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Cost evaluation of sustainable solar: diesel hybrid power for water pumping in refugee camps in Dadaab, Kenya

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Pumping water from boreholes can be a very expensive endeavour in refugee settings. UNHCR and partners intended to solve this problem by decreasing water extraction and investing in PV solar-diesel generator systems in Dadaab Refugee Camps, Kenya. By analysing the costs before and after the solar implementations, it is possible to evaluate if the investments reached expectations. The results show that 10 PV solar-diesel generator systems in this study save up to 16,000 litres of diesel a month, or 25% of the camps total fuel demand. For the boreholes with PV solar-diesel generator systems, almost 40% of the diesel could be reduced. With 2016 diesel prices in Kenya, the estimated return period would be 6.25 years.

Introduction

Kenya hosts a large number of refugees of different nationalities in Garissa County, Dadaab Refugee Camps. Provision of basic services such as water is an expensive endeavour. In 2013, 1,177,908 litres of diesel with an estimated cost of US$ 1.4 million (by December 2013 prices (KNBS, 2013)), was used to produce about 3.65 million cubic meters of water from the 27 operational boreholes. In addition, there are other operation and maintenance costs of 7 - 10% concerning water extraction.

One suggested solution for the high costs is the use of renewable energy sources such as Solar Photovoltaic (PV) systems. The upsides of PV systems are substantial cost savings in a medium to long term perspective, less pollution, and sustainable water supply less dependent on funding. Another upside of coupling PV systems with water pumping is that the energy can be stored in elevated tanks, avoiding the problems caused by the use of batteries.

One of the main problems with standalone PV Solar energy systems is that they depend on daily solar radiation and thus are restricted to daytime pumping only. A common circumvention of this problem is to combine PV systems with Diesel generators, supplementing each other. This is commonly known as a hybrid PV Solar-Diesel generation system.

However, the biggest threshold for implementation of PV solar-diesel generator systems is often the relatively high investment costs. The economical return period can be several years. It is therefore of great importance to be able to perform accurate economical predictions before investments, as well as to adequately design the system. Economical predictions on implementation of PV Solar-Diesel generator systems have been done for refugee camp settings, with promising results. It is important to make sure that these predictions correspond to actual savings after implementation.

One purpose of this study is to report on the experiences with Solar water pumping in a refugee setting, e.g. Dadaab Refugee Camps, Kenya. The other purpose is to review the actual cost savings done after the initial investments. This knowledge will be essential for UNHCR and other actors before undertaking new solar system projects in other refugee camps.

14 PV Solar-Diesel generator systems have been constructed in Dadaab Refugee Camps, Kenya, between 2014 and 2015. The outcome on water production and fuel usage has been carefullymeasured for every borehole, and the results have been used to compare with predicted savings.

Context

Since 1991, the civil war in Somalia displaced hundreds of thousands of people, both internally and across borders to Kenya. Since then, UNHCR has supported the government of Kenya with the provision of WASH services for both the refugees and the surrounding host communities. Three refugee camps in Dadaab were established in 1992. In 2011, two more camps were opened for a new wave of refugee influx, caused by the the severe drought in the greater Horn of Africa. There are now five camps in Dadaab hosting 347,980 people: Dagahaley, Hagadera, Ifo 1, Ifo 2 and Kambioos (UNHCR, 2015). Dadaab refugee camps are situated approximately 100 kilometres north east of the town of Garissa and about a similar distance from the Kenya-Somalia border. The local population traditionally consists of nomadic Somalis, who herd camels, cattle, sheep and goats.

Water supply in Dadaab refugee camps

The Dadaab Refugee Camps are situated on the water rich Merti ground water system. Merti aquifer fresh water lens has an annual discharge of 12-62 million m^3 per year and an estimated ground water extraction of about 4.8 million m^3 per year (L. Blandenier, 2015). There are 30 boreholes serving refugees in Dadaab Refugee Camps. The depths of the boreholes vary between 150 to 180m and the extractions vary between 25 to $60m^3$ per hour. The energy source for 16 of these boreholes is diesel powered generators, while 13 operate on hybrid solar-diesel generator systems. The 30th borehole relies on a standalone solar system but is not in use yet. The total water storage capacity is $6{,}050m^3$ in 46 tanks, and water is conveyed through a pipeline network long of 314km and distributed via 900 tap stands.

