SOLAR WATER PUMP

TECHNOLOGY ROADMAP EXECUTIVE SUMMARY

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EFFICIENCY FOR ACCESS COALITION

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Executive Summary

1.0 Introduction

Efficiency for Access (EforA) is a global coalition promoting energy efficiency as a potent catalyst in clean energy access efforts. Since its founding in 2015, Efficiency for Access has grown from a year-long call to action and collaborative effort under Global LEAP and Sustainable Energy for All to a coalition of 13 donor organizations. Coalition programmes aim to scale up markets and reduce prices for super-efficient, off- and weak-grid appropriate products, support technological innovation, and improve sector coordination. In an effort to accelerate the global market for highly energy-efficient appliances, Efficiency for Access introduced a new UKaid funded research and innovation program in early 2017, Low-Energy Inclusive Appliances (LEIA) program, with the goal to double the efficiency and halve the cost of a suite of appliances that are well-suited for energy access contexts.

Solar water pumps (SWPs) were selected as a LEIA focus technology due to the immense potential for productive use and agricultural productivity. Forty percent of the global population relies on agriculture as its main source of income, yet access to water remains an ongoing struggle for many. Cost reductions for SWPs has the potential to make modern irrigation accessible and cost-effective for nearly 500 million small-scale farmers worldwide.

The objective of the SWP technology roadmap is to provide a pathway to accelerate the availability and affordability of technologies that can help improve the efficiency and performance of solar water pumps used in weak- and off-grid areas. In this roadmap, we aim to identify and prioritize research and development (R&D) initiatives that provide the best opportunities for accelerating development and commercialization of emerging technologies for solar water pumps. For the scope of this roadmap, we focused on small (50W-1,000W) sized solar water pumps, as those are the majority of pumps used in Africa by small hold farmers.

2.0 Technology and Market Scope

Moving water using solar pumping systems offers a clean and simple alternative to electric and diesel-driven pump sets. SWPs are often used for agricultural operations in remote areas or where the use of an alternative energy source is desired. If properly designed, solar pumping systems can result in significant long-term cost savings and increased agricultural productivity to farmers.

Solar Water Pump Technology

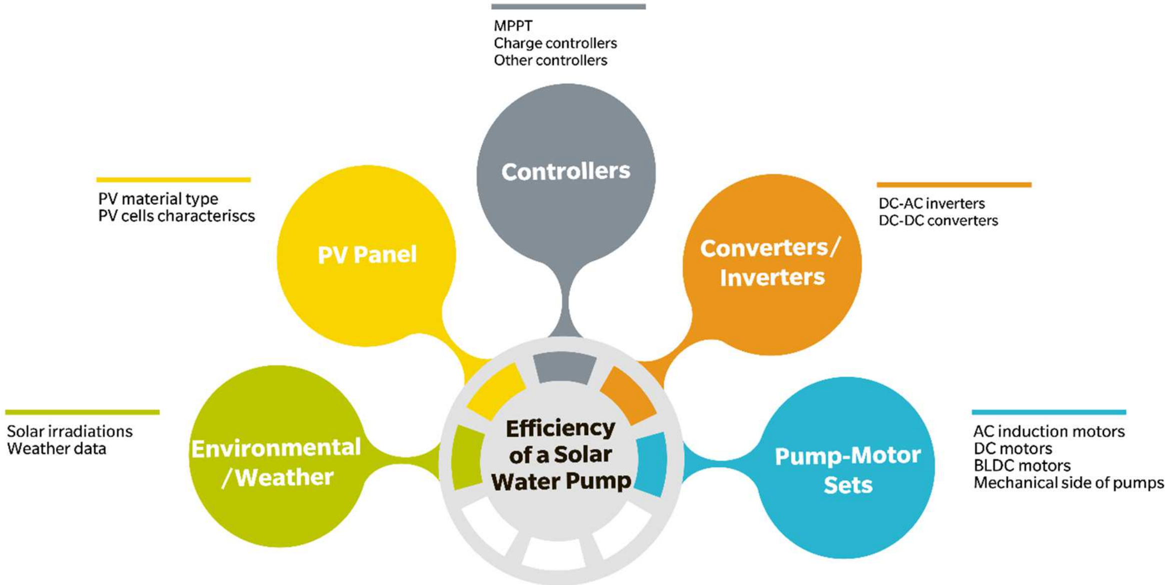
A solar pumping system consists of a number of key components, including a photovoltaic (PV) array, an electric motor, and a pump. Solar water pumping systems are broadly classified as either direct current (DC) or alternating current (AC) motor-based pumping systems. Recently, manufacturers have started using brushless DC (BLDC) motors for solar water pumping applications. BLDC motors are expensive compared to AC motors, but they are more efficient and require less maintenance.

