter 5: Transaction Costs, Efficiency and Supportive Governance".

Task 4: Design of project implementation and identification of next steps

12 Implementation recommendations

12.1 Scope of the project

German Development Cooperation, through KfW (Financial Cooperation) and GIZ (Technical Cooperation), intends to assist Government of Kenya in promoting the development of new medium-sized hybrid mini-grids (PV-/Wind-Diesel) focused on nascent small and medium-sized growth centres with an expected load of up to 1MW.

In addition, as part of the project, institutional support to the Kenyan Rural Electrification Authority (REA) as the main official Kenyan institution responsible for rural electrification and to MoEP as well as to the Energy Regulatory Commission (ERC) will be provided. The Project will be supported by German Development Cooperation, as part of the German Climate Technology Initiative (DKTI).

This assignment is to support MoEP and REA with the preparation of an implementation-ready project design for an off-grid rural electrification program (with an initial focus on three pilot mini-grids) with private sector participation.

The three locations that have been selected for the pilot projects are:

- Kalokol (Turkana county, pop. 11,500) – the proposed power plant has been sized at 370 kWp of solar energy, 2.2 MWh of battery storage and a 200 kW diesel genset. The budgeted investment for the project (including the distribution costs) is of 3.3 million USD.

- Dukana (Marsabit county, pop. 18,000) - the proposed power plant has been sized at 180 kWp of solar energy, 1.1 MWh of battery storage and a 100 kW diesel genset. The budgeted investment for the project (including the distribution costs) is of 1.7 million USD.

- Ngurunit (Marsabit county, pop. 11,000) - the proposed power plant has been sized at 140 kWp of solar energy, 1.0 MWh of battery storage and a 100 kW diesel genset. The budgeted investment for the project (including the distribution costs) is of 1.5 million USD.

With regards to the participation of the private sector, the consultant to this project, Economic Consulting Associates, has recommended that mini-grids be delivered under a fully private model (i.e. a private developer and operator will invest and retain ownership of the assets, as well as supplying electricity to end-users and charging for the service). An alternative delivery model, which is preferred by the Government of Kenya, is a mixed model where a private generator sells power to the public utility

KPLC under a Power Purchase Agreement. KPLC then distributes and supplies power to customers.

The Project's Technical Assistance will support the Government of Kenya in the implementation of one of these models.

12.2 Objectives of the project

The main objective of the project is to contribute to the cost-effective, reliable and sustainable power supply in rural growth centres and thus to foster efficient and sustainable use of power ("productive use"; i.e. use of energy for agro-processing, storage, cooling, transportation/handling of goods to be sold).

This objective can be broken down into the following sub-objectives:

- Contribution to access to electricity
- Contribution to the improvement of the social and economic framework condition in Kenya
- Contribution to mitigation of climate change
- Establish a viable model for delivery of hybrid mini-grids with private sector leverage.

12.3 Expected results of the project

In relation to the objectives stated above, the expected results of the projects are the following:

- **Contribution to access to a reliable supply of electricity:** a total of 700 electricity connections[92] by year 5, including:
  - Providing electricity connections to 500 households
  - Improvement of education conditions by connecting 15 schools
  - Improvement of health conditions by connecting 3 health centres and providing power to 6 water pumps
  - Improvement of economic conditions by connecting 100 productive applications (businesses, cottage industry, etc.)
  - Improvement of security by connecting 5 police stations and 50 street lights

[92] Totals for the three sites

- **Contribution to the improvement of the social and economic framework condition in Kenya:** 1.0 GWh/year (by year 5) of electricity, of which 60% is to be used in commercial and industrial activities and 20% in public services.
- **Contribution to mitigation of climate change:** 1.0 GWh/year (by year 5) of electricity, of which >90% is generated from solar. Emission reductions of 16,800 tonnes CO_2 in the life cycle of the project.
- **Establish a viable model for delivery of hybrid mini-grids with private sector leverage:** licensing and operation of 3 off-grid private concessions (for generation, distribution and supply or generation only), helping streamline licensing procedures for other private developers.

