2013 Team at Minazi Energy Kiosk

Summer 2013 Expedition Report

December 2013

We would like to thank the IC Trust for funding the flight subsidy for the expedition. This allowed us to take a diverse 15 member expedition team to Rwanda to gain invaluable practical experience. The expedition gave all members exposure to the complex process of working in a diverse and adaptable work environment. All expedition members will agree that they learnt a huge deal from the trip not only in terms of a new cultural experience but also the logistical and technical skills gained.

The e.quinox Summer Expedition 2013 was overall a success and most task which the team set out to complete were accomplished. The expedition was spread across three months from July to September and incorporated four distinct e.quinox projects. These include Battery Box, Stand-Alone/Franchise, Hydroelectric turbine and Data-logging. The report that follows is a compilation of the tasks carried out by each team during their time in Rwanda. Some of the technical project reports are still being compiled as we are waiting on customer feedback from customers in Rwanda however the major goals which were accomplished are outlined below.

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1 DATA-LOGGING BATIMA INSTALLATION

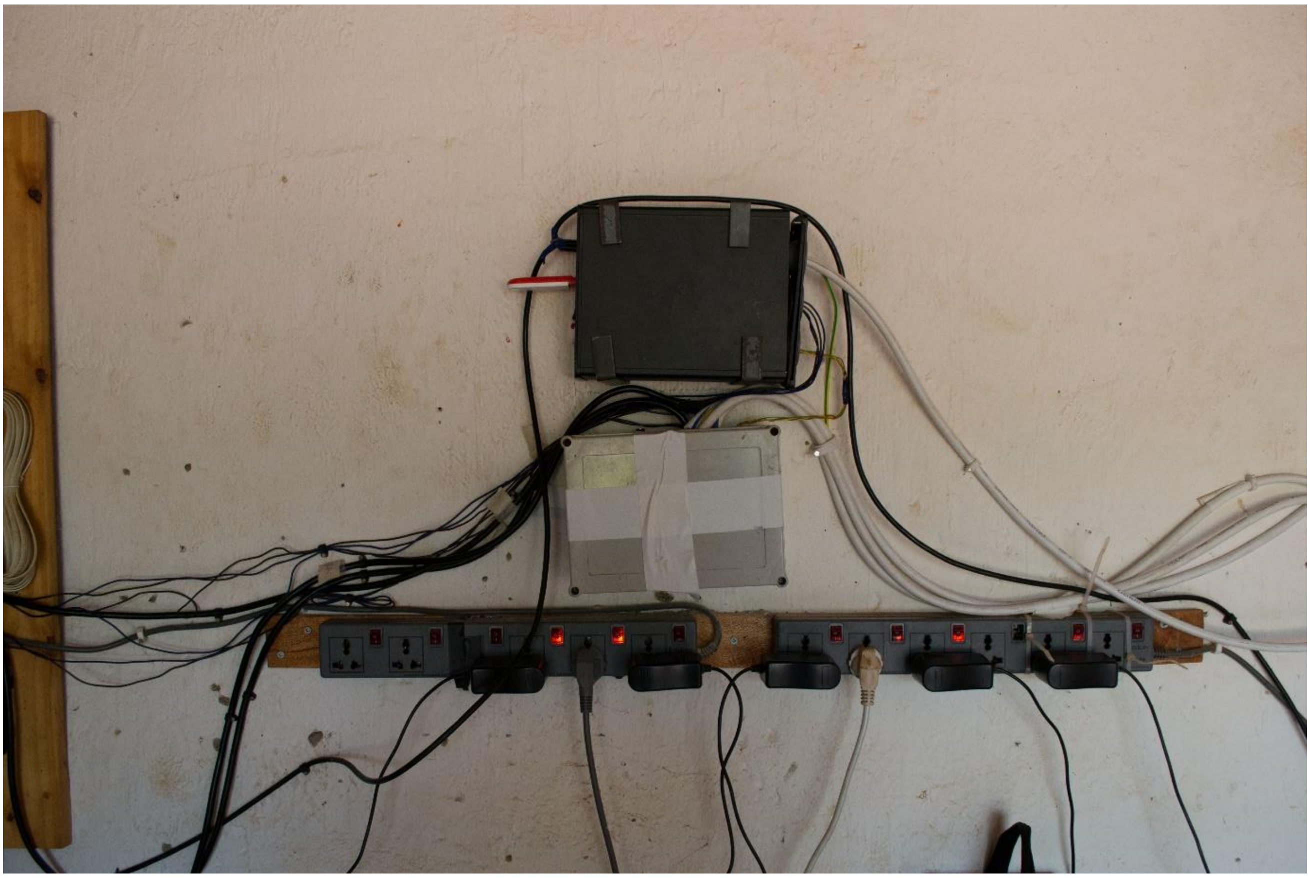

Figure 1 Batima Kiosk after Installation

1.1 Technical Specification

1.1.1 Power Supply

The power supply for the data-logger was taken directly from the storage batteries to ensure that it runs at all times and as the board is completely DC this eliminates unnecessary conversions. Wire is connected to the battery terminals and is fed up to the data-logger where it is plugged in using a DC Jack. The configuration is as follows:

DC Jack:

- Inner conductor - Positive (+)
- Outer conductor -Negative (-)

Storage Battery (at installation):

- Left – Power Supply 1
- Right – Power Supply 2

1.1.2 Sensor Configuration

Each cable is marked with white tape and labelled with its Board ID for easy identification.

Sensor	Location	Board ID	Connection Polarity	Cable Rating	Cable
AC Voltage Left	Extension Cord Cable	ACV1	N/A	6A/500V	2 Thin Blue/Brown
AC Voltage Right	Extension Cord Cable	ACV2	N/A	6A/500V	White 3-Core
AC Current Left	Extension Cord Cable	ACC1	Blue incoming Brown outgoing	15A/500V	Black 2-Core
AC Current Right	Extension Cord Cable	ACC2	Blue incoming Brown outgoing	15A/500V	White 3-Core
