Safe WATER NETWORK

IMPROVING STATION VIABILITY WITH SOLAR

Understanding the Economics of Solar for Community Water Supply in Ghana

Investing in solar power improves station financial viability and supports affordable pricing to reach more consumers. Solar power generation via a photovoltaic (PV) system provides reliable electricity for water purification and reduces operating costs compared to powering the station via the electric utility grid or diesel generators. Our evidence suggests that PV systems can contribute to the long-term sustainability of providing water to rural and peri-urban communities in Ghana.

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KEY INSIGHTS

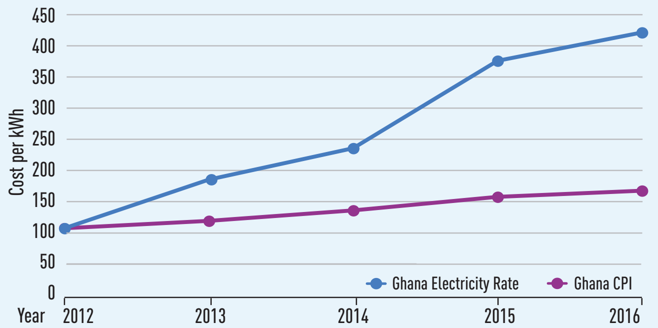
- At a capital cost of USD 11K-15K per PV system (USD 0.25 per person per year), solar increases the project capital cost for a base water station by 15% but reduces OpEx by almost 20% throughout the 20-year useful life of the PV system.
- Conservative estimates show that the incremental cost of a PV system is recovered in an 11.5-year period through decreased electricity and generator fuel expenditures. (Typical small-scale PV system cost recovery can take up to 15 years[1].)
- Solar power helps to ensure water remains affordable to remote, low-income populations. Importantly, it also enables safe water provision to off-grid communities that were previously inaccessible due to electricity grid limitations.
- In addition to improving financial performance, solar increases service reliability, operational uptime, and reduces the station's carbon footprint.

Safe Water Network Ghana currently supports 60 locally-operated **H2OME! Water Stations** – community-level water treatment facilities that produce high-quality water sold at affordable[2] rates – providing access to a population of nearly 300,000 people. Our goal is to prove our model at scale with 200 stations providing access to half a million people in Ghana by 2021. The analysis in this *Field Insight* is based on operational data from 26 **H2OME!** Water Stations that have been operating for more than 12 months.

Background

In recent years, Ghana has been experiencing an energy crisis owing to a mixture of factors, including: a power deficiency of 600 megawatts[3]; heavier reliance on thermal instead of hydro power; and rising petroleum product costs. Electricity tariffs have escalated by an average of 80% per annum (compared with 15% Ghana CPI inflation per annum, as in Figure 1) from GHS 0.23 per kWh in 2012 to GHS 0.97 per kWh in 2016[4] (USD 0.05/kWh in 2012 to USD 0.23/kWh in 2016[5]). With energy accounting for ~20% of a **H2OME!** Water Station's operating costs over the 20-year life of the PV system, the case for converting to solar as an alternative energy source is compelling (see 3. Financial Performance). Further, solar insulates **H2OME!** Water Stations from erratic grid power and enables reliable water service delivery to rural and peri-urban communities.

Figure 1: Inflation Comparison
Ghana Electricity Rate vs. Consumer Price Index



Ghana Electricity Rate Source: Public Utility Regulatory Commission and Electricity Company of Ghana
Ghana CPI Source: data.worldbank.org