12.4 Monitoring indicators for the project

In relation to the expected results of the project stated above, we propose the following monitoring indicators:

- **Contribution to access to electricity:** total number of electricity connections; number of connections to schools, health centres, productive applications, police stations and street lights; MWh of electricity sold
- **Contribution to the improvement of the economic framework condition in Kenya:** % of electricity used in commercial and industrial activities
- **Contribution to mitigation of climate change:** MWh of electricity generated from solar, CO_2 emission reduction through the generation of electricity from solar
- **Establish a viable model for delivery of hybrid mini-grids with private sector leverage:** private concessions (or PPA) granted, licensing procedures streamlined (time and cost)

12.5 Proposed implementation modalities

As explained in section 10.4, our recommendation is that the primary delivery model should be the fully Private Model, but note that the views expressed by County Governments were strongly in favour of the alternative PPA model. Our dissemination workshop recommended that a stronger policy direction should be laid out by the Central Government in consultation with the County Governments in order to define the model to be applied for these pilots.

Implementation modalities should be defined in detail after agreeing on the delivery model to be implemented (i.e. private model or PPA model). In the following sections we provide general recommendations for the implementation of either of these models.

Implementation of fully private model

With the proposed fully private delivery model:

- The private developer/operator would finance the scheme and receive a grant equal to between 84% and 92% of the capital cost. This amounts to $ 5.7 million (EUR 4.3 million)[93].

- The source of the capital for the pilots would be subject to discussion with GoK. What is proposed is that:

    - KfW to provide the 84-92% capex subsidy for the power generation. For the three pilots this is estimated at $ 4.4 million (EUR 3.4 million).

    - The GoK contributes the portion of the subsidy related to the distribution infrastructure of $ 1.2 million (EUR 1.0 million). This can be done through REA constructing the distribution network

    - The remaining part of the capital investment is for the private developer(s) and amounts to $ 0.8 million (EUR 0.6 million) for the total of three sites.

- The assets would be developed under a concession agreement and handed to GoK at the end of the concession period with compensation based on the non-depreciated value of the assets.

- Competitive bidding for the concession is recommended to achieve the best value for money. Bidders can compete to provide a fixed number of connections and specified minimum service levels[94] on the basis of the smallest subsidy they would need to achieve the targets. Competitive bidding can be done through REA. Technical and financial assistance should be provided for this process.

- The private operator would charge customers a tariff calculated according to their willingness-to-pay – currently estimated at 0.54 $/kWh in average. This could be self-regulating since the operator is constrained from charging higher tariffs because of affordability. Tariffs would need to be monitored rather than regulated[95].

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[93] The level of subsidy requirement may vary in the proposals received at the competitive bidding stage. This level of subsidy has been calculated based on the designs and budgets proposed in section 8. The competitive process may reduce the level of subsidy requirements.

[94] This should include plant availability, energy sold, % of power generated from renewables, etc.

[95] See “Five Reasons to Not Regulate the Retail Prices of Small, Isolated, Rural Mini-Grids” on p. 318-320 of Tenenbaum et, al (2014).

- ❑ Changes may be necessary to the regulatory framework to allow a simplified approach to smaller licensees. Technical assistance to the MoEP and ERC is proposed to streamline licensing procedures for small private operators.
- ❑ Finally, agreements with local banks could be made to provide loans to private developers to match their equity contributions.

Table 64 presents a general overview of activities to be undertaken during the project's cycle.

Table 64 Project implementation activities (Fully private model)

Activity	Details	Who	Indicative timeline
Agreement with GoK regarding implementation modalities	- Agreement with GoK regarding delivery model (fully private model versus PPA model) - Agreements on project organisation, management and administration - Financing agreement - Agreement on technical assistance	KfW, GoK	3 months
Hiring consultants for project management and technical assistance	- Technical assistance to REA and counties regarding project implementation - Technical assistance to MoEP/ERC regarding licensing procedures	KfW	3 months
Develop standardised concession agreements (pre-requisites for elaboration of bids)	- Standardised concession agreements (including guidelines on tariffs negotiation and grid connection) - Technical standards, service standards, conditions for disbursement of funds, etc. - Conditions for disbursement of subsidies	GoK (with technical assistance)	3 months
Competitive bidding for private concession of 3 mini-grid sites	- Bidding procedures and documents (quality based pre-selection followed by financial proposal recommended) - Bidding process and selection	GoK (with technical assistance)	6 months
Permitting and licensing activities	Develop procedures that are as streamlined as possible in order to reduce transaction costs and time (minimisation of number of regulatory processes, standardised documents, etc.) including: - Acquisition of land, development permit, NEMA permit, permit for	Concessionaire GoK (with technical assistance)	6 months

