Technology brief

Solar pumping

The cost of using solar power to pump water from boreholes has fallen dramatically in recent years, so it is increasingly being used as a means of getting water to people. However, as is the case with any technology, if solar pumping is badly implemented or poorly managed, it will not be sustainable.

A view of the water tower with solar installation inside the yard of the Community Health Centre (CSCom) in Bogoni, district of Bla, Mali, October 2018.

The water resource

Water quantity

Solar pumps are used to pump water from boreholes supplied by underground groundwater aquifers.

Solar pumping can extract higher yields than a hand pump, so test pumping and well development must be done to make sure the borehole can provide enough water to match the capacity of the pump.

Water quality

Groundwater is often of high quality, as it is protected from surface pollution by a layer of soil and rock. However, this natural protection can be weaker if the top of the groundwater (the water table) is near the ground surface. Groundwater can also contain chemical contaminants that can affect the taste or colour (such as iron), make it undrinkable (various salts) or cause health problems (such as arsenic or fluoride).

See Selecting the water source technology brief for more information on groundwater quality.

As with any borehole-drilling project, water quality from nearby boreholes should be researched during the siting process, tested during and after the drilling, and protected by sealing the top section of the borehole.

WaterAid

Selecting solar pumping

It is not realistic to expect rural communities to be able to manage solar-powered systems without external support, so an **appropriate management model** should be identified before deciding if solar pumping is feasible for a given location and starting to design. This management model should be selected in accordance with the community's ability and willingness to pay for operations and maintenance, and the level of external support available from government or the private sector. The WASHTech Technology Applicability Framework tool (available at: https://technologyapplicability.wordpress.com/) can help you assess if solar pumping will work for a given context.

Components of a solar-powered system

When planning a solar-powered system, it is important to research the supply chain for all of the parts shown in the diagram, to ensure replacements can be sourced locally.

The solar photovoltaic panels convert the sun's energy into electricity. The electricity powers a submersible pump, which pumps water from a borehole up to a storage tank. The water is then gravity-fed through pipes to water points.

