Humanitarian Aid
and Civil Protection

Global Solar and
Water Initiative

Global Solar and Water Initiative

Visit Report to Borno State Nigeria
12th – 19th June 2017

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1. Executive Summary and Recommendations

The Global Solar and Water Initiative team undertook a visit to Nigeria in order to assess selected existing solar pumping schemes, evaluate the feasibility to solarize water supply points in selected camps and raise awareness and solar technical expertise among WASH stakeholders in the country. 19 water supply schemes were visited in Maiduguri and Gwoza with 9 systems already solarised but with majority having insufficient data for analysis of the design and performance.

Some of the sites could only be accessed through helicopter and this hampered some planned visits due to bad weather.

Solarisation has been done in all the locations visited. Whereas a technical and economic feasibility study is absolutely vital not only to ensure coherent design but also to determine the cost effectiveness of the solarisatio, this has not been the case. Certain parameters have not been taken into account when planning installation with some agencies using a one-size fits all approach.

In all the cases where underperformance of existing solar systems was reported, it was found that it had to do with lack of technical understanding to be able to design or replace a system to meet the requirements.

The visit entailed collection of relevant data needed for full techno-economic analysis of the systems, in order to determine feasibility for solar pumping as well as gauge the design and performance of solarised schemes. Absence of basic data such as safe yields, water outputs or water levels made not possible to analyse all the visited water points. Its absence put into question the basis for some of the existing solar designs.

Climatological and hydrogeological conditions in the locations visited were favourable, making the use of solar pumping a technically feasible solution for each and every borehole assessed.

Wide support and prioritization given by some donors to solar solutions in Nigeria, together with a high solar irradiation through the year make the context good to use solar pumping in the country. The Nigeria government has solar pumping technology explicitly mentioned in the Partnership for Expanded WASH (PEWASH) Programme towards as the preffered source of energy motorised schemes.

Other enabling factors in favour to the use of solar pumping are summarized in the following table:

CLIMATE & HYDROGEOLOGY All boreholes analyzed conducive to be solarised	**SOLAR PRICES** Competitive prices of solar equipment in Nigeria market	**NATIONAL TECHNICAL EXPERTISE** Available in the Private Sector at capital level.
INVESTMENT IN SOLAR Solar pumping not new in Nigeria, projects since 2006	**RELIABILITY OF TECHNOLOGY** Presence of high quality products in Nigerian market	**CURRENT CONTEXTUAL SITUATION** Erratic fuel supply, absence of grid, difficult access (rain, insecurity)

Following the visit, a technical and economic analysis of the water points was carried out. The technical analysis took into consideration the water demand based on the population data provided by implementing agencies as well as either the safe yield of the boreholes -when available- or the current pumping rate, in order to ensure over-abstraction would not occur. Several sites had insufficient data for analysis.

From the economic point of view, a Present Worth analysis over the longer lifespan of equipment (solar panel, 25 years) was carried out, using an average Real Interest Rate of 9.6% (World Bank data, details of methodology in annex A). This rate implies an amelioration of economic conditions over time; in case this would not become true, the case for solar would be stronger since future costs related to O&M are much lower for solar systems than for diesel ones.