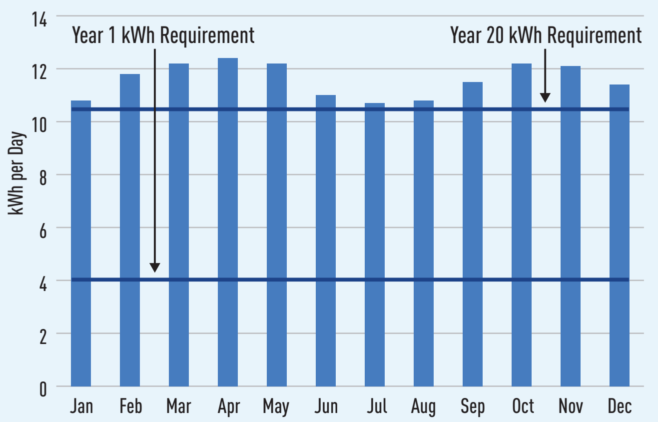
[1] Winkler, Shea C., "Small-Scale Solar Photovoltaic Investment: Payback Periods, Net Present Value, and the Impact of EPA 111(D)" (2015).
[2] On average, Station water is GHS 0.12/20L (USD 0.03/20L). Assuming individuals spend 3% of their income on water, this is affordable to people who live on GHS 4.00 (USD 1.00) per day or more.
[3] "Ghana's Power Crisis Intensifies." Ghana Business & Finance, 23 Oct. 2015, www.ghanabizfinance.com
[4] Public Utility Regulatory Commission (PURC) and Electricity Company of Ghana
[5] Exchange Rate of GHS 4.30 per USD

ANALYSIS

1. System & Power

For this analysis, we focus on the energy requirements to power *limited mechanization systems* (LMS), which comprise 80% of the **H$_2$OME!** Water Station portfolio. An LMS retrofits an existing borehole with a mechanized pump. The water is treated to remove iron (if present in the source), then chlorinated and stored in an overhead tank. From there it is distributed to multiple access points within the community through a gravity-fed piping system. The LMS systems require electricity to pump water from the borehole to overhead purification and storage tanks.

Figure 2: Seasonality of Average Daily Electricity Generation for a 3 kW Solar Array (Accra, Ghana)



Note: Solar array generation data provided by Safe Water Network PV panel vendor.

Based on Safe Water Network's operating experience, water consumption by an average community ramps up over time and is expected to reach approximately 26,000 liters per day by year 20. With a pump capacity of 3,600 liters per hour, the average water system can be configured with a 2-horsepower submersible pump that will consume approximately 10.5 kWh per day to produce 26,000 liters of water[6]. There are seasonal variations in solar irradiation (power per unit area received through solar radiation), therefore the PV system must be sized to accommodate the 20-year daily electricity requirement during the month with the lowest expected generation capacity (see Figure 2). A 3 kW solar system generates between 11-15 kWh per day in Greater Accra, Ghana, with average annual solar irradiation of around 5 kWh/m^2-day[7].

Table 1. Capital Expenditure by Scenario (USD)

Scenario	Base Station	3 kW Solar + Grid
Technology	USD 15,000	USD 25,000
Water System	*12,000*	*12,000*
PV System	*-*	*12,000*
Generator	*1,900*	*-*
Grid Connect	*1,500*	*1,500*
Civil Works	35,000	35,000
Land	2,600	2,600
Start-up Costs	18,000	20,000
Total CapEx	**USD 71,000**	**USD 83,000**

2. Capital Expenditure

Capital expenditure increases by about 15% (USD 12K) with solar power, which may vary depending on solar array sizing and whether the system is newly constructed or a retrofit. An average water system without solar costs USD 71K and includes technology costs[8] as well as civil works[9], land donated by the community, and start-up costs[10] (see Table 1). The capital requirement for the PV system includes the cost of the solar array, panel support structure and parts, a switchbox, and an AC/DC-compatible submersible pump (in lieu of an AC submersible pump). The PV system configuration eliminates the need for start-up batteries, inverters, and a backup generator.

3. Financial Performance

Due to the high cost and erratic supply of electricity in Ghana, the financial proposition for solar is strong. In the financial analysis shown in Table 2, the 3 kW solar array with a 20-year useful life is used to power an LMS water station that is expected to produce 26,000 liters per day by year 20. Solar is the primary source of power while the utility grid is used as backup in the event of solar downtime due to maintenance or inclement weather.

Table 2. Assumptions for Financial Analysis

Station Technology	Limited Mechanized System
Power Source	Solar with grid power as backup
% of Time on Backup	20%
Electricity Rate	USD 0.23/kWh before fees and VAT
Electricity Rate Escalation	No escalation over 20-year period
Station Volume	Increasing to 9.4M liters by Year 20

[6] Borehole characteristics significantly affect the electricity requirement. For this analysis we assumed a dynamic water level of 45m, 5m of static lift above ground level, and borehole yield of approximately 60 liters per minute.

