SOLAR WATER PUMP OUTLOOK 2019: GLOBAL TRENDS AND MARKET OPPORTUNITIES

SEPTEMBER 2019

EFFICIENCY FOR ACCESS COALITION

PHOTO CREDIT: Simusolar

TABLE OF CONTENTS

ACKNOWLEDGMENT

This report was developed by Dalberg with support from the Efficiency for Access Coalition Secretariat.

The Efficiency for Access Coalition is jointly coordinated by CLASP, an international appliance energy efficiency and market development specialist not-for-profit organization, and the UK's Energy Saving Trust, which specializes in energy efficiency product verification, data and insight, advice, and research.

This material has been funded by UK aid from the UK government. However, the views expressed do not necessarily reflect the UK government's official policies.

ABBREVIATIONS

AC	Alternating current
BOP	Base of the pyramid
CAGR	Compound annual growth rate
DC	Direct current
DESCO	Distributed energy service company
DFID	UK Department for International Development
EEI	Energy efficiency index
FSP	Financial service provider
IRENA	The International Renewable Energy Agency
kWh	Kilowatt hour
MECS	Modern Energy Cooking Services
MFI	Microfinance institution
MSME	Micro, small, and medium-sized enterprise
OGA	Off-grid appliance
OGS	Off-grid solar
PAYGO	Pay as you go
PV	Photovoltaic
RBF	Results-based financing
SDG	United Nations Sustainable Development Goals
SEWA	Self Employed Women's Association
SHS	Solar home systems
SME	Small and medium-sized enterprise
UNCDF	United Nations Capital Development Fund
UNEP	United Nations Environment Program
VAT	Value-added tax
VIB	Vertically integrated business
VIM	Vertically integrated manufacturer
W	Watt
Wp	Watt peak capacity

EXECUTIVE SUMMARY

Situated at the heart of the water-food-energy nexus, the solar water pump plays a critical role in improving the incomes and resilience of rural households while unlocking environmental benefits. Approximately 95% of farmed land in sub-Saharan Africa and 60% of land in South Asia relies solely on unpredictable seasonal rainfall to meet water needs.[1] Around the world, there are more than 500 million farming households that could benefit significantly from adopting irrigation technology. Solar water pumps—a clean, modern irrigaiton solution—have the potential to increase yields by as much as two to three fold depending on crop and climate. Solar water pumps also expand seasonal growing cycles and mitigate periods of low or irregular rainfall. This, in turn, provides households with more predictable and disposable income to pay for education and save for emergencies, thereby reducing vulnerability to risks. Beyond these social and economic benefits, solar water pumps can significantly reduce irrigation-related environmental damage. They can achieve a similar level of performance as diesel pumps without the carbon emissions associated with fossil fuels and can reduce farmers' water consumption when used in conjunction with more efficient irrigation techniques. The use of solar water pumps also helps farmers become more resilient to natural disasters, especially droughts and other changes in rainfall patterns.

Scaling the use of solar water pumps can contribute significantly to many of the Sustainable Development Goals (SDGs). The yield uplift and greater resilience from solar-powered irrigation make considerable progress towards SDG 1: No poverty and SDG 2: Zero hunger. Beyond irrigation, solar water pumps can be used for diverse household activities such as washing, cleaning, and income generation, or to provide access to drinking water for livestock. By mechanizing the process of water collection for households, solar water pumps can also reduce the amount of time spent on collecting water, a task most commonly undertaken by women. Water collection takes on average over 30 minutes per day in sub-Saharan Africa, and therefore the reduction of women's time spent on this activity makes progress towards SDG 5: Gender equality.[2] Solar water pumps can provide households, schools, hospitals, and other community centers with reliable sources of clean water and can thereby reduce the incidence of water-borne diseases, supporting SDG 6: Clean water and sanitation and SDG 3: Good health and well-being. Finally, the environmental benefits of solar water pumps, compared to alternatives such as diesel pumps, contribute toward furthering SDG 7: Affordable and renewable energy and SDG 13: Climate action.

With advances in solar technology bringing down costs and an increasing number of pumps tailored for small-scale use in the market, there is now a growing business case for smallholder farmers to adopt solar water pumps. Expansion in photovoltaic (PV) technology over the past four decades has facilitated a reduction in the cost of PV panels and, subsequently, the retail prices of solar irrigation systems.[3] An increasing number of solar water pump manufacturers, both startups and large established manufacturers, have entered the market, focusing on adapting the technology and their business models to design and sell pumps suitable for a wider customer base. As a result, there are now more products tailored for smallholder farmers available. While the upfront costs are typically still higher than equivalent diesel pumps—the average entry-level diesel pump starts at USD 200 compared to approximately USD 600 to 800 for a solar equivalent—solar water pumps have lower lifetime costs.[4] For example, for a typical farm in Kenya, the total cost over five years to irrigate one

1. "Managing Water for Rainfed Agriculture", IWMI, 2010.
2. "Collecting water is often a colossal waste of time for women and girls", Unicef, August 2016.
3. "Solar Water Pump Technology Roadmap," Efficiency for Access Coalition, May 2019.

acre is estimated at USD 3,000 when using a solar water pump compared to USD 6,000 when using an equivalent diesel pump.[5] For high-value crops, the upfront cost of a solar water pump is recovered within 12–18 months through increased yields, and the solar water pump can break even financially with the diesel pump within two years depending on fuel prices and utilization of the pump.[6,7] Given these market trends, the business case for farmers to adopt solar water pumps versus diesel and other alternatives is strong provided the farmer can make the initial and ongoing payments.

The market for solar water pumps is vastly underpenetrated in both Sub-Saharan Africa and India, the two geographies covered in this report. In sub-Saharan Africa, though data is limited, it is clear that the market is nascent. The most recent market survey conducted by GOGLA in partnership with Efficiency for Access indicates that approximately 5,000 solar water pumps were sold in sub-Saharan Africa in the second half of 2018, of which over 3,000 were sold in East Africa.[8] Though they indicate very limited sales to date, these figures likely only capture a minority of actual sales, because they do not take into account solar water pump sales by non-GOGLA affiliates or sales of large solar irrigation solutions for commercial farms.[9] Compared to sub-Saharan Africa, uptake is higher in India, where an estimated 150,000 solar water pumps are in use today due to government subsidies. Though considerable, this figure represents only a fraction of the 28 million irrigation pumps in use in the country.[10] India's government has ambitious plans to reach its goal of 1 million solar water pumps over the next few years, yet even this would represent only about 3% of the national water pump market. Beyond price, a major reason for the low uptake of solar water pumps in both regions is limited awareness. A recent study in Tanzania showed no awareness or uptake of solar water pumps among a sample of smallholder farmers despite market availability, and in India, only 2% of smallholder farmers are aware of the government subsidy program for solar water pumps.[11,12]

The estimated addressable market for solar water pumps today in sub-Saharan Africa and India is approximately USD 15.6 billion, representing 4.9 million units.

In sub-Saharan Africa, we size the market based on the cost of small solar water pumps suitable for irrigating two acres or less, while in India we estimate size based on the cost of larger solar water pumps. Larger solar water pumps are more dominant in India due to the water intensity of crops such as rice, the government subsidy scheme, and greater groundwater depth in some parts of the country. In India we estimate that there are currently 4.2 million farming households that have demand for a solar water pump and can afford one, versus 700,000 households in sub-Saharan Africa.[13] With increasing household income and decreasing product prices, over the next decade we estimate that the market for solar water pumps in sub-Saharan Africa will expand to as many as 2.8 million households and a value of USD 1.6 billion by 2030.[14]

However, in India we expect the possible removal of the government subsidy on solar water pumps to offset this trend in prices and incomes, and we project a contraction in the market to 3.7 million households with a value of USD 9.4 billion by 2030.[15] This market estimation assumes that all farmers have a base level of access to credit to purchase the solar water pump, which in reality they do not always have.[16] Affordability remains one of the greatest challenges to growing the market for solar water pumps, with a small pump costing the equivalent of about 6–12 months of income for a typical farming household.[17] Addressing the gap in affordability can be done through a number of levers: technology improvements, declining costs along the supply chain, increasing access to finance, and targeted fiscal incentives. As the India example demonstrates, strategic subsidies can also drive uptake, but they can also be costly and distort markets.

4. Dalberg stakeholder interviews, 2019.
5. "The Opportunity for Productive Use Leveraging Solar Energy", IFC, June 2019.
6. Agricultural yields refer to the amount of agricultural production, typically measured in weight, per unit land area.
7. "The Opportunity for Productive Use Leveraging Solar Energy", IFC, June 2019.
8. GOGLA Off-grid appliance market survey, 2019.
9. Dalberg stakeholder interviews, 2019.
10. "Policy Design and Implementation Support for Solar Pumps Programme at National and State Level, Using a Survey and Impact Assessment-based Approach," Shakti Sustainable Energy Foundation, 2017.
11. "Horticulture Value Chains and Potential for Solar Water Pump Technology," Efficiency for Access Coalition, 2019.
12. "Financing Solar for Irrigation in India," CEEW policy brief, 2018.
13. Ibid.
14. Ibid.
15. Ibid.
16. Refers to off-grid farmers excluding subsistence farmers. Dalberg analysis, 2019.
17. Data from The Human Account suggests that the average monthly income of a farming household in India is USD 133, USD 95 in Kenya, USD 78 in Myanmar, USD 53 in Nigeria and USD 36 in Tanzania. The retail price of a basic surface pump is approximately USD 600 – 800. Source: The Human Account, 2019. Source: The Human Account, 2019; Dalberg analysis

For this technology to benefit farmers, solar water pump industry players need to ensure that the prerequisites for a well-functioning agricultural system are in place. Irrigation fits into a broader chain of factors that affect agricultural productivity, including access to farming inputs such as seeds and fertilizer, adoption of agronomic best practices, and access to markets. Where agriculture systems are weak, they need to be strengthened by a system of agricultural extension services that enable farmers to develop technical knowledge of best practices in deciding which crops to grow, nurturing healthy crop growth, and reducing crop loss. In addition, farmers need training on how to install, use, and maintain solar water pumps, as well as access to quality seed and fertilizers. Farmers must also be able to find an off-taker (a buyer that purchases crops from many farmers) who offers a fair market price. Without this broader set of value chain factors, there is a risk that the pumps break or go unused, that the irrigation system does not significantly improve yields, or that farmers are unable to realize an increase in income in the absence of a fair buyer for their produce. Agricultural value chains are complex, and solar water pump businesses can benefit from coordination with value chain actors to ensure solar water pumps are distributed into supported agricultural value chains. This complexity is a key distinction between solar water pumps and some household appliances (e.g. TVs, fans), which can lend themselves relatively more easily to "plug and play" distribution models.

Solar water pump technology needs to be accessible to the mass market of smallholder farmers across Sub-Saharan Africa and South Asia to realize its full potential. To achieve this, industry players will need to respond in a coordinated manner to the severe affordability barriers faced by many farmers. A growing number of smallholder farmers stand to benefit from and can afford solar water pumps. Relatively higher-income farmers, who often farm higher value commercial crops and sell to established buyers, present a commercial opportunity for solar water pump companies. However, this group of farmers represents a small proportion of the addressable market. For the mass market of smallholder farmers across sub-Saharan Africa and South Asia, affordability remains a major barrier to uptake, particularly as suitable financial products are largely unavailable. Furthermore, many farmers face conditions that undermine their ability to fully take advantage of solar water pumps, including limited access to agricultural inputs such as seeds and fertilizer, as well as weak market linkages. A variety of levers are needed to stimulate the solar water pump market to reach scale, including government policy, innovative finance, technology and product adaptation, and partnerships among various stakeholders.

- ***Creating a favorable policy environment that links off-grid solar irrigation to broader national development agendas and creates attractive fiscal and non-fiscal incentives:*** Off-grid solar irrigation is likely to attract the most political support and success when it is connected to major national development efforts, typically including agricultural transformation, electrification, and industrialization. Coordination among ministries of agriculture, water and energy will be critical to achieve integrated policies and programs. To spark growth in the space, interventions should target both the demand and supply-side of the market. These can include smart subsidies, VAT, or tariff policies to lower-end retail prices; or mechanisms such as results-based financing to incentivize distribution at the last mile.

- ***Promoting innovation in financing models (e.g. PAYGO, leasing, asset loans, off-taker structures) to expand access to finance for consumers:*** Given the high upfront costs of solar water pumps, an expansion of financing options and approaches is needed to unlock growth. Financing products need to respond to farmers' needs. For example, farmers earn income at certain time(s) of year when they harvest produce. Pay-as-you go (PAYGO) financing options can be designed to match growing cycles for specific crops. Local banks are often reluctant to lend to farmers due to common challenges of credit risk and lack of collateral. They can be incentivized to increase lending into the sector through targeted credit guarantees, access to concessional wholesale financing, and support to develop market research and alternative approaches to assess risk. They can also explore partnerships to lend into de-risked structures such as off-taker setups, where a contract with a buyer is in place, or out-grower schemes, where smallholder farmers are connected to a larger commercial anchor farm. For distribution companies, the ability to access working capital to order and hold more stock and offer purchase terms on credit will be essential to expand of the market.