Battery Voltage Left	Charge Controller	DCV4	Blue +ve Brown -ve	6A/500V	2 Thin Blue/Brown
Battery Voltage Right	Charge Controller	DCV2	Blue +ve Brown -ve	6A/500V	White 3-Core
Battery Current Left	Fuse Box	DCC4	Blue incoming Brown outgoing	15A/500V	Black 2-Core
Battery Current Right	Fuse Box	DCC2	Blue incoming Brown outgoing	15A/500V	White 3-Core
Solar Panel Voltage Left	Charge Controller	DCV3	Blue +ve Brown -ve	6A/500V	2 Thin Blue/Brown
Solar Panel Voltage Right	Charge Controller	DCV1	Blue +ve Brown -ve	6A/500V	White 3-Core
Solar Panel Current Left	Charge Controller +ve terminal	DCC3	Blue incoming Brown outgoing	15A/500V	Black 2-Core
Solar Panel Current Right	Charge Controller +ve terminal	DCC1	Blue incoming Brown outgoing	15A/500V	White 3-Core

1.1.3 Modem and connectivity

The modem is able to connect to 2G(GSM).
Mobile No: (+250) 0789528522
Balance at installation: 1000 RWF

1.2 Installation and Troubleshooting Log

05/09/2013
The data-logger was mounted on the wall and the left-side system was hooked up to the sensors. There was not enough cable to complete the right-side system so only one half was installed and tested. The system functioned as expected reading in sensor data and then posting to the app engine.

22/09/2013
3-Core cable was bought in Kigali to reduce the number of wires on the wall. The right side system was installed however the DC Current and AC boards were placed in a separate box to accommodate all the wires. The system worked however the DC voltage board was posting 0V. This was identified in Minazi as an issue with the power board which arose either due to cold solder or a lose connection.

24/09/2013
The inverters shut down and the shopkeeper said that there was a burning smell after this happened. After inspection of the entire system the DC current board had been affected. The battery current sensors had completely burned out. The tracts were no longer connected and the terminal blocks had melted. The solar panel sensors however had minor damage but current path was present and ACS217 chip was intact. The physical damage suggested a short-circuit of the battery. After checking the system it seems that the data-logger created an alternative path for the current to flow as none of the circuit-breakers had been activated. The most obvious possible place where the short could have occurred was at the battery voltage sensor on the DC Voltage Board however there were no signs of sparking.

