Uganda Solar Water Pumping Report

Africa Clean Energy
Technical Assistance Facility

Africa Clean Energy
Catalysing Africa's Solar Markets

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UKaid
from the British people

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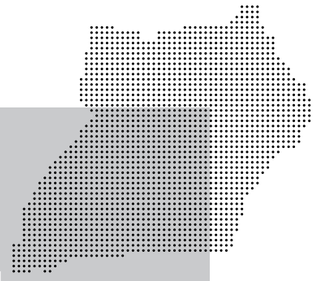

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Department for International Development (DFID)
Africa Clean Energy Technical Assistance Facility

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Coffey International Development Ltd

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Abbreviations

AC	Alternating Current
ACE TAF	Africa Clean Energy- Technical Assistance Facility
CSR	Corporate Social Responsibility
CREEC	Centre for Research in Energy and Energy Conservation
DC	Direct Current
DFID	Department for International Development
EA	East Africa
EnDev	Energising Development
FAO	Food and Agricultural Organisation
GoU	Government of Uganda
LEIAP	Low Energy Inclusive Appliances Programme
MAAIF	Ministry of Agriculture, Animal Industries and Fisheries
MEMD	Ministry of Energy and Mineral Development
M&E	Monitoring and Evaluation
NGO	Non-Governmental Organisation
OCA	Open Capital Advisors
OPIC	Overseas Private Investment Corporation
PAYG	Pay-As-You-Go
PV	Photo-Voltaic
REA	Rural Electrification Agency
SIDA	Swedish International Development Agency
SHS	Solar Home Systems
SPIS	Solar-Powered Irrigation System
SSA	Sub-Saharan Africa
SDGs	Sustainable Development Goals
SOGE	Scaling Off-Grid Energy
TAF	Technical Assistance Facility
UNCDF	United Nations Capital Development Fund
UOMA	Uganda Off-Grid Energy Market Accelerator
USAID	United States Agency for International Development
USD	United States Dollar
VAT	Value Added Tax
VfM	Value for Money
WASH	Water, Sanitation and Hygiene

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Executive Summary

Off-grid technologies – including standalone systems and mini-grids – have struggled to reach many consumer groups in Uganda due to low demand and slow growth. Currently, 70 per cent of the population lacks access to electricity, and the Government of Uganda (GoU) projects that over 30 per cent of the population is unlikely to be reached by the national grid for the next several decades[1]. This re-emphasises the need to increase the uptake of off-grid technology among low- to middle-income rural communities, which have often struggled to afford them. Productive use appliances are a viable way of increasing energy access through raising consumers' productivity and income, eventually unlocking more disposable income that can then be spent on additional energy consumption.

In 2018, the GoU expressed interest in promoting the productive use of energy as one of their strategies for increasing energy access and promoting more holistic development in rural communities. Given that the agriculture sector employs approximately 65 per cent of the total population, GoU has identified solar irrigation as a particularly powerful avenue for social and economic impact in the promotion of energy access[2].

Despite the expressed interest in productive use, the government is yet to implement policies and strategies to promote their uptake, especially for solar irrigation water pumps. The existing National Irrigation Policy only focuses on large-scale, on-grid irrigation systems. Similarly, while the Ministry of Energy and Mineral Development (MEMD) is interested in including productive use products in their upcoming Off-Grid Strategy, they have expressed a need for support to identify commercially scalable productive use strategies, including solar water pumping[3].

Historically, the GoU has been more engaged in promoting large-scale irrigation for commercial farmers due to a limited understanding of the business case for small-scale irrigation. As such, it is vital to provide information to the government and development partners on the state of the market, existing challenges and potential interventions to scale the market sustainably.

The purpose of this advisory paper is to identify existing gaps in scaling solar water pumping systems, enhance understanding of the sector, and highlight opportunities for collaboration between the GoU, private sector players, development partners, financiers and other relevant stakeholders. This paper specifically highlights effective business models for supporting solar irrigation, required government interventions, policies and regulations to accelerate the sector, and the investment required for scale both from public and private funders.

Finally, based on consultations and analysis , the following interventions are recommended:

- Increasing coordination within government agencies and other stakeholders
- Creating a framework or adapting metrics for quality and standards
- Developing fiscal policy interventions to support the sector such as tax incentives and subsidies
- Improving farmers' knowledge and access to resources needed to maximise productivity.

[1] Rural Electrification Agency, Draft Off-Grid Strategy (June 2018)
[2] Uganda Bureau of Statistics, Statistical Abstract, 2018
[3] Expert interviews with government officials

1. Introduction

1.1 OBJECTIVE OF THE ADVISORY PAPER AND METHODOLOGY

1.1.1. GOAL OF THE ADVISORY PAPER

According to the Government of Uganda (GoU), hydropower is the dominant form of energy generation on the grid. However, off-grid agricultural and industrial activities are facilitated primarily by biomass and fossil fuels. In order to reduce greenhouse gas emissions and improve environmental sustainability, the government's attention on energy in agricultural and industrial activities is shifting towards cleaner energy sources. Stakeholders further believe that productive use technologies, such as solar water pumps, solar mills, and solar refrigerators – if properly targeted – have the potential to significantly stimulate overall demand and affordability of solar home systems (SHS) by increasing household income and willingness to spend on energy.