- ***Funding for Research and Development to reduce prices and better tailor products to smallholder farmers:*** Research and development (R&D) efforts can bring about a spectrum of improvements in solar water pump technology, product design, and value-added offerings. First, progress in photovoltaic (PV) panel technology can yield continued knock-on benefits for the solar water pump market. Given decreasing costs of PV panels, the prices of solar water pump systems are declining, having dropped by 80% between 1998 and 2013.[18] Second, innovations in product design, particularly to suit specific target markets, could expand the solar water pump customer base. These could include developing more compact products suitable for small-scale use; improving the mobility of solar water

18. "Solar Water Pump Technology Roadmap," Efficiency for Access Coalition, May 2019. The Roadmap is available at: https://efficiencyforaccess.org/publications/solar-water-pump-technology-roadmap
19. Ibid.

pump installations for shared use across several small farms; developing tailored product offerings to accommodate more flow on larger farms; or improving the modularity of systems to allow farmers to add panels or share panels with other solar appliances. Third, improvements in underlying water pump technology could drive efficiency. One promising area of innovation noted in the Efficiency for Access Coalition's Solar Water Pump Technology Roadmap is in brushless DC (BLDC) motors. These motors are more efficient and lower maintenance than conventional motors.[19] BLDC motors are more expensive to produce, and efforts to reduce this cost could deliver long term benefits to consumers. Finally, downstream technology innovations could expand the range of services available to farmers, for example, by providing weather information, agricultural market pricing data, and farming tips. Some manufacturers are already developing PAYGO packages that deliver these services using remote monitoring systems.

- ***Brokering partnerships across the value chain among product manufacturers, distributors, finance providers, and organizations that have access to end customers:*** While individual businesses and industry players are often interested in expanding activities in the solar water pump space, they are often uncoordinated, yet few can expand their activities in isolation. Partnerships among financiers, manufacturers and distributors could provide needed capital for product development and distribution to target markets. At the same time, manufacturers and distributors will need to partner with value chain actors—such as off-takers, governments and donors—who can reach and aggregate smallholder farmers through existing extension programs.

- ***Expanding research into solar water pumps to equip businesses with the information needed to invest at the base of the pyramid; and enabling governments and donors to design targeted interventions:*** Businesses report that they need more market information, including customer and market segmentation information; consumer insights about purchasing decisions and product usage; and analyses of countries and markets that have the highest growth potential. Governments can benefit from research on the broader impacts of solar water pump technologies—for example, strengthening and updating evidence about the proportion of farmland that is irrigated, the social and economic impact of solar water pumps, the benefits and costs versus alternative technologies, and lessons learned from policies and programs to promote uptake of these technologies.


PHOTO CREDIT: Solartech

The solar water pump industry is at an important inflection point, with technology increasingly well-adapted for small-scale users and prices on the decline. Solar water pumps extract water from a surface or groundwater source using energy supplied by PV panels. Though they have many functions, solar water pumps are commonly used as part of solar-powered irrigation systems. An increasing variety of pumps and irrigation systems are available that are suited to smallholder farmers' needs, with smaller pumps extracting enough water to irrigate about one acre of land and starting at a price of approximately USD 600 to 800. Solar water pumps and associated irrigation systems have the potential to benefit off-grid populations in numerous ways—through improvements in agricultural productivity, resilience to environmental disasters, access to clean drinking water, and strengthened health outcomes.

However, critical challenges remain to unlock the potential of solar water pumps in sub-Saharan Africa and South Asia. For many smallholder farmers, solar water pumps remain unaffordable. Manufacturers and distributors struggle to access rural markets in a cost-efficient manner. Though many governments and development actors are prioritizing agricultural productivity as a path to economic growth and food security, in most cases this has not translated into improved policy incentives and funding to support the expansion of solar water pumps. The market and impact potential of solar water pumps is vast, but realizing this potential is likely to require innovation and coordination throughout the value chain, including in product development, distribution, finance, and policy.

This report seeks to provide an overview of the solar water pump market today, estimate the size of the addressable market, and share perspectives on what it will take to achieve this potential scale. We consider six diverse countries in sub-Saharan Africa—Cote d'Ivoire, Ethiopia, Kenya, Nigeria, Sierra Leone, and Uganda—as well as India.[20] We focus on solar water pumps designed for small-scale use. This includes smaller pumps which are typical in the sub-Saharan Africa context (ranging in system capacity from ~75W to ~370W) and larger pumps such as those financed in India through a public subsidy scheme (ranging from ~2kW to ~4kW). This range of pump capacities is most relevant for off-grid rural households because such pumps produce the appropriate flow rate for a typical smallholder plot size. Our analysis looks at current market penetration, total addressable market size, and the expected 2030 market size. We identify key trends and barriers shaping the market across the following areas: technology, customer demand, emerging business models, and policy. Finally, we provide recommendations on how private sector, industry stakeholders, donors, and policymakers globally can help accelerate the growth of the solar water pump market.

Why are solar water pumps especially relevant now?

By increasing access to irrigation, solar water pumps can significantly improve smallholder incomes and livelihoods. Currently, the majority of the world's 500 million smallholder farmers lack access to any modern irrigation solution.[21] Most of these smallholder farmers live in sub-Saharan Africa and South Asia, where 95% and 60% of cultivated land relies on seasonal rainfall, respectively.[22] This lack of irrigation is one of the key reasons for the comparatively low agricultural yields in sub-Saharan Africa. For example, yields for maize, a major staple crop in many parts of sub-Saharan Africa, average about 2 tons per hectare compared to commercial yields of approximately 8 tons per hectare in the Americas.[23] Solar water pumps can have a dramatic impact on smallholder farmer yields, with some case studies showing an increase in yields of as much as two to three times.[24,25] Yield uplift results in better financial outcomes for farmers—for example, interviews in India showed an increase in a farmer's profitability of up to 50% with the use of a solar water pump.[26] This was driven either by an increased quantity of produce or by savings in fuel costs. Farmers' financial health can also become more stable with irrigation—a survey of solar water pump customers in East Africa found that 82% experienced an improvement in their quality of life, mainly through increased income, better yields, and greater savings.[27] Access to water pumps also improved farmers' resilience to climate shocks such as unreliable rainfall patterns and drought.

In sub-Saharan Africa and South Asia, the solar water pump industry is growing due to recent advances in technology and falling prices. Diesel pumps and electric pumps connected to the grid are traditionally the most common types of water pumps. Solar water pumps were first introduced in sub-Saharan Africa in the 1970s; however, it has only been in the last 10 years, following the sharp decline in the price of PV panels, that they have begun to gain traction. The most common types of solar water pumps are submersible pumps and surface

20. Countries were selected for their diversity in terms of both geography and degree of development of their off-grid markets.
21. "Reaching Scale in Energy Access," Hystra, 2017.
22. "Managing water for rainfed agriculture", IWMI, 2010.
23. "OECD FAO Agricultural Outlook 2018 2027", FAO, 2017.
24. "How a Kenyan Company is Helping Farmers with Irrigation," CDC Story, 2017.
25. The same studies also show that the impact of irrigation is more probable when accompanied by other services such as access to quality inputs and markets.
26. "Reaching Scale in Energy Access," Hystra, 2017.
27. "Use and Benefits of Solar Water Pumps: Kenya, Tanzania, and Uganda Consumer Research," Efficiency for Access Coalition, 2019.

pumps. Submersible pumps are used in deep water such as wells or boreholes and may require up to ~4kW, while surface pumps are used for surface water and require as little as ~75W. A range of pumps is available in both sub-Saharan Africa and South Asia. In India, large 2-4kW pumps that cost from USD 1,000 to over 3,000 are more commonly owned by smallholder farmers. Small solar water pumps requiring ~500W or less are more prevalent among smallholder farmers in sub-Saharan Africa and are priced around USD 600 to 800.

At smallholder scale, the technology and business models for solar power water pumps have primarily been driven by innovative start-ups and are now maturing to the point where they are market ready. Innovators such as Future pump, Ecozen, Shakti Pumps, and Bengal Renewable Energy have been working to make their technology and business models affordable and accessible for smallholder farmers. As the industry grows and more actors see the market potential, there have been significant changes to the landscape of players who manufacture and distribute products. Generic manufacturers are entering the market with products that tend to be competitively priced but are often unreliable. For example, some generic manufacturers sell 750W submersible pumps for as low as ~USD 200.[28] At the same time, players traditionally focused on larger scale irrigation products, such as Lorentz, are starting to develop solar water pumps for small-scale irrigation. Solar home system and mini-grid players are recognizing that many of their existing customers are farmers, and accordingly they are taking an interest in cross-selling solar water pumps. This increasing activity in solar water pumps represents an opportunity for both market players and development actors to capitalize on the commercial potential of solar water pumps while improving livelihoods for rural households.

28. FOB price. Dalberg review of public pricing information for a range of generics manufacturers, 2019.

How large is the solar water pump market today?

The current market penetration for solar water pumps remains low but is growing. In India, the most developed market in South Asia, an estimated 150,000 solar water pumps have been sold to date.[29] These represent a small fraction of the 9 million diesel water pumps and 19 million electric pumps present in the country.[30] Compared to India, the solar water pump market in sub-Saharan Africa is much more nascent. Recent data from GOGLA affiliates estimates that approximately 5,000 solar water pumps were sold in sub-Saharan Africa in the second half of 2018, of which 3,000 were sold in East Africa.[31] Though these figures indicate very low market penetration to date, it is expected that actual sales figures are higher because some companies did not participate in reporting.[32] The primary market constraint is affordability, driven by higher retail prices than in India in the absence of subsidies and lower average farmer incomes. In addition, in many countries in sub-Saharan Africa, smallholder farmers are less familiar with irrigation technologies and how to farm with them. Distribution is also more challenging because rural population densities are often lower, roads may be poorer, and fewer formal businesses are set up to serve many of sub-Saharan Africa's rural markets. There is anecdotal evidence that sales are growing, albeit off of a low base. One distributor estimates that they sold 200 solar water pumps per month in Kenya in the first half of 2019, double their monthly sales figures for 2018.[33] As players expand into new geographies—Futurepump now distributes their solar water pumps to 14 countries, for example—this small market appears to have the potential to grow quickly.

What is the solar water pump market opportunity over the next 10 years?

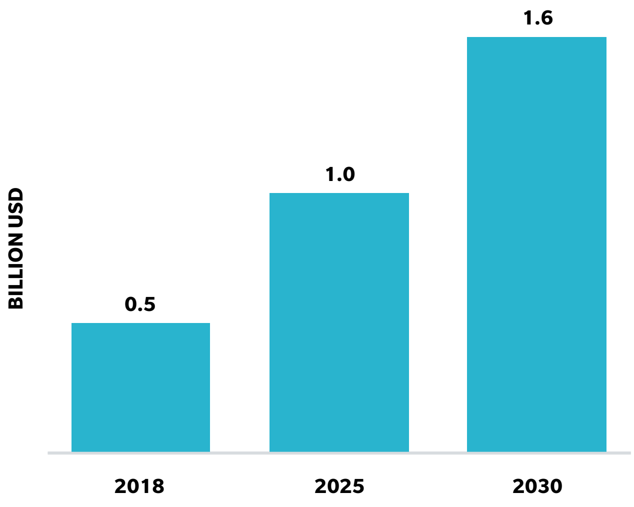
For our market sizing, we estimate the total addressable market for solar water pumps in sub-Saharan Africa and India. We define the addressable market to be the number of farming households who have demand for a solar water pump and can afford one, assuming access to finance over 36 months with a 10% upfront payment. For these purposes, we include off-grid and weak-grid farming households which have access to a water source. For sub-Saharan Africa, we exclude subsistence farmers since they do not have an agricultural income source, but we do include farmers engaging in a blend of subsistence and cash agriculture. In India, we do not exclude subsistence farmers because they are an important target group for the government's current subsidy policy.

We estimate the two markets separately, focusing on small, 75–370W pumps in sub-Saharan Africa, and large, 2–4kW pumps in India. We assume a pump price of USD 650 in sub-Saharan Africa, and in India a pump price of USD 3,600 before subsidy and USD 504 after subsidy.[34] We conservatively assume a 1% annual reduction in the price of solar water pumps. Data on smallholder farmer household incomes is scarce, so we use survey data in countries where available and extrapolate a ratio of average smallholder farmer income to average national income in countries where such data is unavailable. This market sizing exercise has been conducted for this study only, and estimations should be taken as preliminary and directional. Further research and additional resources are needed to develop more accurate projections.

The addressable market in sub-Saharan Africa is expected to triple in the next decade, driven by income growth and falling prices. In sub-Saharan Africa, we estimate that the addressable market for small solar water pumps currently stands at 700,000 households and is worth USD 0.5 billion.[35] With household incomes increasing due to overall economic growth and agricultural transformation efforts, and with product prices decreasing due to technological improvements, the affordability constraint will likely decrease in the next decade. These solar water pumps have the potential to reach up to 1.6 million households in sub-Saharan Africa by 2025 and as many as 2.8 million households by 2030—a value of approximately USD 1.6 billion by 2030.[36] This market sizing represents a small share of the 500 million farmers in sub-Saharan Africa—most of whom would be unable to afford solar water pumps, even with financing, given their current income levels.

