# Night fishing with solar powered LED lights on Lake Tanganyika

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## Abstract

Kigoma is located in the western extent of Tanzania, on the eastern shores of Lake Tanganyika. Kigoma Town and its rural surrounds are not linked to the national electricity grid, having instead to rely on small diesel-based mini-grid systems reticulated through the urban village centres. Fishing is an important economic activity in the Kigoma region, focused on Lake Tanganyika. The fishermen fish at night using pressurized kerosene lanterns to attract fish to the surface and their nets. This has important environmental as well as financial consequences for the lake, fishermen, local community and wider region. As part of a solar photovoltaic market development project funded by the Millennium Challenge Corporation, solar-powered LED lighting systems were designed and supplied to the fishermen on financed terms. This paper looks at how this was done, including technical design aspects, financial feasibility and commercial sustainability; as well as the eventual outcomes and the greater opportunity presented by this intervention.

**Keywords:** Night-fishing, Kerosene, LEDs, Solar, Productive Use,

## Introduction

The Millennium Challenge Corporation (MCC) has a compact with the Government of Tanzania, managed through the Millennium Challenge Account-Tanzania (MCA-T). There are three basic areas of investment within the compact framework: Transport, Energy and Water. Under the Energy sector activities, a solar PV programme was proposed which would provide investment in energy access for the Kigoma region. A $5 million project was designed by MCA-T and appointed consultants.


*Figure 1: Kigoma region*

The programme design utilised the Sustainable Solar Marketing Package (SSMP) framework, with a baseload of public sector solar PV installations, including secondary schools, dispensaries, health centres and village markets, with additional components designed to support the overall sustainability of the solar installations. For the desired effect of stimulating a regional PV economy, opportunities within the private and household sector needed to be identified and leveraged. Important amongst these opportunities were the night fishing activities on Lake Tanganyika: boating pairs, consisting of two boats with three to four people per boat, fish at night using kerosene lanterns to attract the fish to their nets. Each boating pair consumes around 20 to 30 litres of kerosene per night. The Kigoma Solar PV programme presented an opportunity to pilot the introduction of solar powered, battery-operated LED lights as a replacement for these inefficient, dangerous and polluting kerosene lanterns.

*Figure 2: Fishing boats on the Lake Tanganyika shore*

As part of the Kigoma Solar PV Programme, the contactor was therefore required to pilot 30 double systems of solar powered LED lighting rigs with 30 boating pairs on Lake Tanganyika. The night fishing sector represents an important private sector market which has the potential to contribute significantly to a longer-term sustainable, commercial solar PV industry in the region. The principal objective was to successfully pilot the solar powered LED lighting systems to showcase an effective and sustainable alternative energy source for night fishing. There are an estimated 8,000 night fishing boats operating on the Lake Tanganyika and over 17,000 across the full extent of Tanzania's lakes and oceans (Gengnagel, T. et al: 2013). This represents a significant long-term market.

## Counting the costs of kerosene

The current practice of using kerosene lamps is extremely costly to the fishing boat owners. Kerosene is a hydrocarbon, the price of which is directly linked to the global oil price. In addition, the cost of transporting the fuel from Dar es Salaam some 1200 km inland to Kigoma exerts additional upward pressure on fuel prices. The introduction of solar powered LED lighting rigs was aimed at reducing the overhead costs associated with night fishing. According to a recent report, the costs of kerosene represent 35%-50% of the fishermen's earnings (Gengnagel, T. et al: 2013). A significant reduction or elimination of kerosene use for lighting would significantly lower the overheads faced by the fishers, in turn increasing their profits. The night fishing industry is a key regional economic activity.

## Developing an appropriate lighting rig design

The lighting setup currently utilized by the fishermen is based on eight kerosene lamps, positioned around the boat. Light is ineffectively directed downwards with a reflective collar.

The solar system designed for the night fishing application has the following features:

- Dedicated solar array (270Wp) with central battery (120Ah/12V, sealed) and five water proof LED spotlights (6W), switched individually;
- State of charge controller with LCD bar graph or % display in IP65 housing;
- DC connector between solar array and change controller, suitable for multiple reconnection while maintaining good contact (Anderson connector);
- The solar array is land-based;
- The charge controller and battery is housed in a plastic crate, with a cut out for the LCD display, while the Anderson connectors for the solar input and the light output are located on the side of the crate. The crate can be carried to and from the boat by either one or two persons;
- The five LED spot lights come with a 5m rubberized cable lead each that is connected to a single junction box with switches.