There are two categories of pumps used in stand-alone solar pumping systems: rotating and positive displacement pumps. Centrifugal pumps are one of the most commonly used types of rotating pumps. Centrifugal pumps are designed for fixed head applications and their water output increases in proportion to their speed of rotation. Positive displacement pumps have a water output independent of the head but directly proportional to speed.

Pumps are also classified as submersible and surface pumps. A submersible pump remains underwater, such as in a well or any other water body, while a surface pump is mounted above the waterline or adjacent to the water source. Most submersible pumps have high lift capability, but they are sensitive to dirt and sand in the water and should not be run if the water level drops below the pump. Surface pumps are more accessible for maintenance and less expensive than submersible pumps, but not well suited for suction and can only draw water from about 6 vertical meters. Surface pumps are preferred for pushing water long distances horizontally.

The efficiency of a solar water pump is dependent on three variables: pressure, flow, and input power to the pump. Wire-to-water efficiency is the commonly used metric to determine the overall efficiency of a solar water pump; it is the ratio of the hydraulic energy of the water coming out from the pipe outlet to the energy that came in over the electrical wires through solar panels. Based on discussion with Technical Working Group (TWG) members and other research, key factors influencing the performance and efficiency of SWPs are in Figure 1, below.

Figure 1: Key factors influencing the efficiency and performance of a solar water pump



The cost of solar water pumps has decreased significantly in the last two decades mainly because of a fall in PV panel prices. As prices have dropped, more small-sized solar water pumping systems have entered the market and are becoming more accessible to small scale farmers. In 2013, 80 percent of farms (or 33 million) in Africa were less than 2 hectares. Small pump systems typically range in cost from about $400-$3,000. A 20-year life cycle cost comparison between a fuel and solar powered pumping system for a 1-acre farm found that the breakeven point between the two systems occurs during the fifth year of operation. Additionally, Winrock International was able to provide data to financial institutions during their Kenya Smallholder Solar Irrigation (KSSI) project that shows payback periods of 1.5 years or less. Warranties for the pumps average between 1 to 2 years and require replacement every 5-10 years, depending on the pump and water quality. Solar panels have a typical lifespan of 20-25 years and typically come with 20-year warranties.

Global Solar Water Pump Market

Over the last two decades, the solar water pump market has grown rapidly. Factors driving the growth are: (1) reduction in prices of PV panels; (2) increase in the number of solar water pump manufacturers and suppliers across the globe; (3) increased awareness of solar water pumping due to various national and local governments' initiatives; and (4) expanded SWP system capacity and efficiency.

In developing countries, the agricultural sector presents an enormous opportunity for the solar water pump market. In rural areas, where farmers face erratic fuel prices, inconsistent access to the electric grid, and the desire for more environmentally sound solutions, solar pumps offer a great alternative to the traditional electric and diesel pumps. The most significant growth of the market has occurred in the Asia Pacific region, accounting for 40% of market share in 2017. Africa and the Middle East are two other major markets for solar water pumps, where there has been an increased water demand for irrigation and community water supplies as well as a growing trend away from fossil fuels.