Activity	Details	Who	Indicative timeline
	power generation and distribution, etc. - Standardised licencing procedures and licence templates		
Disbursement of capital subsidies	Based on the fulfilment of previously determined conditions	GoK	3 months
Construction and operation	Involving the concessionaire and REA. Coordination between the two (in the implementation of the power generation plant and distribution network) is vital.	Concessionaire, REA, (KPLC)	6 months for construction
Monitoring performance and reporting	As per monitoring and review, reporting and evaluation	Concessionaire, REA	

Implementation of PPA model (mixed model 2)

With the proposed PPA delivery model:

- The private developer/operator would finance the power generation plant and receive a grant equal to between 84% and 92% of the capital cost[96]. The construction, operation and financing of the distribution infrastructure would be responsibility of the GoK, through REA in construction and KPLC in operation.

- The source of the capital for the pilots would be subject to discussion with GoK. What is proposed is that:

  - KfW provides the 84-92% capex subsidy for the power generation. For the three pilots this is estimated at $ 4.4 million (EUR 3.4 million).

  - The GoK through REA develops the distribution network as public contribution to the capex. For the 3 pilots this is estimated at $ 1.4 million (EUR 1.1 million).

  - The remaining part of the capital investment is for the private developer(s) and amounts to $ 0.6 million (EUR 0.5 million) for the total of three sites.

[96] The level of subsidy requirement may vary in the proposals received at the competitive bidding stage. This level of subsidy has been calculated based on the designs and budgets proposed in section 8. The competitive process may reduce the level of subsidy requirements.

- The power generation assets would be developed under a PPA agreement and handed to GoK at the end of the PPA period with compensation based on the non-depreciated value of the assets.

- Competitive bidding for the concession is recommended to achieve the best value for money. Bidders can compete on the basis of smallest subsidy required for a given PPA tariff and specified minimum service levels[97], or on the basis of the lowest tariff for a given level of subsidy. The latter option is preferred given its potential to minimise the requirement of on-going subsidies in favour of upfront capital subsidies. Competitive bidding can be done through REA. Technical and financial assistance should be provided for this process.

- The successful bidder would become the private operator of the power station and would receive the agreed tariff from KPLC.

- Changes will be necessary to the regulatory framework to simplify procedures and to provide specific conditions for off-grid PPAs (for example, a clear framework for renegotiation of tariffs based on significant variations in energy demand and for the situation where the mini-grid is connected to the main grid). Technical assistance to the MoEP and ERC is proposed for these tasks.

- Finally, agreements with local banks could be made to provide loans to private developers to match their equity contributions.

Technical assistance in the implementation of this project will be needed in relation to:

- Technical, economic and legal aspects of Power Purchase Agreements

- Procurement and management of the competitive bidding process

- In streamlining licensing procedures for independent power producers.

Development of standardised Power Purchase Agreement

Defining the conditions of the PPA and the technical requirements of power supply is a pre-requisite for potential investors to prepare bids. These will need to be developed before the competitive bidding process. We recommend that PPAs are standardised to the extent possible to minimise transaction costs.

While there already is a PPA framework in Kenya, there is no precedent of off-grid PPAs. PPAs for hybrid mini-grids will differ in their requirement to integrate energy storage and back-up generators, which is best done by a single operator having control of the entire hybrid system. The other most important differences with grid connected PPAs are:

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[97] This should include plant availability, % of power generated from renewables, etc.

- ❑ The variability in power demand both in the short and long term - this will require agreeing with the distributor on the projected demand and special off-take clauses in case of significant variations from the forecast.

- ❑ The risk that the arrival of the main grid represents for the private investor – which requires defining provisions in advance. Options were presented in section 15110.6 and include selling power to the national grid or buyout by the utility. Whichever the case, the solution needs to compensate the IPP for assets that may become obsolete due to the arrival of the grid (such as batteries).

Other clauses that the PPA will have to include are the tariffs and/or tariff calculations or formulas, the term of the PPA, conditions and procedures for the termination of the PPA and in the case of default, procedures and rules of operation of the plant, metering and operational obligations of the parties, procedures for billing and payment, the general risk management of the PPA, and procedures for dispute resolution.

Technical requirements

Technical requirements that will have to be defined prior to the bidding process include:

- ❑ Renewable energy targets – this project design document was done on the basis of solar penetration of above 90%

- ❑ Standards of quality of supply and service – plant availability, voltage and frequency, harmonic distortion, etc.

- ❑ Applicable safety regulations

- ❑ Environmental standards, specifically with regards to disposal of battery waste and management of diesel fuel transportation and storage.