Another problem, which was noted, was that the MBED seems to have been affected. The data-logger was going through the sampling routine but at a much slower rate and would then reset before posting data to the app-engine. This indicates that the isolation between the sensor inputs and the MBED is not sufficient and can be attributed to a number of factors. As the all the sensor board share a common supply and ground they are susceptible to current surges anywhere in the system. The sensor inputs also have a ground plane underneath them and the melting of the terminal blocks/the tracts blowing up may have caused the large current to flow through the common ground plane thus reaching the MBED.

1.3 System Status

The data-logger is currently not functioning due to the electrical failures mentioned above. The sensor wiring however is still intact and power is still being supplied to the system. With the exception of the solar panel current wires all other connection still go through the data-logger.

2 DATA-LOGGING MINAZI INSTALLATION

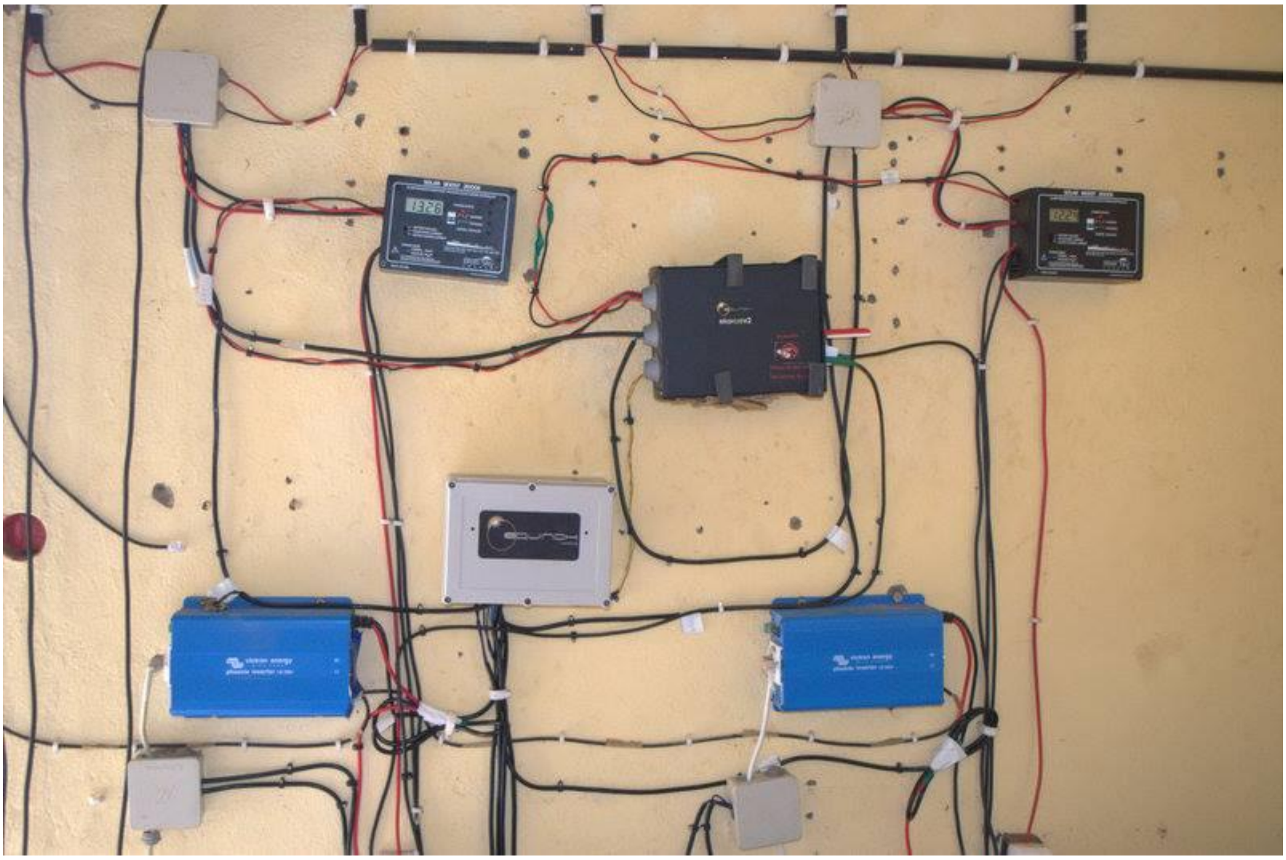

Figure 2 Minazi Kiosk after Installation

2.1 Technical Specification

2.1.1 Power Supply

The power supply for the data-logger was taken directly from the storage batteries to ensure that it runs at all times and as the board is completely DC this eliminates unnecessary conversions. Wire is connected to the battery terminals and is fed up to the data-logger where it is plugged in using a DC Jack. The configuration is as follows:

DC Jack:

- Inner conductor - Positive (+)
- Outer conductor -Negative (-)

Storage Battery (at installation):

- Left – Power Supply 1
- Right – Power Supply 2

2.1.2 Sensor Configuration

Each cable is marked with white tape and labelled with its Board ID for easy identification.

Sensor	Location	Board ID	Connection Polarity	Cable Rating	Cable
AC Voltage Left	Extension Cord Cable	ACV1	N/A	10A/500V	Black 2-Core
AC Voltage Right	Extension Cord Cable	ACV2	N/A	10A/500V	Black 2-Core
AC Current Left	Extension Cord Cable	ACC1	Blue incoming Brown outgoing	10A/500V	Black 2-Core
AC Current Right	Extension Cord Cable	ACC2	Blue incoming Brown outgoing	10A/500V	Black 2-Core
Battery Voltage Left	Charge Controller	DCV4	Blue +ve Brown -ve	10A/500V	Black 2-Core
Battery Voltage Right	Charge Controller	DCV2	Blue +ve Brown -ve	10A/500V	Black 2-Core
Battery Current Left	Fuse Box	DCC4	Blue incoming Brown outgoing	10A/500V	Black 2-Core
