Figure 4.6.8: Power Distribution Board

4.6.3 Operation and Maintenance status

i) Operation situation

The installation of the Biogas plant was carried out in year 2007 and early 2008. The system was tested and commissioned in April 2008.

According to the Manager, the biogas system has operated well from the time it was commissioned until early this year. The system failed when he was suspended since he was the only one who knew how to operate the plant.

When the plant used to operate, it would run the generator for almost 24 hours providing enough power for the slaughterhouse operations namely lighting, pumping water from ground storage, security lighting and charging mobile phones and few LED lamps used in the slaughterhouse.

When the plant was operating, the plant operation involved feeding the slaughterhouse waste 6 times and stirring it three times per day.

Currently the system is not operational and plans are underway to revive it.

ii) Maintenance Situation

The system was abandoned over 6 months ago and it is in poor condition.

No maintenance and user manuals were provided to the plant and the Manager knows how to operate the plant because he was involved in its construction and commissioning and took keen interest in the system.

It is expected that the biogas plant would keep an inventory of consumables and spares for maintaining and servicing such a systems. No such inventory exists.

iv) Technical capacities for operation and maintenance

Well designed and operated RE systems require little attention to keep them in good operating condition. There is therefore a need to build appropriate technical capacities for operation and maintenance for such systems.

According to the Manager, no one was properly trained to operate, maintain and service the systems properly except himself who took keen interest and learnt on the job.

In general, this plant does not have good technical capacity for proper operation, servicing and maintenance of the biogas plant. This is evident from the fact that the system collapsed once Mr. Wafula was suspended from work.

v) Performance monitoring, evaluation and reporting

It would be expected that the Biogas plant would set up a monitoring system that would involve data capture, evaluation and reporting on the system operation. One would expect to see a record of biogas generated, electricity generated, records on servicing, repair and maintenance operations, monthly reports and even annual reports.

The Manager only used to monitor the digester temperature.

Therefore no performance monitoring and evaluation system was put in place.

vi) Technical design, equipment procurement and construction plans

The Consultant did not gain access to the technical designs, procurement and construction plans used. UNIDO played the lead role in all cases and took charge of the technical designs, equipment procurement and construction planning of the Biogas plant.

That the systems were procured, installed and operated well for over 3 years is testimony to good planning by UNIDO.

4.6.4 Business Status

The Bungoma biaogas plant was set up for electricity generation from slaughterhouse waste as part of waste management and also to promote renewable energy.

The system operated quite well for 3 years and ceased operating due to poor operation after an untrained operator took charge.

The system certainly reduced the electricity use from the grid. However, no monitoring and verification system was put in place hence no records have been kept to quantify the benefits.

Though not quantifiable, it is clear that Bungoma biogas presents a good business case.

4.6.5 Financial Analysis

The CPC project was fully financed by UNIDO and with the support of the Bungoma Municipal Council which provided the land and contributed in kind.

The cost of the system to UNIDO was $ 109,642 (KShs 9.32 million).

Without records of quantities of biogas generated, electricity generated, reduction in waste disposal, amount of manure produced, operation and maintenance costs, and all other costs including projected O&M costs, it is not possible to undertake any financial analysis.

The biogas equipment was financed by UNIDO and donated to the Council. UNIDO does not expect any monetary returns from the investment.

Even though no data exists to show that the project is financially viable, reports by the Manager show that the Biogas system can displace electricity from the grid for the slaughterhouse.

4.6.6 Institutional Analysis

i) Ownership and management

This is a joint pilot project of UNIDO and Bungoma Municipal Council.

UNIDO handed over the plant to BMC after commissioning. The plant is therefore owned by and managed by BMC.

ii) Organization structure

As stated above, there is no formal organization structure for the biogas plant perse. The plant is one other asset of BMC which is under the management of the Town Clerk through the department of environment and public health.

iii) Management Challenges

There are no major management challenges facing the biogas plant.

4.7 Kamahuha Bananas CBO Biogas Project

4.7.1 Introduction

Kamahuha Biogas Project (Kamahuha Biogas) was a joint project of Kamahuha Bananas CBO and UNIDO.

Kamahuha Bananas CBO biogas project is located within Kamahuha Market Services Centre, in Muranga District, 85 kilometres from Nairobi. Grid power has been extended to the centre but there was no grid power at the site when the Community Power Centre (CPC) was established.

Figure 4.7.1: Kamahuha market services centre

The idea of establishing the biogas plant was floated to the group by a biogas consultant/contractor, Mr. Peter Gichohi who linked the CBO with UNIDO who developed it under its community power centre programme in collaboration with Technoserve.

The Kamahuha Biogas Project was designed to generate biogas from banana stems. The biogas would then be used for electricity generation for productive uses. The biogas would also be sold to the nearby school for cooking and also be used to heat water for cleaning dairy utensils such as milk Cans.

The electricity would be used for:

- Charging of mobile phones, rechargeable LED lamps and Car batteries.
- Powering an ICT centre that would provide internet access and ICT services such as photocopying, printing, computer use training, etc.

Figure 4.7.2: Kamahuha Biogas Plant

The persons listed in Table 4.7.1 were interviewed during the performance audit survey.

Table 4.7.1: Kamahuha Biogas project personnel interviewed during the survey

	Name	**Designation/Role**
1	Chrispin Kinyanjui	Chairman of the CBO
2	Joseph Kangethe	Chairman of the Energy Kiosk Committee
3	Joseph Kimani	Vice Chairman

4.7.2 Power System Status

i) Renewable energy sources and harnessing technologies

The main energy source for Kamahuha Biogas Project was banana stems. This was motivated by the fact that the area is a banana growing area and the CBO is mostly involved in banana growing and marketing.

The harnessing technologies employed are high performance temperature controlled (HPTC) anaerobic digestion and Biogas/Diesel duo-fuel generator.

The choice of these technologies is good since the feedstock is readily available and HPTC technology is much more superior to the traditional biogas technology as it produces close to 15 times more gas for the same amount of feedstock.

ii) System configuration, capacities and Loads

The system is configured to operate as illustrated in Figure 4.7.3.

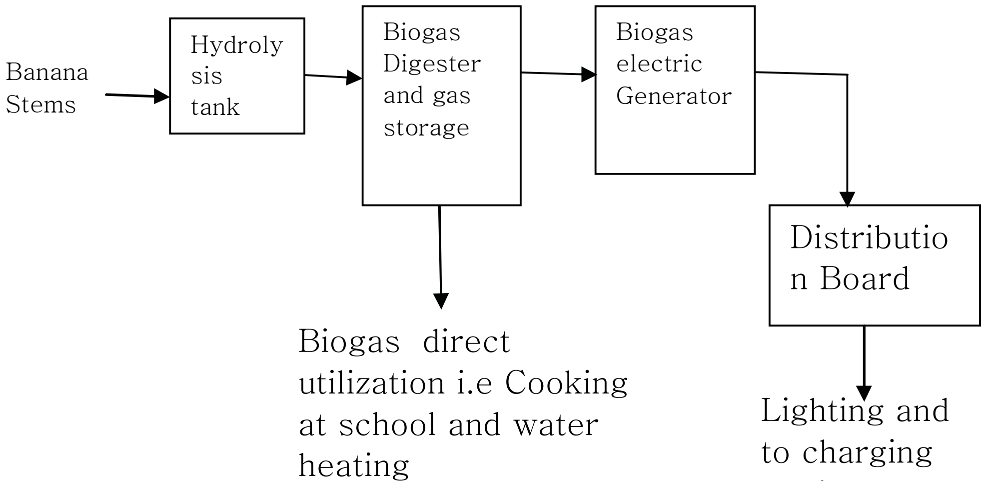

Figure 4.7.3: Biogas system configuration

The Biogas production design capacity is 25 m³/day. The biogas generator is rated at 10 kW.

iii) Suppliers and equipment source countries

The Biogas system equipment was supplied and installed by BME GmbH of Germany. The equipment, supplier and/or manufacturers and source countries are provided in Table 4.7.2.

Table 4.7.2: Equipment suppliers and source Countries

	Equipment/Component Description	***Supplier***	***Manufacturer***	***Source Country***
1	Biogas digester c/w controls	BME	Rottaler	Germany
2	Solar water heating system	BME	Microsolar	Malaysia
2	Biogas Generator	Comhard Kenya Ltd	Jianguai engine works	China
3	Back up Power Inverter/Charger	-	Tripplite	China
4	Back up power batteries (3 types installed)	-	Gaston Chloride Exide and Voltmaster	China Kenya

Figure 4.7.4: Underground Digester tank

Figure 4.7.5: Digester Solar water heating system

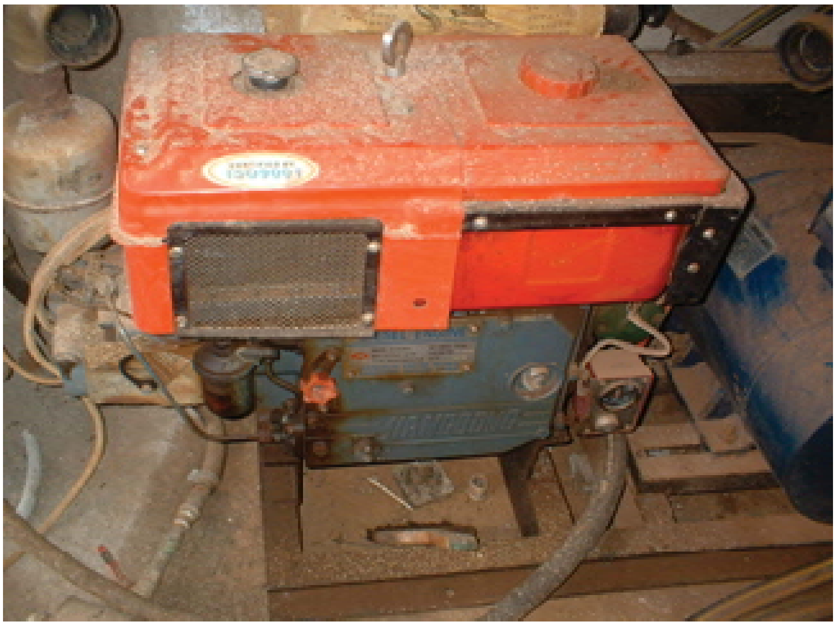

Figure 4.7.6: The 10 kW Biogas Electric Generator

The system was designed, installed and commissioned by the UNIDO appointed contractor, BME of Germany.