Cost of water extraction

The fuel used to generate water supply from the boreholes was 1,177,908 litres and 1,102,791 litres in 2013 and 2014, respectively. The refugee operations in Dadaab require continued annual funding to maintain delivery of basic water services. Because of the decrease of funding with time and the high costs of the operations, UNHCR has launched a cost reduction strategy and aims for a more sustainable water supply service. A first step in reduction of annual costs has previously been taken by reducing fuel theft (NRC, 2013). The second step involves two measures: (i) the reduction of the average daily per capita available water from 29.4 litres to 24 litres, and (ii) in the procurement of solar energy to complement diesel generation in all the boreholes. The quantity of water supplied remains above the UNHCR standard which is of minimum 20 litres per person per day (UNHCR, 2014).

Use of solar-diesel generators

A study conducted by UNHCR reveals that the use of solar-diesel generator systems can save up to 40% on fuel and operation and maintenance costs, while initial capital investment can be recouped in the first three years (M. Kraehenbuehl et al., 2015). UNHCR and its WASH Partners started piloting on the solar-diesel generator systems for water supply in March, 2014. Norwegian Refugee Council and Kenya Red Cross Society began installing solar systems in Hagadera (Borehole 8) and at KRCS head office in Dadaab. This generated a further interest in the broader WASH sector, triggering more investments in solar water pumping (Table 1).

Table 1. Progress of the Solarization process in Dadaab refugee camps in December 2015

Camp	Population	No. of bore-holes	Solarization			Total Solar BHs	Total daily water produced (m^3) - December 2015
			Existing (Dec. 2015)	Construction ongoing	Planned 2016		
Dagahaley	87,223	7	2	5	0	7	2,733
Ifo 2	50,627	7	7	0	0	7	2,797
Ifo 1	84,088	7	2	3	2	7	2,796
Hagadera	105,998	7	3	4	0	7	1,764

Kambioos	20,044	2	0	0	1	1	549
Total	**347,980**	**30**	**14**	**12**	**3**	**29**	**10,640**

Methodology

Water extraction and fuel usage data has been collected daily for every borehole since 2013 by UNHCR partners. Water extraction has been measured with flow meters and fuel usage has been documented at each borehole generator. The data has been compiled to monthly averages and used for monitoring water production and fuel demand before and after investments of solar-diesel generator systems. For hybrid systems, water extraction from solar and from generators has been measured separately. The data originates from 20 boreholes in 4 Dadaab camps, Dagahaley, Hagadera, Ifo 2 and Kambioos. The analysis is performed on all camps together, this in order to include a holistic camp perspective on investments.

From the pre-solar monitoring of water extraction and fuel usage, the fuel demand for producing 1 m^3 can be calculated (this can vary depending on the efficiency of the boreholes and the generators). By subtracting the replaced solar extracted water, the predicted fuel savings can be displayed in a time series. Fuel savings can then easily be concerted to money savings, and further used for comparing with investments. Maintenance costs have not been included in this evaluation.

Results

A gradual decrease of monthly water production has reduced water extraction from around 250,000 m^3 to around 200,000 m^3 (Figure 1), reaching target water distribution of 24 litres/person/day (Figure 2). Concurrently there has been an implementation of PV Solar-Diesel generator systems, gradually reducing diesel pumped water (Figure 1). By December 2015 solar pumped water represents around 25% of all pumped water in Dagahaley, Hagadera, Ifo 2 and Kambioos. The boreholes with installed solar-diesel generator systems save between 38% and 39% of the energy (not shown in a Figure).

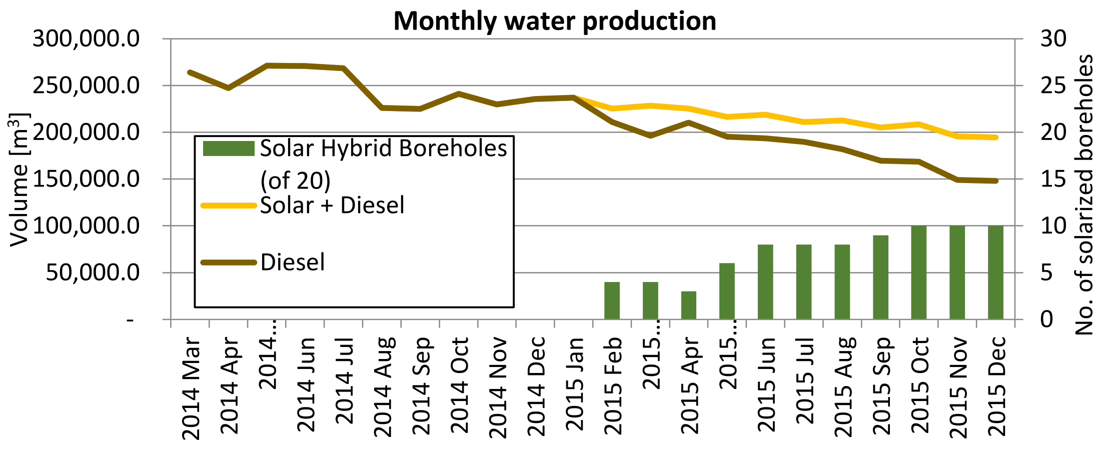

Figure 1. Monthly water production of diesel pumped water and solar pumped water. The implementation of solar-diesel generator system during 2015 is visualized in a time series histogram.