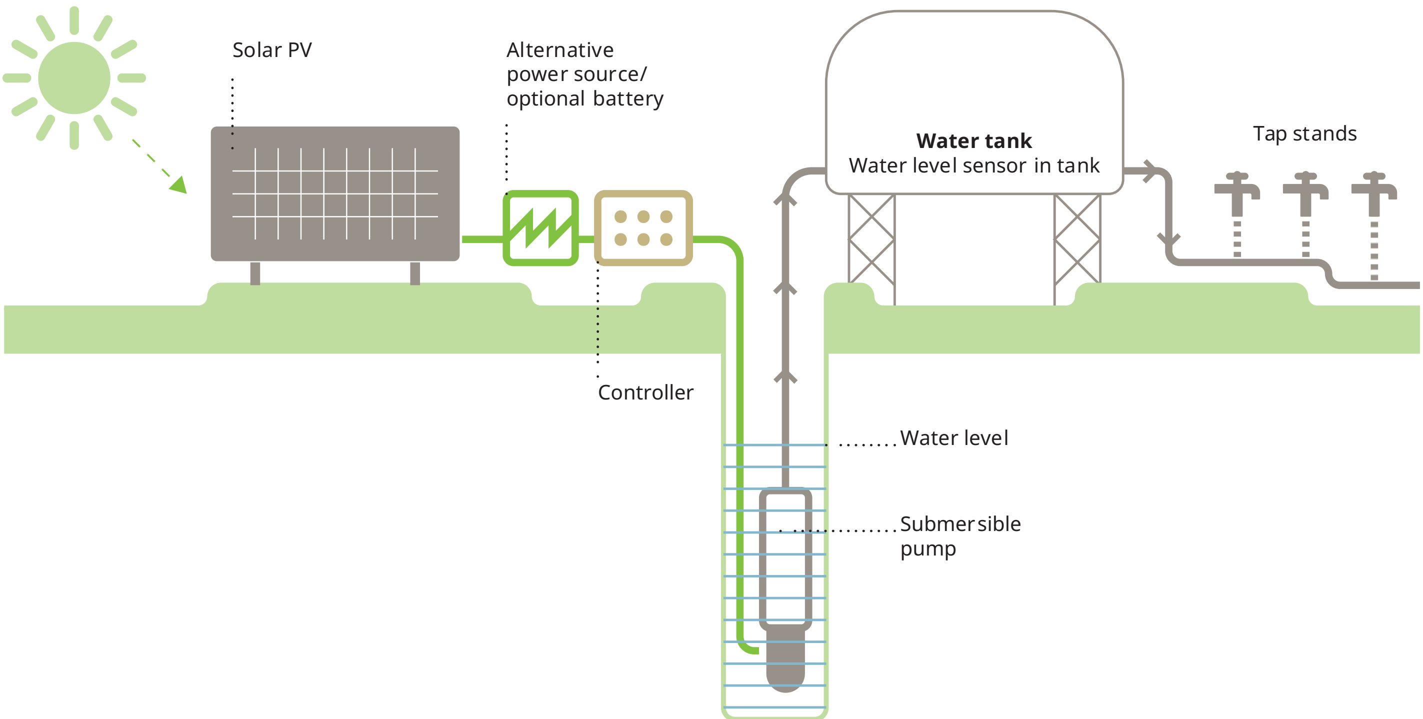
Solar panels

Photovoltaic (PV) panels are required to convert the sun's energy into electricity. A group of panels is referred to as an **array**.

Solar arrays are mounted on frames or poles, and positioned to receive maximum sunlight. It is important to size the panels accurately to minimise cost and maximise efficiency. It is also critical to select an appropriate pump that is able to work efficiently with the power inputs provided by the PV panels. The PV panels generate direct current (DC). In the simplest solar-powered systems, electricity generated by the panels is used to run the pump directly.

Solar panels are vulnerable to theft, so appropriate measures must be taken to protect them and replacement panels should be readily available for purchase locally to ensure sustainability.

This document does not contain sufficient information to size or design a solar-powered system but should be used to ensure staff adequately plan to implement one that will last. A typical solar-powered system for domestic water supply consists of the components shown in the diagram below.



Submersible pumps

Various pump types can be used with solar schemes, but **submersible pumps** are most commonly used in domestic supply configurations. The whole pump assembly, including the pump motor, is submerged below the surface of the water in the borehole being pumped. The pump is connected to an electric cable that runs from the power source into the borehole.

There are two main types of submersible pump:

1. Helical rotor positive displacement pumps

2 . Centrifugal pumps

Helical rotor positive displacement pumps are able to operate at high head (the distance from the water being pumped from the borehole to the storage tank) of up to 200m, but with low flow. They have a higher electrical-to-hydraulic efficiency (up to 70%) than the centrifugal variety and so require smaller PV panels. These have no minimum speed, unlike centrifugal pumps, so even when it is cloudy the pump will keep delivering water, although more slowly.

Centrifugal pumps perform better with higher flow volumes and lower head (up to 70m). The low efficiency and high power requirements of centrifugal pumps translate into very high cost systems when compared with the low power and higher efficiencies of positive displacement pumps.

There are many producers of pumps, including: Grundfos, which produces both displacement pumps and centrifugal pumps; Mono, which produces displacement pumps; and Lorentz, another reputable producer of both types. A pump model should be chosen that is available locally, with pump mechanics in the district familiar with the model.

Power conditioning and control

When using diesel generator back-up power supplies (in case of low outputs from solar panels), it may be necessary to install some power conditioning to convert the alternating current (AC) produced by the generator into direct current (DC) to run the pump. Some pumps can accept both AC or DC power, but where this is not the case, an inverter will be needed to convert the current. If the pump is required to run at specific times, for example on very cloudy days or at night, then batteries may be used to store energy and run the pump when no sunlight is available. Additional maintenance is required for battery units, charge controllers and power conditioning, so they should generally be avoided in locations where they may be difficult to service.

Some control may be needed to adjust the speed and output power of the pump according to the input from the solar panels. A **pump controller (current booster)** is an electronic device used with most solar pumps. It enables solar pumps to operate more efficiently in low sunlight and provides input points for float switch and water-level sensors (used to turn the pump off when the water tank fills).

Storage tank

Storage is a critical feature of solar-powered systems. It is needed to bridge periods when pumping is limited, for example on cloudy days. A three to five-day storage tank will be required, depending on the climate, water usage and the possible risk of water quality problems in storage tanks. To prevent overflow, a float switch can be used.

Distribution network

The storage tank feeds into a distribution network, which uses gravity to transport water to tap stands and the people who need it.