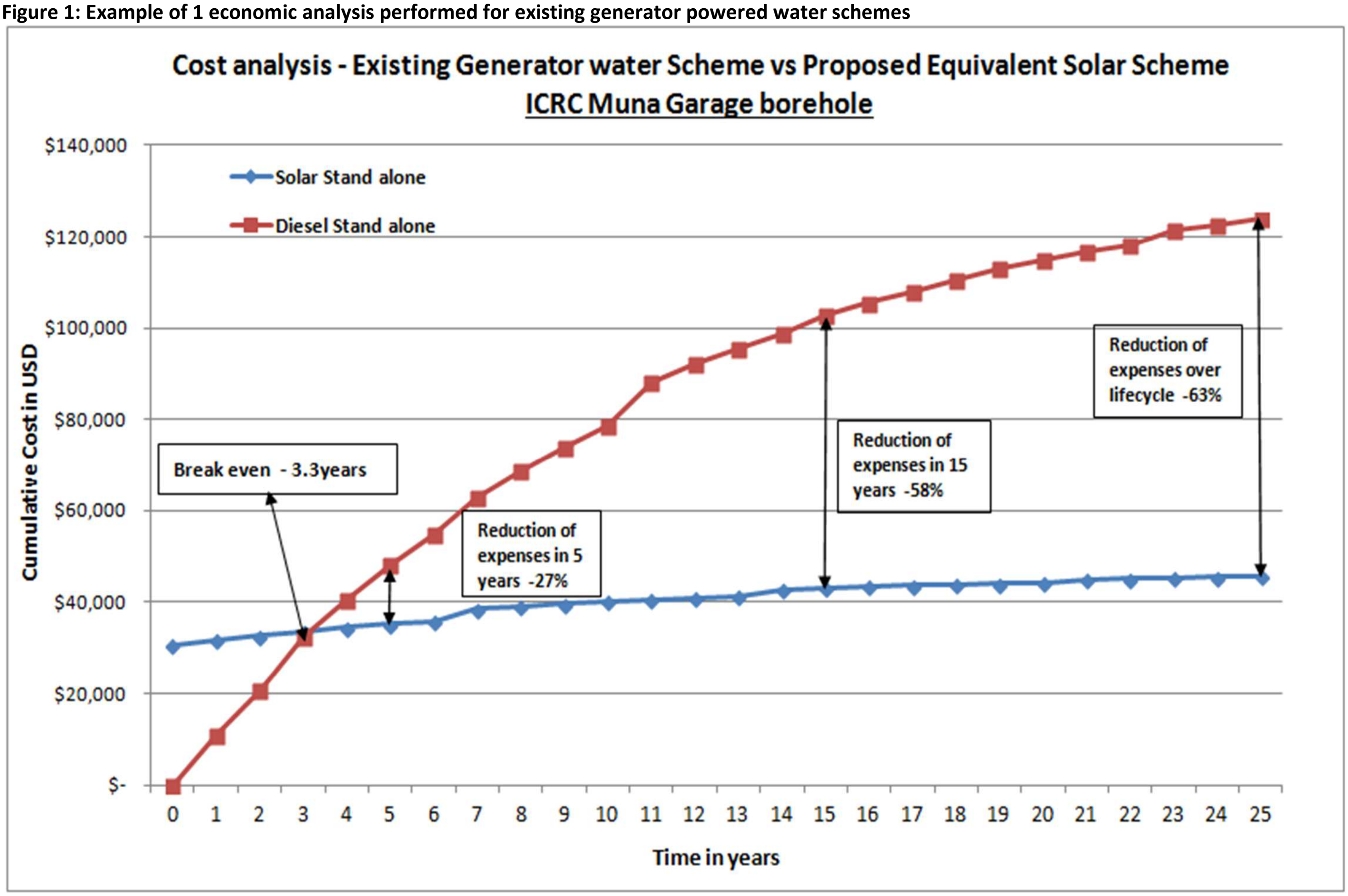
Solar material prices were received from private sectors players in Lagos and these were used against existing quotations given by implementing agencies to prepare a generic pricing matrix for the analysis.

1.1 Existing water schemes powered with stand-alone generators

Visits to 3 schemes which are powered with generators alone, with proper data collected or provided by the implementing NGO, was carried out. Recommendations were produced to motorize them all with either small or medium-sized solar stand-alone systems (see Table 1).

An economic analysis was run comparing the proposed solar systems with the existing stand-alone generator ones. The analysis shows an average breakeven point for the solar investment of 3.5 years, and an average reduction of overall expenses (capital costs plus O&M over time) of -52%. In other words, overall cost of the solar systems proposed is less than half of their equivalent diesel generator ones.

Figure 1: Example of 1 economic analysis performed for existing generator powered water schemes