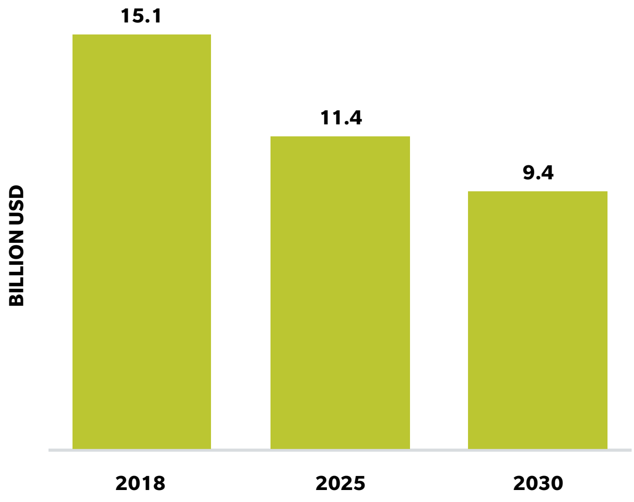
29. "Adopting Solar for Irrigation – Farmers' Perspectives from Uttar Pradesh," Jain, Abishek and Shahidi, Tauseef, Council on Energy, Environment and Water, 2018.
30. Ibid.
31. GOGLA Off-grid appliance market survey, 2019.
32. Ibid.
33. Dalberg stakeholder interviews, 2019.
34. Dalberg analysis based on average retail prices of the leading products in respective markets, 2019.
35. Dalberg market sizing, 2019.
36. Dalberg market sizing, 2019.
37. Dalberg market sizing, 2019.

Figure 1: Market potential in sub-Saharan Africa



Source: Dalberg analysis

Figure 2: Market potential in India



Source: Dalberg analysis

The Indian market may contract due to the possible removal or reduction in the government's subsidy scheme for solar water pumps. The current addressable market for large solar water pumps in India is estimated at 4.2 million households or USD 15.1 billion and the presence of a subsidy on solar water pumps has a heavy influence on the market.[37] The current subsidy scheme is slated to end in 2022, and it is not known whether the scheme will be replicated or adjusted in the future. We assume a 50% reduction in government subsidies over the next ten years, as is consistent with the expectations of some industry players. Therefore, we estimate that the market will decrease to 3.7 million households by 2030, amounting to a potential market of USD 9.4 billion.[38] Despite decreasing pump prices over the next ten years, the reduction of the subsidy could effectively triple the prices buyers will have to pay compared to the current subsidized prices.

Where are the most significant solar water pump market opportunities?

Market potential varies by geography depending on the prevalence of incumbent technologies, smallholder income levels, presence of commercial value chains, and relative maturity of the solar industry. Markets are evolving from very different baseline levels of irrigated land and irrigation needs. Asian markets, because of their higher production of rice, have an existing high base for irrigation, and smallholder farmers can access larger pumps. In sub-Saharan Africa, mechanized irrigation is generally low, and a high percentage of farmers are subsistence farmers or sell small quantities of produce to informal traders. Because farmer incomes are low and affordability is constrained, these markets demand more innovative business models from private sector players and more donor and government support.

Four key factors characterize the growth potential for solar water pumps in the markets studied for this report—the profile and structure of the agriculture sector, the presence of incumbent technologies, the maturity of the solar industry, and the size and wealth of the smallholder farmer population. First, regarding the structure of the agriculture sector, the yield and income benefits of solar water pumps are most significant for high value crops, such as vegetables and horticulture; therefore, the technology would be most attractive in areas where those value chains are active and developed. The strength and structure of value chain development depend on factors such as the share of farmers who are organized into cooperatives and the strength of market linkages between producers and off-takers. Second, incumbent technologies determine customers' awareness and comfort with irrigation systems. In countries where alternative irrigation technologies are used by smallholder farmers—for example diesel irrigation in India—there is an opportunity to switch farmers to solar pumps. In these markets the main determinants of growth will be the benefits to farmers of switching to solar pumps, such as lower medium-term financial and labor costs compared to diesel pumps. In markets with less

38. Dalberg market sizing, 2019.

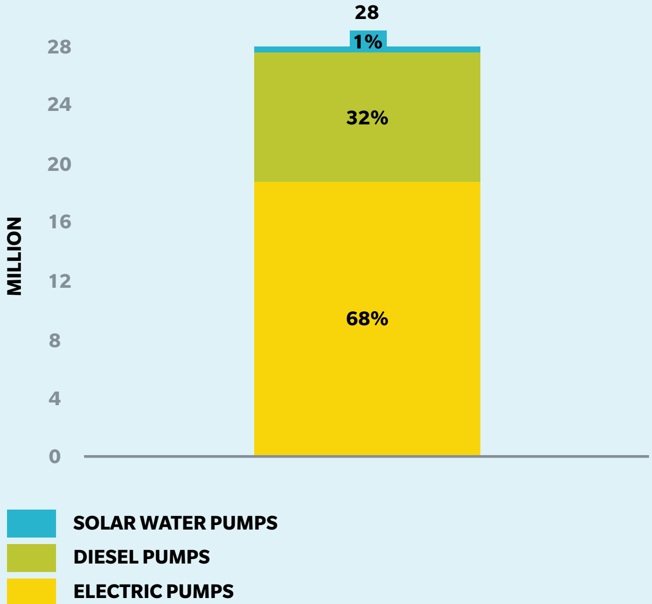
use of incumbent technologies, distributors need to invest more in educating customers about irrigation and its benefits. Third, countries with an active solar energy industry, notably those with policies conducive to solar water pump distribution and developed solar home systems and solar PV markets (e.g., Kenya and Cote d'Ivoire), are likely to see the emergence of innovations in distribution and financing models. These models can stimulate the uptake of solar water pumps, even where the markets are nascent. Finally, as solar water pumps are a nascent and still relatively expensive technology, the size and income level of the population of smallholder farmers in a country will directly impact the attractiveness of a market for growth in the near term. Although financial levers such as subsidies and increased access to credit can help farmers afford solar water pumps, these interventions may have limited impact without further support. Important to success are national efforts toward agricultural transformation and an engaged and dynamic private sector driving innovation and successful technical, market, and financing support to farmers. Notably, even where the ideal pre-conditions are in place, at the level of the individual farm, adoption of solar water pump technology is only possible where there is suitable access to water—whether surface water or groundwater—at a depth that can be accessed using an affordable submersible pump.

How have solar water pump subsidies influenced the market?

The Indian government is strongly promoting the uptake of solar water pumps as half of all farmers do not have access to a modern irrigation solution, and those that do mostly use electric and diesel pumps. The high share of fossil fuel-dependent pumps not only creates negative environmental side effects, but it is also expensive for national and local governments and end users. The power consumption of all diesel and electric pumps in the Indian market is equivalent to 85 million tons of coal for electricity generation and four billion liters of diesel—representing about 20% of the country's electricity consumption and 3% of its diesel use.[39] Due to this non-renewable energy use, approximately 200 million metric tons of CO2 are emitted each year. The annual expenditure on subsidies for diesel powered or electric pumps is as high as USD 6 billion.[40] The Indian government aims to reduce its dependency on fuel powered pumps by deploying a minimum of 100,000 solar water pumps annually to achieve a target of 1,000,000 solar water pumps by 2021.[41]

While subsidy schemes have helped equip a substantial number of farmers with solar water pumps, India is not on track to achieve its target of one million solar water pumps by 2021. The main reasons for the low uptake are lack of policy enforcement at a state level, lack of awareness of available government subsidy schemes, and limited knowledge of the use case and economic value of solar water pumps. Even with subsidies, most solar water pumps are too expensive for smallholder farmers to afford. In particular, smallholder farmers have low capacity to save and limited access to credit.

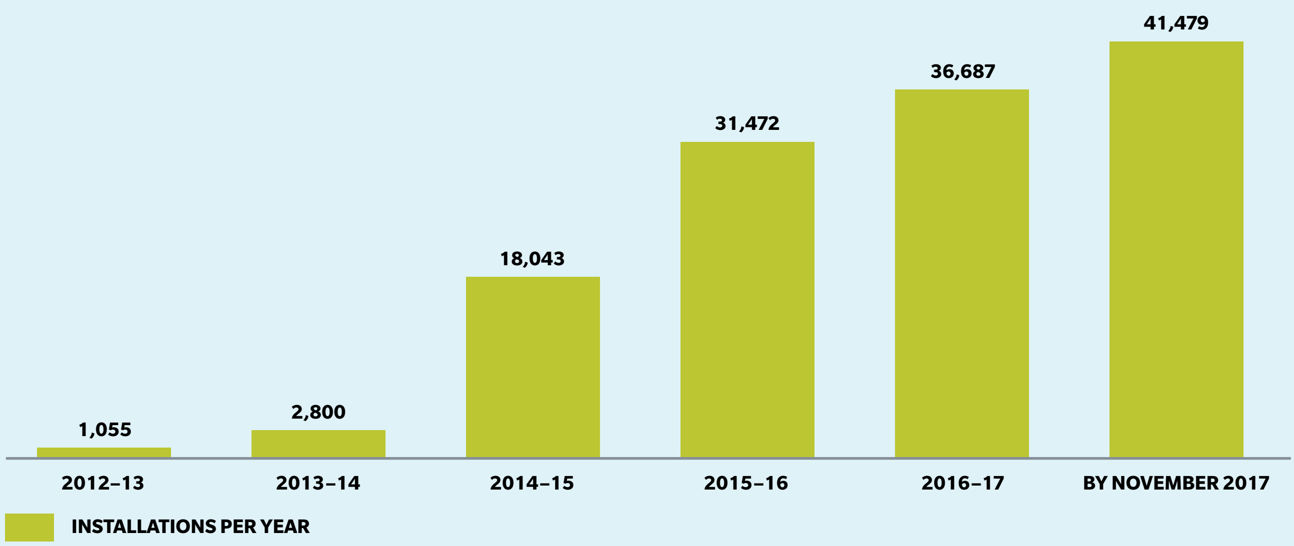
Figure 3: Types of water pumps in use in India



Source: Adopting Solar for Irrigation: Farmers' Perspectives from Uttar Pradesh," CEEW, 2018.

On the supply side, with limited knowledge of the return on investment of solar water pumps or their resale value, financial institutions have a higher perception of the risk of financing smallholder farmers' purchases of these pumps. Furthermore, many farmers still do not have a sufficient understanding of solar water pumps and supportive government schemes. In a recent survey, only 27% of farmers had heard about solar water pumps, and only 2% knew of the government subsidy schemes that were meant to promote them.[42]

Figure 4: New installations of solar water pumps in India per year from 2012 to November 2017



Source: Shalu Agrawal and Abishek Jain, "Financing Solar for Irrigation in India – Risk, Challenges, Solutions", Council on Energy, Environment and Water, 2018.

39. "Policy Design and Implementation Support for Solar Pumps Programme at National and State Level, Using a Survey and Impact Assessment-based Approach," Shakti Sustainable Energy Foundation, 2017.
40. Mehra, Varun, "Solar Pumps: India's Potential to Link Electricity Access and Irrigation Needs?" The Energy Collective. 2015.
41. "Policy Design and Implementation Support for Solar Pumps Programme at National and State Level, Using a Survey and Impact Assessment-based Approach," Shakti Sustainable Energy Foundation, 2017.
42. Ibid.

Solar water pump basics

Solar water pumps are appliances powered using energy generated by PV panels to extract water from a well, stream, or another water source. While the water can be used for household or small-scale business needs, the most common use for solar water pumps is as part of solar-powered irrigation systems for crop irrigation and animal husbandry in off-grid areas. Irrigation needs depend on several considerations, but the primary factors are the type of crop, the proximity to a water source, the terrain, and weather patterns. The three most common types of irrigation used by smallholder farmers are surface irrigation, sprinkler irrigation, and drip irrigation.

Solar water pumps tailored for smallholder use come in the form of both submersible and surface pumps. Power consumption and efficiency vary significantly between these two types of pumps. Submersible pumps work in wells and boreholes at depths at and above 100 meters, require more horsepower and larger solar installations, and tend to be more expensive. They are more prevalent in areas where more water is needed or where water is only available at greater depths. More cost-effective micro-submersible pumps use similar technology at less depth and can lift to ~20-65 meters. By contrast, surface pumps are installed next to a water source such as a lake or stream and can pump from a maximum depth of ~5-10 meters. Micro-submersible and surface pumps are more prevalent on smallholder farms due to their lower cost and easy installation.

The most common use for solar water pumps is as part of solar-powered irrigation systems, which allow a more mechanized approach to irrigation. The critical components of a solar-powered irrigation system are the pump itself, panels, charge controller, and irrigation hardware tailored to the land and crop (e.g., irrigation piping).[43] Systems typically also include other equipment such as a reservoir (e.g., water tank). Most solar water pumps do not include a battery for cost reasons and because irrigation typically takes place during the daytime. However, the relative costs of small batteries required for small solar water pumps are not prohibitive, and companies that focus on smaller-sized pumps are experimenting with batteries to ensure continuity of supply during short cloudy periods.[44] Because they are modular and not standardized, solar water pump systems differ from other off-grid appliances in their application and installation. Some suppliers sell and install bundles that include all of the main components of an irrigation system, while others supply only pieces of the system, such as the pump, motor, and controller. This modularity also impacts the interpretation of technical specifications for products, with pump performance and efficiency metrics differing based on both the PV array and the design of irrigation piping.