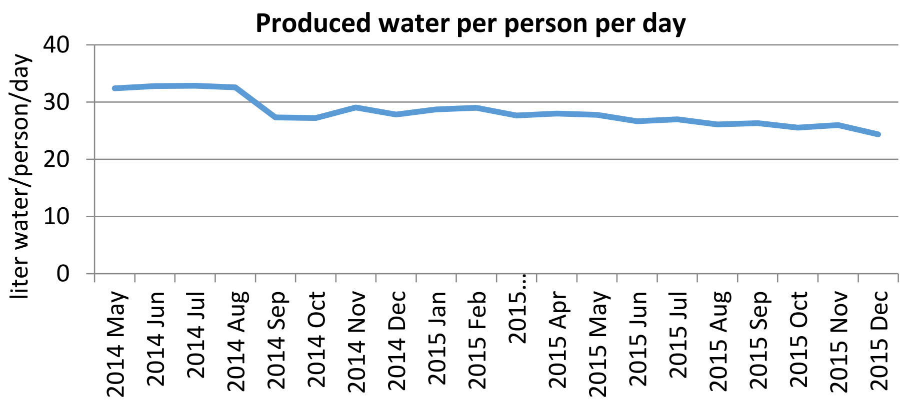

Figure 2. A time series of monthly averages of produced water per person per day. The UNHCR minimum standard is 20 litres of water per person per day

The fuel required for the extraction of 1m^3 of water was on average stable at approximately 0.26 litres of diesel between March 2014 and the implementation of PV Solar-Diesel generator systems in February 2015 (Figure 3). With the assumption that diesel demand per m^3 remains the same after solar implementation (boreholes and generators efficiency is the same), the total diesel demand per produced m^3 of water is calculated to decrease to less than 0.2 litres of diesel per m^3 of water.

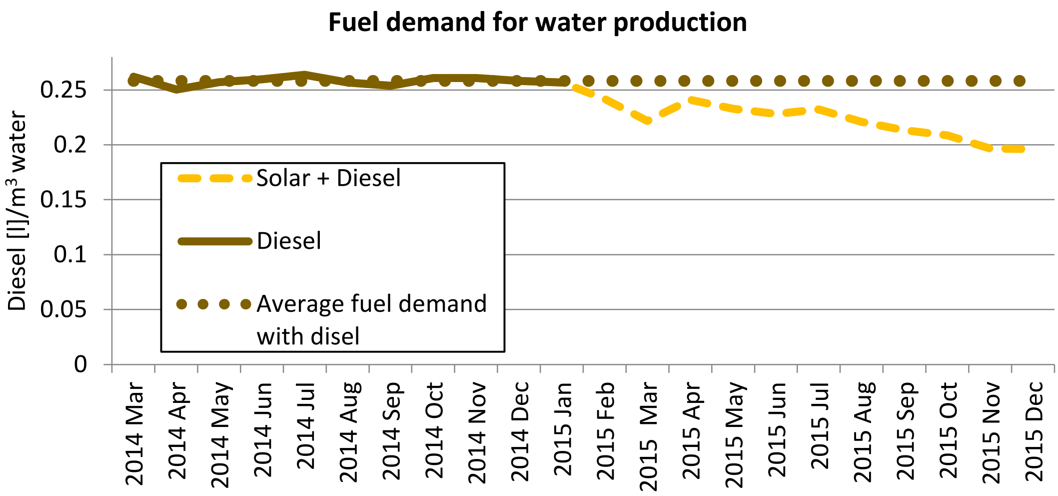

Figure 3. Shows how much diesel is required to produce 1m^3 of water. Before February, only diesel was used to extract water. Without implementing solar, it can be predicted that the diesel demand per 1m^3 of water would remain the same. After solar implementation, the diesel demand per m^3 of water decreases on the camp scale.