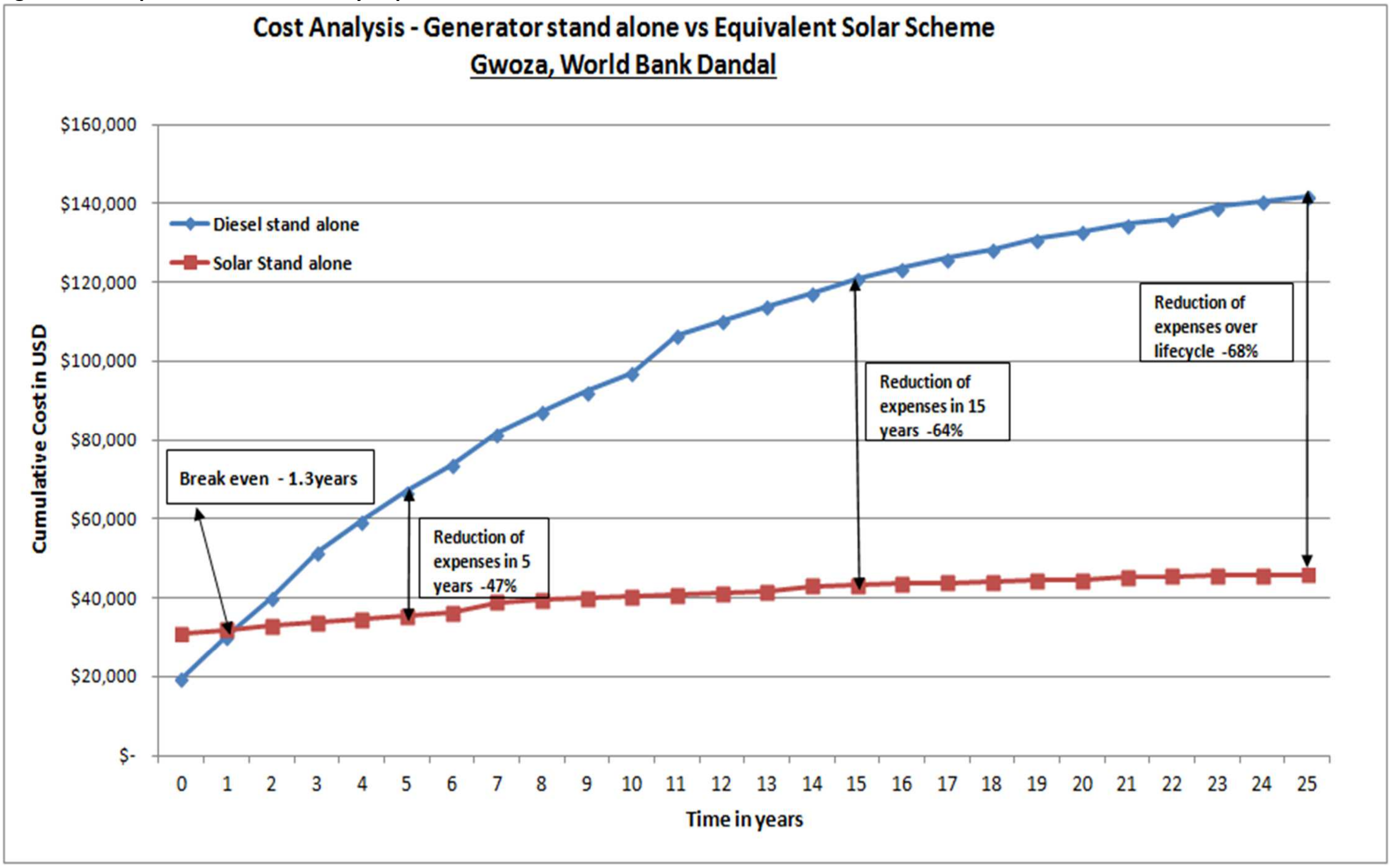


1.2 Existing non-motorised water schemes

7 non-motorised systems were encountered and recommendations were produced to motorize them all with either small or medium-sized solar stand-alone systems (see Table 1).

A similar economic analysis carried out comparing the cost of generator stand alone with equivalent solar stand alone. The analysis shows an average breakeven point for the solar investment of **1.0 years, and an average reduction of overall expenses (capital costs plus O&M over time) of -57%.**

Figure 2: Example of 1 economic analysis performed for non-motorised boreholes



In both of the above scenarios (i.e. existing generator powered and non-motorised systems), the overall cost of the solar systems proposed is less than half of their equivalent diesel generator ones meaning over a 25 year period, a generator operated system costs 2-3 times as much to own as a solar system.

Even though the initial investment for solar powered systems is still slightly higher than for motorised systems, solar powered systems are becoming more competitive in price where strong market competition exists.

It is clear also that the more organizations can maximize solar water output of each borehole, the shorter the Return on Investment will be and the more cost-effective the scheme will prove.
Besides cost factors, higher attention should be given to places where security of equipment and its maintenance can be better warranted, and especially if fuel supply is erratic.

It is also to note that given the context, priority of solar-diesel hybrid systems (as opposed to stand alone solar ones) should be given in camps where population figures are not well known or can significantly increase in the short term, where the behaviour of the exploited aquifer remains largely unknown or for isolated boreholes where malfunctioning of the system would have severe impact in the served population.

Otherwise and whenever possible, stand-alone solar systems should be prioritized as they are the most cost effective solutions and the payback period of the investment cost is shorter. A well calculated safe yield coming from a proper 72h pumping test is a critical factor for the right sizing of any solar scheme, and this should come before proposing any definitive technical design to mechanize a borehole.