4.7.3 Operation and Maintenance status

i) Operation situation

The installation of the Biogas plant was carried out in year 2008. The system was tested and commissioned in March 2008.

According to the officials interviewed, the biogas system worked poorly for about 6 months after commissioning then failed completely. The system generated very little biogas. The reading from the biogas meter shows that the total amount of gas generated by the system since installation was 387 m^3. If this is divided by its design capacity of 25 m^3/day, then the system worked for an equivalent of 16 days!

When the plant used to operate, it would supply some gas to the school Kitchen and also generate some electricity.

Currently the system is not operational and there are no plans to revive it.

ii) Maintenance Situation

The system was abandoned over 3 years ago and it is in very poor condition.

iv) Technical capacities for operation and maintenance

Well designed and operated RE systems require little attention to keep them in good operating condition. There is therefore a need to build appropriate technical capacities for operation and maintenance for such systems.

According to the officials interviewed, two people were trained to operate the system. The trained people did not however have any technical background.

In general, this plant did not have good technical capacity for proper operation, servicing and maintenance of the biogas plant.

v) Performance monitoring, evaluation and reporting

It would be expected that the Biogas plant would set up a monitoring system that would involve data capture, evaluation and reporting on the system operation. One would expect to see a record of biogas generated, electricity generated, records on servicing, repair and maintenance operations, monthly reports and even annual reports.

Therefore no performance monitoring and evaluation system was put in place.

vi) Technical design, equipment procurement and construction plans

The Consultant did not gain access to the technical designs, procurement and construction plans used. UNIDO played the lead role in all cases and took charge of the technical designs, equipment procurement and construction planning of the Biogas plant.

That the systems were procured, installed and operated, though briefly is testimony to good planning by UNIDO.

4.7.4 Business Status

The Kamahuha biaogas plant was set up to generate biogas from banana stems. The biogas was then used for cooking at the School Kitchen, heating water at the Centre and for electricity generation. The generated electricity was used for charging mobile phones and rechargeable LED Lamps, car battery charging and operating an ICT centre which used to train people on computer applications.

i) Charging station

The charging station is simply a bank of power sockets that are connected to the power supply. It was used to charge mobile phones, rechargeable LED solar lanterns and car batteries. Mobile phones and LED lamps have own power adaptors so one needs only plug them into the socket. Car batteries need a conventional mains Charger.

UNIDO provided 40 LED rechargeable lamps which created a client base for the charging station in addition to mobile phones charging. UNIDO also provide a car battery charger.

This business operated briefly when the plant was working but closed when the biogas system failed completely.

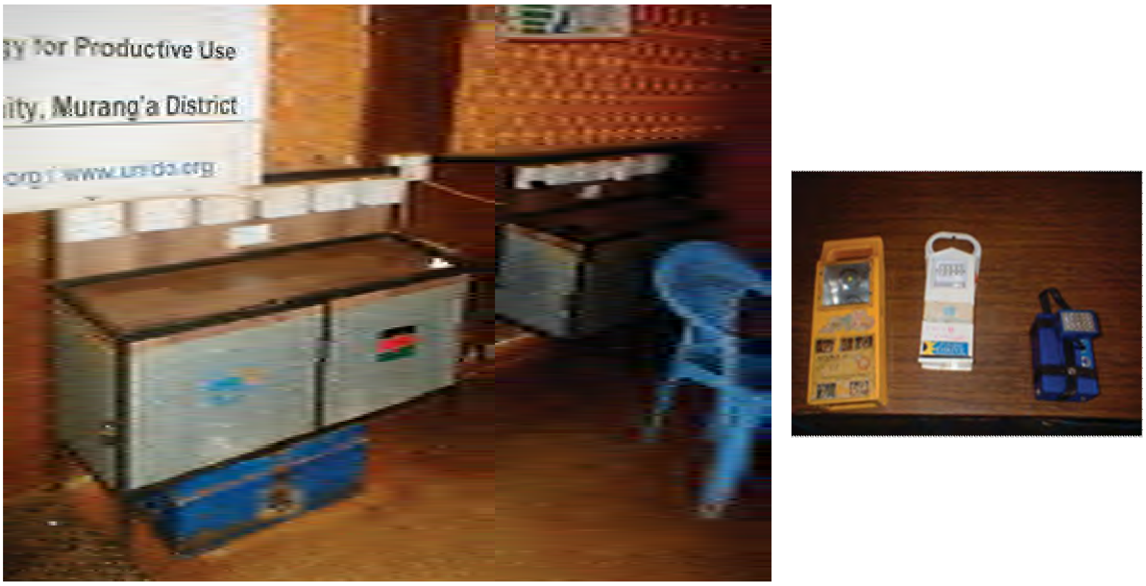

Figure 4.7.7: Charging station. The LED lamps :Accendo, Seco and N-Sunlight make, all from India,

ii) ICT Training Services

This business started immediately the power centre was operational and was being conducted by a Trainer who was on a KShs 10,000 per month fee. UNIDO facilitated the business by donating 7 computers.

Figure 4.7.8: Computers donated by UNIDO in a store at Kamahuha

This business closed when the system collapsed and Trainer ofcourse left. The Kamahuha CBO still owes the Teacher KShs 20,000.

iii) Gas Supply to School

This was offered as free service on trial basis but the biogas plant failed before this could be formalized.

4.7.5 Financial Analysis

The Biogas project was fully financed by UNIDO and with the support of the Kamahuha Bananas CBO which provided the land and buildings and contributed some cash.

The cost of the system to UNIDO was $ 109,642 (KShs 9.32 million).

The Biogas poor performance and eventual collapse in less than 6 months did not afford the project adequate time to collect any data for financial analysis.

4.7.6 Institutional Analysis

i) Ownership and management

This is a joint project of UNIDO and Kamahuha Bananas CBO

UNIDO handed over the plant to the CBO after commissioning. The plant is therefore owned by the CBO, which is responsible for its management.

ii) Organization structure

The Kamahuha Bananas CBO is well organized membership organization that has 86 members. The CBO is run by a committee of elected officials led by the Chairman Mr. Chrispin Kinyanjui and Vice chairman Mr. Joseph Kimani. A subcommittee chaired by Joseph Kang'ethe had been elected for the Biogas project.

iii) Management Challenges

The plant failed due to technical problems that the management could not solve due to lack of qualified experts to repair and maintain the system in working condition.

4.8 Wema Centre Biogas Project

4.8.1 Introduction

Wema Centre is a Non-Government Orgainsation (NGO) running a Children's home that takes care of mainly street children.

Wema Centre biogas project is located within Wema Centre children's home in Bamburi area, Mombasa. The centre is connected to the power grid.

Wema Centre has been using Biogas from the traditional Chinese Puxin plant for cooking. The centre also uses solar for lighting.

In 2007, UNIDO offered to augment biogas generation to further reduce the usage of wood and electricity from the power grid, hence reducing energy costs. The Biogas would supplement existing system for cooking. It would also be used to generate electricity for internal use and also introduce mobile phones charging service at its entrance to serve the neighbourhood community.

The Wema Centre Biogas Project was designed to generate biogas from Kongowea market fruits and vegetable waste.

Figure 4.8.1: Wema Centre Biogas Plant

The persons listed in Table 4.8.1 were interviewed during the performance audit survey.

Table 4.8.1: Wema Centre Biogas project personnel interviewed during the survey

	Name	Designation/Role
1	Henry Otieno	Programme Manager

4.8.2 Power System Status

i) Renewable energy sources and harnessing technologies

The main energy source for Wema Centre Biogas Project was Kongowea fruits market wastes. This was motivated by the fact that the market is not very far from the centre and generates substantial amount of waste.

The harnessing technologies employed are high performance temperature controlled (HPTC) anaerobic digestion and Biogas/Diesel duo-fuel generator.

The choice of these technologies is good since the feedstock is readily available and HPTC technology is much more superior to the traditional biogas technology as it produces close to 15 times more gas for the same amount of feedstock.

ii) System configuration, capacities and Loads

The system was configured to operate as illustrated in Figure 4.8.2.

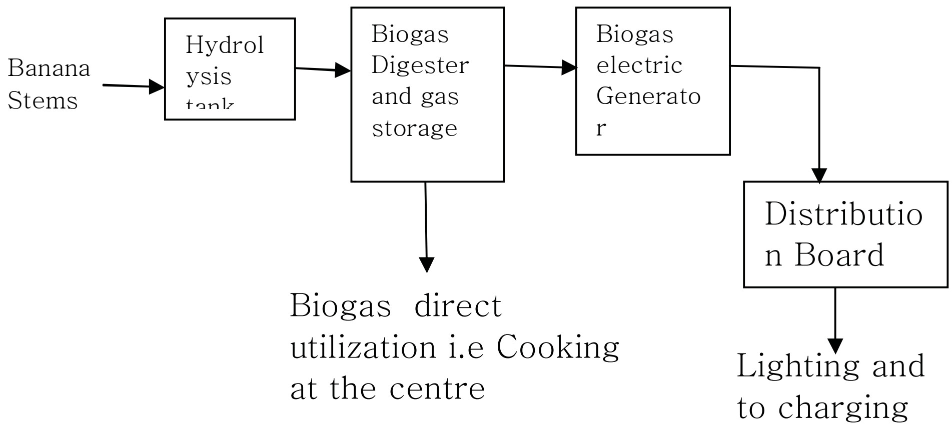

Figure 4.8.2: Biogas system configuration

The Biogas production design capacity was 20 m^3/day.

iii) Suppliers and equipment source countries

Most of the system equipment has been dismantled save for some plastic tanks and the solar water heating system.