- ❑ Flexibility – conditions regarding deviations from forecasted energy demand

- ❑ Technical requirements for main grid interconnection

Procurement and management of the competitive bidding process Technical and management assistance will be required for the bidding process. We recommend that this be a two-stage process, and that final evaluation is done taking into consideration both the quality of the proposal as well as the financial aspects (two-envelope bid).

An effective competitive bidding process for a mini-grid starts with a clearly articulated series of steps which are made public, together with the associated timetable:

- ❑ Pre-bid announcement

- ❑ Bidders conference

- ❑ Expression of interest and bidder short list

- ❑ Issuance of Request for Proposals (RFP)
- ❑ Receipt and adjudication of proposals
- ❑ Negotiation with preferred bidder
- ❑ Finalisation of contracts
- ❑ Project implementation and performance monitoring.

Before inviting formal bids, it is important to screen the potential applicants for suitability through an Expression of Interest and bidder short list. Key indicators to be provided in an expression of interest are technical competence to operate a generation system, commercial capability and financial capacity.

Once a short list of competent bidders is available, the next stage is to move to the tender process itself. A package of documents will need to be made available to the bidders. This will include detailed information on the sites and forecasted energy demand, pro-forma PPA, pro-forma licenses, technical requirements, etc.

As discussed, we recommend that selection is done on the basis of a two-envelope process (technical and financial proposals). The proposals should be judged on their quality and financial merit. For the financial proposal, bidders can compete either on the basis of lowest tariff needed for a fixed level of subsidy or lowest subsidy requirements for a fixed tariff.

Licensing procedures

Licensing procedures for relatively small PPA projects as the proposed in this project need to be streamlined as much as possible in order to reduce transaction costs and time. This will require minimising the number of regulatory processes, producing standardised documents, etc.). These processes include the acquisition of land, development permit, NEMA permit, permit for power generation and distribution, etc.

A summary of the technical assistance requirements of the project is presented in Table 65.

Table 65 Technical assistance requirements for projects delivered under PPA model

Area of TA	Details
Development of standardised Power Purchase Agreement and technical requirements	- Standardised to the extent possible to minimise transaction costs - Emphasis on specific aspects of off-grid PPAs: (i) clauses regarding off-take when significant variability from forecast (in both short and long term) can be expected, (ii) provision for grid interconnection. - Technical requirements of power supply: renewable energy targets, standards of quality of supply and service, applicable safety regulations, environmental standards, flexibility requirements and technical requirements for main grid interconnection.

Area of TA	Details
Procurement and management of the competitive bidding process	- Design of bidding procedures and tender documents - Assistance in selection of bidders - Assistance in negotiation and finalisation of contracts
Technical assistance regarding licensing procedures	- Develop procedures that are as streamlined as possible - Standardised licence templates

Finally, Table 66 presents a general overview and estimated timeline of activities to be undertaken during the project's cycle, including the above technical and management assistance activities as well as the construction phase.

Table 66 Project implementation activities (PPA model)

Activity	Details	Who	Indicative timeline
Agreement with GoK regarding implementation modalities	- Agreement with GoK regarding delivery model (fully private model versus PPA model) - Agreements on project organisation, management and administration - Financing agreement - Agreement on technical assistance	KfW, GoK	3 months
Hiring consultants for project management and technical assistance	- Technical assistance to REA and counties regarding project implementation - Technical assistance to MoEP/ERC regarding licensing procedures	KfW	3 months
Develop standardised PPA agreements (pre-requisites for elaboration of bids)	- Standardised PPA agreements (including guidelines on tariffs negotiation and grid connection) - Technical standards, service standards, conditions for disbursement of funds, etc.	GoK (with technical assistance)	3 months
Competitive bidding for private concession of 3 mini-grid sites	- Bidding procedures and documents (quality based pre-selection followed by financial proposal recommended) - Bidding process and selection	GoK (with technical assistance)	6 months
Permitting and licensing activities	- Develop procedures that are as streamlined (minimisation of number of regulatory processes, standardised documents, etc.) - Standardised licencing procedures	Concessionaire GoK (with technical assistance)	6 months

Activity	Details	Who	Indicative timeline
	and licence templates		
Disbursement of capital subsidies	Based on the fulfilment of previously determined conditions	GoK	3 months
Construction and operation	Involving the concessionaire and REA. Coordination between the two (in the implementation of the power generation plant and distribution network) is vital.	Concessionaire, REA, (KPLC)	6 months for construction
Monitoring performance and reporting	As per monitoring and review, reporting and evaluation	Concessionaire, REA	

13 LogFrame Matrix

The below Logframe Matrix includes the relation between the objectives, outputs and activities of the project.