Battery Current Right	Fuse Box	DCC2	Blue incoming Brown outgoing	10A/500V	Black 2-Core
Solar Panel Voltage Left	Charge Controller	DCV3	Blue +ve Brown -ve	10A/500V	Black 2-Core
Solar Panel Voltage Right	Charge Controller	DCV1	Blue +ve Brown -ve	?A/?V*	Black/Red Solid Core
Solar Panel Current Left	Charge Controller +ve terminal	DCC3	Blue incoming Brown outgoing	10A/500V	Black 2-Core
Solar Panel Current Right	Charge Controller +ve terminal	DCC1	Blue incoming Brown outgoing	10A/500V	Black 2-Core

*Cable from previous data-logger used for this connection however electrical ratings are unknown.

2.1.3 Modem and connectivity

The modem is able to connect to both 2G(GSM) and 3G(HSPA).
Mobile No: (+250) 0789428168
Balance at installation: 1000 RWF

2.2 Installation and Troubleshooting Log

09/09/2013

Old non-functioning ekoHUB system was removed from the kiosk. Required temporary shutdown of kiosk in order to replace unnecessary connections and re-route sensor connections.

10/09/2013

ekoHUBv2 tested for internet connectivity, sensor function and data storage. After successful testing the system was fixed to the wall however this required a few modifications to the original design. All of the sensing wires did not fit through the grommets in the main box. As a result we had to move the DC Current and AC boards into a separate housing. As the I2C bus can be up to 2 metres long without picking up too much interference this solution was deemed viable.

Figure 3 Extra data-logger housing.

After testing the system over a period of 6 hours we found that the system ran smoothly without any signs of overheating or lose connections. The sensor data was reliable and code ran every 2 minutes as expected. The kiosk does however have a number of dead-spots for mobile connectivity and the data-logger does occasionally suffer from this. The dongle tries to connect to a 3G network which has a weak signal where the data-logger is mounted which results in the connection timing out which resets the program. As a result we tend to get data more often than required.

11/09/2013

The DC voltage sensor was posting 0V values to the app-engine. The supply voltages were checked and the second 5V supply to the board, which drives the initial section of the sensor circuit, was not on. The voltage on the power board output terminals occasionally showed 5V. This suggested either a lose connection or cold solder so the board was re-soldered. Once this was done the voltage sensor board worked reliably.