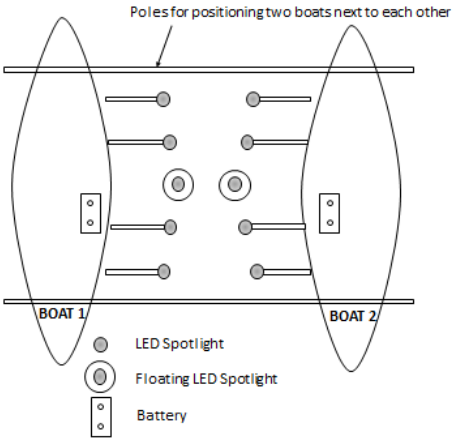


*Figure 3: Diagrammatic presentation of lighting setup*

The system was sized with the objective to recharge the batteries even under inclement weather conditions. Although the typical draw down during a night on the lake is approximately 25Ah (or 20% daily depth of discharge) the solar array is capable of charging approximately 2.5 times as much on a clear day. The overdesign is essential as to avoid the fishermen having to switch back to kerosene lamps in the rainy season.

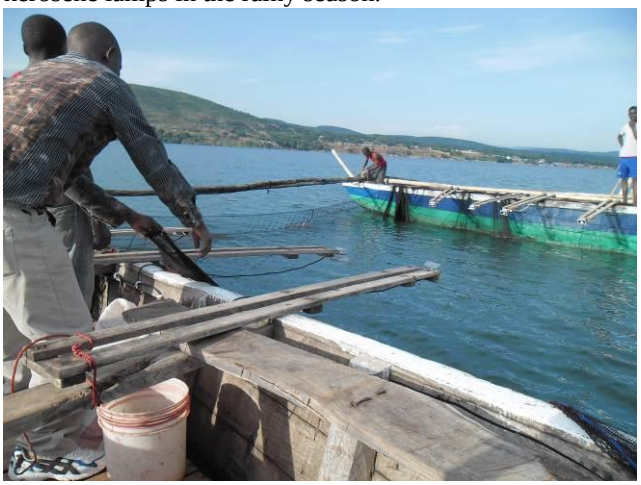

*Figure 4: The LED lights on the boats*

## Improving health and safety aspects

The widespread use of a flammable fuel such as kerosene will always be accompanied by some level of hazard. These night fishing activities are no exception. Anecdotal evidence pointed out that boat-fires caused by falling lanterns was a relatively common occurrence[1], while other researchers have noted that fishermen had sometimes complained of vertigo caused by the vapour of kerosene lanterns (Gengnagel, T. et al:2013).

## Promoting environmental benefits

The key environmental concern linked to the use of kerosene is the carbon dioxide ($CO_2$) emissions associated with its burning. One litre of kerosene emits approximately 2.69 kgs of $CO_2$ (US EPA, 2011). Considering the extent to which night fishing practices rely on kerosene (20-30 litres/boating pair/night) the associated $CO_2$ emissions are considerable and have a very clear and negative environmental impact in terms of climate change. In addition, the Black Carbon[2] associated with burning kerosene lanterns is a further environmental concern (Jacobson, A. et al: 2013).

## Piloting systems

While the costs of the systems were covered by the MCA-T investment, the approach agreed upon by contractor and monitoring consultants was that 30 double systems could be made available at a discounted rate to facilitate access to this unfamiliar technology, while at the same time underscoring the long-term commercial nature

[1] Personal correspondence with a number of fishing boat owners and boat captains in and around Kigoma

[2] A particle rather than a gas, Black Carbon is a powerful absorber of sunlight. Black Carbon comes from incomplete combustion and is closely associated with, amongst other sources, rudimentary, wick-based, kerosene lanterns.

of this opportunity. The systems were distributed on the following basis:

- The first 10 double systems were made available to local boat owners who had expressed an interest in the technology through participating in the design tests, workshops and meetings. These were made available at $600 a system, which amounts to $1,200 for the required double system. Participants were allowed a two-month trial period, after which they either had to return the system or purchase at the agreed rate.
- The remaining 20 double systems were made available after the 2 month trial involving the 10 systems. These remaining systems were made available at $800 a system or $1,600 for the double system required. No trial period was applied as the 2 month pilot had provided enough time to understand the benefits (or otherwise) of the systems.
- The contactor provided a level of finance, allowing fishing boat owners to pay off the system in three monthly installments.

## Research Objectives

This paper's objective is to assess the feasibility, outcomes and potential impacts of the night fishing component of the Kigoma Solar PV programme.

## Methods

Research methods employed include surveys, focus groups and interviews. Results were triangulated using different research methods.