Figure 4.8.3: Digester Solar water heating system – the only major component still in place

4.8.3 Operation and Maintenance status

i) Operation situation

The installation of the Biogas plant was carried out in year 2007. The system was tested and commissioned in September of the same year.

After 2 weeks of commissioning a wall separating the Digester and the overflow tank collapsed causing damage to the system. The system was repaired and put back into operation in one week. The gas generated could not however generate adequate pressure for operating the burners. The system was modified by introducing a blower.

The system worked for about 12 months but very poorly and producing very little gas which was only used for cooking. The solar heating system could not achieve the required digester temperature, one of the main determinants of gas production.

ii) Maintenance Situation

The system has been abandoned and main equipment dismantled. Only the solar heating system and some plastic tanks are in place.

iv) Technical capacities for operation and maintenance

Well designed and operated RE systems require little attention to keep them in good operating condition. There is therefore a need to build appropriate technical capacities for operation and maintenance for such systems.

According to the official interviewed, two people were trained to operate the system.

That the system failed and could not be made to work indicates that there was inadequate technical capacity for proper operation, servicing and maintenance of the biogas plant.

v) Performance monitoring, evaluation and reporting

It would be expected that the Biogas plant would set up a monitoring system that would involve data capture, evaluation and reporting on the system operation. One would expect to see a record of biogas generated, electricity generated, records on servicing, repair and maintenance operations, monthly reports and even annual reports.

There was no performance monitoring and evaluation system put in place as the system never worked properly before it completely failed.

vi) Technical design, equipment procurement and construction plans

The Consultant did not gain access to the technical designs, procurement and construction plans used. UNIDO played the lead role in all cases and took charge of the technical designs, equipment procurement and construction planning of the Biogas plant.

That the systems were procured, installed and operated, though briefly is testimony to good planning by UNIDO. That the system could not achieve Digester operating temperature, leading to poor performance, could have been caused by factors including system design or operation.

4.8.4 Business Status

The little gas generated during the 12 months it worked was used in the Kitchen.

The charging station was never used even though a container provided and wired for the purpose was at site. The biogas generator never worked at all.

The Wema Centre biaogas plant never worked well to start any productive activities.

4.8.5 Financial Analysis

The Biogas project was financed by both UNIDO and Wema Centre.

The Biogas plant's poor performance and eventual collapse in less than a year did not afford the project adequate time to collect any data for financial analysis.

4.8.6 Institutional Analysis

i) Ownership and management

This was a joint project of UNIDO and Wema Centre

UNIDO handed over the plant to Wema after commissioning. The plant and whatever remains of it is owned by Wema.

ii) Organization structure

Wema Centre is well organized NGO founded in 1993. It has 7 Trustees and also a management board of 7 people. A management committee headed by the Executive Director handles the day-to-day functions of Wema.

iii) Management Challenges

The plant failed due to technical problems that the management could not solve due to lack of qualified experts to repair and maintain the system in working condition.

4.9 Makandune Community Power Centre

4.9.1 Introduction

Makandune is a market centre located 4 km from Mitunguu market in Imenti South District of Meru County.

Grid power has been extended to the market but the CPC was established when there was no grid connection nearby.

The idea of establishment of the Makandune CPC was generated by the Kenya Agricultural Productivity Project (KAPP) that is being implemented by Kenya Agricultural Research Institute and the Ministry of Agriculture. KAPP is a capacity building project for value addition to agricultural produce by farmers. At Makandune, it focuses on cotton, poultry, mangoes and dairy goats.

Through KAPP, a common interest group of Mango farmers, called Makandune Commercial Mango Processing and Market (Makandune CIG) was formed. The area Member of Parliament introduced the group to UNIDO after which UNIDO developed a CPC at the market.

Figure 4.9.1: Makandune CPC Building housing generator and fruits processing machines.

The Makandune CPC was designed to generate electricity for the following applications within the community:

- Running fruits processing machines for value addition.
- Charging of mobile phones
- Powering social entertainment centre equipped with Satellite TV and Video players
- Powering an ICT centre that would provide internet access and ICT services such as photocopying, printing, computer use training, etc.

The persons listed in Table 4.9.1 were interviewed during the performance audit survey:

Table 4.9.1: CPC personnel interviewed during the survey

	Name	**Designation/Role**
1	James Thuri	CPC patron and Committee Member of Makandune CIG
2	John Mwebia	Chairman of CIG

4.9.2 Power System Status

xvi) Renewable energy sources and harnessing technologies

The energy source for Makandune CPC was Straight Vegetable Oil and automotive Diesel.

The harnessing technology employed was Duo-fuel, straight vegetable oil (SVO)/Diesel, electric generator.

The choice of SVO generator was based on the assumption that farmers would grow Sunflower from which the oil could be extracted. Sunflower is also grown in the area for other purposes.

According to UNIDO, the Makandune community undertook to grow Sunflower for the production of vegetable oil not only for fuel but also for human consumption.

xvii) System configuration, capacities and Loads

The system is configured to operate as illustrated in Figure 4.9.2.

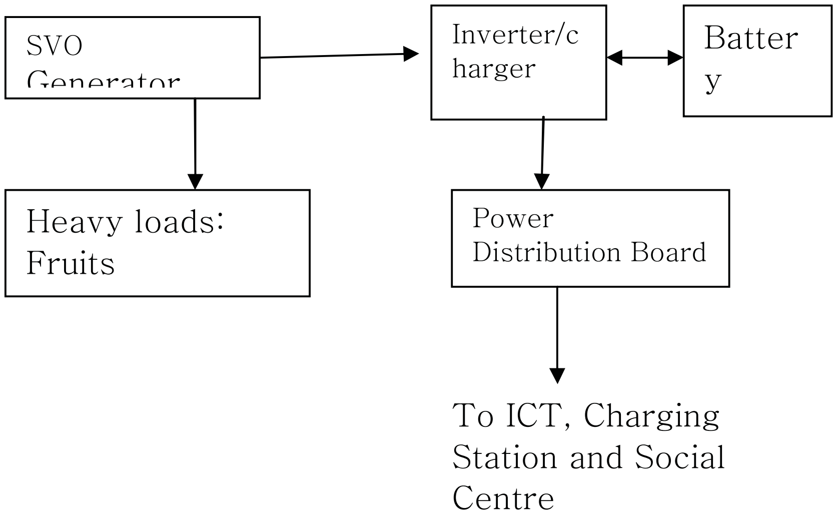

Figure 4.9.2: Power system configuration

The installed total system peak capacity is 8 kW.

xviii) Manufcaturers/Suppliers and equipment source countries

The power system was supplied and installed by UNIDO appointed contractor. The equipment manufacturers/suppliers and source countries are provided in Table 4.9.2.

Table 4.9.2. Equipment manufacturer/suppliers and source Countries

	Equipment/Component Description	***Manufacturer/Supplier***	***Source Country***
1	8 kW Duo-Fuel (SVO/Diesel) Raptor Generator	Eternal Energy	Germany
2	Seed Oil Press/Expeller	Double Engineering	China
3	Inverter / charger 1No.	Tripp-lite	China
4	Back up Battery bank 200AH.	International Battery Co.	China

Figure 4.9.3: The SVO Generator

Figure 4.9.4: Makandune Vegetable Oil Press

Figure 4.9.5: The Inverter and battery back up

The power system system was designed, installed and commissioned by UNIDO appointed contractors.

The connected loads are provided in Table 4.9.3.

Table 4.9.3: Makandune CPC Installed Load

	Load Description
1	Mobile phones and LED lanterns charging bay
2	ICT Centre with 4 No. Dell desktop computers and accessories.
3	Small Juice processing machines: Pulper, Pasteurizer and packaging machine

KAPP and the Makandune CIG procured and installed the juice processing equipment.

4.9.3 Operation and Maintenance status

i) Operation situation

The installation of the CPC was carried out in year 2008. The system was commissioned in October of the same year.

According to the official interviewed, the SVO generator worked well for about three months and developed mechanical problems. Since then, the Generator has never been repaired successfully for continuous operation

The vegetable oil press was tried and it never worked from the beginning. The generator uses the expensive diesel fuel. No Vegetable Oil production and supply mechanism was therefore established.

Over the 4 years the CPC has been in existence, the generator has operated for less than 6 months cumulatively. The SVO generator is not operating at the moment.

ii) Maintenance Situation

No maintenance activities are undertaken as the CPC is closed. The equipment is in poor state.

iv) Technical capacities for operation and maintenance

Well designed and operated RE systems require little attention to keep them in good operating condition. There is therefore a need to build appropriate technical capacities for operation and maintenance for such systems.

According to the Interviewee only the current chairman was shown how to operate the system. No operation and user manuals were provided save for the Inverter user manual.

In general, no significant technical capacity for proper operation, servicing and maintenance exists at the CPC.

v) Performance monitoring, evaluation and reporting

It would be expected that the CPC, being a centre generating and selling energy and related services would set up a monitoring system that would involve data capture, evaluation and reporting on the system operation. One would expect to see a record of energy generated, energy sold, record on servicing, repair and maintenance operations, monthly reports and even annual reports.

The CPC had at the beginning employed two people to manage the operations and a record of daily collections was being kept. This lasted for the first 3 months when the generator worked. No other records were generated or kept.

This CPC did not establish any performance monitoring and evaluation system.

vi) Technical design, equipment procurement and construction plans

The Consultant did not gain access to the technical designs, procurement and construction plans used. UNIDO played the lead role in all cases and took charge of the technical designs, equipment procurement and construction planning of the CPC.

In this CPC, UNIDO used external contractors for the design, supply, construction and commissioning. That the systems were procured, installed and commissioned before they were handed over is not in doubt. UNIDO role in this respect was good.

4.9.4 Business Status

The CPC was set up to provide electricity for productive uses. Hence the establishment of the Makandune CPC was accompanied with the establishment of business activities which are provided in Table 4.9.4. Their status is also provided.

Table 4.9.4: Business activities at the CPC and current Status

	Business Activity	Current Status
1	Charging station	Not operating
2	Electricity sales (micro-grid system)	Not operating
3	ICT services	Not operating
4	Fruits juice processing machines	Not operating

The above business activities started off after the CPC was established but all closed down after 3 months when the Generator failed.