2.3 System Status

The system is fully functional and data is being received by the app engine.

3 DATA-LOGGER PERFORMANCE & EVALUATION

3.1 Sensor Performance

DC Voltage Sensors

The sensor worked as expected and the values were consistent with direct voltmeter readings with an uncertainty of ±0.1V. The raw data readings stayed within range and successfully registered both positive and negative currents.

DC Current Sensors

The sensor worked like the DC voltage sensor however the uncertainty was slightly larger at ±0.3A. The raw data readings stayed within range and peaked at around 900.

AC Voltage Sensors

The sensor suffered heavily from noise interference. This can be seen in the raw data values received over the course of a day. Even though the voltage is constant at around 228 Volts the raw data values sent to the app engine vary from 250 to 600.

AC Current Sensors

The sensor was consistent and reliable however the exact values could not be checked. The raw data values varied with the changing load giving the following results: 5 without load, 10-20 with medium load and 30-40 with high load.

3.2 Possible Improvements

The improvement suggestions below have come from the experience of installing the equipment on-site and are mainly addressing issues faced on the ground. Therefore it will not include significant circuit level suggestions but rather will focus on the design elements of the data-logger.

3.2.1 Mechanical Design

The physical design of the box within which the data-logger is put needs considerable improvement as many of the delays faced during installation occurred due to difficulties in accessing certain parts of the circuit.

- Access to sensor boards - In order to test the sensor boards voltage readings at test points need to be taken and this requires a certain amount of space above the PCB to access.
- External programming cable - While installing the MBED was reprogrammed a number of times and this proved to be very difficult with the current model and resulted in a number of connections being broken every time this had to be done. To make this easier the mini USB port on the MBED could be extended to the faceplate (the way in which the modem and power supplies currently are).
- External SD card slot - For similar reasons as above a port on the faceplate for the SD card would make it easier to retrieve the data.

3.2.2 Electrical Design

- Molex connectors - The terminal blocks currently used for the sensor and power inputs to each PCB are not robust enough to ensure that connections will hold over time. In addition they make the board highly susceptible to short-circuits as wires have to stripped before being inserted into the terminal blocks. Molex connectors would solve this and they use crimps and are then insulated. Also physically they use clips making it less likely for a connection to be pulled out.
- Cable selection - The wire used for voltage sensing can be much smaller as the currents drawn will be very small. This will make it easier to identify the different sensor wires and also reduce cost. The current sensor wires should be kept at a rating above 15A to ensure that the maximum capacity is not reached as on a sunny, clear day the solar panel currents have risen to up to 12A.
- Isolation and Protection **-** The isolation in the system is insufficient as evident from what has happened in Batima. One minor change that could be made to the PCBs is that the ground planes not be extended to the terminal blocks. This will reduce the possibility of large current reaching the common ground and affecting the whole system. Also fuses can be placed at the inputs according to the cable ratings and at the supply input to each board. The points at which the voltages and current are tested must be chosen with caution to ensure that the circuit breakers are not compromised and alternate current paths created.
- Electromagnetic Interference Testing - As the kiosks charge multiple phones and the data-logger itself uses a modem for internet connectivity the EMI susceptibility of the sensors should be tested and account for in the next revision of the ekoHUB.

3.2.3 Others Ideas

- Weather Station **-** In order to give meaning and context to the data received on the app-engine the weather conditions are required. This would include ambient light, temperature, humidity and wind speed all of which influence the power produced by the solar panels.
- Battery Box Integration **-** A possible integration of the battery boxes with the data-logger to get accurate usage data would be to use the data output of the PIC to register a charging cycle.

4 FRANCHISE MODEL

The Franchise Model concept was initiated from the lessons learnt from the Energy Kiosk model and the development of the Stand-alone since 2012. The idea has been undergoing vigorous development and serious thinking process in late 2012, and has undergone major changes. In 2013, the fundraising team has won £1,000 from IC Startup for the project.