We undertook a two-month baseline study involving five boating pairs. Boat owners were requested to record every expense associated with the kerosene lamps, including the lamps themselves, wicks, mantles, chimneys, matches and the kerosene fuel. We also monitored the fishing catches associated with both the LED using fishing boats and non-LED using fishing boats. This was a very limited study (over four days, involving five boating pairs) but was supplemented by additional feedback gained through monthly meetings with boat owners' unions as well as a workshop held towards the end of the project where all boat owners and captains were invited.

## Results

The results from the baseline survey are presented in the table below. With the exception of Boating pair_2, the monthly costs of kerosene were fairly similar, with a range of $485 - $655 spent in a month. The relatively low costs associated with Boating pair_2 ($223) is due the lower number of fishing trips[3] undertaken. The average monthly cost of utilizing kerosene lanterns for night fishing was determined at $515 a month.

*Table 1: Monthly cost of kerosene*

| | Boat pair_1 | Boat pair_2 | Boat pair_3 | Boat pair_4 | Boat pair_5 |
|---|---|---|---|---|---|
| Total TZS* | TZS 1 509 550 | TZS 691 550 | TZS 1 737 520 | TZS 2 029 800 | TZS 2 029 800 |
| Total $ | $973.90 | $446.16 | $1 120.98 | $1 309.55 | $1 309.55 |
| Total $/month | $486.95 | $223.08 | $560.49 | $654.77 | $654.77 |
| **Average monthly expenditure:** | | | **$516.01** | | |

* TZS is the Tanzanian Shilling. The exchange rate with the US$ was 1600/1

Once the two month trial period for the first 10 double systems was concluded, all boat owners elected to buy their systems and paid a 1/3 deposit ($400). Five months after the introduction of the first system and three months after the conclusion of the initial pilot, all 30 double systems were sold, installed and operational on the lake.

In terms of the fishing catch associated with the use of LED lights as opposed to kerosene lanterns, we were able to monitor the catch of 5 fishing boat pairs (two with LED lighting systems and three with kerosene) over a four day period. The results are included in the table below.

*Table 2: Catch rates for LED & kerosene boats*

| | Catch (crates) | | | |
|---|---|---|---|---|
| | Day 1 | Day 2 | Day 3 | Day 4 |
| LED boating pair 1 | 1.5 | 0.25 | 0.5 | 1.75 |
| LED boating pair 2 | - | - | 1.75 | 1.75 |
| Kerosene boating pair 1 | 5 | 0 | 0 | 0 |
| Kerosene boating pair 2 | 1 | 0 | 0 | 0 |
| Kerosene boating pair 3 | 0.5 | 0 | 0 | 0 |

The catch is recorded in crates, which hold in the region of 80kgs of fish. Each of the three kerosene boats only caught once out of the four days, while the first LED boating pair caught every day. The second LED boating pair caught on day three and four but did not launch on the first two days. While the kerosene boating pair 1 caught the most over the four day period, it was the LED boats that were the most consistent catchers. Although the monitoring opportunity was limited, the results suggest that solar powered LED lights offer an effective alternative to the kerosene lanterns.

In addition to this limited monitoring of the five selected boating pairs, a number of meetings were held with the fishing boat owners and the boat owners'/captain's unions. The overall impression was that solar powered LED lighting rigs were as effective (if not more so) than kerosene lanterns and would prove to be significantly cheaper in the long-run.

At a workshop held for boat owners and captains towards the end of the MCA-T Compact in 2013, slightly more than 20 of the 30 boat owners that had bought the pilot systems were in attendance, as were many of the boat captains. While some issues were raised around security on the Lake[4] and moisture within the lamps, all participants pointed out how costs have been significantly reduced, while catches had remained constant, if not increasing; as one representative from the local Department of Fisheries pointed out: "for the first time in many years, there are fishermen on the lake making a profit"[5]. Comparing the lifecycle or integrated costs of kerosene and solar powered LEDs over a 5 year period, it is clear from the tables below that the potential savings are considerable.

[3] Boat owners may decide not to send out their boats due to poor weather, crew availability, cashflow, engine problems, etc.

[4] Pirates have been known to harass the night fishing boats.

[5] Recorded as part of the minutes from workshop proceedings.

*Table 3: Costs over 5 years for solar LED lighting rigs*

| System costs | Battery costs* | Cabling** | Lights*** | Unforeseen**** | Total |
|---|---|---|---|---|---|
| $3 240 | $800 | $800 | $1 000 | $584 | $5 840 |
| * Battery replacement every 2 years @ $200/battery | | | | | |
| ** Replace cables every year @ $200/year (system costs cover 1st year) | | | | | |
| *** Lights - estimated $250/year (system costs cover 1st year) | | | | | |
| **** May include post-warranty technical issues. Calculated at 10% of total | | | | | |

The estimated commercial cost of a 270Wp solar PV system in Kigoma would be in the region of $6/Wp fully installed. The market related cost of a double system is therefore $3240. By looking at costs over a longer period, the on-going or ancillary costs such as battery replacements, new cabling, replacement lamps, etc. offer a more integrated cost profile, allowing for a comparable cost analysis with kerosene.