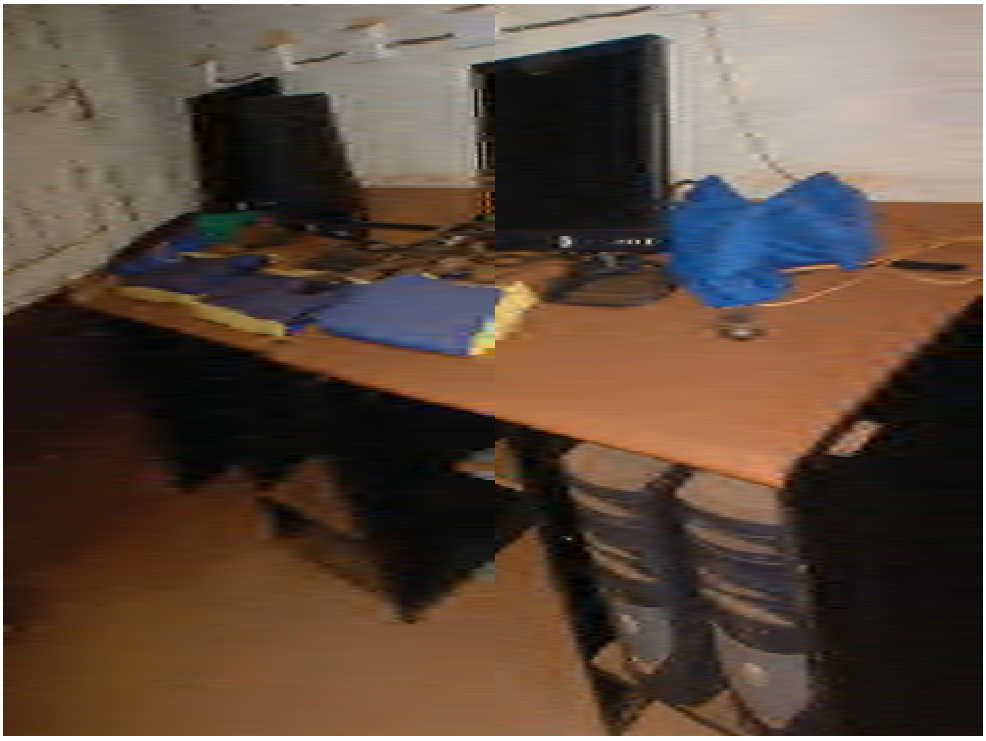

Figure 4.9.6: The idle equipment at the ICT Centre

Figure 4.9.7: The idle charging station

Figure 4.9.8: Idle fruit juice processing machinery

4.9.5 Financial Analysis

The CPC was financed by both UNIDO and the Makandune Mango processors group.

The CPCs SVO generator poor performance and eventual collapse in less than 3 months resulted in closure of the productive activities hence no data is available for financial analysis.

4.9.6 Institutional Analysis

i) Ownership and management

This was a joint project of UNIDO and Makandune CIG

UNIDO handed over the plant to Makandune after commissioning. The plant and whatever remains of it is owned by Makandune CIG .

ii) Organization structure

The Makandune group is well organized for the growing and marketing of mangoes. It has 42 active members. The group is managed by a committee elected by the members. The committee is currently led by Mr. John Mwebia the Chairman, Mr. Julius Magiri, the Treasurer and Martha Karimi who is the Secretary.

iii) Management Challenges

The plant failed due to technical problems with the SVO generator that the management could not solve due to the cost of repairs.

4.10 Mutunguru Hydropower CPC,

4.10.1 Introduction

Mutunguru Hydro power project was initiated by James Boore who was inspired when he saw a bicycle dynamo light a house while driven by flowing water.

In year 2003, James invited other member of the community to form a self-help group for the purpose of establishing a hydropower station to generate electricity which would be connected to their households.

In 2007, the Mutunguru Hydro power group sent a proposal to UNIDO for support which was accepted.

UNIDO then offered to provide the requisite technical assistance and the power generating equipment to establish a CPC.

Figure 4.10.1: Mutunguru Microhydro powerhouse

The mutunguru hydropower site is located on bank of a river 3km away from Murungurune market, which is 200km from Nairobi.

The Mutunguru CPC was designed to generate electricity for the following applications within the community:

- Supplying electricity to 1,200 households within the locations of Igoki, Igoji and Kinoro
- Supplying power to nearby markets such as Murungurune market and Ikumbo Tea buying centre

- Charging of mobile phones and car batteries

The persons listed in Table 4.10.1 were interviewed during the performance audit survey:

Table 4.10.1: CPC personnel interviewed during the survey

	Name	Designation/Role
1	James Boore	Chairman
2	Daniel Mutwiri	Committee Member
3	Catherine Kathure	Office Secretary

4.10.2 Power System Status

xix) Renewable energy sources and harnessing technologies

The energy source for Mutunguru CPC is small waterfall. The harnessing technology employed is water turbine generator, which is an old proven technology.

Figure 4.10.2: The resource - waterfall

xx) System configuration, capacities and Loads

A hydropower system comprises a Weir, Penstock, Water Turbine and generator and the necessary switchgear and controls. Where power has to be transmitted to distant loads (above 1km) then step-up and step-down transformers and power distribution lines are necessary.

The system UNIDO installed is small and did not involve step-up and step-down transformers.

Power was supplied directly from the generator switchgear to3 houses, a mobile and car battery charging station and a welding workshop.

The installed generator is rated at 36kW.

At the time of the survey, the system was not connected to any loads and had been shut down.

xxi) Manufcaturers/Suppliers and equipment source countries

The power system was supplied and installed by UNIDO appointed contractor. The Generator, Turbine and controls were made in China by Zhejiang Yueqin Machinery Factory in Yufong and supervision of International Centre of Small Hydro Power, Hanzhou.

Figure 4.10.3: The Turbine/Generator set

The power system was designed, installed and commissioned by UNIDO appointed contractor from Sri Lanka.

4.10.3 Operation and Maintenance status

i) Operation situation

The installation of the CPC was carried out in early 2009 and commissioned in July the same year.

Three houses, a welding shop and a mobile charging bay were connected to the system. According to the officials interviewed, the generator worked well for 4 months then failed. Investigations showed that water seal had been broken and water leaked into the generator resulting in windings burning out.

The generator was taken to Nairobi for rewinding and repair. This repair took a whole year before the generator was brought back, remounted on the turbine and tested. The testing confirmed the generator to be okay.

The generator is therefore in working condition only that its idle as no loads are connected.

ii) Maintenance Situation

The power generator is in good condition but currently not in use. The switchgear is also in good condition.

iv) Technical capacities for operation and maintenance

Well designed and operated RE systems require little attention to keep them in good operating condition. There is therefore a need to build appropriate technical capacities for operation and maintenance for such systems.

According to the interviewees, two people, one of them a technician, were trained to operate and maintain the system. However, no operation and user manuals were provided.

Technical capacity for operation and maintenance for proper operation and maintenance of the system exists at the CPC.

v) Performance monitoring, evaluation and reporting

It would be expected that the CPC, being a centre generating and selling energy and related services would set up a monitoring system that would involve data capture, evaluation and reporting on the system operation. One would expect to see a record of energy generated, energy sold, record on servicing, repair and maintenance operations, monthly reports and even annual reports.

This CPC did not establish any performance monitoring and evaluation system.

vi) Technical design, equipment procurement and construction plans

The Consultant did not gain access to the technical designs, procurement and construction plans used. UNIDO played the lead role in all cases and took charge of the technical designs, equipment procurement and construction planning of the CPC.

In this CPC, UNIDO used external contractors and consultants for the design, supply, construction and commissioning. That the systems were procured, installed and commissioned before they were handed over is not in doubt. UNIDO's role in this respect was good.

4.10.4 Business Status

The ultimate aim of the hydro power project is to supply power to households and markets within three locations.

UNIDO helped to set up the CPC which was used for battery and mobile phones charging and welding on trial basis for four months before the generator broke down.

Due to the one year delay in repairing the generator, the three businesses closed down and have not reopened.

The CPC is not supporting any businesses currently.

4.10.5 Financial Analysis

The CPC was financed by both UNIDO and the Mutunguru hydropower self-help group. The group contributed a total of KShs 5.9 million to the project. UNIDOs contribution not included.

The CPC's generator failure and prolonged delay in its repair resulted in closure of the productive activities hence no data is available for financial analysis.

The Government has stepped in to assist the community to realize its ultimate objective of connecting households. Through Rural Electrification Authority, the government is financing the supply and installation of step-up and step-down transformers, and distribution lines.

4.10.6 Institutional Analysis

i) Ownership and management

This was a joint project of UNIDO and Mutunguru hydropower self-help group.

UNIDO handed over the plant to Mutunguru after commissioning. The plant therefore belongs to the group.

ii) Organization structure

The Mutunguru group is well organized group. It has 1112 active members. The group is managed by a committee of 7 elected by the members. The committee is currently led by Mr. James Boore as the chairman. The members in each of the three locations have also elected a total of 11 delegates. The delegates work closely with the management committee.

The group has employed a Clerk/Secretary who runs the office and keeps records of members contributions and expenses.

The self-help group is transforming itself into a limited company called Mutunguru Hydropower Company Ltd which plans to augment the power system in future and become an independent power producer.

iii) Management Challenges

The hydropower project started over 9 years ago. The main challenge facing the project is raising funds and availability of the highly skilled technical expertise required for the implementation of the project.

4.11 Somorio Hydropower Project

4.11.1 Introduction

Somorio Hydro power project was initiated by a group of 10 people led by the chairman in year 2003. The 10 founders mobilised the people for the purpose of building a hydropower station to generate electricity which would be connected to their households as well as markets.

In 2007, the Somorio Hydro power group sent a proposal to UNIDO for support which was accepted.

UNIDO then offered to provide the requisite technical assistance and the power generating equipment to establish a microhydro power station under its CPC program.