The original plan was to deploy a small scale franchisee as a pilot start to test the feasibility of the idea, with 10 USB charged LED lanterns and using the new Izuba.Pro as the solar system for the franchisee to charge the lanterns. However, due to manufacture delays, Izuba.Pro was not delivered in time and hence the pilot scheme was not deployed. Instead, a more thorough market research was done on the franchisee. The team realised that phone charging business has become extremely popular, even in the most remote village of Rwanda, and therefore developing new ideas to be based the model on existing phone charging business instead.

Until now, the project is still under R&D team and Stand-alone Project. It is hoping to spin off as a formal project in the coming year.

4.1 Conclusion from Market Research

A thorough investigation on the market of Franchisee was done during the expedition. There have been a number of findings, as listed below:

4.1.1 Phone Charging Business is very popular

Nearly all village centres have a shop or store operating phone charging business, regardless of the supply of grid electricity. For villages that are not grid connected, they operate on car batteries, and charge their batteries every 3-5 days at the nearest grid connected spot (usually the spot where they import their goods sold into the village). Most shops charge 10-20 phones a day, and it seems quite a profitable business. There exist some villages where there were more than 4 phone charging businesses, with one buying solar panels (which was deemed oversized by us) and was set up by some freelance technicians working in the health centre or schools equipped with solar.

From this information, it seems that it may be a good idea to reposition our model so that it is based around phone charging, as supposed to that being an extra feature. The market has shown a demand for good quality cheap solar setup that allows businesses to charge the customers' phones without making the trip frequently. The team has interviewed many phone charging businesses in non-grided areas, and most of them has shown interest.

But continuing the initial aim to provide lighting, the rechargeable LED lanterns can be provided to the franchisee as part of the product range. Logistically they can be recharged from the battery, just as the phones.

An advantage for us if we take on this model is that we would not need to provide much training since this is the format existing businesses are used to. Also, the technicians mentioned above could be employed to deploy more franchisees and provide after sales service.

4.1.2 Larger sizing

With the findings in this market research and consideration of repositioning our product, we found that the original Izuba.Pro would not have fitted the franchisee's purpose in their phone charging business, given that they charge 10-20 phones per day. A “Super Pro”, sizing range around 100 W panel and 50-70 Ah, is a much better technical solution. Here is a rough calculation:

Assuming:
Phone / LED lantern charge per day: 30
Battery size: 2000 mAh
Battery charging voltage: 5V
Energy used per day: 30*2*5=300Wh

The Stand-alone team has already planned to develop such sizing solar system in the coming year.

4.1.3 Non-grid connected area is logistically difficult

More and more villages along the main roads of Rwanda are getting connected with grid, thanks to its expansion. Since the Franchise Model is designed to work only in non-grid areas, location for deployment should not be part of the government’s plans of electrification in the next 5 years. However, such places would usually be extremely remote. During the expedition, our team has faced the toughest transport we have ever experienced when we visited some of these potential locations.

This means that future visits to the franchisee could present logistic and operation problems; hence why both the business and technical solutions require further improvements, so that it can be self-sustaining and future proof. It is recommended to hire local technicians to help with maintenance, but we have to ensure that the technicians are well trained and be of integrity.

4.2 Evaluation and future plan

After the expedition, our team has understood much better on how the market is working and its current trend. It has been an invaluable experience to further develop the model. Some major changes have been made from the lessons learnt, and the model has become more realistic and answering market demand.

It is perhaps fortunate that we were not able to deploy the pilot scheme, since it was based on conjecturing and unrealistic break-even analysis and sizing. It is recommended that for any future project in e.quinox, a market research like this should be done before further development and deployment.

5 BATTERY BOX

The Battery box project 2013 took a step away from the previous year's initiative to manufacture the product in Rwanda. The reasons for this stemmed from wanting to reassert our image at the Rugaragara hydro site, where reports were received of the boxes failing. This meant creating a high quality, professional looking product which would restore local faith in the project.

We also wanted to evaluate the potential for more modular assembly, which could be adopted by a large NGO or charity as a simple but effective investment in an area. This meant doing away with the manual manufacture, adjustment and assembly carried out by locals. We found in 2012 that employing local people, whilst rewarding to the community, required a high level of supervision and effort for a relatively low state of reliability and quality.