In addition, it has to be considered that mismanagement of fuel supplies and theft is a common issue; therefore, any option involving adoption of solar technology will limit this problem, with cost-savings likely higher than the ones expressed in the analysis below.

Finally other aspects beyond economic considerations (such as sustainability, reliability, possibility of running equipment regardless of access to area and environmental issues) should be discussed in favor of the solar option.

1.3 On existing solar pumping schemes

Solar water schemes have been implemented in Nigeria for the last 10years with agencies favouring the use of existing boreholes for solarisation often without sufficient hydrogeological testing which could lead to problems post-installation. In addition a technical and economic feasibility study is important not only to ensure coherent design but also to determine the cost effectiveness of the solarisation, but this has not been done and certain parameters have not been taken into account when planning installations with some agencies using a one-size fits all approach. One solarised borehole was found abandoned due to low yield bringing to light the problem of widespread unavailability of borehole data on which to base design as well as the lack of proper analysis to determine the feasibility for solarisation.

In all the cases where underperformance of existing solar systems was reported, it was found that it had to do with a lack of technical understanding to be able to do a design that meets the requirements and also lack of knowledge on expected performance of the installed systems. Case in point is the Chad Basin Development Authority where the original pump was replaced with a lower stage pump effectively reducing the output.

A variety of other problems were also encountered, namely: wrong pump dimensioning, wrong orientation of modules, panels being blown off due to inadequate fastening and weak support structures, systems with inappropriate starting switches and unnecessary use of generator when solar is sufficient to meet the demand. Majority of the systems visited were manually operated and on one instance a tank was seen visibly overflowing leading to water wastage and safety concerns.

The low solar technical expertise encountered among humanitarian WASH staff might explain these problems, bringing to light the need for field teams to have skills to be able to correctly monitor installations. Finally, and on the issue of theft of panels, which is a common problem in other countries visited, there were no cases of panel theft reported which could be due to their close proximity to the users.

The absence of data (safe yield and water output) for some 6 solarised boreholes made it not possible to carry out the analysis to see whether the solar potential of the water points were maximized.

It terms of costs, it should be noted that the economic analysis done for the existing solar systems (see Table 4), show that the 3 the solar schemes installed by Oxfam in Maiduguri and Gwoza have already paid back the solar capital investment.

1.4 Solar Pumping at Community level

While technical solar pumping offers similar advantages as in camps, working at community level has an extra-layer of complexity related to the O&M of equipment.
Contrary to the widespread idea that once installed, solar schemes will last long years on their own, after installation support is important especially from the first 18-24 months to ensure long lasting solar schemes.

Therefore, when considering to use solar at host community level, supporting technology alone is not a recommended approach since models for proper O&M should come before technology.

A well thought approach, involving contribution from users and a good system to provide after sale support when needed (either from district water office, water utilities or private sector companies) is of great importance, as most likely communities won't be able to solve certain problems on their own, even if trained.

Agencies intending to undertake such projects should also have a management plan in place in the form of a service and maintenance schedule with local private sector (or other relevant and knowledgeable party), for sustainability.

1.5 Other issues

The single most important barrier towards a successful solarisation of water points in the camps is the low solar technical expertise of WASH field teams involved in water supply projects.

WASH organizations are reliant on the private sector to provide solutions which has the risk of commercial interests taking precedence over optimal solutions.

In addition there has been an ad hoc approach towards adoption of solar pumping without proper life cycle analysis to inform decisions and funding. Towards this 3-day training was conducted in Maiduguri between 20-22 November with the presence of 34 WASH officers coming from 10 WASH organizations that are implementing in Northern Nigeria. Tools, documents and contacts for remote technical support were provided during the training.

However it would be important that all organizations and specially coordinating agencies build their own technical capacity and take a lead to organize refreshment trainings.

This could be done by taking advantage of the knowledge already present at private sector level and widening and adapting the scope of these trainings to address real problems encountered in the field.

Besides, capital costs can be reduced through bulk procurement and/ or signing of framework agreements to get large quantities of solar panels at once, as solar panels represents 35 to 50% of costs in any solar pumping scheme and they can be used in any water point (unlike pumps or inverters that are specific to each water point characteristics).

Finally, the use of remote monitoring is to be considered in selected critical and/or distant boreholes.