*Table 4: Costs over 5 years for kerosene lighting*

| Monthly costs* | Active months/yr** | # of yrs | Total cost |
|---|---|---|---|
| $500 | 9 | 5 | $22 500 |
| * Rounded down outcome of baseline survey | | | |
| ** Assuming boats are inactive for 3 months a year | | | |

The costs of using kerosene lanterns over a similar period were considerably higher at $22,500. The shift to solar powered LED lights therefore offers a saving in the first 5 years of over $275 a month, or 55%.

*Table 5: Cost savings using solar powered LED lights*

| | |
|---|---|
| Estimated savings over 5 years | $16 660 |
| Average annual saving | $3 332 |
| Average monthly saving | $277.67 |

If we extrapolate these findings to the wider Kigoma region, as well as the rest of Tanzania, we get the following potential financial savings:

*Table 6: Potential Financial Impact*

| | |
|---|---|
| Annual savings/boat | $ 1 666.00 |
| Night fishing boats: Kigoma | 8 000 |
| Annual savings: Kigoma | $ 13 328 000.00 |
| Night fishing boats: Tanzania | 17 000 |
| Annual savings: Tanzania | $ 28 322 000.00 |

In terms environmental impacts, the following $CO_2$ emissions savings are estimated based on current results:

*Table 7: Potential Environmental Impact*

| | |
|---|---|
| CO2 emissions per litre kerosene (kg) | 2.69 |
| Litres of kerosene used per lantern/night | 1.25 |
| Lanterns per boat | 7 |
| Fishing nights per month | 20 |
| Monthly CO2 emissions/boat (kg) | 470.75 |
| Annual CO2 emissions/boat (kg) | 5 649 |
| Annual CO2 emissions: Kigoma | 45 192 000 |
| Annual CO2 emissions: Tanzania | 96 033 000 |

## Discussion

This study faces a number of limitations, primarily the small study/pilot population and the short time-frames used to measure impacts. Where possible, these have been addressed through triangulating results. Still, there is a need for ongoing monitoring and robust evaluation of the results and impacts related to this initiative.

Nevertheless, the pilot of 30 solar powered LED lighting systems for night fishing has demonstrated the feasibility and effectiveness of alternative lighting technologies. The 'test pilots' have reduced the perceived risks associated with investing in new technologies for the other boat owners. There is little doubt that solar PV lighting will play an increasingly important role in night fishing activities on Lake Tanganyika.

The program showed that overall the components held up well. Challenges included batteries not being fully recharged (not connected to the solar array in time, or technical problems), poor seals in the LED spotlights (IP65 was not maintained), cable breakage (daily reinstallation on boats) and wear and tear on waterproof light switches.

Perhaps the most important feature of this initiative is its potential contribution in terms of creating a sustainable solar PV market in the region. The long-term objective behind solar PV initiatives in developing countries is to establish a sustainable commercial market for the technology, leveraging further investment in the sector.

The commercial approach implied resonates closely with other global energy technology initiatives within developing countries, including the Global Alliance for Clean Cookstoves and Lighting Africa[6]. With this overall objective in mind, the development of the Solar PV LED lighting solutions amongst fishing communities is crucial for the long-term commercial underpinning of the Kigoma Solar PV Programme.

To this end, further efforts are required to develop and shape this commercial opportunity. These include:

- Developing finance solutions and products that facilitate access to this technology. While solar powered LED lights make financial sense over time, the 'first cost' constraints will need to be addressed to improve access. There are a number of traditional savings associations (SACCOs) and micro finance institutions (MFIs) which could develop appropriate solutions for this purpose[7].
- Technical standards should be developed, agreed on and enforced by the Department of Energy, Tanzanian Bureau of Standards as well as the Solar Industry to guide the design of these solar PV units and accompanying lighting rigs,.
- The Department of Fisheries and other relevant government entities need to promote the use of solar PV lighting solutions on Lake Tanganyika as well as other lakes and coastlines across Tanzania.

## References


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[6] www.cleancookstoves.org and www.lightingafrica.org

[7] The Kigoma representative of Pride (MFI) agreed to explore partnering opportunities with the local fishing boat owners union (Kiribizi) in the coming months.