Figure 5: Illustration of submersible pump

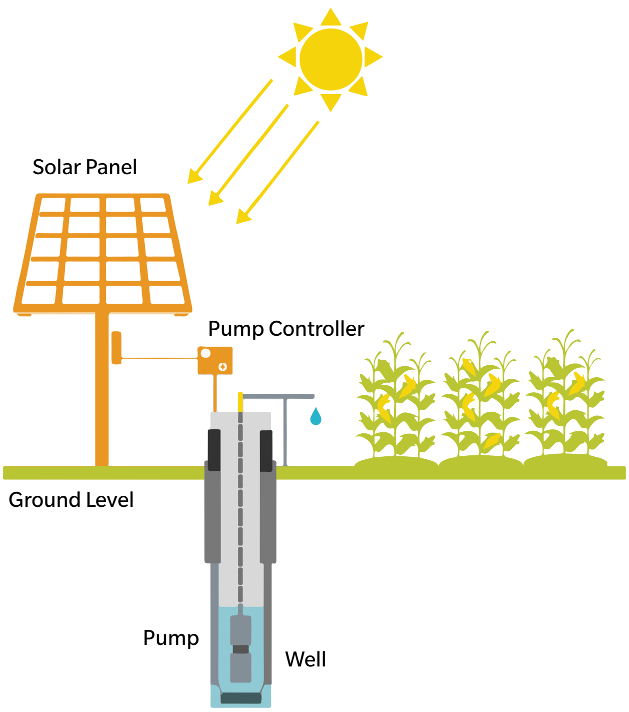
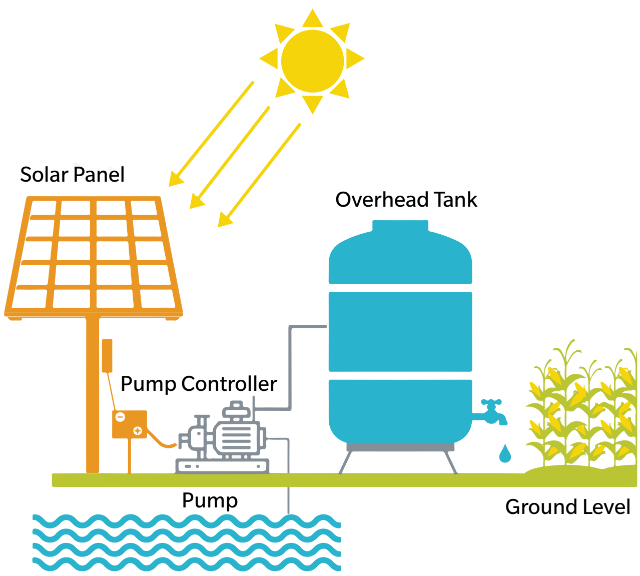


Figure 6: Illustration of surface water pump



43. "Solar-powered Irrigation Systems," SPIS Toolbox, 2017.
44. Ibid

Figure 7: Illustrative overview of types of submersible and surface pumps

	SUBMERSIBLE PUMP - LARGER	SUBMERSIBLE PUMP - MICRO	SURFACE PUMPS
			
DESCRIPTION	Fixed pump and PV panels, tailored installation	Semi-fixed pump and PV panels, guided installation	Mobile pump and PV panel, guided installation
TECHNICAL SPECS	3-5 HP. Maximum suction lift of 350m	Works on a 160-260W panel, with a flow rate of up to 3,000 liters/hr. Maximum suction lift of 65 meters.	Works on an 80-120W panel, with a flow rate of up to 3,600 liters/hr. Maximum suction lift of 7 meters.
STARTING PRICE (BRANDED)	3,500 USD	650 USD	695 USD

Source: Dalberg analysis of company product offerings and price lists, 2019.

When selecting irrigation systems, farmers consider several factors, including the type of crop, the topography of their farm, and the price. The choice of irrigation type is dependent on the type of crop the farmer is cultivating—for example, drip irrigation is the most common for horticulture. An assessment must then be done on the water demand, based not just on the type of crop but also on the soil properties, evaporation rates, spacing, and other factors.[45] Agronomists most commonly do this assessment, but some countries use regionally determined standards.[46] Determining these factors—the type of crop, type of irrigation, and water demand—allows a farmer to build his or her irrigation system. Some distributors sell kits that include the irrigation system and the irrigation hardware (drip irrigation pipes, etc.). Smallholder farmers who are price sensitive will often not purchase irrigation kits with pipes but will purchase the pump to extract water and then do the irrigation manually.

How has solar water pump technology been evolving?

Reductions in the cost of PV panels and increased interest from pump manufacturers in smaller applications are contributing to falling prices and improvements in solar water pump technology. Since the 1970s, the price of PV panels has fallen from ~$76/W to ~$0.3/W.[47] The PV panel now accounts for approximately a quarter of the production cost of a solar water pump, with the remaining costs going to the pump technology and add-on devices (Figure 8). At the same time, more pump manufacturers have entered the market, drawn by decreasing production costs and increasing demand. The combined effects of falling PV prices and increased numbers of market players have facilitated a decrease in the price of solar water pump systems, with prices falling by 80% over the past two decades.[48] With the smallholder farmer in mind, manufacturers are increasingly developing smaller applications for individual use. However, although their lifetime costs are more favorable, the upfront costs of solar water pumps are still high when compared to diesel alternatives. While entry-level solar pumps can cost between USD 600 and 800, diesel pump prices can be as low as USD 200 not including ongoing fuel costs. Comparably high upfront prices make solar water pumps unaffordable for many smallholder formers without access to finance.

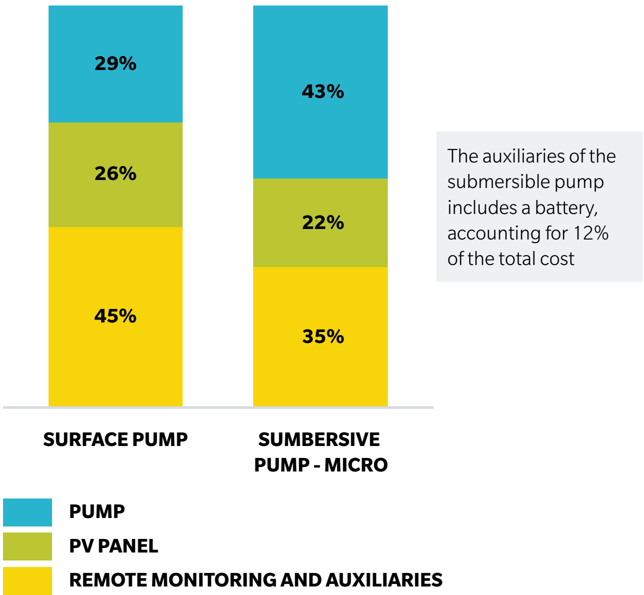
45. "Solar Pumping: The Basics," World Bank. 2018.

46. For example, Rwanda's Ministry of Agriculture and Natural Resources developed an "Irrigation Master Plan" (2010) specifying irrigation needs for different areas of the country based on a variety of factors including the crop focus for each region, rainfall patterns and soil characteristics.

47. "Solar Water Pump Technology Roadmap," Efficiency for Access Coalition, May 2019.

48. Ibid.

Figure 8: Estimated cost breakdown for solar water pump components



Source: Dalberg stakeholder interviews, 2019. The auxiliaries of the submersible pump include a battery, accounting for 12% of the total cost.

Innovations in solar water pumps are moving towards Internet of Things (IoT)-enabled improvements—notably, sensors and remote monitoring—and brushless DC motors (BLDC). IoT functionality can increase the overall utility, efficiency and affordability of solar water pumps. GSM-enabled machine-to-machine systems installed in pump controllers are being piloted in several ways: (i) to provide manufacturers with data—such as customer usage, system performance, and downtime—to help improve their product or offer maintenance remotely; (ii) to allow farmers to monitor how much water they are pumping; and (iii) to allow distributors to remotely shut-off solar water pumps using PAYGO technology. Access to usage data and remote maintenance could expand the efficiency and lower the lifetime cost of solar water pumps for farmers. Remote access to pumps for PAYGO distributors could lower transactional costs of lending and encourage expansion of financing to smallholder farmers.[49] India's Ecozen has established a Farm Connect platform that enables users to monitor and control their solar pump setups remotely from their mobile phones. Farmers can switch the pump on or off and view both energy generation and water output from the system, as well as contacting Ecozen's customer support. There is also ongoing innovation via using BLDC motors in solar water pumps due to their higher efficiency and lower maintenance requirements compared to AC induction and conventional DC motors. BLDC motors are on average 85-90% efficient whereas traditional brush motors are 75-80% efficient.[50] However, while many newer products feature BLDC motors, several technical and market barriers limit their full adoption in solar water pumps. These include the higher upfront cost of BLDC motors, limited research on low-cost production techniques, little market awareness of the benefits of BLDC motors, and fewer service providers in rural areas.[51]

CASE STUDY
Proximity Design

Proximity Design, based in Myanmar, was seeking to extend its existing irrigation product line for smallholder farmers in Myanmar when it began investigating solar water pumps. Traditional submersible pumps did not fit into the narrow tube wells that are most common in Myanmar, effectively preventing farmers from employing solar powered irrigation.

After studying the market and not finding a suitable pump for the 2-inch tube wells, the company designed its own—with a focus on durability, given the large investment a solar water pump represented for farmers. In good sunlight, it pumps at 50 liters per minute at five meters. Proximity Design distributed its first batch in early 2016 and has so far tested the product with 500 farmers, focusing on those that farm horticulture. The product sells for under USD 400 on a payment plan that requires an up-front payment and six further installments that align with agricultural seasons. With both a pump design and a financing plan tailored to its customer's needs, Proximity Design has built the foundation for a successful and impactful product.

49. "Low-Energy Inclusive Appliance Technology Summaries," Efficiency for Access Coalition, 2017.
50. Ibid.
51. Ibid.

What are the use cases for solar water pumps and, who are the customers using them?

Across the developing world, solar water pump customers are most commonly farmers who use the pumps for a range of agricultural purposes, including for both crops and livestock. There is a range of solar irrigation solutions serving larger commercial farmers—the focus of this report is small solar water pumps tailored for use by smallholder farmers. These pumps are beneficial to smallholder farmers whose crops require a consistent water source, including some of the most commonly grown crops in sub-Saharan Africa and India, such as rice, maize and horticulture. One study in India found that 87% of farmers believe that reliable irrigation would improve crop productivity.[52] Access to solar water pumps can also provide a regular water source for livestock, particularly for milk production. On average cows need three liters of water for every liter of milk produced.[53] In sub-Saharan Africa, where average output per dairy cow can be as low as 5 liters per day, smallholder farmers would require at least 15 liters of water per day per cow. In East Africa, 61% of solar water pump customers surveyed raised livestock, notably cows and goats.[54]

Household and community uses are other important applications for solar water pumps, both as primary and secondary uses. A study in East Africa found that 22% of solar water pump customers do not use their pumps for farming at all, but rather for domestic or small-scale commercial use (e.g., as water sources for schools, places of worship, or construction sites).[55] Similarly, many solar water pump users in India use the pump for household water rather than farming.[56] This additional use case has a positive impact particularly on women, who tend to be responsible for collecting water for the household.[57] Farmers can also use pumps in the household during times of a crop cycle when irrigation is not needed for agriculture—about 30–40% of a season on average.[58]

While there is limited data available, anecdotal evidence suggests that generally speaking, solar water pump customers tend to be from a higher income bracket and are better educated relative to most smallholder farmers.[59] This is to be expected given the high upfront costs of the solar water pump themselves and the likelihood for better educated customers to be more aware of the benefits of irrigation and to have a greater level of comfort with solar products. In Kenya, data suggests that pump users are wealthier than the average person, with 75% of users living above the USD 3.10 per day poverty line compared to the national average of 53%.[60] Still, access to finance is a critical enabler for solar water pump customers as 70% use a loan to finance their new solar water pump.[61] Given that the solar water pump market in East Africa is nascent, current customers are likely to be early adopters who are relatively risk tolerant and have more disposable income. Further research on typical solar water pump customers—their demographics and profile, as well as how they make their purchase decision and what they use the pumps for—is needed to understand purchase and use dynamics better.

52. Adopting Solar for Irrigation: Farmers' Perspectives from Uttar Pradesh," CEEW, 2018.
53. "Water Use of Livestock Production Systems and Supply Chains," FAO, 2018.
54. "Use and Benefits of Solar Water Pumps: Kenya, Tanzania, and Uganda Consumer Research," Efficiency for Access Coalition, 2019.
55. Ibid.
56. "Impact Assessment of the National Solar Pumps Programme," Shakti Foundation, 2018.
57. "Gender Dimensions of Community-based groundwater Governance in Ethiopia," Nigussie et al., IWMI, 2017.
58. "Renewable Energy for Smallholder Irrigation: A Desk Study on the Current State and Future Potential of Using Renewable Energy Sources," SNV, 2014
59. "Use and Benefits of Solar Water Pumps: Kenya, Tanzania, and Uganda Consumer Research," Efficiency for Access Coalition, 2019.
60. Ibid.
61. Ibid.

MEET GALIWANGO GEOFREY, A COFFEE AND BANANA FARMER FROM UGANDA

Galiwango bought his solar pump after attending an exhibition and seeing a group of people talk about power saving technologies in agriculture. He doesn't know anyone else with a solar pump and had not heard of the use of solar technology in agriculture before. He paid for the pump upfront in cash.