Design considerations

Demand

The daily water demand figure is used to size the system, as the flow will vary throughout the day. Unless power conditioning is installed, solar pumping will only work during daylight hours. It is unlikely that systems will receive more than an average of eight hours of full flow a day. Primary considerations when estimating the length of the solar day are the geographic region and impact of the rainy season. The pumping design should be based on the sunlight available in the given region for the duration of the shortest day of the year (as opposed to the average sunlight and average length of day). The pump and panels must be sized appropriately to make the most of the sun's power without oversizing the system.

Head

The distance from the water being pumped from the borehole to the storage tank – known as the head – dictates the energy required from the system to pump the water. Friction and pressure losses should be taken into account.

Recharge flow

The rate at which water flows back into the borehole to recharge it limits the amount of water that can be pumped per day. It is critical that adequate yield tests are performed on boreholes that are intended to be fitted with any type of motorised pump. Test pumping should be carried out for up to 24 hours to establish the rate at which the borehole can support pumping. In areas where there a risk of salinity or other water quality problems, it should be considered whether motorised pumping would make the situation worse.

Angle of the panel

The angle of the PV panel affects how much power it produces. Even at the equator, it is recommended that panels have a 15 degree tilt to encourage rain run-off/cleaning. The efficiency lost in this is less than that when dust gathers on flat solar panel surfaces.

Shading

Shading during the day must be avoided by positioning the array away from tall buildings or trees. PV arrays are usually wired in series, so stopping electricity production in one part of the panel would render the rest of the panel ineffective.

Array and capacity

The Grundfos systems typically use 80W solar panels with up to 28 forming an array. This information can be used to calculate the amount of power that can be generated (the watt-peak or Wp) – 28 panels x 80W would be equivalent to 2,240Wp. Mono uses 175W panels up to a maximum of 2800Wp.

As an example, both of these systems at maximum size would deliver around 100,000L water per day from a total head of about 30m. This would serve a population of around 1,400 people. The space needed for a system of this size would be dependent principally on the solar array. Each 175W panel is 1.6m x 0.8m, positioned on top of a pole. Alternatively, the array could be secured on an elevated rack with adequate concrete footings and bracing to prevent wind and seismic loading. For this system, the total array size would be 6.4m by 3.2m.

Issues to consider

The following are common issues that are likely to reduce the effectiveness of a solar-powered system:

Physical issues

There are a number of common physical issues that reduce the effectiveness of solar-powered systems, including:

- Dirt accumulating on the panel – the panels should be cleaned at least once a year and kept generally free of debris
- Panel not optimally sited – the north-south tilt may need to change throughout the year
- Inappropriate pump type selected for the context – especially in situations where boreholes with hand pumps are used for solar pumps without pump testing to establish if they can sustain the increased pumping rate
- System sized incorrectly

Environmental issues

As solar pumps are capable of abstracting high volumes of water, more water might be taken from the system than is required or than the aquifer is able to support. This should be considered before deciding whether a motorised pump is the right choice, and if so, before the type of pump is selected.

Economic issues

It is important to be clear how repairs will be financed before selecting solar pumping as a water supply solution. As maintenance occurs less regularly than for other types of systems, it may be more difficult to secure regular tariffs from the community.

Tariffs will need to be based on full calculated lifecycle costs of the whole system, including the cost of replacing component parts and management. Subsidies should be sought if full cost recovery is not possible from user fees.

Social issues

The comparatively high cost of installing and running a solar-powered system can result in high tariffs, resulting in more marginalised communities not being able to afford access (With careful planning and a full understanding of the lifecycle cost this can be avoided, for example the government or higher-income users could subsidise the cost of water for those less able to pay.).

Management issues

It is a myth that solar-powered schemes require minimal maintenance. When something goes wrong with them, repairs can be costly and require qualified technicians. It is also a myth that solar powered schemes can be managed entirely by communities without access to any external support.

Solar-powered systems need to be professionally managed by well-trained individuals who have access to finance for the replacement of costly components. Without this, the system will fail. There are many examples of failed solar-powered systems across Africa and Asia. A common cause of failure is insufficient attention to management arrangements.

It may be necessary to establish a board or association to run a number of schemes together.

Futhermore, careful planning should be done to ensure systems do not break down due to a lack of access to finance for replacement system components or after-sales servicing of existing parts.