At the time of the establishment of the CPC there was no grid power nearby but the power grid has now been extended to the villages.

The Somorio hydropower site is located on bank of a river which lies between Kaptien and Somorio villages.

The Somorio CPC was designed to generate electricity for the following applications within the community:

- Supplying electricity to households in Kaptein and Somorio villages for lighting and TV.
- Supplying businesses, mainly general shops and mobile phones charging stations

The persons listed in Table 4.11.1 were interviewed during the performance audit survey:

Table 4.11.1: CPC personnel interviewed during the survey

	Name	**Designation/Role**
1	Shadrack Busieney	Chairman
2	Richard Bengati	Project Coordinator
3	Richard Kosgey	Treasurer

4.11.2 Power System Status

xxii) Renewable energy sources and harnessing technologies

The energy source for Somorio CPC is a small waterfall. The harnessing technology employed is water turbine generator, which is an old proven technology.

Figure 4.11.1: The resource - waterfall

xxiii) System configuration, capacities and Loads

A hydropower system comprises a Weir, Penstock, Water Turbine and generator and the necessary switchgear and controls. Where power has to be transmitted to distant loads (above 1km) then step-up and step-down transformers and power distribution lines are necessary.

The system UNIDO installed is small and did not involve step-up and step-down transformers.

Power was supplied directly from the generator switchgear to houses and shops for lighting, mobile phones charging and TV.

Two microturbines rated at 0.75kW were installed resulting in a total of 1.5kW capacity.

At the time of the survey, the system was connected to 8 houses in Somorio village and the residence of the engineers who are upgrading the power station at the site.

xxiv) Manufcaturers/Suppliers and equipment source countries

The power system was supplied and installed by UNIDO appointed contractor, Hydro Dynamics Consultants of Srilanka. The Generator, Turbine and controls were made in China by Zhejiang Yueqin Machinery Factory in Yufong and supervision of International Centre of Small Hydro Power, Hanzhou.

Figure 4.11.2: The Micro-turbine/generator sets

4.11.3 Operation and Maintenance status

i) *Operation situation*

The installation of the CPC was carried out in the middle of 2007 and commissioned in October the same year.

The two generators have operated very well since and they are still working.

ii) *Maintenance Situation*

The power generators are in good working condition.

iv) *Technical capacities for operation and maintenance*

Well designed and operated RE systems require little attention to keep them in good operating condition. There is therefore a need to build appropriate technical capacities for operation and maintenance for such systems.

According to the interviewees, three people, two of them technicians, were trained to operate and maintain the system. Operation and user manuals were provided.

Technical capacity for operation and maintenance for proper operation and maintenance of the system exists at the CPC.

v) Performance monitoring, evaluation and reporting

It would be expected that the CPC, being a centre generating and selling energy and related services would set up a monitoring system that would involve data capture, evaluation and reporting on the system operation. One would expect to see a record of energy generated, energy sold, record on servicing, repair and maintenance operations, monthly reports and even annual reports.

According to the Chairman, this was a pilot demonstration system for motivating the community and the CPC did not establish any performance monitoring and evaluation system.

vi) Technical design, equipment procurement and construction plans

The Consultant did not gain access to the technical designs, procurement and construction plans used. UNIDO played the lead role in all cases and took charge of the technical designs, equipment procurement and construction planning of the CPC.

In this CPC, UNIDO used external contractors and consultants for the design, supply, construction and commissioning. That the systems were procured, installed and commissioned before they were handed over is not in doubt. UNIDO's role in this respect was good.

4.11.4 Business Status

The ultimate aim of the hydro power project is to supply power to households and markets within three locations.

UNIDO helped to set up the demonstration system which was used for lighting and power in households and shops. The users were only asked to contribute enough for paying power station security guard.

Figure 4.11.3: Mobile phones charging in a Shop at Somorio village

There are no financial records kept but monthly income varies between KShs 2000 and KShs 5000 which is used to pay the security guard and undertake some maintenance, mainly unclogging the turbines.

The CPC has achieved the purpose for which it was established – awareness creation and motivation for the community

4.11.5 Financial Analysis

The CPC was financed by both UNIDO except for the powerhouse.

No formal business operation structures were established and hence no financial records of income and expenditure are kept. Without this data no financial analysis can be done.

4.11.6 Institutional Analysis

i) Ownership and management

This was a joint project of UNIDO and Somorio hydropower self-help group.

UNIDO handed over the plant to Somorio after commissioning. The plant therefore belongs to the group.

ii) Organization structure

The Somorio group is well organized group. It has about 1000 members.

The group has now been transformed into Savings and Credit Society called Iria-Maina Multi-purpose Cooperative Society (IMMCOSO) which is managed by a committee elected by members. The committee is currently led by Mr. Shadrack Busieney, the chairman.

The group has employed a Clerk/Secretary who runs the office and keeps records.

iii) Management Challenges

The hydropower project started in 2003. The main challenge facing the project is raising funds and availability of the highly skilled technical expertise required for the implementation of the project.

UNIDO's involvement has been of great help.

4.11.7 Site Redevelopment

The Japanese Government, UNDP and UNIDO are now financing the redevelopment of site to increase the capacity to 200kW.

Hydrodynamics Consultants of Srilanka have been contracted to undertake the works and have commenced the construction already.

Figure 4.11.4: Site redevelopment Work in progress

4.12 CPCs and Implementation

4.12.1 Kariti Ngando CPC

This CPC is located 6km from Sagana Town in Kirinyaga County. It is 0.5km away from the nearest low voltage (430V) grid line and 2.5km from the nearest power transformer at Karima.

The CPC will use solar PV and Straight Vegetable oil generators which have already been delivered to site. Solar PV has been installed.

The power will be used to supply a school and a church and also for light industrial productive activities. The CPC is nearly complete and should start operating before December 2012.

Figure 4.12.1: Kiriti Ngando CPC.

Figure 4.12.2: Kariti Ngando CPC workshop with PV panels on the roof.

4.12.2 Rembo Centre CPC

This CPC is located in Likoni about 2km from Likoni Ferry in Mombasa South Coast on the Shelly beach road. The centre is connected to power grid.

It is planned to utilize Straight Vegetable oil generators for generating power for own use and also for light industrial productive activities such as Coconut Oil processing and making briquettes. The civil works are nearly complete and equipment has started arriving.

Figure 4.12.3: Rembo Centre CPC Buildings

Figure 4.12.4: Crate with some equipment that has started arriving

4.12.3 Salaban CPC

This CPC is located in Salaban, a village 15km from Marigat town and 6km from the Marigat Baringo highway. The centre is 6km away from the nearest power grid line.

It is planned to utilize solar PV and Straight Vegetable oil generators for generating power for own use and also for light industrial productive activities such as making briquettes. The civil works have just started.

Figure 4.12.5: Civil works in progress at Salaban CPC

5. CONCLUSIONS

This survey set out to establish the status and performance of CPCs established by UNIDO to assist the Rural Electrification Authority (REA)/Ministry of Energy (MoE) in the development, financing and implementation of rural renewable energy business model. The survey looked at both technical and business performance of 11 CPCs established between year 2007 and 2010.

The survey has established that:

i) National power grid has been extended to all the CPCs even though most of them were established when there was no grid power connection nearby. The only exceptions were Nyongara, Wema and Bungoma biogas CPCs.

ii) The RE sources selected for exploitation at various CPCs were wind, hydropower, solar, biogas from slaughterhouse and market wastes and straight vegetable oils from oil crops.

iii) The harnessing technologies were wind turbine generators, solar photovoltaic, hydro turbine generators, HPTC biogas digester and biogas electric generator, biogas cookers and the SVO electric generator.

iv) Solar PV, Wind Turbines, hydro Turbine and biogas electric generators have performed well.

v) The HPTC biogas technology requires high quality feedstock (ideally animal wastes) and maintenance of nearly constant digester temperature for it to work well.

vi) The SVO generators were only run on diesel fuel because no mechanisms were established for the supply of SVO fuel.

vii) The SVO generators that were used on Diesel have performed poorly due to technical breakdowns that have been difficult to fix.

viii) The systems were technically well designed, installed and commissioned by UNIDO selected contractors and consultants. However, the selection of equipment appears not to have been based on a well-defined quality and performance based technical specification.

ix) The source of most of the equipment installed in the CPCs is China. Germany supplied the biogas equipment.

x) Most systems are not operational and are in poor state of operation and maintenance. One biogas system, three PV systems and one hydropower systems are in operation.

xi) Lack of adequate and suitable technical capacity for operation and maintenance is the primary course of the poor state of power systems operation and maintenance.

xii) A combination of technical and management problems are the causes of the poor operational and are in poor state of operation and maintenance. Only one biogas system, three PV systems and one hydro power CPCs are working.

xiii) No single CPC put in place any credible technical performance monitoring and evaluation system. No quantitative data was available for technical performance evaluation.

xiv) Only one CPC, Uhuru in Siaya provided 18 month income and expenditure data. The other CPCs never bothered to keep proper financial records. Based on the analysis of this data, Uhuru CPC is not sustainable as a business.

xv) The UNIDO's CPC program business model was based on general assumptions with no credible supporting data or information. The model was implemented without any business plan.

xvi) The UNIDO's CPC program business model did not address the full supply chain of the targeted biofuels, hence no SVO generator has ever been operated on SVO.

xvii) The CPCs surveyed did not create any sustainable jobs and only mobile phones charging and Hair cutting and ICT and entertainment services using satellite TV are supported in the 3 CPCs. The envisaged light industrial productive activities never took off. The CPCs have contributed little in terms of social and economic development of the targeted communities.

The overall conclusion is that the status and performance of the CPCs established by UNIDO is poor both from the technical and business aspects. Lack of business planning and technical and management capacities are the main causes of the poor performance.

The UNIDO CPC program model needs a major overhaul for it to be used as a business model for the development, financing and implementation of rural renewable energy businesses.

6. DISCUSSIONS AND RECOMMENDATIONS

The results of this survey show that of the 11 CPCs established by UNIDO and its partners between 2007 and 2010, only two have operated very well from a technical point of view and none has performed well from a business perspective. A combination of CPC design model, technology and management issues have contributed to this state of affairs.