Before the SWP he used a watering can to irrigate his crops, but has stopped using it since purchasing his solar pump. On his farm, he grows coffee, banana, maize and vegetables; but mostly irrigate the 3 acre of young coffee and the vegetables.

Galiwango recommends the pump to all his friends and family because of its cost effectiveness and because it's easy to use.

"I no longer spend a lot of time irrigating crops and the exercise is not very exhausting as it was before. My life is better because I am not using a lot of time and energy while carrying out the irrigation."

PHOTO CREDIT: Futurepump

What is shaping consumer demand for solar water pumps?

AWARENESS AND KNOW-HOW

Despite solar water pumps being on the market for years, awareness of solar technology, and specifically its use to power water pumps, remains limited in many markets. This lack of awareness is even more significant when it comes to solar-powered irrigation. In East Africa, although 64% of solar water pump customers owned a solar lighting product before purchasing a solar water pump, 57% had not heard of using solar technology for irrigation prior to owning a pump themselves.[62] Studies in India likewise reveal low levels of awareness.[63] Furthermore, awareness of the spectrum of modern irrigation solutions, and the full extent of the potential benefits of irrigation, also remain limited in some markets.

Without training and guidance to farmers, investments in solar water pumps are unlikely to lead to agricultural gains. Irrigation adds complexity to a farmer's agricultural system—it affects other farming decisions such as fertilizer use and harvest timing. Farmers switching from manual irrigation techniques must learn both how to set up and manage the irrigation system.[64] Many sellers provide training at the point of installation, yet fewer provide after-sales service support. Farmers switching from diesel pumps also face a learning curve as they adjust their irrigation techniques from high-flow pumps to more moderate flow pumps. For farmers that are not part of technical assistance programs, learning these skills and techniques can be challenging.

The decision to purchase a solar water pump is highly dependent on trust in the authenticity of the technology and the impact it can have on a farmer's livelihood. The purchase cycle (the steps involved in converting a sale) for a solar water pump is longer than those for more basic solar appliances. Convincing farmers of the value of the technology requires time, with more education needed on how the product works and in particular how it can benefit their farms.[65] Distributors recognize this, and many report that they have to visit a farm multiple times to close a sale.[66] The demonstration of use is critical in converting sales. Farmers who have seen a solar water pump operate successfully, and have positive views about the operation, are twice as likely to adopt one themselves compared to farmers who are not aware of this technology.[67] Farmers often need additional time after they made their decision to save funds for purchase given the relatively high upfront cost of a solar water pump.

AFFORDABILITY

Financing for solar water pumps is critical—without it, solar water pumps are inaccessible to the vast majority of farmers in sub-Saharan Africa and South-East Asia. The price of a small-scale pump is equivalent to at least 6-12 months' income for a typical farming household.[68] This price means that farmers without access to some form of institutional credit are only able to afford a solar water pump if they manage to save a significant amount of their income over a long time, borrow from friends and relatives, or purchase a solar water pump collectively with other households. A study of the Kenyan solar water pump market found that the lack of smallholder financing for irrigation was a key obstacle to solar water pump sales.[69] It is clear that affordability is top of mind for farmers once they do have the opportunity to buy a pump—farmers cited price as the top purchase driver when selecting a solar water pump.[70]

Current financing solutions for solar water pumps are limited, and many available options are unattractive for smallholder farmers given their high costs and unfavorable terms. PAYGO solutions are starting to take hold in the solar water pump space. For example, SunCulture has launched a "Pay as You Grow" model that not only provides financing but also recognizes the need for a broader spectrum of post-purchase support enabling farmers to grow and earn more. However, beyond PAYGO, alternative forms of financing for solar water pumps are limited. Traditional commercial banks often do not have the risk appetite to lend directly to smallholder farmers, while the size of loans typically provided by microfinance institutions are too small to cover the cost of solar water pumps. Furthermore, financial institutions prefer to lend to farmers where there is a reliable off-taker that can provide some certainty of a market for the farmers' produce and even stand as a guarantor for the asset loan. In many cases, financing terms offered by traditional financial institutions for solar water pumps carry high annualized interest rates and require a minimum 30% down payment—which is out of the reach of many smallholder farmers.[71] These loan terms often do not account for unpredictability in repayment schedules; if loans come with insurance, it is added as an extra cost to the total loan value. In addition to being expensive, the financing process can be challenging for smallholder farmers who may not have experience accessing credit through a financial institution. In one study in India, the complicated process and harassment by bank officials both ranked above the high interest rate as challenges faced by farmers in accessing loans from banks.[72]

62. "Use and Benefits of Solar Water Pumps: Kenya, Tanzania, and Uganda Consumer Research," Efficiency for Access Coalition, 2019.
63. "Adopting Solar for Irrigation: Farmers' Perspectives from Uttar Pradesh," CEEW, 2018.
64. "Solar Pumping: The Basics," World Bank, 2018.
65. Dalberg stakeholder interviews, 2019.
66. Ibid.
67. "Adopting Solar for Irrigation: Farmers' Perspectives from Uttar Pradesh," CEEW, 2018.
68. Data from The Human Account suggests that the average monthly income of a farming household in India is USD 133, USD 95 in Kenya, USD 78 in Myanmar, USD 53 in Nigeria and USD 36 in Tanzania. The retail price of a basic surface pump is approximately USD 600 – 800. Source: The Human Account, 2019. Source: The Human Account, 2019; Dalberg analysis.
69. "Accelerating Solar Water Pump Sales in Kenya: Return on Investment Case Studies," Solar World Congress, 2017.
70. "Use and Benefits of Solar Water Pumps: Kenya, Tanzania, and Uganda Consumer Research," Efficiency for Access Coalition, 2019.
71. "Accelerating Solar Water Pump Sales in Kenya: Return on Investment Case Studies," Solar World Congress, 2017.
72. "Adopting Solar for Irrigation: Farmers' Perspectives from Uttar Pradesh," CEEW, 2018.

WATER ACCESS

Solar water pumping relies on access to water—either a surface water source or a borehole—which, particularly in sub-Saharan Africa, presents a significant constraint to the uptake of solar water pumps. In sub-Saharan Africa, approximately 78% of large- and small-scale irrigation schemes use surface water, while 20% make use of groundwater resources.[73] Farmers are very aware of the limitations posed by water access and view their water source as a critical factor in their choice of irrigation method.[74] Across the continent, the total area under irrigation could potentially be increased 120 times over by using groundwater resources in 13 countries—Nigeria, Tanzania, Ghana, Zambia, Burkina Faso, Ethiopia, Niger, Kenya, Mali, Mozambique, Rwanda, Uganda, and Malawi.[75] Using optimal irrigation approaches, such as drip irrigation for horticulture, could achieve this expansion while limiting groundwater use. While surface water remains a key water source, the expansion of groundwater access is one of the critical factors to be addressed if land under irrigation is to expand and if solar water pump adoption is to increase. The expansion of access to groundwater requires significant coordination by national and local governments to expand use of groundwater resources at the same time as ensuring this is done sustainably to avoid over depletion.

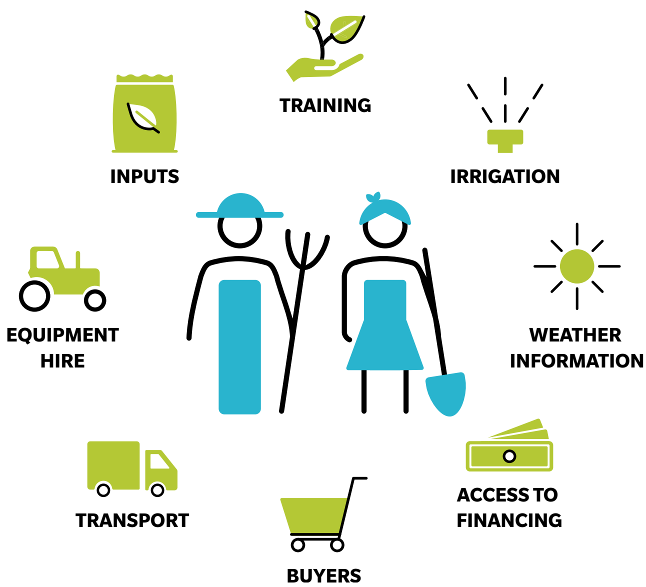
In India, where groundwater access is more developed than sub-Saharan Africa, groundwater depletion is a major concern. With solar technology, the marginal costs of pumping water for longer are minimal; whereas with diesel pumps, there is proportional incremental fuel cost the longer the pump is on. Switching from diesel pumps to solar water pumps brings with it a risk that owners of solar water pumps will lack the incentive to irrigate efficiently. This has the potential to lead to groundwater depletion, which is particularly worrisome in India where 30% of aquifers are already at critical status.[76] Potential solutions currently being tested by various actors include government mapping of water tables and making this data available to solar water pump companies and smallholder farmers. It also includes encouraging pump sharing to increase more efficient utilization and rigorous water accounting to regulate groundwater use. Smart metering on pumps is a potential solution that allows farmers to track water usage and pre-set pump operation times based on water flow.

What impact can solar water pumps have on smallholder farmers?

Solar water pumps can significantly contribute to improving livelihoods and quality of life when used for either agricultural or household purposes. As irrigation devices, solar water pumps result in higher yields, in some cases tripling agricultural output, and can lower costs. This can be due to increased production resulting from larger cultivated areas or multi-season cultivation, and decreased spending on water acquisition or alternative irrigation methods. Depending on the type of crop, yield increases can result in significant income gains for farmers, particularly for high-value crops with short growing seasons. Access to irrigation and solar water pumps increase farmers' resilience to climate-related risks like drought and unpredictable rainfall. Also, solar water pumps are an environmentally sustainable alternative to other irrigation products such as diesel pumps. When used within a home or in a public institution, solar water pumps can provide a source of regular, clean water, resulting in improved health and wellbeing. Women are particularly well-positioned to benefit from solar water pumps, both as farmers and as the primary laborers in the household, due to their suitability for vegetable and fruit cultivation—crops that are commonly grown by women—and the time saved using a pump as a water source in the home.

To benefit from this technology, smallholder farmers need solar water pumps to be introduced upon a foundation of prerequisites, including access to agricultural inputs and markets. Small-scale farming is part of an integrated system – providing one solution in isolation is not enough to produce significant results. A concerted approach is particularly important when introducing irrigation solutions because the use of irrigation affects every step in a farmer's growing and sales cycle. First, access to inputs is critical. If farmers do not have access to improved seeds, fertilizers, and pesticides alongside the irrigation provided by solar water pumps, agricultural yields may remain well below

Figure 9: Core farmer needs



Source: Dalberg analysis

73. "Water Wise: Smart Irrigation Strategies for Africa," Malabo Montpellier Panel, 2018.
74. "Tanzania Market Snapshot: Horticulture Value Chains," Efficiency for Access Coalition, March 2019.
75. "Water Wise: Smart Irrigation Strategies for Africa," Malabo Montpellier Panel, 2018.
76. "Dynamic Ground Water Resources of India as of 2011," Central Ground Water Board of India, 2014.

their potential.[77] Furthermore, irrigation requires farmers to change how they use these inputs and in what quantities—for example, fertilizer is commonly injected into water used for irrigation. Access to these agricultural inputs typically depends on local networks of agro-dealers, as well as a farmer's ability to access credit for them. Second, throughout crop production, farmers need the technical expertise to realize their crops' potential yields, including understanding how to operate more sophisticated irrigation technologies. Extension services provide agronomic support to farmers, but these services often lack the resources and capacity to do so efficiently. A transition from rainfed agriculture to irrigation further complicates this challenge because extension officers are unlikely to know how to farm with irrigation. Third, the use of irrigation can change when and how farmers go to market. Irrigation ensures that farmers reach sufficient output levels of production to justify transportation to more distant markets.[78] Beyond improving crop yields, irrigation can allow farmers to adjust growing cycles, in some cases enabling them to harvest at off-peak times of year when prices are higher; or to grow on pre-set schedules as required by some commercial buyers. Irrigation can also allow farmers to switch from lower to higher-value crops, requiring them to find new markets for their produce. Each of these changes in production only translate to greater income when the farmer has access to buyers offering a fair price. Fourth, value-added services throughout the production cycle, such as weather information, equipment hire, transport, and training are also critical to the farmers' ability to realize the full impact of solar-powered irrigation.[79] Overall, farmers need well-coordinated, targeted support throughout their growing and sales cycle to realize the benefits of irrigation.