This is applicable to both delivery models, fully private and PPA model.

Summary	Success indicators	Verification sources	Assumptions / Risks
Programme objective Contribution to increased access to electricity in Kenya Contribution to the improvement of the economic framework condition in Kenya. Contribution to mitigation of climate change	**Indicator Name / Description:** **1.** Number of electricity connections (total as well as number of schools, health centres, etc. as detailed in section 12 above) **2.** MWh of electricity sold **3.** MWh of electricity generated from solar **4.** % of electricity used in commercial and industrial activities **5.** CO_2 emission reduction through the generation of electricity from solar **Baseline value:** **1.** 0 **2.** 0 **3.** 0 **4.** N.A. **5.** 0 **Target values:** **1.** 700 connections (end of year 5) (as well as specific targets for schools, health centres, productive applications, etc. as detailed in section 12 above) **2.** 1,000 MWh/year (year 5) **3.** >900 MWh/year (year 5) **4.** >50% **5.** >16,000 tons in project life cycle	CO_2 Calculator Statistics of Company M&E reports from consultant or REA/ERC	/
Module objective: Establish a viable model for delivery of hybrid mini-grids with private sector leverage.	**Indicator Name / Description:** **1.** Licensing of 3 off-grid private concessions (or PPAs) **2.** Streamline license procedures for private concession (or PPAs)	Tender platform REA/Consultant reports	**Assumptions / Risks regarding programme objective:** ▪ Licensee(s) ensure a sustainable operation of the power plants ▪ There is enough demand for

Summary	Success indicators	Verification sources	Assumptions / Risks
	3. 3 hybrid mini-grids in operation **Target value:** **1.** 3 licensed off-grid mini-grids in operation **2.** Streamlined licensing procedures for private concession (or PPAs) (time and cost)		connections and electricity ▪ The conditions for economic growth do not deteriorate ▪ No deterioration concerning the condition of the electricity generation system. ▪ Tariff structure for electricity allows an economically sustainable operation of the mini-grid.
Outputs **1.** Selection of developer(s) of mini-grid sites **2.** Private completes pre-requisites for licensing (approval of EOI for 3 pilot sites, feasibility studies) **3.** 3 Pilot sites operational and delivering power **4.** Programme for more mini-grids implemented	**Baseline value:** / **Target value:** **1.** 3 implementation-ready (pre-requisites complete) mini-grid projects **2.** Land acquired and clearances obtained (development permit, NEMA permit, etc.) **3.** 3 Pilot sites operational and delivering power **4.** Programme for more mini-grids implemented	Reports of the Consultants Reports of NEMA and MoE	**Assumptions / Risks regarding module objective:** ▪ The framework conditions with regard to private concessioning (or PPAs) remain adequate ▪ Tariff (or tariff subsidy) negotiations/ agreements are favourable ▪ Willingness of GoK to streamline licensing procedures for small projects and simplify regulatory requirements ▪ Other economic and political conditions do not change adversely ▪ The Kenyan government (REA) provides the timely financing and implementation of distribution networks ▪ The private concessionaire implements construction works of power generation equipment
(Key) activities in the module ▪ Competitive bidding for private concession (or PPA for power	**Target value:** **1.** Technical assistance agreements with MoEP, REA and ERC	Report of the consultant Reports of NEMA and MoE	**Assumptions / Risks regarding outputs:** ▪ Enough interest from qualified private firms for competitive bid

Summary	Success indicators	Verification sources	Assumptions / Risks
generation) of 3 mini-grid sites ▪ Technical assistance to MoEP/ERC regarding licensing procedures ▪ Technical assistance to REA and counties regarding project implementation ▪ Assistance to project developers going through the licensing process	2. Consultants for Technical Assistance contracted 3. Established competitive bidding mechanism and documents		▪ Mini-grid project is feasible (feasibility study)
			Assumptions / Risks regarding main activities: ▪ Agreement of GoK with recommended approach and implementation modalities ▪ The financial means (KFW) are made available

14 Organisation, management and administration

The proposed roles for the execution of the pilot project are:

- REA is the leader in the implementation of the project. It will be in charge of managing the competitive bidding process and the disbursement of subsidies to the selected developers as well as guiding them through the development process. This tasks will be conducted with technical and project management assistance from KfW (consultants).