Feasibility studies are used to establish the technical and financial viability of an investment. With the exception of Nyongara CPC, the CPCs established by UNIDO were based on a model CPC that was based on general assumptions and very limited data from the field. Under these circumstances, some systems work but most do not. This is exactly what has happened to the CPC program.

5.1 RE Resource Assessment and choice of technologies

All the CPCs were designed to use locally available renewable energy sources namely:

- Hydro power
- Wind Power
- Solar energy
- Biogas
- Straight Vegetable Oil

All the RE resources above are available in Kenya in varying quantities at different locations. A site specific assessment is therefore critical in determining the availability and adequacy of the RE resource.

5.1.1 Hydropower

Hydropower site are fairly easy to locate since they will generally involve a waterfall but an assessment of its suitability and adequacy for power generation has to be done by a qualified expert. For the two hydropower based CPCs, UNIDO identified an expert who assessed the sites for adequacy and suitability and made recommendations on system capacities, choice of turbines and generators and proposed appropriate designs.

The expert recommended old and proven turbine/generator technologies and eventually designed and actually undertook the installation and commissioning of the power station. The technology has low maintenance and local expertise is available in the country for maintenance and repair.

Other than for the generator failure at Mutunguru, which was repaired locally successfully, the hydropower stations have worked very well.

5.1.2 Wind Power

Wind power sites are not easy to locate and long duration data gathering and analysis are needed to determine the suitability of a site for wind power generation. UNIDO used information from the local people and also the presence of the KenGen 5.1 MW wind farm on nearby Ngong Hills to recommend a wind turbine for Olosho-Oibor.

Small wind turbines have been in use in Kenya for many years and the technology has low maintenance requiring little attention to work. Local expertise is available in the country for maintenance and repair.

The wind turbine at Olosho is still operational and the choice of wind energy resource and wind turbine for Olosho Oibor was good and appropriate.

5.1.3 Solar Power

Solar energy resource is enormous in Kenya and the national annual average is 5.5 kWh/m²/day. It varies between 4 and 6.5 kWh/m²/day. The insolation is highest in the drier north and north eastern Kenya. It is lowest in the mountain region but still good

The solar PV technology has been in use in Kenya for over 30 years and there are many small enterprises offering equipment and services locally. The technology is well proven and requires little attention to keep it working.

The choice of PV technology by UNIDO for 3 CPCs cannot be faulted. The solar PV systems at the three CPCs are still operational.

5.1.4 Biogas

Biogas is a combination of methane (60 -70 %), carbon dioxide and traces of other gases. It is produced through anaerobic digestion of biomass or biomass wastes in a digester.

Biogas production requires biomass inputs, water and ofcouse bacteria suitable for anaerobic digestion. The best raw material for biogas production is animal manure or wastes. Municipal solid and liquid wastes (sewage) are other good raw materials for biogas production. For biogas plant to operate, there must be a constant and reliable supply of quality biomass wastes.

Animal wastes especially cow dung are high quality raw materials for biogas production processes and have been used for a long time for biogas production in institutions and households using traditional biogas technology where digestion takes place in a single tank. Animal wastes are readily available at slaughterhouses in Bungoma, Homabay and Nyongara the choice of biogas as the RE resource for the three was very good.

The choice of biogas for Wema Centre to use Kongowea market fruits and vegetable waste was also good but failure by UNIDO to establish the quality and cost of collection, transportation and sorting became a major drawback in plant operation.

The choice of banana stems for the raw inputs at Kamahuha was not based on any practical experience. The CPC chairman reported that they were asked to look for cow dung and mix it with the banana stems to get the plant working. Even though the area has banana stems waste, failure by UNIDO to establish the suitability of banana stems for biogas production and the cost of collection and transportation became a major drawback in plant operation.

The process of anaerobic digestion involves hydrolysis, acidification and fermentation. In a traditional biogas production, the three processes take place in the same tank but biogas production is limited because these three processes proceed at different rates and are affected by daily environment temperature variations. However, this traditional biogas technology is well proven, cheap and requires little attention – only to feed the digester with waste and water. UNIDO did not recommend this biogas technology for the CPCs.

A recent technology called high performance temperature controlled (HPTC) biogas technology ensures that hydrolysis, acidification and fermentation takes place in three separate tanks. The Digester is kept at optimum operating temperature for the anaerobic bacteria (35 to 40 °C) for maximum digestion. To do this the digester is covered with hot water insulated jacket. The hot water is circulated in the jacket to maintain the operating temperature. In the case of the CPCs where biogas was recommended, solar water heating systems were installed for this purpose. UNIDO recommended this technology for the CPCs.

The HPTC technology is relatively new and expensive. There is no local experience with it and no local support infrastructure exists. Its operation requires continuous attention to monitor and maintain digester temperature since too high temperature variation will result in very poor performance and may even kill the bacteria.

That the HPTC technology works is not in doubt as is evident from Nyongara and Bungoma experience. It is however too sensitive to temperature variations and quality of feedstocks. It requires a lot of attention to keep it working. The recommendation of this technology by UNIDO should have been accompanied by extended technical support for operation and maintenance so that the CPCs can gain adequate experience and establishment of an after sales support system for provision of spares and major repairs.

5.1.5 Straight Vegetable Oil

Straight vegetable oil (SVO) is mostly produced from oil seeds of oil crops. It is extracted from the seeds by oil presses also called oil expellers. It is an unrefined and unblended oil. After extraction from seeds, it is just filtered and used.

To produce SVO requires planting of oil crops such as Sunflower, Cotton etc and oil presses to extract the oil. It therefore requires land and farmers motivated enough to plant oilcrops, extract the seeds and deliver them to the CPC. UNIDO recommended SVO on the assumption that farmers and members of the community will automatically plant oil crops. This assumption has proved to be erroneous. Indeed no single CPC has run a generator on SVO since no farmer ventured into oil crops farming. Farmers who grow such crops sell their produce to edible oil producing companies.

SVO generators are essentially Diesel generators that are modified to also run on SVO and should have no problem running on Diesel. Diesel generator technologies are well proven.

The operation and performance of the supplied SVO generators has been big issue, yet they are being run on automotive diesel. Where they were used, the generators worked for a brief period then started malfunctioning. These generators are all imported and no one has been able to successfully diagnose and fix them. In the case of Changara, an improvised cooling system had to be fabricated for the type of generator also installed in some other CPC.

The recommendation of the SVO generator technology by UNIDO should have been accompanied by extended technical support for operation and maintenance so that the CPCs can gain adequate experience and establishment of an after sales support system for provision of spares and major repairs.

Recommendations

The choice of RE resource and harnessing technology should be based on detailed technical assessments.

The availability and adequacy of the RE resource and the supporting infrastructure and logistics should be based on credible data and information.

The RE harnessing technologies should be chosen on the basis of technology maturity, level of commercialization and proven performance. New technologies should be chosen with a lot of care and be accompanied by extended technical support for operation and maintenance and the establishment of an after sales support system for provision of spares and major repairs.

5.2 Systems Design, Procurement, Installation and Commissioning

The systems were technically well designed, installed and commissioned. A good design does not guarantee the quality and performance of the equipment to be procured.

Recommendation

To ensure that good quality equipment and systems are procured, a detailed well-defined quality and performance based technical specification should be the basis of equipment and supplier selection. Equipment with a good performance history from reputable manufacturers should be selected.

5.3 Technical Capacity for Systems operation and Maintenance

Most systems are not operational and are in poor state of operation and maintenance. This state of affairs has been caused by a combination of technical and management challenges.

In almost all cases, technical training for operation, maintenance and repair was given little attention. Not everyone can be trained to operate and maintain technical equipment Technically qualified people should have been identified and adequate training provided to them. The training should include preparation and provision of system operation and maintenance manuals. This was not done except in Mutunguru and Somorio. In all other

CPCs, non-technical people were shown how to start and stop machines and asked to contact UNIDO in case of any problems. UNIDO having handed over the CPCs had exhausted its budget and could not respond promptly to calls for assistance. Consequently, many system would stay for prolonged period without functioning. Many CPCs felt that UNIDO failed them after handing over the systems.

There are essential spares such as fuses that should as a matter of good practice be kept by the CPC. Suppliers should always supply a list of such spares for their systems. No CPC has an inventory of such spares. This could be attributed to lack of proper training and/or poor management and also lack of funds.

CPC management should strive to keep in employment all properly trained operation and maintenance personnel. UNIDO was of the view that most CPCs lost the people who were trained since they could not pay them.

Recommendation

It is recommended that technical capacity development for operation and maintenance management be included in program designs and be carried out.

5.4 Performance Monitoring and Evaluation

It would be expected that the CPC, being a centre generating and selling energy and related services would set up a monitoring system that would involve data capture, evaluation and reporting on the system operation. One would expect to see a record of energy generated, energy sold, record on servicing, repair and maintenance operations, monthly reports and even annual reports.

No single CPC put in place any credible performance monitoring and verification system. Metering is essential for monitoring energy generation and consumption. Some systems had gas meters and electricity meters but others did not have. Even where meters were provided, no systematic and credible data was collected.

Recommendation

It is recommended that the importance of performance monitoring and evaluation be emphasized and that systems be put in place for data gathering and storage for evaluation purposes.

5.6 Business Model

UNIDO's business model is fairly simple.

The initial cost of establishing the CPC would mostly be a donation to the community. The community may contribute in kind in form of labour, provision of land and at times in form of cash to finance the procurement of some materials.

Once the CPC is commissioned and handed over, UNIDO's contribution ends. The community is left to finance and manage the CPC. It is anticipated that the energy generated and the services offered by the CPC would generate adequate revenue to finance its operation and generate some profits for the CPC.

The model is okay and should work if well implemented in a business-like manner taking all pertinent issues into consideration based on a business plan.

