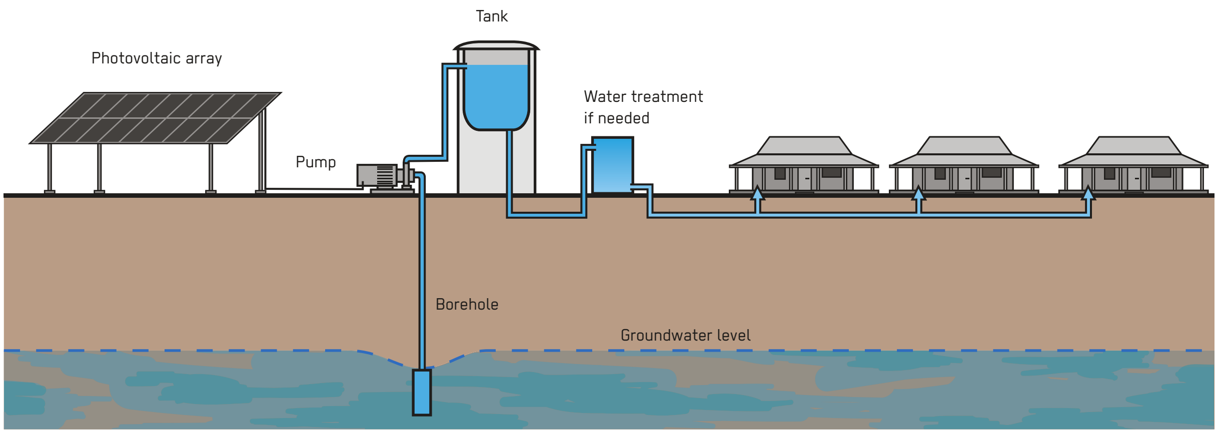
Solar-Powered Energy System

Response Phase	Application Level	Management Level	Objectives / Key Features
* Acute Response ** Stabilisation ** Recovery	* Household ** Neighbourhood ** City	* Household ** Shared ** Public	Abstraction, transport and treatment of water using solar power
Local Availability	**Technical Complexity**	**Maturity Level**	
** Medium	** Medium	*** High	



Solar electrical energy is produced when photovoltaic (PV) cells convert solar energy to electricity, which usually then powers a submersible or surface pump to abstract raw water. Solar-Powered pumping systems (SPPS) should be combined with an elevated water storage tank (or if unavoidable, with batteries) to store energy, ensuring a continued water supply on cloudy days and at night.

PV cells are commonly made from silicon and arranged together under a protective glass plate to form a PV module. Commonly, several of these modules are arranged in a PV array, with the total number depending on the amount of water to be supplied per day, the total dynamic head of the water scheme and the available solar energy. The average amount of solar energy typically available in an area during a day is referred to as 'peak sun hours', which differs from 'hours of daylight', as solar intensity changes during the day. For example, in areas in locations with an average of eight hours of daylight, the average peak sun hours can be much lower. Identifying the yearly and seasonal average peak sun hours is important for deciding whether solar panels are a feasible energy source in an area. The fewer peak sun hours available, the higher the investment costs, as a higher number of PV modules is needed. Generally, SPPS need peak sun hours of at least 3–4 kW/m^2 to be a viable option for community water supplies.

Design Considerations: Apart from the geographical location, peak sun hours and available space on site, the other considerations for SPPS design are the same as for any of the water schemes powered by a generator or the grid (e.g. safe yield of water point, drawdown and total dynamic head). Solar panels need to be completely exposed to sunlight to produce the maximum solar electricity. The electricity generated by solar energy on cloudy days is significantly reduced (usually by between 25–40 % compared to sunny days). To maximise direct radiation, solar arrays should be securely mounted on a tilted rack, facing the equator at a tilt angle equal to the latitude of the location and in an area without trees or nearby buildings to prevent shadows on the panels. The solar panels should also be protected from strong winds, lightning storms, falling objects (e.g. tree branches) and theft.
There are numerous software packages available to aid the design of Solar Powered systems. This software computes all factors and geographical locations and proposes designs, including solar panel layout and power, cable sizes, inverter or control box models, pumps and balance of systems components. These software-based solutions also ensure that the performance and electrical characteristics of the components are matched so that the expected electrical and water outputs are ensured. The electricity generated from PV systems is in the form

of direct current (DC). For alternating current (AC) motors, inverters must be installed to change the supply from DC to AC. Standard inverters should be avoided in favour of a variable frequency drive (VFD), which will vary the required voltage and frequency (suited to smaller single-phase pumps without start capacitors or any three-phase pump).