PRODUCTION

Solar water pumps improve crop yields and can allow farmers to diversify their crops. Access to water through modern irrigation is critical to increasing the productivity of farm households. Several studies have looked at the impact of small-scale irrigation on farmers. In sub-Saharan Africa, one study found that irrigation could boost maize yields by 141–195%, although this varies by country and also depends on several other factors.[80] An early study of SunCulture's impact in East Africa showed that farmers who had been using a pump for more than a few months reported an average increase in crop yield of up to 300% per year.[81,82] Evidence from Asia also shows a reduced risk of crop failure and more diversified cropping patterns.[83] These results are due to increased access to water, but also to the time freed by using a solar water pump—estimated at more than 17 hours a week.[84] These agricultural impacts are a critical first step on a "productivity ladder" which can expand household incomes and allow farm households to make more productivity investments and improvements at the farm level over time. For example, with income gains from access to irrigation, a maize farmer can potentially in time invest in silos or a dairy farmer in a milk chiller.[85]

NET INCOME

When used correctly for agriculture, solar water pumps present a strong business case for smallholder farmers. The benefits to farmers of increased yield from irrigation vary by crop, with a higher return on investment (ROI) often reported for crops with shorter growing seasons. For example, over two years, the ROI for solar water pumps ranges from 150%-250% for horticulture farmers.[86] The high ROI for horticulture is driven not only by increased yields due to solar water pump usage, but also by an increased number of annual harvests—e.g., from two to three harvests per year. Farmers switching to solar water pumps from a diesel pump save on ongoing fuel costs. Those using a small solar water pump report saving USD 268 per acre per year after the switch to solar irrigation.[87] While the initial cost of a typical solar water pump system is higher than that of a diesel pump, when accounting for fuel costs the solar water pump costs 36% less over a pump lifecycle, as illustrated in 10. The fact that in East Africa over 40% of farmers used a fuel pump before switching to a solar water pump indicates that farmers can, where there is high awareness of solar technology, recognize the long-term benefit of the solar alternative despite a higher up-front cost.[88] Farmers switching from manual irrigation also experience reduced ongoing costs with the decreased need for hiring casual labor.[89] Additionally, farmers can optimize returns on the pump by bringing in additional revenue from leasing it to other farmers or sharing the costs of the pump among multiple households. A minority of farmers (10%) also mentioned deriving an extra income through loaning out their solar water pump to friends and neighbors. On average, this group generates an additional USD 20.65 per week.[90] The boost in net income increases the ability of farmers to save and pay for larger expenditures such as school fees and can help mitigate unforeseen risks.

77. "Building an Effective Advocacy Movement for Sustainable and Equitable Agricultural Development in Africa Modernisation of Smallholder Agriculture and Policy Making in Uganda," Emmanuel, Kisiangani, 2012.

78. "Agricultural Water Management and Poverty Linkages," Agricultural Water Management, Namara, R.E., et al., 2010

79. Dalberg research, 2018.

80. "Water Wise: Smart Irrigation Strategies for Africa," Malabo Montpellier Panel, 2018.

81. "How a Kenyan Company is Helping Farmers with Irrigation," CDC Story, 2017.

82. However, potentially due to differences in crop growing cyles, other farmers say that even a full year is not enough time to tell whether irrigation has improved their yields. Source: "Use and Benefits of Solar Water Pumps: Kenya, Tanzania, and Uganda Consumer Research," Efficiency for Access Coalition, 2019.

83. "The Economic Lives of Smallholder Farmers," FAO, 2015.

84. "How a Kenyan Company is Helping Farmers with Irrigation," CDC Story, 2017.

85. "How Can Solar-Powered Assets Expand Household Incomes? The Case of SunCulture'sRainmaker," Mercy Corps AGRIFIN, 2019.

86. "The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa," International Finance Corporation, 2019.

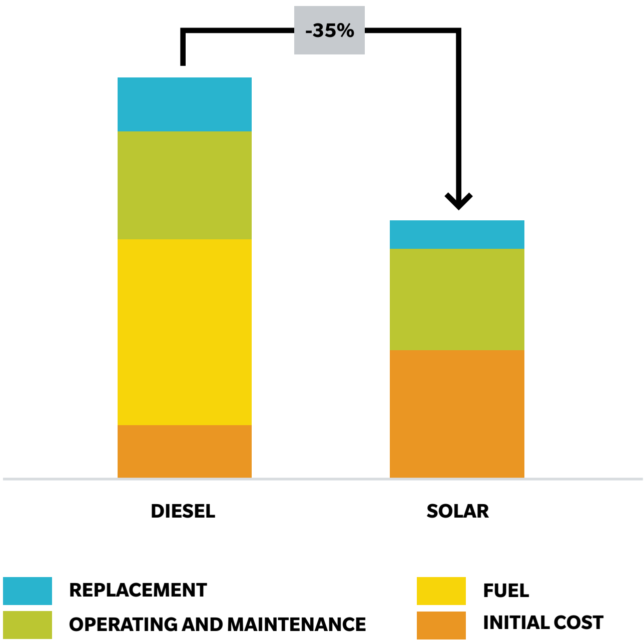
87. "Reaching Scale in Energy Access," Hystra, 2017.

88. "Use and Benefits of Solar Water Pumps: Kenya, Tanzania, and Uganda Consumer Research," Efficiency for Access Coalition, 2019.

89. Ibid.

90. Lean Data, Efficiency for Access. Solar Water Pump Customer Research Report Kenya, Tanzania, & Uganda. February 2019.

Figure 10: Economic comparison of diesel versus solar pumping (lifecycle cost of typical system)



Source: World Bank. 2018. "Solar Pumping: The Basics."

The purchase of solar water pumps can also help farmers build credit history and secure further financing. When a farmer buys a solar water pump with a "buy to own" model, or through PAYGO, he or she is effectively entering an asset financing arrangement. The credit history built through the repayment of the loan can be taken into consideration when the farmer seeks further financing for other assets. In addition, financial institutions are beginning to recognize that solar water pumps have the potential to de-risk other agricultural loans and potentially lower default rates in their existing agriculture portfolio.[91] Taking these knock-on benefits into account, financing for solar water pumps can have a significant impact on overall access to finance for smallholder farmers.

GENDER

Solar water pumps can have a particularly positive impact on female farmers. In South Asia and sub-Saharan Africa, women make up almost 50% of the agricultural labor force and are more likely to farm fruits and vegetables—crops that can particularly benefit from irrigation.[92] The use of solar water pumps could reduce the time women spend tending these crops. In addition, in some cultures, horticultural produce is not only farmed but also taken to market by women, and in these cases, women are likely to pocket increases in revenue that result from higher crop yields. Revenue from crops that are tended to by women is more likely to be used on health and education, providing a knock-on effect in terms of impact on children.[93] As women are also more likely to be responsible for water collection, solar water pumps can provide further time savings, especially if they are used not just for agricultural purposes but also as a water source for the household, as is commonly the case.[94]

CLIMATE RESILIENCE

Access to irrigation improves farmers' resilience to climate change. Today, 25% of all economic damage caused by climate-related disasters is linked to agriculture, and drought causes 84% of that damage.[95] Studies also indicate that maize, a staple crop in much of sub-Saharan Africa, will have lower yields with increasing temperatures, especially in regions where rainfall is expected to diminish.[96] With droughts, irregular rainfall patterns, and temperature spikes predicted to become more frequent and severe in many places as a result of climate change, it is critical for smallholder farmers—the most vulnerable communities in agriculture—to have tools to mitigate these risks. Irrigation can form part of the solution, and solar water pumps are important means of making this irrigation accessible to smallholder farmers. Specifically, solar water pumps enable farmers to offset some of the risks of low or unpredictable rainfall with an additional water source. The technology also allows farmers to plant more diverse crops and can increase the number of planting seasons, thereby diversifying revenue streams. More stable income streams are also shown to lead to more stable security environments, since drought and low agricultural yields are correlated to the growth of extremist armed groups.[97]

More broadly, promoting solar-powered irrigation avoids carbon emissions from alternative technologies. This is critical both in switching current diesel pump users to solar pumps and in mitigating incremental emissions as more farms mechanize and irrigate. For example, in Bangladesh, a financing program that encourages replacement of the existing 1.3 million diesel pumps nationwide with solar pumps is projected to eliminate 1.2 billion liters of diesel, or 3.2 million tonnes of GHG emissions per year.[98] With a potential one to three million farmers moving into irrigation in the coming ten years, it is critical that the transition takes place without the potentially steep environmental cost.[99]

91. Solar World Congress - International Solar Energy Society, 2017, "Accelerating Solar Water Pump Sales in Kenya: Return on Investment Case Studies," Solar World Congress, 2017.
92. "The Economic Lives of Smallholder Farmers," FAO, 2015; "Solar Pumping for Irrigation: Improving Livelihoods and Sustainability," IRENA, 2016.
93. Ibid.
94. "The Benefits and Risks of Solar-powered Irrigation – a Global Overview," FAO, 2018.
95. "Building Resilience," International Water Management Institute, retrieved in May 2019.
96. "Responses of Crop Yield Growth to Global Temperature and Socioeconomic Changes," Iizumi, T. et al., 2017.
97. "In Rain-short Mali, Villagers Enlist Irrigation to Ward off Extremism," BRACED, 2018.
98. CLASP calculations & IDCOL, 2018.
99. Assuming no subsidies but access to financing, we estimate that around 1.3 million farmers will be able to afford larger scale 2200W solar water pumps in 2030 in India, compared to around 150,000 solar water pumps currently deployed. Assuming subsidies of around 50%, the number of households in this market would be as high as 3 million.

Which players are the main market actors?

Given the rural profile of the customer base and relative complexity of the solar water pump product category, manufacturers and distributors need to take specialized approaches to serving solar water pump customers. Farmers are the primary customers for solar water pumps. Many are located in hard-to-reach, sparsely populated rural areas, making distribution and ongoing servicing more challenging. Furthermore, the installation of solar water pumps is more technical than that of domestic off-grid appliances such as TVs and fans. In addition to the correct positioning of the solar array, there must be a selection of the appropriate type of pump and irrigation system. Farmers also require training to be able to operate the pump correctly. Solar water pumps are closely linked to a customer's source of income, so correct installation and provision of technical support after-purchase (where needed) are essential. Each of these challenges impacts the distribution business model for solar water pumps. Compared to solar home systems, solar water pumps need to be in a more specialized manner—through channels that can physically reach farmers and offer agronomic and irrigation expertise.

MANUFACTURERS

Branded manufacturers produce durable solar water pumps that are tailored specifically to smallholder farmers' needs. These manufacturers include both early-stage startups and established large appliance manufacturers. Early-stage startups have driven innovation in solar water pump technology and have been at the forefront of developing pumps for small-scale use. Their products feature high-quality DC motors, and they are designed with the smallholder farmer in mind. This includes ensuring straightforward installation mechanisms and designing remote monitoring sensors that allow for better data collection and remote servicing, if necessary. More established brands are beginning to explore the potential of serving smallholder farmers more intentionally. These manufacturers have been active in the solar water pump industry for years and have the scale to produce, manufacture and distribute pumps for smallholder farmers and to drive down the price of solar water pumps overall. Currently, however, they are still largely focused on serving medium- to large-scale farmers due to the high costs and challenges of serving rural smallholder farmers who are difficult to reach.

Generic manufacturers are companies that produce solar water pumps targeting the lowest cost market, with limited installation and technical support. These companies are primarily based in China and Taiwan and distribute their products widely across sub-Saharan Africa and India. The low price of these products is their main selling point for farmers. These solar water pumps typically have a warranty of one to two years and do not last as long in the field.[100] However, the quality of generic products is improving, especially as innovation from branded manufacturers advances. Some of the distributors of generic solar water pumps have made efforts to avoid selling products that may not be of high enough quality to last past the warranty period. In particular, some have begun conducting product testing and then listing only those products that meet the distributor's standards.

DISTRIBUTORS

Large water and irrigation equipment distributors have been at the forefront of water pump distribution for medium and large farms, and are beginning to see the value of offering solar water pumps for smallholder farmers. Their expertise in both solar equipment and water pumping has made them the current leaders in trusted distribution of solar water pumps. These distributors have a business model tailored to equipment handling—including storage, transport, and after-sales service. They are also highly trained in working with farmers to establish which system the farmer needs and then providing installation. Many of these distributors stock a range of solar water pumps, from low-cost, generic pumps to expensive branded pumps. They are responsible for marketing these products to farmers; however, their market is mainly medium and large farmers primarily due to low affordability, lack of demand by smallholder farmers and the high transaction costs of selling to rural, smallholder farmers. To reach smallholder farmers, these distributors rely on partners who provide complementary services, including financing solutions and access to de-risked pools of farmers. For example, Davis & Shirtliff, a leading regional irrigation solutions provider in East and Southern Africa, recently partnered with the equipment leasing company Rent to Own to provide financing for agricultural equipment.

Agro-dealers and retailers have close relationships with smallholder farmers and therefore have strong expertise in how best to meet their needs. These smaller retailers tend to supply farmers with a range of agricultural inputs, from seeds to fertilizers to equipment. Agro-dealers and retailers range from small local businesses to larger chains with branches in various regions of a country. Despite differences in size, they all have deep networks in rural areas and tend to build strong relationship with their customers to become trusted suppliers. While these retailers have a very strong knowledge of the suite of products and services that smallholder farmers need, they may not have the technical expertise to install or service solar water pumps. Some large water and energy distributors are now working in partnership with agricultural

100. Dalberg stakeholder interviews, 2019.

retail distributors to expand their reach and improve the technical expertise of the retail distributors. These distributors can be particularly effective because they can provide support for the introduction of irrigation with a solar water pump in the context of other inputs and services, ensuring that all the elements work together to optimize a farmer's yields.