[7] *"Average Monthly Hours of Sunshine in Accra." World Weather & Climate Information,* www.weather-and-climate.com

[8] Technology costs include: pumps and purification equipment, generators, and grid connection

[9] Civil costs include: site preparation, construction, fencing and housing, piping, etc.

[10] Start-up costs include: site assessment, training and community mobilization, commissioning and branding, etc.

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- **80% reduction in energy operating costs (see Table 3)**
  Solar fulfills the majority of the **H$_2$OME!** Water Station's electricity requirement at no cost and use of the grid as backup eliminates the need to run and maintain a generator.
- **11.5-year capital recovery for solar system**
  The Station is able to recover the incremental capital investment for the PV system within 11.5 years of operation due to energy cost savings.

Solar panel maintenance (e.g. inspections, cleaning, etc.) is managed by existing Station staff at minimal cost. Meanwhile, solar protects the Station from power fluctuations that stress electrical components, reducing equipment (particularly pump) breakdowns. The time and cost savings from reduced equipment breakdowns are expected to cover the expected costs for solar system repairs and maintenance.

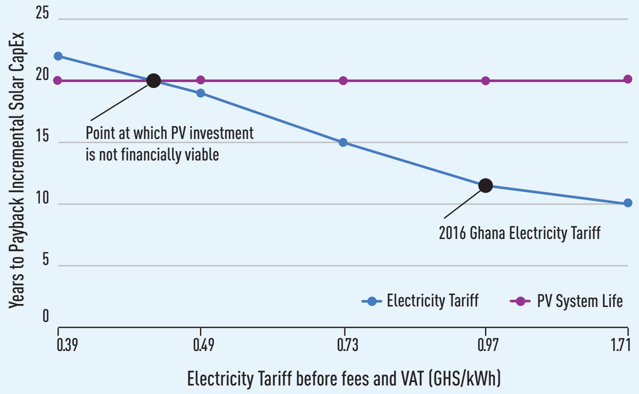
Table 3. H$_2$OME! Water Station Financial Performance — Cumulative Over 20 Years (USD)

	Base Station	3 kW Solar + Grid	% Delta
Volume Sold (L)	146 M	146 M	0%
Revenue	USD 190,000	USD 190,000	0%
Energy	27,900	5,200	-81%
Electricity	*26,000*	*5,200*	*-80%*
Generator Fuel	*1,900*	*-*	*-100%*
Non-Energy OpEx	139,000	124,800	-5%
Total OpEx	USD 160,000	USD 130,000	-19%
Energy as a % of OpEx	17%	4%	-77%
Free Cash after OpEx	**USD 32,000**	**USD 57,000**	**+78%**

4. Electricity Rate Considerations

Investment in solar is financially viable if a Station can recover the incremental capital required for solar in less than the 20-year life of the solar system. Solar-equipped Station cost savings are driven primarily by avoiding the cost to purchase electricity from the local utility. Electricity tariffs (current and future) are therefore critical in determining the business case for PV systems. In 2016, Safe Water Network's typical **H$_2$OME!** Water Station in Ghana was charged on average between 0.97 and 1 GHS per kWh of electricity consumed (before fees and VAT). For our analysis, we assume that electricity rates today are held constant for the 20-year project life. Even with this conservative approach toward electricity rate inflation, the Stations are expected to recover their solar capital investment within 11.5 years. Electricity rate reductions would diminish the business case for solar. For example, a 35% rate reduction would extend the solar capital recovery beyond the 20-year project life and render the project unviable (see Figure 3). However, the probability for a rate reduction of this magnitude is very low (see Background section).