Barriers to Adoption of Energy Efficient Solar Water Pumps

Despite significant market growth and technological innovation in the past decade, there are still significant barriers to the widespread adoption of high-quality energy efficient solar water pumps. Our research and discussions with industry stakeholders suggest that solar water pump technology has potential to improve, but broader market barriers to widespread adoption need to be addressed in parallel, such as lack of awareness and availability of financing. For example, there are limited number of financing tools currently available for solar water pumps, and of those, most small farmers are unable to meet the eligibility requirements to access the financing. We would recommend further research to explore how best to address in-country market barriers. Market barriers identified include: (1) relatively high cost of initial investment; (2) energy subsidies; (3) lack of education of solar water pump technology; and (4) concerns over the quality of products.

3.0 Roadmap Approach

The approach used for this technology roadmap was based on the Sandia report, "Fundamentals of Technology Roadmapping" and U.S. Department of Energy's (DOE) reports and technology roadmap for next-generation appliances. For the purposes of LEIA, the roadmap identifies critical technologies, gaps, and best practices to inform research and development investments.

We conducted preliminary research on use cases, market demands, and technologies. We also reviewed existing test methods and requirements to understand targets and parameters, and conducted desk research on reports, case studies, product information and published papers that exists on solar water pumps. This includes publications from the World Bank, academic institutions, non-profits, and donor funded programs.

The Solar Water Pump Technical Working Group was convened from May 2018 to May 2019, participating in a number of roundtable meetings, focus groups, and one-on-one calls. Industry input informed the crafting of this roadmap from the beginning, identifying key technologies to be investigated and providing feedback on working drafts.

Most technology roadmaps start with a focus on market needs and then develop the critical linkages to the products, technologies, and R&D activities necessary to meet them. Product requirements and performance targets are normally designated to be needed by a particular date and the associated technology options are then evaluated ahead of that date to inform any trade-offs necessary to achieve the desired performance, taking into account cost, availability, and other factors. This Roadmap is typical insofar as it has been prepared via consultation with a broad array of stakeholders in order to provide an industry-wide perspective on the solar water pump market. However, it includes recommendations for areas to achieve cost and efficiency improvements, but does not go as far as to develop performance targets and milestone dates.

4.0 Technical Working Group Findings

The technical working group's input and feedback was an integral component of the roadmap's development. This section briefly summaries our findings.

For the purposes of this roadmap, the product definition of a solar water pumping system is defined as, a PV pumping system in operation, may or may not connected to a mini-grid/ microgrid or any other form of renewable energy power supply. Critical system requirements, including technical, operational, and environmental, were considered. The working group members identified four major technology areas for the SWP roadmap: low-cost sensors and controllers; high efficiency motors; power systems; and saline water tolerance and filtration. In this roadmap, we are limiting our focus on remote monitoring systems, which include low cost sensors and controllers, and high efficiency motors use in SWPs.

We recommend further research on power systems and saline water tolerance and filtration. Also, modularity and operational requirements such as easy to use, easy to service, and availability of spare parts are critical to greater penetration of SWPs, but they were not considered in the limited scope of this technology roadmap. We highly recommend LEIA to conduct further research in these areas to understand issues and solutions related to operation and maintenance requirements of SWPs.

5.0 Technology Roadmap

This roadmap identifies technology alternatives that, if adopted, could improve the efficiency and performance of solar water pumps used in weak and off-grid contexts.

Remote Monitoring Systems (RMS)

Remote monitoring systems (RMS) allow manufacturers and service providers to remotely manage, service, and analyze solar water pumping systems, thus addressing one of the challenges associated with systems installed in isolated and remote locations. These systems can perform predictive maintenance, track system failures, and communicate directly with end-users to schedule maintenance. Not only do these systems contribute to the existing solar water pump's performance and end user experience, but they also help manufacturers improve their design and specifications for future products.

Basic components of an RMS include a microcontroller chip, a GSM/ GPRS module, a Bluetooth module (optional), and RS 232 interface. While remote monitoring systems can potentially provide a number of benefits to the end consumers, distributor, and manufacturers, they are not very prevalent in the market. Below, Table 1 provides an overview of technical and market barriers facing the widespread adoption of RMS and Table 2 highlights action items and key stakeholders identified.