Solar home system and PAYGO companies have recently begun looking at solar water pumps as a way of expanding their product offering and reaching more rural households. Several solar home system distributors indicate that they are in the testing phase of bringing solar water pumps to their customers.[101] This poses the potential to unlock a base of customers in more rural areas that could potentially use a modular system for their pump and household appliances. Solar home system players are unique in that they provide both distribution and financing services. Therefore, as distributors, they have rural customer networks and frequent touchpoints with smallholder farmers, access that they can leverage to introduce solar water pumps to this market. As financiers, they can use their customer profiles and repayment data to make credit assessments and offer PAYGO financing for solar water pumps to smallholder farmers. However, solar home system companies may need to develop new expertise in agriculture and solar irrigation. They will need to adjust their business models accordingly, for example by providing long-term and high-volume financing, adjusting distribution approaches to accommodate bulkier products, and providing more after-sales services to help farmers use complex water pump technologies.[102]

CASE STUDY Ecozen Solutions

Ecozen Solutions is an India-based renewable energy company that offers products and solutions in agriculture focused markets. It's flagship product, the Ecotron, is a powerful solar water pump (750W -7,500W capacity) that is connected via a web-based analytics platform. Ecozen Solutions is able to improve its service by analyzing the data from its users, a critical value addition in the highly subsidized Indian market for solar water pumps. The company is exploring sensors that could provide real-time feedback to farmers, thereby equipping farmers with information about their water sources and mitigating the risk of groundwater depletion.

PHOTO CREDIT: Sunculture

101. Dalberg stakeholder interviews, 2019.
102. "The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa," International Finance Corporation, 2019.

KEY VALUE CHAIN ACTORS

Aggregators

Value chain actors that pool together groups of farmers can provide an attractive point of sale for solar water pump distributors. The most common value chain actors with significant convening power are off-takers and cooperatives. Their importance in the value chain is often dependent on the crop and the region. At the crop level, factors such as the level of commercialization and organization of the value chain will influence the prevalence of cooperatives and off-taking arrangements. At the regional or country-level, key factors include the strength of the national distribution system and of domestic and export markets.

Off-takers can play a potentially transformative role in the solar water pump ecosystem. Off-takers are purchasers of crops that source from many farmers, in some cases providing pre-harvest contracts to farmers with a set price. The presence of a market for the additional harvest is one of the most important factors for solar water pump and irrigation success. An off-taker can facilitate credit to smallholder farmers by acting as a counterparty with financial institutions, reducing the risk for the financial institution and promoting fair terms for farmers. By aggregating numerous orders for solar water pumps and streamlining distribution, off-takers may also be able to provide solar water pumps to farmers at a lower cost due to economies of scale.[103] This aggregation can also reduce costs of technical support. For the off-takers themselves, there is a clear benefit to promoting access to solar water pumps, as the technology helps ensure a more regular stream of quality product. For regions such as Kenya, where horticulture exports are growing, this is a particularly important benefit.

Cooperatives are well placed to build awareness of solar water pumps and to provide the needed financing to smallholder farmers. Cooperatives charge a membership fee to farmers and provide value-added services including selling inputs, providing access to markets and, in some cases, offering financing. They typically bring together between 200 and 1,000 farmers. By promoting and financing solar water pumps and irrigation, cooperatives can offer their members a valuable service. Studies show that cooperatives are particularly effective at financing agricultural technology—in fact, credit offered through cooperatives has a greater impact on agricultural technology adoption than does credit offered through micro-finance institutions (MFIs).[104] For distributors, selling through a cooperative can increase the value of the sale because it provides the distributor with a single point of contact, both lowering the cost of outreach and simplifying payment recovery. In addition, co-guarantees through group lending among cooperative members can be used to mitigate lending risks.[105]

Cooperatives can also represent customers to equipment distributors, allowing members to pool funds to purchase a single shared piece of equipment. Today, cooperatives occasionally help members procure shared irrigation solutions. They could play a similar role to support the shared purchase of solar water pumps; however, the ability to easily move the pump across multiple nearby farms is a critical prerequisite for such an arrangement. Though cooperatives are not yet active in the solar water pump space, they will potentially be critical players in the future—both in building awareness and expanding access to financing.[106] Development actors and government programs that focus on improving agricultural organization and smallholder productivity usually have strong ties to agricultural cooperatives and could be useful partners to help solar water pump distributors reach smallholder farmers.

Financiers

Though irrigation has the potential to improve a smallholder farmer's financial wellbeing and credit risk profile, financial institutions remain hesitant to provide water pump loans to this segment. While financial institutions are beginning to recognize the potential impact of solar water pumps in decreasing overall agricultural loan risk, they typically lack the needed expertise to assess the potential income uplift of modern irrigation. Winrock's interviews with over 20 financial institutions in Kenya found that while institutions acknowledged the high demand for solar water pumps, they were hesitant to offer financing. This hesitation was due to a lack of familiarity with solar irrigation products and limited understanding of the impact solar water pumps could have on their clients. Financial institutions also cannot yet recognize solar water pumps as collateral, incur high costs to service smallholder farmers, and are uncomfortable providing agricultural loans outside of a few more commercially established value chains. For MFIs specifically, typical loan amounts are often too low to be considered viable financial options for solar water pumps. Drawing from and adapting existing models for larger farm equipment, banks and leasing firms could potentially scale asset loans or leasing models to lower the upfront costs of solar water pumps.

103. "Accelerating Solar Water Pump Sales in Kenya: Return on Investment Case Studies," Solar World Congress, 2017.

104. "Improving the Availability and Effectiveness of Rural and 'Micro' Finance for Small-scale Irrigation in Sub-Saharan Africa: A Review of Lessons Learned," Merrey, D. J. and Lefore, N., International Water Management Institute, 2018.

105. "Accelerating Solar Water Pump Sales in Kenya: Return on Investment Case Studies," Solar World Congress, 2017.

106. Dalberg stakeholder interviews, 2019.

Figure 11: Financial institution barriers to smallholder financing for solar water pumps

BARRIER	CURRENT APPROACH FROM FINANCIAL INSTITUTIONS
COLLATERAL	Most financial institutions need a significant amount of collateral for agricultural lending—the requirement can be as high as 100% depending on both bank policies and national regulations. The collateral requirement is particularly challenging for smallholder farmers who do not own their land, a constraint which disproportionately affects women. Because robust buyback and secondary markets have not been developed, financial institutions do not yet see PV panels or solar water pumps as acceptable forms of collateral.
PERCEIVED RISK	Smallholder farmers are considered a highly risky segment because they often have no credit history and are unbanked. There are promising innovative approaches to qualify borrowers, for example using alternative sources of data and group lending, but few commercial banks are using these approaches today.
LACK OF OFFTAKER CONTRACTS	Financial institutions are more comfortable lending to smallholder farmers when they have a formal contract with an offtaker. This model of outgrower farming is expanding, particularly in sub-Saharan Africa. However, it is still limited, typically applies to high value crops, and is not always in the best interests of the farmer (e.g., in certain crops, informal traders may normally offer higher prices than agro-processors).
TRANSACTION COSTS	It is expensive for financial institutions to service smallholder farmers individually due to their rural location. Because servicing costs are high, while loan sizes are low, banks see this as an unprofitable segment. Banks are more likely to lend to farmer groups, since this helps to spread servicing costs across multiple customers.
DESIGN OF LOAN PRODUCTS	Loans are typically structured with a regular payment schedule (daily, weekly, monthly), but this does not match smallholder farmers' income streams, which are inconsistent and spike during harvests. Lenders can tailor repayment schedules to individual crops and seasons—doing so requires a close understanding of the needs of specific types of farmers and harvest schedules in particular regions.
LIMITS OF TECHNICAL SUPPORT	Because farmers' ability to repay water pump loans requires them to realize an increase in income, financial institutions see a risk in supporting farmers to buy equipment that they likely do not know how to use. This risk can be mitigated through partnerships with extension services or other agricultural support players.

Source: Dalberg analysis

In the absence of smallholder financing from financial institutions, some distributors are testing the use of PAYGO schemes. Solar home system distributors are seeking to expand their product offerings to include PAYGO models for solar water pumps. SunCulture has been one of the pioneers of this approach, using a PAYGO model with remote switch-off functionality and providing a broader range of customer support post-purchase. The objectives are both to reduce the cost of servicing loans and to increase borrowers' willingness to repay.[107] While initiatives such as these do increase the affordability of solar water pumps for farmers, there are unresolved challenges in their execution. Scaling PAYGO for solar water pumps will require both agronomic and technical understanding on the side of the distributors. On the agronomic side, challenges include the unpredictability of agricultural processes including external and unforeseeable risks to harvests, such as pests or disease, that could limit a farmer's ability to repay. On the technical side, solar water pumps have a relatively higher value compared to most prevailing solar home systems and are more complex to use. They require additional time and investment from the distributor in customer education and after-sales support to ensure the correct use of the asset. Though solar water pumps are high in value, there is a high cost associated with recovering and reusing the equipment, and in most cases no secondary market that would enable the equipment to function as traditional collateral. Additionally, there are questions around the effectiveness of the remote switch-off feature of the PAYGO model in encouraging repayment in the long run, and of the practicality and ethicality of switching off a key productive asset for a farmers' livelihood.

107. "Where do we PayGo from here? PAYGo beyond solar," CGAP, 2018.

Other distributors are testing new partnership models to assess credit risk and provide financing. One of the largest challenges for traditional financial institutions is completing an effective credit check, as loan officers often do not have a good sense of how to assess smallholder farmer business models. Solar water pump distribution businesses can use their strong customer understanding and presence in rural areas to help financial institutions overcome this challenge. For example, SolarNow in Uganda has built a distribution model that relies on partnerships with MFIs. As a specialist solar home system distributor with experience in product design, sales, installation and after-sales, SolarNow is well-positioned to facilitate credit assessments for MFIs to finance solar water pumps to smallholder farmers. SolarNow collects information through reference checks, farm visits, and the Central Referencing Bureau to make financing decisions, while its partner MFIs take on the liability and financial risk of the loan.[108] This is still an early initiative, but the lessons it provides are expected to help expand the financing model.

Another challenge in smallholder financing is the seasonal and volatile nature of agricultural incomes. A smallholder farmer's income is based on crop harvest seasons, while the repayment terms on traditional solar water pump financing tend to be daily, weekly, or monthly. Proximity Design in Myanmar is seeking to address this challenge and is testing a seasonal repayment schedule for its solar water pump customers.[109] Beyond challenges related to seasonal income streams, farmers remain highly exposed to shocks that can disrupt their incomes, including changes in climate patterns and natural disasters, as well as swings in global commodity prices. Farmers are even more financially exposed when they take out a water pump loan in the face of these uncertainties. To help mitigate these risks, financial products can be bundled with climate insurance, procurement contracts that offer fixed pricing, and other forms of support.

How can market players leverage complementary capabilities?

Achieving scale will require partnerships among product designers and manufacturers, financers, and actors with strong connections to farmers. The off-grid solar water pump space, and relatedly the solar-powered irrigation space, sits at the nexus of three economic sub-sectors: energy, agriculture, and finance. Many players have strengths in one or two of these sub-sectors, or in an aspect of the value chain, but few are situated to deliver end-to-end solar water pump solutions. In this space, many potential partners have shared interests and complementary strengths, and they can benefit from working together. Branded solar water pump innovators have irrigation products tailored to smallholder farmer needs, but they may need partners to establish distribution networks with a heavy rural footprint. Large generic solar water pump manufacturers, meanwhile, sell irrigation solutions through a diffuse network of distributors. Both types of manufacturers need relationships with more downstream actors with connections to smallholder farmers to ensure the effective distribution of their products. Large distributors have wide networks and have developed tailored approaches to distributing solar water pumps to farmers.

However, due to low demand from smallholder farmers and high transaction costs of reaching this group, they lack networks at the last mile and also need distribution partners. Solar home system and PAYGO businesses have existing relationships with rural households and experience developing consumer financing for off-grid assets, but they have limited knowledge of agriculture and solar water pumps. They may also need to partner with cooperatives, aggregators, or agricultural support providers to ensure that farmers benefit from their products. Off-takers and cooperatives have access to groups of organized smallholder farmers and can help de-risk financing and lower the upfront cost of solar water pumps by bringing together smallholder farmers in large numbers. However, they need to partner with manufacturers and distributors to do so. Financial institutions have the capital needed to finance the distribution or purchase of solar water pumps and may have targets to expand irrigation financing, but they often have minimal agriculture experience beyond lending to large-scale commercial farms and have low risk appetite for lending to smallholder farmers. Strategic partnerships among these players across the value chain will be critical to unlocking the potential of the solar water pump market.

108. Dalberg stakeholder interviews, 2019.
109. Ibid.

Where will the solar water pump market be in 10 years?

The solar water pump market is on the cusp of substantial growth—the technology is expected to improve, resulting in cost reductions, while some of the most innovative distribution and financing businesses currently are likely to grow and mature. As manufacturers increase production, they stand to benefit from scale efficiencies leading to better solar water pump technology and lower costs. Additionally, increased competition among both large and start-up manufacturers, particularly those that aim to reach the small-scale end of the solar water pump market, could further lower the costs of pumps and stimulate more innovations in technology. Nascent distribution and financing approaches, such as those leveraging solar home system distributors and PAYGO models, are also likely to improve reach and access to solar water pumps for smallholder farmers. On the demand-side, with increasing awareness of solar water pumps and decreasing prices, a growing number of commercial farmers stand to benefit from the strong business case that solar water pumps offer, notably those in well-organized value chains with access to distribution networks and access to finance.