1.6 Recommendations

For implementing organizations:

- Build technical capacity in order to know what designs, products and layouts are the best suited for every borehole. In addition build the technical capacity of technicians to be able to trouble shoot and repair simple solar failures.
- Favor 1-supplier policy for complete supply installation, using quality equipment for purposes of warranty, after sales support and training.
- Ensure after sale support service for the first 18-24 months after installation in the contract at the time of tendering or purchase e.g. 1 year warranty and free of charge service and training, followed by 1-2 years paid for service contract.
- Ensure regular monitoring of water levels, at least in the most critical boreholes, considering the possibility of using remote monitoring technologies.
- Look at lifecycle cost analysis to attract funding and in making decisions for solar pumping adoption.
- Adopt familiar quality technology that is readily available and can be supported from within the country.
- Prioritize solarization for locations where there is relative peace and stability, strong social cohesion, where fuel costs are higher or its supply is erratic.

For coordinating organizations:

- Name/recruit a focal solar person at organizational level. Reinforce inter-agency collaboration among partners, in order to build up internal technical capacity. Tap into the private sector to organize workshops and trainings and raise technical expertise among relevant NGOs and government technical staff.
- Coordinate solar work (possibly through a solar working group) in order to, among others; provide technical guidance for the standardization of solar pumping design, installation, care and maintenance for all WASH actors in Nigeria.
- Coordinate mapping of areas with higher potential for solar adoption in order to prioritize funding.
- Assess different modalities for buying solar panels in bulk (at country level or through regional offices)
- Build up evidence through supporting evaluation of existing older solar systems.

For Government/ Donors:

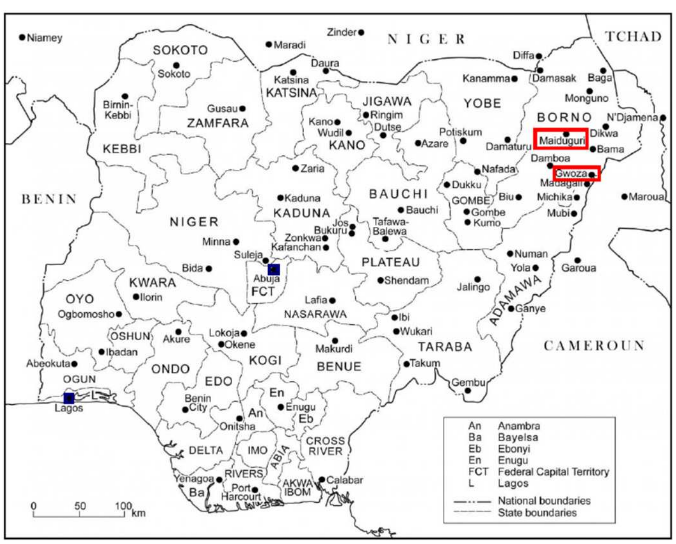
- Base funding decision in costs over life cycle of equipment rather than on capital costs of installations. As much as possible extend funding lines for a period of 2 years or more, so that the use of solar technology can be more strongly supported.
- Consider the possibility to make a more explicit mention on the use of solar water technologies in relevant strategic documents and/or develop a clear framework for the use of solar technology in water supply projects.
- Consider the possibility to support the creation of a focal solar expert at country level to support all WASH actors in the mainstreaming of solar technologies.

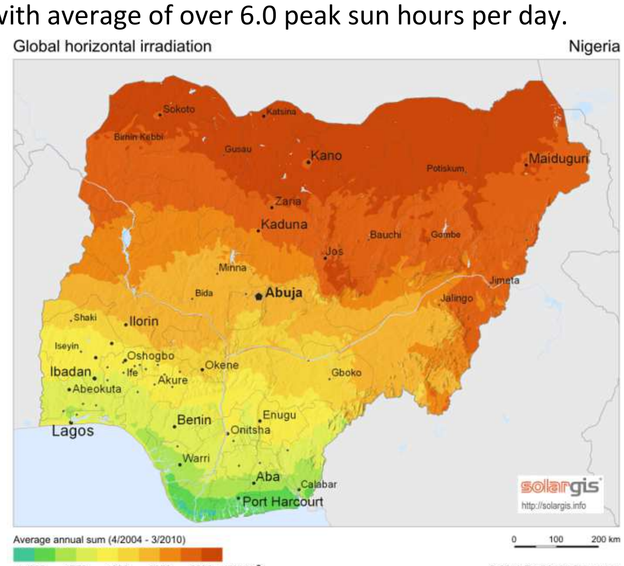
2. Objectives of Mission and Team

Objectives and terms of reference were drawn and agreed in coordination with Oxfam in Northern Nigeria (see Annex B).