Materials: Good quality solar panels, inverters, control boxes, water pumps, pipes and balance of systems components (cables, switches, etc.) can be found in most countries. Due to the proliferation of fake and low performance solar materials (especially solar panels), it is of upmost importance to ensure that purchased components are manufactured according to the relevant specifications and international standards to ensure long and correct functionality.

Applicability: In an emergency context, it is possible to effectively accelerate the SPPS installation process by equipping existing handpump-operated boreholes, which is feasible when the borehole yield is sufficient to serve the targeted number of beneficiaries and the technical specifications of the borehole are known. The scope for the application of SPPS during the acute response significantly improves with the use of emergency solar pumping kits that contain all necessary components. SPPS are applicable for a wide range of water needs. A single SPPS scheme can supply communities from 50 households up to entire towns or camps with over 100,000 people. Since SPPS are able to pump groundwater from 5 metres to up to 500 metres in depth ('pumping head') and with inverters made for solar pumping applications to match pumps of over 210 kW, almost any water scheme in a humanitarian context can be solarised. Water Storage Tanks **(D.5, D.6)** should be included in the water system for periods when the pump is not running (e.g. during cloudy days and night) as well as to balance daily fluctuations in demand. In SPPS design, the storage tank volume usually covers at least two days of community water supply, wherein the tank acts like a battery to deliver water via gravity when it is needed. If sufficient water storage at elevation is not available, different back-up power options exist. However, batteries reduce SPPS efficiency and increase costs as well as O&M and replacement requirements. Alternatively, a SPPS can be made hybrid by combining different energy sources (e.g. electric grid or diesel generator with solar). Piston **(A.4)**, Progressive Cavity **(A.5)**, Diaphragm **(A.6)**, and Radial Flow **(A.8)** pumps are all available as submersible Solar-Powered pumps from different manufacturers.

Operation and Maintenance: While a good quality solar panel has a warranty of 25 years and requires only simple maintenance, batteries (if used), inverters and pumps need more frequent servicing from skilled operators. The system should be occasionally inspected to check pumping rate, condition of the panels, storage tanks and pipes. Maintenance involves regularly cleaning the dirt and dust from the panels and protecting the panels from animal and human damage. A secure fence should be built around solar panels to prevent theft or vandalism. To ensure regular preventative maintenance and speedy repairs, the establishment of post-sale service agreements with knowledgeable contractors is recommended. A well designed and maintained SPPS can work for over 10 years without any major problems.

Health and Safety: Electrical shocks are possible in schemes with solar arrays of more than a few panels, so only trained technicians with adequate protective equipment should be allowed access when repairs are made. DC switches should be installed at critical points in the scheme to isolate different components and ensure electrical safety.

Costs: Capital costs of SPPS vary greatly depending on the size of the system, ranging from several thousand USD to over 100,000 USD, with the solar array typically being the most expensive component. The high potential for cost reduction compared with other pumping technologies (especially those based on diesel) is realised if the analysis is based on costs over the life cycle of the scheme rather than the capital costs of installation only. While capital costs will normally be higher than those of equivalent diesel generator schemes, studies show that SPPS offer a high potential for cost reduction over time, with the return on investment ranging generally from between 1–4 years.

Social and Environmental Considerations: SPPS are a well-accepted technology. As a renewable energy source, they reduce the need for energy derived from fossil fuels, thus reducing the system's carbon footprint and improving air quality. SPPS also have a low running cost, and the operation and use are simple and reliable.

Strengths and Weaknesses:

(+) Reliable, lasting and robust systems with easy O&M, and free, renewable energy source
(+) Modular system can be closely matched to required water supply
(+) No dependency on erratic or expensive fuel chain supply, and no pollution or noise produced

(−) Has high capital investment, including risk of theft of panels, which are a valuable commodity in some areas
(−) Generally requires a larger water storage capacity than for equivalent diesel systems
(−) Is dependent on solar radiation levels
(−) Spare parts and knowledgeable technicians often only available at level of the capital city

→ **References and further reading material for this technology can be found on page 213**