The total monthly fuel demand for Dagahaley, Hagadera, Ifo 2 and Kambioos has gone down from on average 62,000 litres of diesel per month to 38,000 litres per month (Figure 4). The savings are approximately 18,000USD per month, or 216,000USD per year (1liter diesel=0.75USD, February 2016). The savings are a combination of reduced water supply and solar investment (Figure 1 and Figure 2). Subtracting the reduction of water extraction, the predicted savings of the solar investment is 16,000 litres of fuel a month or 12,000USD a month. The yearly solar investment of 144,000USD can be compared to the investment cost of approximately 900,000USD. The return period could quickly be estimated to around 6.25 years.

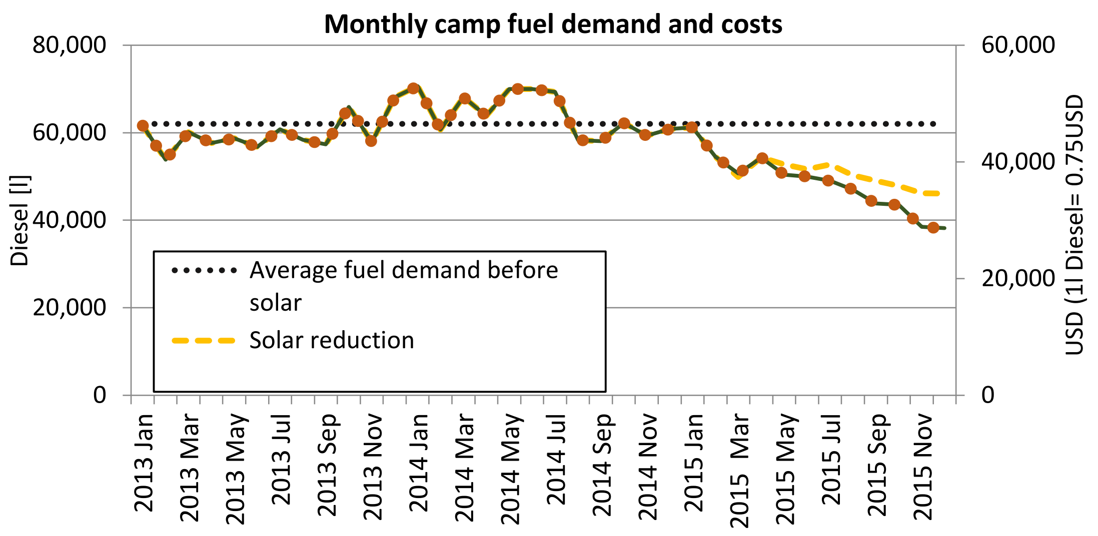

Figure 4. The fuel demand in the camps is the product of water production by diesel generators and the diesel demand for each m^3 of diesel pumped water. A reduced water production and replacement of diesel with solar produced water will reduce the fuel demand at the camp level. For comparison, the average fuel demand without interventions is displayed.

Discussion

By reducing the water production and implementing solar-diesel generator systems, the fuel needed for water production was reduced by almost 40%. The PV Solar-Diesel generator systems reduced the fuel demand by around 25%, with savings of around 16,000 litres of diesel a month on the camp scale (20 boreholes). The reduction of fuel only at the solar invested boreholes was around 38%. These results will be valuable for UNHCR when budgeting for fuel in these camps.

The annual savings of 144,000USD generate a return of investment of 6.25 years, excluding maintenance costs. This is a longer time than the predicted return of investment in these camps, which was 4 years. The lifespan of a PV system can be between 20-25years. However an extended study on return of investment needs to be performed with proper cost analysis, including discounts and interest rates of future fuel purchases and maintenance costs. This can come to increase the return on investment period even more. However, at the same time the diesel price used in the calculations (February 2016) is historically low, and an increase in Diesel price could decrease the return period significantly (return period would be close to 4 years if prices were at the levels of December 2013 (KNBS, 2013)).

Future investment analysis is required on this data, and the next step is to compare the predicted water production of PV Solar-Diesel generator systems with the real water production.

Conclusions

For boreholes where investment in PV Solar-Diesel generator systems was made, close to 40% of the initial diesel demand could be reduced after implementation. Installing 10 solar-diesel generator systems has reduced the fuel demand for water production by 16,000 litres of diesel per month (25%) in Dagahaley, Hagadera, Ifo 2 and Kambioos altogether. The calculated return on investment period is estimated to approximately 7 years, but can vary depending on diesel prices and how future costs are assessed.

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Note
Views expressed herein are not necessarily from UNHCR but the authors.

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