3. Selection of Areas Visited

Maiduguri and Gwoza IDP camps were selected for the visits based on existence of solar schemes, generator schemes targeted for solarisation as well as accessibility. Some targeted sites were not visited due to security and access challenges. All the locations get a high solar radiation through the year, with average of over 6.0 peak sun hours per day.





Map1: Visited locations ***Map 2: Average annual Solar Irradiation – 1994-2010***

4. Existing Systems and Proposed Solarisation

12 existing boreholes were analysed in the 2 locations mentioned above – 5 motorized with generator and 7 non-motorised boreholes. It was noticed the lack of water level monitoring in all boreholes visited, absence of water meters in some indicating a lack of knowledge of demand and system performance. As expected, operating generators remains the biggest challenge due to logistical challenges, generator failure and frequent replacement.

Population data in areas to be served by motorised boreholes, as well as safe yields of boreholes, were largely unknown. In this sense, the solar systems proposed in the table below correspond to the largest possible ones taking as a reference the current water output supplied by generators together with some of the estimated data provided by agencies.

Population figures and hence daily water requirements should be clear before a final design is proposed. In case they are not or it is likely that population increases in the short or medium term, a hybrid system should be favoured till a clear understanding of population to be served is gained. Likewise and due to the low O&M available at province level, DC systems have been prioritized over AC, due to their longer lifespan, higher efficiency and robustness.

Table 1: proposed solarizations

Site Details			Technical Design							Priority of recommendation
Camp	BH ID	Managing Agency	Proposed Power Pump kW	Proposed Solar Power Size	Daily Water Demand (m3/day)	Daily Output Solar (m^3/day) in average month	Daily Output Generator (m^3/day)	Combined Daily Output (m3/day)	Comment /Recommendation	
Maiduguri	Jakana 1	Oxfam	4.0	10000	44.0	44.0	0.0	44.0	Equip with stand alone solar pump to meet demand	Medium
Maiduguri	Farm Centre (Vegetable Garden)	Oxfam	1.4	2500	25.0	27.4	0.0	27.4	Equip with stand alone solar pump to meet demand. Ensure the installed pump is a 3" diameter pump due to the casing limitation.	High
Maiduguri	Mala Khariri Public Sch	Oxfam	0.3	600	10.0	10.0	0.0	10.0	Equip with stand alone solar pump to meet demand. Ensure the installed pump is a 3" diameter pump due to the casing limitation.	High
Maiduguri	Kushari	Oxfam	5.5	11000	85.0	100.0	0.0	100.0	Equip with stand alone solar pump to meet demand. The borehole is reported to have high turbidity and should be treated before distribution.	Medium
Maiduguri	ICRC Muna Garage	ICRC	7.5	11500	130.0	131.0	0.0	131.0	This diesel powered scheme should be converted to stand alone solar pump using the existing AC pump. The generator can be retained for supplementary pumping of 1-2hrs during the cold months if need be.	High
Gwoza	Tesan Damboa 1	Oxfam	1.4	1800	20.0	24.0	0.0	24.0	Equip with stand alone solar pump to meet demand	High
Gwoza	Wakani B Mosque Jummah	Oxfam	1.4	1600	21.0	26.2	0.0	26.2	Equip with stand alone solar pump to meet demand	High
Gwoza	World Bank Dandal	Oxfam	7.5	12500	144.0	154.0	0.0	154.0	Equip with stand alone solar pump to meet demand	High
Gwoza	Baba Yakubu (Private BH)	Oxfam	0.7	750	12.0	14.0	0.0	14.0	Equip with stand alone solar pump to meet demand	Medium
Gwoza	Hamma A. Gagamayo	Oxfam	1.4	750	21.0	24.1	0.0	24.1	Equip with stand alone solar pump to meet demand	Medium
Pulka	Camp 2 Oxfam BH 1	Oxfam	1.4	800	22.5	24.4	0.0	24.4	Replace existing pump with solar stand alone to meet demand	High
Pulka	Camp 2 Oxfam BH3	Oxfam	1.4	800	22.5	24.4	0.0	24.4	Replace existing pump with solar stand alone to meet demand	High

Full technical reports for any of the systems proposed I the below table are available upon request at solarquery@iom.int

A table with the main characteristic and recommendations for the **existing solarized boreholes** is shown below.