However, without coordinated action across public, private, and development actors, this growth will remain incremental and the sector will not reach the scale needed to deliver productivity gains for large numbers of farmers. The market for small scale solar water pumps faces several challenges, including agricultural value chain constraints such as poor organization, weak linkages to input suppliers, and insufficient access to markets. These limit the overall productivity and bankability of smallholder farmers. While existing models can readily serve a segment of commercial farmers, the majority of smallholder farmers in sub-Saharan Africa and South Asia still cannot afford solar water pumps. These farmers are also expensive to serve and less commercially attractive for pump distribution companies. Reaching this group of farmers will require support and coordination beyond traditional commercial market actors.

What will accelerate this transition?

To accelerate the growth and uptake of solar water pumps in sub-Saharan Africa and South Asia, four broad types of interventions could be introduced: policy incentives, financial solutions, technological improvements, and strengthened partnerships. A coordinated government approach that intersects water, energy and food policy is necessary to ensure strategic coherence across initiatives to promote uptake of solar water pumps. Example interventions include water resource management initiatives such as groundwater mapping; tax exemptions for solar technology developments and imports; and agricultural extension programs that promote solar water pumps. Beyond this water-energy-food nexus, other policy interventions such as smart subsidies and financial sector reforms could be implemented to improve affordability of pumps for smallholder farmers. Financing approaches will need to include working capital and growth loans for industry players (manufacturers and distributors); and innovative products that target smallholder farmers and are designed around their needs. Continued innovation in technology could entail improving water pumps themselves, strengthening compatibility between solar water pumps and solar home systems, or redesigning products to respond better to consumer needs. Finally, partnerships between the myriad of actors involved in solar water pump technology and improving farmer livelihoods can help build awareness and scale uptake. Achieving this will require manufacturers and distributors partnering not only among themselves, but with governments, donors, financiers, farmer cooperatives, non-government organizations, and other actors that can help bring the technology closer to smallholder farmers.

POLICY

Solar water pumps are an important technology that supports policy objectives across the water-energy-food nexus. Agricultural transformation is high on many government agendas, and irrigation can enable these efforts by bringing about improvements in yields, a shift to higher-value agriculture, and strengthened rural economies. Relatedly, solar water pumps can support food security objectives by improving the livelihoods of smallholder farmers and increasing a country's food output. They can also help countries achieve renewable energy objectives and reduce carbon emissions from fossil fuels. Finally, solar water pumps can help countries reach their water access objectives, providing more affordable and effective ways for smallholder farmers to tap into water for domestic and productive use.

Strong integration of efforts across national ministries and parastatals is critical. Solar water pumps may be regulated in different ways by water, agriculture and energy ministries and other bodies. Coordination among government actors is critical but can be challenging because it requires collaboration across diverse areas of specialization bringing together policymakers and technocrats. Furthermore, policy priorities may be different across government ministries, and actors, often working in silos, may be unaware of the initiatives of other ministries. Ethiopia provides an example of a government that is implementing an irrigation policy with a clear national agenda and demarcation of responsibilities across government ministries. The Ministry of Water and

Energy is responsible for developing largescale irrigation schemes, while the Ministry of Agriculture is responsible for community-managed small-scale irrigation schemes. These smaller irrigation schemes are in turn supported and implemented by the Agricultural Transformation Agency (ATA).

Governments have an important role to play in increasing water access for smallholder farmers and ensuring sustainable water management. In both sub-Saharan Africa and India, access to groundwater is a significant constraint to the growth of the solar water pump market. Tests are underway into new mapping that use geographic information system (GIS) technology to establish water availability and factors such as sunshine availability. Ethiopia's ATA has successfully tested this technology, and it is being rolled out in Ghana and Mali. Governments can expand the use of this technology to understand where boreholes should be drilled and to support borehole development as part of their national irrigation plans. This would significantly increase groundwater access for smallholder farmers, unlocking their ability to irrigate more effectively with solar water pumps. However, any coordinated policy on nationwide irrigation needs to include provision for groundwater preservation to avoid excessive depletion and ensure sustainable management of water resources.

Providing favorable tax conditions for importers of solar water pumps can accelerate uptake of the technology. In Ethiopia, the ATA and the Ministry of Finance successfully led a reform effort allowing tax-free imports of agricultural mechanization, irrigation and animal feed technologies.[110] More governments could adopt such reforms. An analysis of the trade-off of lost revenue from import duties to increased revenue from more productive smallholder farmers can help provide a strong business case for governments to act.

In some contexts, government or donor support is needed to promote the uptake of solar water pumps. As previously noted, solar water pumps are a high-value asset and unaffordable to most smallholder farmers. Smart subsidies targeted at farmers and distributors, for example in the form of results-based financing for distributors, can help unlock a larger market and incentivize firms to focus on a broader segment of farmers. For example, Global LEAP recently launched such a results-based financing round for solar water pumps. In other cases, subsidies have been used to drive consumers toward solar powered technologies, and away from fossil fuel powered technologies that may be cheaper upfront but more expensive and environmentally detrimental in the long term. As highlighted in this report, the Indian subsidy scheme has helped grow the market for larger solar water pumps; however, questions remain over the sustainability of demand if the scheme is scaled back. Implementing such a program requires prior focused analysis to ensure that these schemes do not distort the market in the long term, but rather are used to increase affordability in a targeted way for the farmers who need them the most.

Other policy areas, such as access to finance and consumer protection, can affect the uptake of solar water pumps for both distributors and smallholder farmers. Financial sector regulations can be reviewed to ensure smallholder farmers can provide collateral for financing, for example by revising land tenure or minimum collateral requirements on lending. Furthermore, policies around digital credit are often behind the curve due to the quickly changing market, putting consumers at risk—specifically there is a lack of policies that protect customers from being over-burdened with debt in many emerging markets. There is no generally accepted technical standard upon which to discern the quality of solar water pumps, and no standards boards to enforce such standards. In the absence of standards, both distributors and customers lack protection from the importation of poor quality or faulty products. The Global LEAP Awards Solar Water Pump Competition, which will test over 30 pumps, represents an important first step toward benchmarking quality and energy performance. As well as ensuring overall quality in the market, strong standards can help to avoid the long-term consequences of allowing low quality products to enter the market, negatively impacting farmers and damaging perceptions of the overall solar water pump space.[111]

FINANCING

Increasing access to finance for farmers, and in turn the supply of corporate finance in this space, will be critical to the growth of the solar water pump market. For distributors, serving smallholder farmers at the last mile can be challenging and costly, and often the business case for targeting this segment may not be as attractive as serving less risky, relatively higher income farmers. Most of the solar water pump companies that target smallholder farmers are innovative startups that do not have access to economies of scale or finance to test new distribution models on a large scale. On the other hand, large financiers face a high opportunity cost of lending to small startups versus larger, more established solar water pump companies or borrowers in other more traditional industries.

Banks, telecommunication companies, and specialist financers can develop new financial products that specifically target smallholder farmers purchasing solar water pumps. To manage risks, companies can qualify borrowers based on a thorough understanding of farmer economics and can explore alternative forms of collateral. As discussed in the previous section, the challenges of smallholder finance are common, including among others, lack of collateral, high perceived risk and limited farmer aggregation. However, the productive use and the strong evidence base for increased revenues from a solar water pump can offer a basis for more favorable financing terms to smallholder farmers. Telecommunication companies can also be engaged more directly in supporting solar water pump financing through data collection and by enabling mobile repayments for rural

110. "Ethiopia allows tax free imports of agricultural mechanization, irrigation and animal feed technologies," Addis Standard, 2019.
111. "Solar Pumping for Irrigation: Improving Livelihoods and Sustainability," IRENA, 2016.

customers. For example, using evidence on the yield and income uplift of solar water pumps as well as data from telecommunications companies, financial institutions can build more nuanced risk profiles of farmers who use pumps. Solar home system providers have already found effective systems to conduct risk assessments, and a variety of new companies that specialize in risk assessments for agricultural lending to smallholder farmers are launching. Building on agricultural equipment lending programs for rural micro and small enterprises like Rent to Own in Zambia and Hello Tractor in Nigeria, financiers can consider leasing solar water pumps in partnership with another organization, and with adjusted financial terms. In the absence of loan guarantees, off-taker contracts and other formers of aggregation common to different types of crops should continue to be valued by financial institutions. Alternatively, the solar panels and solar water pump themselves could be treated as collateral for a loan, although this will require a secondary market and collateral registry system.

Solar water pump companies will need working capital and growth capital to ensure innovation in technology and distribution to low the market. Given the high inventory cost of solar water pumps and the currency risk faced by companies that import parts, retail distributors need working capital to hold stocks. For startups that are innovating and conducting R&D, growth capital is needed to develop and scale pilots. This small business financing is just as important as the consumer financing mechanisms for farmers and should not be overlooked by the industry or donors.

TECHNOLOGY

Improving the compatibility and modularity of the solar water pump, especially as solar home system players enter the market, has the potential to expand market penetration. Solar water pump manufacturers can more intentionally leverage the growth of the solar home system market by developing products that can be powered by the same panels as solar home systems. Most branded products on the market work with their own solar panels, but with improved pump efficiency and battery technology, there may be opportunities to find synergies in how a rural household can power a solar water pump. This could also promote pump use between agricultural seasons, ensuring that smallholder farmers can maximize the utilization of their pumps. A move toward more modular systems could also make it easier for farmers to expand the amount of land under irrigation incrementally without significant further investment – they could add to their panel arrays and achieve a greater flow rate from the same pump.

Industry players indicate that customers sometimes share their pumps with other farmers—developing technology and business models better adapted for shared use could help to grow the market. Today, solar water pumps are designed for single-farm use, needing technicians to support installation and servicing. Since crops do not need require irrigation throughout the growing cycle, it is theoretically possible for numerous farmers to share a single pump, thereby improving affordability. Solar irrigation companies can explore ways to make it easier for farmers to rent pumps or to buy pumps as collectives. This approach would be most relevant for surface solar water pumps that are more mobile in their design. Sharing pumps could also have a positive impact on community water use if combined with better water storage facilities.

PARTNERSHIPS

Irrigation works best when combined as part of a comprehensive offering of agricultural services; the more solar water pumps can be included in those services, the faster awareness of the technology can increase and the technology can achieve better results. For solar water pump use to expand quickly and effectively, it must be integrated into broader agricultural efforts as much as possible. Manufacturers and distributors alike can develop partnerships with actors currently providing agricultural services—government extension workers, agricultural input providers, non-profits, and cooperatives. These actors are the closest to the farmers and are important influencers in the farmers' decisions on farming methods and purchases.

Partnerships among solar water pump companies, financiers and farmer aggregators, such as cooperatives and off-takers, are particularly promising to accelerate uptake of solar water pumps. These aggregators have close relationships with smallholder farmers that are based on trust as well as financial contracts. The scale of the aggregators can lower the cost to reach farmers and allow for more consolidated training and demonstrations. As mentioned above, financiers could partner with off-takers, leveraging the commercial arrangements between them and farmers as a way to de-risk farmers and enable them to access credit. Industry players can leverage aggregators more intentionally to accelerate both awareness and affordability of solar water pumps.

Donors can play an important role in facilitating these partnerships between different actors across the energy, water, finance, and agriculture sectors. As donors interact with a broad network of actors, they have a system-level view which allows them to make important connections between these actors, potentially unlocking new areas of growth across a value chain. Donors also often directly support agricultural development programs, for example, by building the capacity and organization of farmer groups and providing direct technical assistance or building extension services. Each of these programs presents an opportunity to build awareness and uptake of solar water pump technology. Furthermore, donors can work with some of the larger branded manufacturers to accelerate innovation to serve smallholder farmers. This could lead to accelerated product innovation and encourage more branded manufacturers to enter the market.

The combination of interventions most critical to stimulate solar water pump penetration—be they in the areas of policy, finance, technology or partnerships—depends on the maturity of the market. As discussed earlier in this report, markets have different levels of maturity that depend on the structure of the agriculture sector, the existence of incumbent technologies, the development of the solar industry, and the size and wealth of smallholder farmers. Where agricultural value chains are well structured, solar water pump companies should partner with aggregators and existing agricultural programs to leverage the strength of these structures to reach smallholder farmers. There may also be opportunities for financiers to partner with off-takers and extension service providers that reduce the risk of investing in farmers. In markets with incumbent irrigation technologies, government policies such as subsidies or import tax exemptions could help stimulate a switch towards solar water pumps.

By contrast, in markets with developed solar industries, finding ways to channel finance towards solar water companies to expand product innovation will be critical, and government or donor support for smart subsidy programs could incentivize distribution. Finally, in markets where smallholder farmer incomes are too low to present a significant opportunity for solar water pumps, a number of interventions including relating to policy, finance and partnerships may need to be implemented simultaneously. A combination of subsidies and tax exemptions could be adopted by governments, while coordinated activities with agricultural ministries could raise awareness and improve extension services to farmers. Donor partnerships could also be leveraged not only to ramp up services to help increase farm productivity and incomes, but also to lead education on the use of solar water pumps. Critically, smallholder farmers are not homogenous, and even within markets, approaches and interventions may vary based on the target group of farmers – commercial actors may be able to serve some farmers easily, while other actors may need more coordinated efforts that combine policy, extension services, and financial access.


PHOTO CREDIT: Simusolar

EFFICIENCY FOR ACCESS

PHOTO CREDIT: Simusolar

CONTACT US

efficiencyforaccess.org

info@efficiencyforaccess.org

@EforA_Coalition