Figure 3: Electricity Tariff Impact on Payback Period



5. Operational & Environmental Benefits

In addition to the financial savings, there are a number of significant benefits to using solar power:

- Enables safe water access to off-grid communities (55% of rural areas in Ghana do not have electricity access[11]).
- Reduces system downtime due to electricity failure, increasing water supply reliability and building community culture of using safe water.
- Protects operational equipment from grid power quality fluctuations.
- Minimizes Station carbon footprint by eliminating the need to use diesel generators for backup power.
- Insulates the Station from electricity rate escalation and provides the advantage of predictable power costs.

A photovoltaic installation in Ananekrom, Ghana.

[11] "Baffour, A. T. "Universal Access to Energy: Ghana's Rural Electrification – A Case Study." Africa Utility Week Pre-Conference Workshop, 13 May 2013, Cape Town, South Africa.

Case Study: Ananekrom

In June 2013, Safe Water Network implemented an initiative to explore the potential for solar as a sole power source for **H$_2$OME!** Stations and to understand the economics of providing safe water access in off-grid communities.

Ananekrom, a rural community in the Asante Akim District of the Ashanti Region, was selected as our test community. This community of 4,500 crop farmers and traders is not connected to the national electricity grid. Prior to the launch of their **H$_2$OME!** Water Station, residents relied on boreholes for drinking water, the majority of which had high levels of coliforms and other pathogens. They also used batteries as a source of energy for lighting and cell phone charging.

The Ananekrom **H$_2$OME!** Water Station was launched in December 2013, powered by a 2 kW solar system. With minimal generator runtime, the system has been powered almost entirely by solar for the past three years, resulting in a 95% reduction in energy costs compared to the average grid-powered station. Meanwhile, Ananekrom's Station repair costs have been 20% below that of the average Station, and there have been no repair issues related to the solar panels.

"Before the Safe Water Station was built in our community my friends and I usually got to school late because we all had to queue for water. Now there are many standpipes at vantage points in the community and we don't have to pump water. All we have to do is to turn the tap and water flows. I am able to get to school early now."

—**Mary Agyei**, a primary school student in the Ananekrom community

6. Risks & Mitigation

Our experience with the pilot **H$_2$OME!** Water Station in Ananekrom (see Case Study) has indicated that the minimal risks that exist with solar are manageable.

- **Inclement Weather:** Risk of extended poor weather with insufficient sunlight is addressed by providing backup (grid or generator) power to sustain water production on rainy days.
- **Battery Theft:** The batteries at our first solar installation were stolen within months after installation. To mitigate the risk of battery theft, our latest systems are designed to use the grid as backup (or a generator where the grid is unavailable), eliminating the need for backup batteries, and to utilize an AC/DC pump that does not require start-up batteries for peak power demand during pump start-up.
- **Electricity Tariff Reduction:** Although electric utility rates are irrelevant to off-grid communities like Ananekrom, reductions in electricity rates would reduce the financial viability of the solar investment for communities that are on the electric grid. However, as electricity rates have grown 80% per annum on average in the last five years, rate reductions are considered a very minimal risk.

7. Next Steps

As an immediate next step, we are investing in converting all existing **H$_2$OME!** Water Stations to solar and building new Stations with solar from the outset. Secondly, we will undertake several initiatives to further optimize the PV business case for our Stations:

- Track performance of PV systems to confirm business case analysis and financial sustainability.
- Explore feasibility of leveraging PV to generate additional revenue (e.g. cell phone charging).
- Analyze viability of using additional water storage as backup in lieu of the electricity grid.
- Investigate potential to integrate electricity into **H2OME!** Water Stations to enable joint water-electricity service delivery.

CONTACT US

For more information, please visit **www.safewaternetwork.org**, or email the author at **info@safewaternetwork.org.**

ABOUT SAFE WATER NETWORK

Safe Water Network is advancing the potential for small water enterprises to ensure millions in need gain access to the most essential of needs: safe water. Working in hundreds of communities in Ghana and India, we're demonstrating the affordability, effectiveness, and sustainability of the enterprise approach. With a commitment to operational excellence and local capacity-building, we are developing the tools and resources needed to overcome an unconscionable 30- to 60-percent failure rate typical of developing world water systems. Working with government agencies and large implementers, we are expanding this approach to improve the health and livelihoods of millions of people in need of safe water.

THE STONE FAMILY FOUNDATION

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