Table 1: Technical and Market Barriers for RMS

Technical Barriers	Market Barriers
Initial cost	Cost of global certification for communication modules
Limited availability of standardized RMS hardware products & interoperability issues	End-user marketability
Software and agricultural practices integration	
Data Privacy	

Table 2: Action Items and Key Stakeholders

Near-term Action Items (1-3 years)	Mid-term Action Items (3-5 years)	Key Stakeholders
Work with manufacturers & distributors to collect more comprehensive data on use cases for SWPs	Explore an open source platform/ simulation lab to perform simulations and designs for SWPs	Manufactures and Distributors
Standardization in data collection through RMS		Research and Development Organizations
		Groupe Spéciale Mobile Association (GSMA)
		Independent laboratories

Since the SWP market is in a nascent stage and growing in developing countries, SWPs with integrated RMS have the potential to transform the market. If the information collected through RMS is able to be aggregated across regions and sectors, that data has the potential to inform policies and best practices for a more efficient usage of solar water pumps. Finally, any technology improvements in RMS would also be leveraged in other off-grid application for RMS such as refrigerators and solar-home systems.

Brushless DC Motors

BLDC motors, often called permanent magnet motors or electronically commutated motors (ECM), are more efficient than alternative motors for a variety of reasons. Their power consumption is lower compared to induction motors because they do not require current to be induced in rotor windings and the elimination of brushes contributes to increased efficiency, reliability, and durability of these motors. BLDC motors are ideal for use in applications with varied loads such solar water pumps because they have either integrated controls or are paired with drives. Motors are the second most expensive component in SWPs after the PV panels. Table 3, below, highlights the technical and market barriers facing BLDC motors.

Table 3: Technical and Market Barriers for BLDC Motors

Technical Barriers	**Market Barriers**
High initial cost of BLDC motors compared to traditional technologies	Low demand for BLDC motors
High cost and limited availability of scarce rare-earth metals used for permanent magnet	Feasibility of retrofitting high efficiency motors
Lack of research in lower-cost manufacturing techniques for BLDC motors	Limited availability of service and repair for BLDC motors in rural areas.

BLDC motors are a well-established technology, and sensorless control is also something that has been more or less driven to a commodity. TWG members and our research suggested that the challenge in the case of BLDC motors is not technology development, but how to develop awareness and encourage manufacturers to take up a solution which although currently more expensive, offers very significant benefits in performance, efficiency, reliability and total cost of ownership in the long run. Nevertheless, Table 4 identifies a few action items and key stakeholders that will help in removing the barriers for greater adoption of BLDC motors by SWP manufacturers within the scope of this roadmap.

Table 4: Action Items and Key Stakeholders

Near-term Action Items (1-3 years)	Recommendations	Key Stakeholders
Low cost sensorless drive development for BLDC motors Research and identify low cost BLDC motor manufacturing techniques.	Since BLDC motor is a cross cutting technology, we would encourage LEIA to take it up as a cross-cutting issue and propose a separate research piece needed to substantiate the state of development of the BLDC motors.	Research and Development Organizations SWP and Motor Manufacturers Test Laboratories Distributors

BLDC motors requires less maintenance with a longer lifespan, performs at higher efficiencies due to low losses in the motor, and offers increased productivity. The increased reliability and durability of the motor benefits both the end-users and the manufacturers/ distributors through a decrease in service and maintenance requests. As mentioned above, BLDC motor is a cross cutting technology and used in range of products used in off-grid areas. A Global LEAP analysis suggested that the expected market impact of BLDC motors in weak- and off-grid applications could cut energy consumption by 50%.

6.0 Summary and Recommendations

There were a number of topics that were discussed, researched, and ultimately excluded from the limited scope of this technology roadmap but can have significant impact on the affordability and efficiency of SWPs. The opportunities for the two agreed upon areas for collaboration, BLDC motors and remote monitoring systems, are outlined above. We recommend further research into the following areas: connectors and couplers for increased portability and durability; water quality and the impacts it has on durability and maintenance; use of drip irrigation through behavioral change; quality assurance concerns, as well as country specific barriers.