A business plan is the blue print of starting and managing a profitable business. The business plan takes into account the following factors:

i) a description of the nature of business and ownership
ii) The products or services
iii) the market
iv) the marketing plan
v) competition analysis
vi) location and facilities
vii) the management plan
viii) financing plan
ix) other pertinent factors

In UNIDO's CPC program, no business plan was prepared for any of the CPCs. All the above business considerations were based on general assumptions with no credible supporting data or information.

All the above are important in business but in the case of UNIDO CPC program, the most important business considerations should have been the marketing plan, financing plan and management plan.

A good marketing plan would have helped to determine the volume of business that was reasonable to expect at every CPC and how to capture it. UNIDO assumed that sufficient market exists for the various products and services the CPC would introduce.

A financing plan would have helped to determine not only the initial investments but also the projected business operating costs and how they will be met and projected incomes based on prices the community would be willing to pay. UNIDO established the initial costs and assumed the operating and maintenance costs based on generic CPC design.

The management plan would have defined the ownership structures, the organization structures, the qualifications and experience of the required technical and non-technical personnel and their duties and responsibilities and set monitoring and reporting mechanisms.

UNIDO assumed that communities organized into groups can manage the CPCs as businesses. It should be noted that self-help groups, CBOs and Saccos are service and project oriented rather than business oriented. This is one reason why none of the CPCs put in place any performance monitoring and accountability systems.

Recommendation

An RE business model should be based on credible data, information and assumptions supported by a good business plan.

JICA should therefore use the lessons learnt from the UNIDO model to develop new and innovative business model for off-grid rural electrification using renewable energy.

7. ANNEXES

ANNEX 1

THE UNIDO COMMUNITY POWER CENTER PROGRAM DESCRIPTION

Introduction

Energy supply is a basic requirement for sustainable development yet most of the rural populations in Kenya have no access to grid electricity (estimated at 63% by Kenyan Government rural electrification agency -Rural Electrification Authority- 2008)

The population density in some rural areas is generally low and sparsely distributed making it extremely uneconomical for the expansion of electricity grid energy to these areas.

Decentralized (off-grid) technologies such as the use of renewable energy resources for power generation would play an important role in community development particularly in the rural areas.

The **United Nations Industrial Development Organization (UNIDO)** in partnership with the **Government of Kenya** though the Ministries of Energy, Industrialization, Environment and others have identified the need to harness and enhance the use of these off-the-grid renewable energy technologies to produce power that would be used in productive applications that generate income and contribute significantly to alleviation of poverty.

Description of the Community Power Center Program:

The Community Power Center

The Community Power Centre (CPC) or "Energy Kiosk" is a community-managed, decentralized electrical energy service centre powered by renewable energy technologies.

The CPC can utilise a single source of Renewable Energy (RE) system (Stand-alone) or a combination of sources (Hybrid) to produce electricity from locally available RE resources like water, organic wastes, plant oil, solar and wind etc.

This electricity is then used in productive activities that **Add Value** to the community's lives, produce and economic activities.

The community will use power to run small agro-processing industries that add value to their agricultural produce e.g. milling, processing, preserving etc. They will also use energy to meet household energy needs say lighting by using rechargeable LED lamps(Zero carbon Emission) instead of the kerosene lamps widely used (these cause household pollution and the health risk associated with them especially to women and children).

Community-owned business support services Like ICT services at rural trading centres would also be available once electricity is available.

Design and Structure of the CPC:

The Energy Kiosk has 3 main parts, the power source, the power control center and the CPC itself i.e. the Common/ application utility Center

1. **The Power Source,**

This where the power is generated from one or several energy sources which are usually renewable sources.

Note:
(If there is grid locally, it can also be used to power the CPC. It is important to note that even in rural areas that are served by the local grid electricity, the electricity use and penetration is usually low. We have found that typically only 20% of the rural homesteads would afford the grid electricity even when available in the local area)

For our program we are utilizing any of the following sources depending on its availability and applicability:

- Micro hydro power.
- Biomass, biogas digester with a biogas generator.
- Solar photovoltaic (PV) systems
- Wind electric turbines
- Straight Vegetable Oil (SVO) generators

2. **The Power Control Centre (PCC)**

This is the facility where the generated power is brought converted if need be, stored, and distributed from.

Here you find various electrical accessories like battery storage banks, inverters, control units, electric meters etc.

3. **The Common Utility Setup:**

This is the main Energy Kiosk per say. It will include all the applications that the energy produced is used for.

Our program emphasizes on two main areas of application for the energy produced;

- Lighting
- Productive use

The common utility setup will depend on the location of the CPC, the people and the need of services and energy in the community. Thus it would include any of the following applications.

a) A LED lamp recharging facility that also recharges mobile phones and car batteries.
b) An Information Communication Technology (ICT) Centre with computer printing, photocopying, internet and ICT training facilities.
c) A community recreation center with a Television, DVD, satellite connection etc.
d) An industrial center with light industrial activities like flour milling, metal welding, carpentry workshops, hair clipping and salon, poultry incubators, juice making preservation of produce in refrigerator/cold storage etc

Business Model for CPCs

The community power center is supposed to be a financially sustainable facility. Thus the CPC should make enough money to cater for its needs and make a profit.

This is the only way the CPC model can be viable and replicable throughout the country and beyond.

The CPC earns its money from the Energy services or energy sales it makes or supports. These include productive activities like the ones run at the Industrial Center, and the other services like ICT, community recreation, Recharging of LED lamps and phones etc.

A typical CPC would serve 400 households with an average population of 2000 people.
We intend to replace most of the Kerosene lamps in these households. Each household has at least 3 kerosene lamps. Therefore the CPC should push up to 1000 LED lamps to this community.
Also we expect the community to have at least 200 mobile phones

Therefore for the recharging business alone, the CPC would have a market of 1200 items to recharge at least every 2 weeks, summarized as follows;

	Number of Items	Charges per week	Income per charge(Kshs)	Income per week(Kshs)
LED Lamps	1000	1	20	20,000
Mobile phones	200	2	20	4,000
Car batteries	50	1	50	2,500
Total Income per week				**26,000**

Kshs 26,000 per week, therefore per month it s Kshs 105,000 or approx 1400 USD or 1000 Euro.

See the appendix for household economics of using LED lamps instead of Kerosene lamps for lighting in a typical Kenyan rural household.

The CPC also has other energy services and productive activities.

Income from these activities would be as follows;

Services		**Income**
Internet and Computer		10,000
TV Video Facility		8,000
Hair clipping		2,000
Rent and electricity sales		5,000
Soap Making		12,000
Maize milling		3,000
Juice making		4,000
Total		**44,000**

Typical running costs of the facility would be the following;

Cost	**Amount**
Maintenance of equipment	Kshs 15,000
Salaries of 2 caretakers	Kshs 10,000
Consumables	Kshs 5,000
Contingencies	Kshs 5,000
Total Expenses	**Kshs 35,000**

Therefore, the average income for a typical Kiosk would be Kshs (149,000-35,000) = Kshs 114,000 or approx 1500 US $ or 1100 Euros.

Thus the CPC will be able to sustain itself financially.

Cost of CPC Setup
The cost of setting up a CPC is anything from 5000 Euro to 100,000 Euro depending on the size and technology used.

Scalability
A CPC is scalable from a very small one that serves a few hundred people one to a big one that would serve thousands of people.

Impact:

The socio-economic improvement that is possible in the areas that the CPCc are setup become a catalyst for community development. Therefore the following are some of the impacts we have observed from our pilot CPCs

Key features of attraction & Impacts;

- Empowering rural communities especially marginalized groups (unemployed youth and women).
- Use of electricity for productive activities thus spurring employment through small enterprises (agro-processing - value addition to primary products)
- Availability of energy to off-grid rural areas at an affordable cost.
- Elimination of household use of kerosene for lighting by replacing it with LED lamps that are cheaper to operate, provide a clean energy source and better quality of light.
- Use of Renewable Energy Resources to produce energy thus having a positive impact on the environment (Zero carbon emission systems).
- Achievement of the Millennium Development Goals (MDGs) for these communities.

Sustainability:

The communities are involved in the projects development and design from the beginning to ensure future sustainability.

Each Energy Kiosk is an income generation centre through various services it provides (LED lamp sale and recharging, mobile phone charging, ICT services etc.). thus it is a financially sustainable outfit.

The communities are also trained in the operation and maintenance of the respective CPCs and all equipment used.

Conclusion:

From our pilot CPCs, the model has been shown to work. CPCs can bridge the energy gap that exists in most rural areas in Kenya and beyond.

The CPC model is flexible and can be used to fit any community in any part of the world.

The use of Renewable Energy will go a long way in mitigating the environmental degradation caused by use of fossil fuels.

Scalable off-the-grid energy production is the most economic way of provision of energy in remote and or sparsely populated communities.

UNIDO Brief:

UNIDO, a specialized agency of the UN that works towards improving the quality of life of the world's poor by helping countries achieve sustainable industrial development. UNIDO views industrial development as a means of creating employment and income in order to overcome poverty. It helps developing countries produce goods they can trade in the global market, and helps provide the tools – training, technology, and investment – to make them competitive. Its focus is on production processes that will neither harm the environment nor place too heavy a burden on a country's limited energy resources. UNIDO with 172 Member States has its HQ in Vienna, Austria (visit **www.unido.org**).

Currently, UNIDO's rural energy initiative is to support the set up of viable and self sustainable CPCs in selected rural areas that are off-grid to promote productive activities and stimulate economic growth. This is through provision of technical assistance, capacity building and use of appropriate energy technologies.

The programme has so far established several pilot CPCs in Kenya, in areas that are off grid, far from existing energy sources, to facilitate sustainable livelihoods and stimulate economic growth.
These pilot sites have had a positive impact.

(see attached info on pilot projects).

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UNIDO-Kenya CPC program

Appendix

The Household Economics of using LED lamps

Kerosene Lamps Vs White LED lamps

From a survey conducted in Kirinyaga Energy Kiosk area in Kenya, the home economics are as follows:

A typical household has 3 kerosene lamps, one for the kitchen area, one for the sitting room and another for the children for study. These three lamps typically use ½ liter of kerosene per day (average lighting period of 4 hrs per night)

At the current cost of kerosene of about Kshs 80/litre, the kerosene costs Kshs 40 per day, which is Kshs 40x30days which is Kshs 1200/month spent on kerosene alone by the household for lighting.