When planning a solar-powered system, it is necessary to define responsibilities for:

- Day-to-day operation of the system
- Carrying out minor maintenance
- Paying for minor maintenance
- Carrying out major maintenance and asset renewal
- Paying for major maintenance
- Collecting payments from users
- Setting tariffs
- Owning the assets
- Sourcing good quality spare parts
- Training operators
- Repeat-training operators
- Training administrative staff
- Repeat-training administrative staff
- Strategically controlling the scheme
- Monitoring the performance of the operators
- Holding the scheme management to account

Advantages and disadvantages of solar-powered systems

Advantages	Disadvantages
• No fuel costs • Easy installation • Long life • Initial capital costs may be more expensive than diesel but break even after one to three years, after which the ongoing operations and maintenance cost is reduced • It is thought that the overall cost per m3 of water is cheaper than diesel, and the cost of PV panels continues to fall • Environmentally friendly • Can be sited near to where the water is required	• High capital costs • Skilled technicians needed for operation, maintenance and repair • Spare parts are often difficult to source in remote rural locations • Water storage required for cloudy periods • Technology not well understood by users – risk of damage to components • Solar arrays attractive to thieves, though this has been addressed in many communities, through employing guards or welding the panels to the frames

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Case study – Solar-powered system in Ethiopia


(WaterAid/Joey Lawrence)

Lack of access to a reliable water supply is a major issue in communities, schools and healthcare facilities in Bure woreda (district), Ethiopia. The sustainability of existing services is also a major issue, with around a quarter of rural water points being non-functional.

WaterAid has been working to improve service delivery for communities and institutions in Bure through demonstrating sustainable water, sanitation and hygiene service delivery models. One of these communities is Derequa, where the community's main water source before the project was an unprotected spring, as their existing water system was not functional. The path to the spring was slippery, making it inaccessible for older people and those with difficulty walking. Long queues formed at the spring, and girls feared both sexual harassment and hyenas.

As Derequa is not connected to the electricity grid and nearby systems relying on diesel generators had failed (due to the high cost of supply and transport of fuel and the lack of skills to repair the generators), solar pumping was identified as the most sustainable and cost-effective water supply option.

The existing borehole was rehabilitated and equipped with a Grundfos submersible pump and solar array. These now feed a water storage reservoir that supplies nine water points in the village, providing water to approximately 1,000 users. WaterAid worked with the community to develop a business plan and set an appropriate tariff to cover the costs of operation and maintenance of the system and provide a salary for guards and a water vendor at each water point. The community members pay a small fee for each jerry can of water that they collect, or pay per cubic meter if they have a water meter.

A well-organised water, sanitation and hygiene committee (WASHCO), made up of elected community members, was trained in the management, operation and maintenance of the system and provided with the tools needed for maintenance. A member of the WASHCO was trained as a plumber to carry out basic checks and operate the system daily. When there is a larger issue, they contact the district water bureau for additional support. As part of the project, WaterAid worked to support and improve the capacity of the district water bureau.

The WASHCO committee monitors the water quality, which has improved (and along with it, the health of the community). Community members can now use the time saved from water collection to attend school and invest in income-generating activities. The system has also created job opportunities for water vendors, guards and a plumber.


(WaterAid/Joey Lawrence)

- Top: Birhanu Tesfa, 42, WASH committee supervisor, Derequa, Ethiopia.
- Above: Tiru Getahun, a water vendor at one of the water points in Derequa, Ethiopia.

Useful resources

For more information on solar pumping design and installation, see:

UNICEF and Water Mission (2020). Solar powered water systems design and installation guide. Available at: https://globalwatercenter.org/solar-guide-access.

Llario AI and Kiprono AW (2020). Solar pumping for water supply: Harnessing solar power in humanitarian and development contexts. Global Solar and Water Initiative. Available at: https://practicalactionpublishing.com/book/2507/solar-pumping-for-water-supply.

WaterAid is an international not-for-profit, determined to make clean water, decent toilets and good hygiene normal for everyone, everywhere within a generation.

Part of a series of WaterAid technology briefs available at www.wateraid.org/uk/technology

WaterAid (2021). Technology brief: Appropriate technologies for sustainable and inclusive water and sanitation services. London. Available at: washmatters.wateraid.org/publications/technology-resources

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