Table 2: details and comments on existing solar systems

Site Details			Technical Design							Priority of recommendation
Camp	BH ID	Managing Agency	Proposed Power Pump kW	Proposed Solar Power Size	Daily Water Demand (m3/day)	Daily Output Solar (m^3/day) in average month	Daily Output Generator (m^3/day)	Combined Daily Output (m3/day)	Comment /Recommendation	
Maiduguri	Farm Centre (White Tank)	Oxfam	1.4	1500	26.0	27.1	0.0	27.1	The installed Grundfos SQF 5A-7 is too big for this borehole and the solar modules are insufficient for it. Change pump to Grundfos SQF 2.5-2 and increase solar power to 1.5kW	High
Gwoza	Tesan Damboa 2	Oxfam	1.4	1600	20.0	21.0	0.0	21.0	Existing pump is unknown but the installed solar power is sufficient for the assumed demand. A floatswitch should be installed to prevent tank overflow.	High
Gwoza	Wakani A Mosque Jummah	Oxfam	1.4	1200	20.0	22.8	0.0	22.8	Existing pump is unknown but the installed solar power is sufficient for the assumed demand. Diesel pumping should be stopped.	High
Maiduguri	Chad Basin Development Authority.	Oxfam	5.5	7560					The existing 5.5kW solarised pump is reported to be underperfoming. Information available reveals that the pump was replaced with a lower stage pump hence reducing the output. The installed Provolt solar modules is an unknown brand. No problems relating to solar has been reported since installation.	
Maiduguri	Jakana 2	RUWASA	4.0	4560					Insufficient data to carry out analysis. Panels discoloured by water overflowign from the overead tank. One panel is faulty.	
Maiduguri	Muna Custom house 1	RUWASA	1..4	1400					Insufficient data to carry out analysis. Modules. were blown off during a recent storm. Modules cleaned every two weeks.	
Maiduguri	Muna Custom house 3	RUWASA	4.0	4800					Flow reported to be insufficient for the demand but data inadequate for analysis. Modules indicated to be CE and TUV certified but cannot be verified. No cleaning schedule for modules in place.	
Gwoza	Tesan Damboa 3	Oxfam	1.4	1200					Insufficient data to carry out analysis. Existing cable is $4mm^2$ which is okay if all modules are connected in series, if connected in parallel (i.e 3x2), then cable should be increased to $16mm^2$	
Gwoza	Housari B Kamsulum Street	Oxfam	1.4	1200					Insufficient data to carry out analysis.	

Full technical reports for any of the systems proposed I the below table are available upon request at solarquery@iom.int

5. Economic analysis

A Present Worth methodology to compare costs over life cycle of different technology options was used, in order to better inform decisions when it comes to motorizing boreholes. Prices used for this analysis were averaged from real quotations shared by implementing agencies and estimations taken from existing reports on costs of repairs and maintenance of generators. Details of methodology can be found in Annex A.

An economic analysis was done comparing the existing diesel/non-motorised systems with the proposed solar systems (see table 3 below), showing an average breakeven point for solar investment of only 2.0 years, which is short, and so very favorable to Solar schemes. The average reduction of expenses in installation and O&M cost was estimated at -55%. In other words, generator powered water schemes are costing more than double their solar equivalents.

Table 3: economic comparison of existing generator and non-motorised systems vs. proposed solar or hybrid systems.

Site Details						Economic/Life Cycle Analysis					
						Generator stand alone		Solar stand alone or Hybrid		Hybrid/Solar - Diesel Comparison	
Camp	BH ID	Managing Agency	Daily Output Solar (m^3/day) in month with least output	Daily Output Generator (m^3/day)	Combined Daily Output (m3/day)	Initial cost (USD)	Cost over Life Cycle (USD)	Initial cost (USD)	Cost over Life Cycle (USD)	Reduction of expenses Hybrid/Solar vs Genset	Break-even point
Maiduguri	Jakana 1	Oxfam	44.0	0.0	44.0	10,451	108,021	26,657	40,579	-62%	1.3 years
Maiduguri	Farm Centre (Vegetable Garden)	Oxfam	27.4	0.0	27.4	2,613	57,235	11,261	23,116	-60%	0.7 years
Maiduguri	Mala Khariri Public Sch	Oxfam	10.0	0.0	10.0	0	28,280	4,661	16,154	-43%	3.7 years
Maiduguri	Kushari	Oxfam	100.0	0.0	100.0	11,071	94,680	27,755	41,677	-56%	1.7 years
Maiduguri	ICRC Muna Garage	ICRC	131.0	0.0	131.0	0	123,812	30,654	45,601	-63%	3.3 years
Gwoza	Tesan Damboa 1	Oxfam	24.0	0.0	24.0	0	42,097	9,685	21,524	-49%	4.2 years
Gwoza	Wakani B Mosque Jummah	Oxfam	26.2	0.0	26.2	2,613	47,068	9,323	21,214	-55%	0.5 years
Gwoza	World Bank Dandal	Oxfam	154.0	0.0	154.0	11,502	141,739	30,885	45,832	-68%	1.3 years
Gwoza	Baba Yakubu (Private BH)	Oxfam	14.0	0.0	14.0	1,306	32,659	5,972	17,806	-45%	0.7 years
Gwoza	Hamma A. Gagamayo	Oxfam	24.1	0.0	24.1	2,613	47,068	9,359	21,214	-55%	0.7 years
Pulka	Camp 2 Oxfam BH 1	Oxfam	24.4	0.0	24.4	0	42,155	8,277	20,132	-52%	3.2 years
Pulka	Camp 2 Oxfam BH3	Oxfam	24.4	0.0	24.4	0	42,155	8,277	20,132	-52%	3.2 years