Capital costs:

1. The Kerosene lamp scenario:

- Lamp cost = Kshs 500 for hurricane lamp or Kshs 50 for Tin (Koroboi) lamp
- Cost of wicks for a year (replaced once a month) = Kshs 20x12 = Kshs 240
- Cost of kerosene per year Kshs 14,400
- Tin lamp uses 30% more kerosene than hurricane lamp

2. The LED lamps scenario:

Initial cost of a LED lamp= Kshs 1,500
Lamp comes with a new battery that needs to be replaced after 36 months at a cost of Kshs 360.
Therefore the cost of the battery for a month is 360/36 = Kshs 10

The lamp needs re-charging every 7-10 days, if used for 4 hours/day.
If it is recharged once every week, at a cost of Kshs 20 per recharge, the cost for a household per month = 3 lamps x 4 recharges per month x Kshs 20 per recharge = Kshs 240

For a whole year, the cost comparison for Kerosene lamps Vs LED lamps is as follows
Comparison of overall cost:

Lamp	Cost of purchase (Kshs)	Cost of consumables (Wick of battery) (Kshs) per year	Cost of Fuel or recharge per year (Kshs)	Total cost (Kshs)
Rechargeable LED (3 lamps)	4,500	1080	2,880	**7,860**
Kerosene Hurricane lamp (3 lamps)	1500	240	14,400	**16,140**
Kerosene Tin Lamp (3 lamps)	150	200	18,720	**19,070**

Note: LED turns out to be the cheapest. Further, the lamp has a life of 100,000 hours or roughly 12 years. Realistically we give it a life of 5 years.

Therefore a family using and LED lamp would save **Kshs 11,210 or 100 Euro per year for better lighting and no pollution in the household**

Affordability:

It is true that an average family, as in a village may find it difficult to raise upfront, an amount of Kshs 4500 to buy 3 LED lamps. This situation can be overcome by a system of paying in installments (no subsidy, interest included) over a period of 8 months as follows:

The household pays upfront Kshs 500 for each lamp or Kshs 1500 for three.

Then pays every month Kshs 900 (300 for each lamp), for 10 months. During this period, the monthly savings from kerosene is Kshs 1000 which is enough to pay for the lamp installments.

After paying for the lamps in 10 months, the family enjoys the full benefit of savings and better lighting.

Social, Environmental and Health Benefits:

In addition to this saving, domestic indoor pollution from kerosene lamps is eliminated, so are the associated health risks like respiratory and ophthalmic disorders and fire hazards.

Also, we know that the LED lamps give off better quality, steady light as compared to the ‘flickering’ kerosene lamps.

ANNEX 2

SURVEY QUESTIONNAIRE

1. Introduction

1.1. Background Information (for interviewees briefing)

JICA, UNIDO and the Government of Kenya have entered into collaboration to promote rural electrification, growth-led development, poverty alleviation and other targets stipulated in the UN Millennium Development Goals (MDGs), through the installation and management of appropriate renewable energy technology systems.

The partnership wishes to establish the status of the energy kiosks established by UNIDO to determine their technological and socio-economic impacts to assist the in the development, financing and implementation of an appropriate rural renewable energy business model for Kenya.

Rencon has been engaged to undertake the survey. Your cooperation is greatly appreciated.

1.2 Purpose of the Interview Questionnaire

This interview questionnaire is a data capture tool that will guide Rencon during the survey. It will be filled by Rencon experts in face-to-face interviews.

PART A: ENERGY CENTRE MANAGEMENT AND TECHNICAL PERSONNEL

2. Genesis of the Energy Centre Establishment

i) How did this project originate and when? Describe briefly

ii) Who were the founders if not those listed in section 4 below?

iii) According to the founders, what was the original purpose of the project?

iv) Is the current purposes still the same as the original purpose?

v) How did UNIDO get involved?

vi) When did they get involved?

vii) What was the purpose of UNIDO's involvement?

viii) What was UNIDO's contribution to the Project?

ix) Did UNIDO change the original aim of the project to get involved?

3 Particulars of the Energy Centre and Interviewees

Description		**Remarks**
Name of Energy Kiosk		
Physical and Postal Address		
Telephone numbers		
Email Address		
Name of Project Manager/Operator		
Telephone No. PM/O		
Email Address of the PM		
Names of people interviewed at the centre and their roles		

4 Ownership

List below or provide a list of the shareholders/partners/owners of the energy centre

Name	Shareholding	Remarks

5 Energy Centre management, organization structure and challenges

i) Provide below the names and contact persons responsible for management of the energy centre (i.e. management committee) and their respective roles.

Name	Role	Contact Tel. Number/Email

ii) Sketch management organization structure.

iii) How are the managers/committee members chosen?

iv) Have you experienced any management difficulties? (yes/no)

v) If yes what is the nature of the problems? Describe briefly

vi) How do you think the above problems can be solved (capacity enhancement, awareness etc.)

vii) What attempts have been made to solve the problems, if any?

viii) How can JICA/UNIDO help you?

6 Technical Aspects Assessment

This section aims to establish technical details, performance and current status of the energy system installed.

6.1 Power Status

i) Technical details (from literature and also visual inspections):

- What are the energy sources for the energy centre (solar,wind etc)?
- What technologies is being used to harness it (solar PV, Solar Thermal etc)?
- What is the design capacity/capacities (kW/kVA/m^3 etc) of the systems?
- What is the source country of the various equipment (country and manufacturer)?
- What is the estimated distance from power line?

ii) Who designed the systems and do you have the designs?

iii) Did you have a written project implementation plan (design, procurement, construction and operation)? Can we make a copy?

iv) How were the systems procured? (tender, single sourcing, donations etc.)

v) Who supplied the systems or system equipment?

vi) Who installed the system if not the supplier?

vii) When was system installed?

viii) When did the system start operating i.e. commissioning date?

ix) What equipment is the system operating or running?

x) When was the various equipment being operated on the system installed?

x) What are the ratings and duration (hours) and how often (daily, weekly etc.) is the various equipment installed used? Use table below:

Item	**Description**	**Ratings**	**Daily usage duration (hours)**	**Frequency of usage**

6.2 Energy Systems Capacity and parameters Measurements (where appropriate) Results

6.3 System operation and maintenance

i) Is the system currently in operation? (yes/no?)

ii) Kindly describe to us the daily operating procedures of the energy centre

iii) How has the system served you since it was installed? (well, very well, poorly)

iv) Kindly describe problems and frequency of occurrence, if any, that you have encountered since the system started operating?

v) What do you do if the system develops a problem?

vi) Was anyone trained to operate and maintain the system? (yes/no). If yes

- Who provided the training?

- Who were trained (names)?

- What are their basic qualifications: Education (KCPE/KCSE/?) Vocational Training (trade test, technician, artisan etc) for each person.

Name	Education	Vocational training	System training

- What were they trained to do exactly on the energy system?

- Are they still available to operate and maintain system?

- Are the employees full time, part time or on call?

- How long do they take to service a system if it fails?

- Do they do the servicing properly - Are you satisfied? (yes/no?)

vii) Were any manuals left to guide in servicing and maintenance? (yes/no?) If yes, can we see them?

viii) Do you have a spare parts inventory for servicing if needed? (yes/no/). Do you have a list of them and can we have a copy?

ix) How do you manage the spares / equipment inventory? (purchasing, storage, issuance etc.)

x) What performance monitoring records do you keep about the system operation?

- energy generated?
- energy sold?
- maintenance records?
- system breakdowns and repairs carried out?
- monthly reports?
- evaluation reports?

May we make a copy of sample records?

7. Business Aspects Assessment

7.1 Business Description

i) Is the energy centre operated as a business? i.e do you generate any income from the energy generated by the centre..

ii) How many people has the energy centre employed directly and what do they do?

iii) What business activities (income generating) are supported by the energy centre

iv) How is each of the businesses performing in terms of?

- What Products or services are offered

- Payment for the energy supplied – timely and fully?

- Number of employees?

v) Kindly take us to one or two businesses for quick interview on their business operations (See part B for Entrepreneur questions).

vi) What non-business activities does the energy centre support i.e. free water service to community

vii) Please provide us the number of energy centre customers by type and category (small, medium, high energy consumer) as per table

Type	Number	Average Monthly Bill/Units of energy consumed
Households		
Small		
Medium		
High		
Businesses		

Small		
Medium		
High		

7.2 Financing and Financial Performance of the Energy Kiosk

i) How was the project financed (members, donor, loan etc)?

ii) What was the total design, procurement and installation cost of the energy centre project.

iii) Have you employed an account or accounts clerk ?
May we talk to him/her for following questions?

iv) What financial/accounting records do you keep?

v) What financial/accounting records do you prepare?

vi) Do you prepare annual accounts?

vii) Is it possible to share with us at least the balance sheet and income and expenditure (profit and loss) statements for the last 3 years?

viii) If annual accounts aren’t available kindly provide us with:

a) Annual income for the last 3 years or for the duration the centre has been operating if less than 3 years.

- Income from energy sales
  - No. of units generated (if metered) and units sold
  - Revenue accruing
- Other Income attributable to the energy centre (describe)

b) Annual expenditure for the last 3 years or for the duration the centre has been operating if less than 3 years.

- Salaries and wages
- Rents
- Operations and maintenance (fuel, maintenance, repair, spares etc)
- Loans repayment – Principal and interest
- Other (describe)

PART B: ENTREPRENEUR

i) What is your nature of business? (products/services offered)

ii) When did it start?

iii) How has it been performing (well, very well, poorly)

iv) How many employees do you have on full time basis?

v) How many employees do you have on part time basis?

vi) What financial/accounting records do you prepare?

vii) Has the business broken even/are you making a profit?

viii) Do you prepare annual accounts?

ix) Is it possible to share with us at least the balance sheet and income and expenditure (profit and loss) statements for the last 2 years?