The new design was implemented in September 2013 and achieved a very professional finish. The overall cost of the boxes was higher than the previous years, but this was seen as necessary for the investigation, and could be reduced through refinements and mass production.

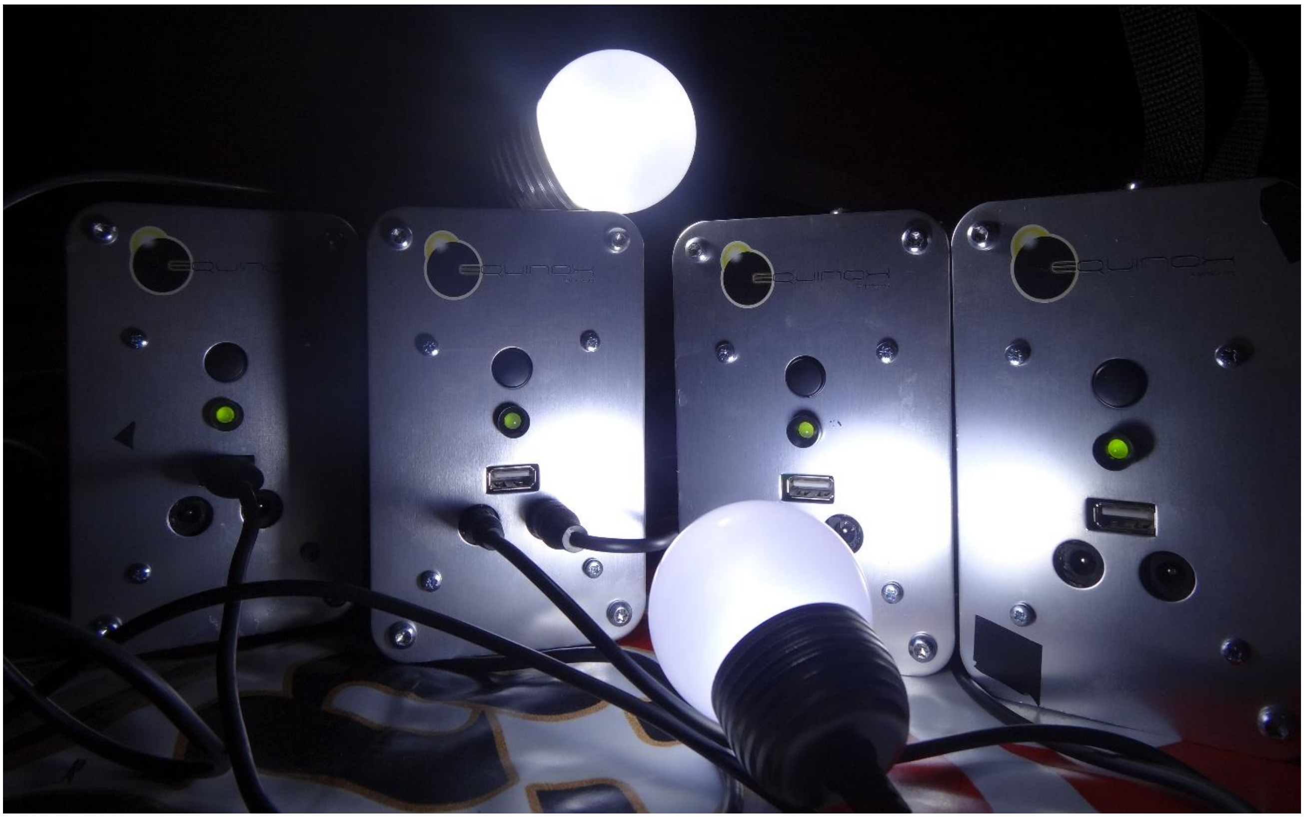

Figure 4 2013 Battery Boxes

6 HYDROELECTRIC TURBINE AT RUGARAGARA

The report includes a large amount of media-rich content and contains a significant amount of technical specifications covering the design and implementation of the hydro-electric turbine installed in Rwanda this year. The report can be found at the following link:

http://www.e.quinox.org/reports/2013_Turbine_Manufacture.pdf