Full economic analysis report for any of the systems in the above table is available upon request at solarquery@iom.int

As it is normally the case, stand alone solar systems have in general shorter breakeven periods and higher reduction in % costs when compared to equivalent diesel generators ones. For all the boreholes above stand alone systems have been recommended as they are sufficient to meet the estimated demand. In case it is envisioned that demand will be higher than reported, the systems can be operated in hybrid mode (solar+diesel) but the effect will be that when compared to stand alone generator systems, hybrid systems have longer breakeven periods and lower reduction in % cost, although net reduction costs are higher.

A similar economic analysis was done comparing existing solar systems with their generator equivalent. The table below shows an average break-even point (or return-on-investment) of 0.3 years and an average cost reduction of -59%. All the systems already have their capital costs paid back, showing a high cost-effectiveness of investment.

Table 4: economic comparison of existing solarised systems vs. their equivalent generator ones.

Site Details						Economic/Life Cycle Analysis					
						Generator stand alone		Solar stand alone or Hybrid		Hybrid/Solar - Diesel Comparison	
Camp	BH ID	Managing Agency	Daily Output Solar (m^3/day) in month with least output	Daily Output Generator (m^3/day)	Combined Daily Output (m3/day)	Initial cost (USD)	Cost over Life Cycle (USD)	Initial cost (USD)	Cost over Life Cycle (USD)	Reduction of expenses Hybrid/Solar vs Genset	Break-even point
Maiduguri	Farm Centre (White Tank)	Oxfam	27.1	0.0	27.1	2,613	55,436	9,221	21,076	-62%	0.3 years
Gwoza	Tesan Damboa 2	Oxfam	21.0	0.0	21.0	2,613	48,743	9,308	21,163	-57%	0.4 years
Gwoza	Wakani A Mosque Jummah	Oxfam	22.8	0.0	22.8	2,613	48,757	8,568	20,422	-58%	0.2 years

Full economic analysis report for any of the systems in the above table is available upon request at solarquery@iom.int

6. Final technical observations

Low solar technical competence is the main obstacle towards a successful solarisation of existing boreholes and organizations including UNICEF & OXFAM, as the leading wASH agencies in Borno State, should discuss on options available at country level to close this gap.

Chlorination (especially in-line) should be standard in any mechanized borehole whether it is powered with solar or not. The size of the tanks for solar schemes (whether stand alone or hybrid) need attention, as normally solar schemes will require larger tanks in order to store as much water as possible during sun hours, even though the demand might be low at that time.

Solar technology beyond water pumping: with the high and constant solar radiation in Northern Nigeria through the year, solar products for lighting and general powering should be given a higher consideration, especially at institutions, offices or compound level, where the constant presence of humanitarian organizations can facilitate the O&M of the systems.

The solar initiative aims to support organizations willing to go solar and in that regard, a technical helpline is open and freely available up to April 2018 at solarquery@iom.int

7. Summary of next agreed steps

- Use of tools and documents provided during training to gauge solar opportunities for existing and future boreholes.
- Internal discussion at organizational level for establishing a technical group, coordinate the solar agenda.
- Naming of 2 solar contact focal people in the country that will be invited by the Solar Initiative to get further training, bring it back to Nigeria
- Further 1-week training will be available at Energy Research Center in Strathmore University, Kenya, through RedR and on-line. The solar team will share dates and details as they are made public.

End.