- REA will also be in charge of the construction of the power distribution infrastructure for the mini-grid (proposed public contribution to the project), to which the GoK (MoEP) has to agree.

- County governments will be involved in the implementation following their framework of collaboration with REA. County governments will also be involved in availing land and wayleaves for the project.

- The MoEP and ERC, with technical assistance from KfW (consultants), is to work on a streamlined regulatory framework (specifically the issues of licensing, technical regulation and standardisation of concession agreement sof PPAs) during the project development cycle of the pilots.

- KfW will provide funds to cover the proposed capex subsidy for the mini-grids (minus the distribution network component) as well as technical assistance to REA, ERC and the ministry in the subjects of project management and technical assistance to REA for the project implementation, monitoring and evaluation; and for the MoEP/ERC in the subject of regulation of (small) mini-grid concessions or independent power producers under a PPA.

- The private operator(s), selected through a competitive bidding process is in charge of conducting feasibility studies, completing all requirements of the project licensing process (land acquisition, pertinent clearances, tariff negotiations, etc.), raising equity and debt for their contribution to capex and working capital, EPC works, project commissioning, operation, maintenance and management during the concession period and finally transfer assets to the GoK at the end of the concession period (with compensation based on the non-depreciated value of the assets).

- KPLC (or a different regional distributor) would have a role in the project only in case the PPA model is the preferred option. In this case, KPLC would be the off-taker of a PPA agreement with a private generator.

15 Monitoring and review, reporting and evaluation

Monitoring and review of the pilot projects is responsibility of REA and the consultants providing technical assistance.

- Reporting on technical assistance activities (to REA and the ERC) will be no less than every three months, or at specific project milestones, until project completion, which will require a final report
- Reporting on the allocation of funds to mini-grid development, REA is to report to KfW semi-annually from the signing of the Loan Agreement (on 31 Dec./ 30 June), and annually after one year after commissioning of the projects.

With regards to the contents and formatting, reporting will follow KfW's Work Instructions no. AW082 "Guidelines for the agreement on reporting obligations of the project executing agency"

16 Financial management and accountability

As described previously, REA will implement the programme and will manage the disbursement of subsidies to the selected developers. REA will be supported in this task with technical and project management assistance from KfW (consultants).

A specific project or programme management unit may need to be established within REA to manage the programme (to be discussed – if there is an existing unit established to manage funds provided by other donors then it may be possible to use an existing unit within REA).

Funds will be disbursed by REA to developers following procedures to verify that works have been completed satisfactorily and customers are receiving an electricity supply. These procedures will need to be laid down in an operating manual. REA will make quarterly projections of disbursements of grants to project developers and provide requests to KfW and GoK to transfer funds to a ring-fenced account established by REA for this purpose.

REA currently administers the Rural Electrification Fund with its own reporting and auditing requirements and GoK procedures are in place covering financial probity of REA in relation to this Fund.

Specific additional procedures and reporting and auditing requirements will need to be implemented to ensure that the programme administered by REA complies with any additional financial management and accountability requirements dictated by KfW and any other donors contributing to the programme.

REA should provide quarterly financial (and operational) reports to KfW and GoK.

17 Project implementation plan and budgets

The estimated budget for the project is shown in the table below:

Table 67 Budget of KfW's pilot programme

Flow of funds	Amount (EUR '000)	Comments
Total capex subsidies	4,320	Estimated maximum. Subsidy requirements may decrease due to competitive bidding process.
Technical assistance to REA	200	Procurement procedures, project development, evaluation of proposals, etc.
Project management of pilot mini-grid implementation	350	
Technical assistance to MoE/ERC	200	Regulatory framework for private mini-grid concessions and off-grid PPAs
Programme monitoring and evaluation	150	
Total cost	**5,220**	
KfW subsidy	***4,270***	
GoK contribution	***950***	Subsidy component of the distribution network

The total cost of the project is of EUR 5.2 million. We propose that the subsidy component relating to the distribution network is a contribution of the government, reducing the KfW subsidy to EUR 4.3 million. If KfW provides additional subsidy for the distribution assets as well, then the total project cost for KfW would be of EUR 5.2 million.

From the perspective of KfW, the budget is the same for both delivery models, i.e. the fully private model or the PPA.

The programme could be expanded to disburse the original budget of EUR 15 million based on other potential sites, as mentioned in section 7.5.