Early results from pilots run by both public and private sector players on solar irrigation among small- to medium-scale off-grid farmers show promising results, with improved income and increased uptake of additional off-grid energy products. Despite this, there are several challenges to enabling sustainable scale. These challenges include high import costs for businesses, unclear land tenure systems for farmers, and limited access to finance for innovative models that enable consumer financing. The GoU has been more engaged in large-scale irrigation for commercial farmers due to a limited understanding of the business case for small-scale irrigation, the most effective business models and existing challenges in the sector. It is vital to provide information to the government and development partners on the state of the market and potential interventions to scale the market sustainably.

This advisory paper highlights:

- Existing business models for supporting solar water pumping systems for local farmers;
- Regulations and policies the public sector can use to accelerate the sector;
- Recommended funding allocations from the government and other funders that could enable scale;
- How the technology can empower women and promote gender equity; and
- Capacity development programmes needed to support farmers, extension workers, local private sector and others to maximise the impact of solar irrigation.

1.1.2. METHODOLOGY

The data in this paper was obtained through a combination of secondary research, pilot studies and interviews. The secondary research focused on the current solar water pumping landscape in Uganda, examining the need for this technology, understanding key stakeholder involvement and reviewing current government policies and plans that will influence the business case. This was further supplemented by results and learnings gained from productive use pilots run by the Uganda Off-grid Energy Market Accelerator (UOMA), and Energy for Impact (E4I). The pilots were run with 10 Ugandan businesses exploring and testing different distribution and financing models to commercially scale off-grid energy and productive use appliances in Uganda.

Additional information was collected through direct interviews with key stakeholders in government, private sector and development partners active in the Uganda market – a full list of interviewees is available in Annex 7.7.

1.2 STATUS OF OFF-GRID ELECTRICITY ACCESS IN UGANDA

With the annual population growth projected at three per cent per annum, expanding from just under eight million households in 2016 to over 12 million households in 2030, the Ugandan energy market needs to connect over nine million unserved households by 2030 to achieve universal energy access. Despite rapid growth in the national grid, which is expected to reach three million new customers by 2027, over 30 per cent of the population is forecast to remain unreached for the next several decades.

In June 2019, the Rural Electrification Agency (REA) was drafting an Off-Grid Strategy, that would articulate and re-emphasise the goal to deliver affordable, reliable and sustainable electricity to rural off-grid areas. Nevertheless, the focus of most off-grid renewable energy strategies and projects in Uganda has been on household lighting through SHS. These off-grid lighting technologies have however struggled to reach many consumer groups in the country, with the main barrier being the cost of connection. The SHS do not automatically trigger local economic activity, and in instances where households and enterprises cannot afford the cost of connection, uptake has been low. This has undermined the economic viability and sustainability of many off-grid electrification programmes.

The Min. of Energy & Material Development (MEMD) and REA now recognise productive use of energy as crucial in the electrification process to increase energy demand, household income and households' willingness to spend on energy, but a clear strategy for promoting the technologies is yet to be implemented. Specifically, while MEMD has expressed interest in supporting productive use products in the upcoming Off-Grid Strategy, they have highlighted the need for additional support to identify strategies to commercially scale these products.

1.3 THE ROLE OF SOLAR WATER PUMPING IN ELECTRIFICATION

Productive use of energy (PUE) is described as any income generating activity involving electricity as a direct input to the production of goods or provision of services[4]. As illustrated in Figure 1, productive use products present a sustainable case for scaling

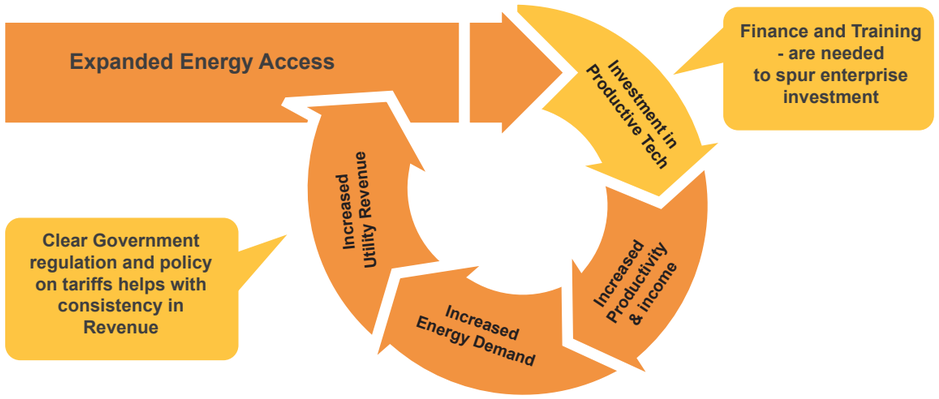

Figure 1 The productive use cycle for increasing energy access and demand

In brief, the appliance increases the user's productivity, subsequently increasing the disposable income available for purchases, including additional energy consumption. This creates a virtuous demand cycle that can mitigate the low uptake experienced in rural Uganda today. Agricultural applications of these appliances, including solar water pumps, are highly relevant for economic growth in Uganda as the sector employs approximately 65 per cent of the total population,

[4] 1. GIZ's "Productive Use of Energy – PRODUSE A Manual for Electrification Practitioners": https://www.giz.de/fachexpertise/downloads/giz-eueipdf-en-productive-use-manual.pdf

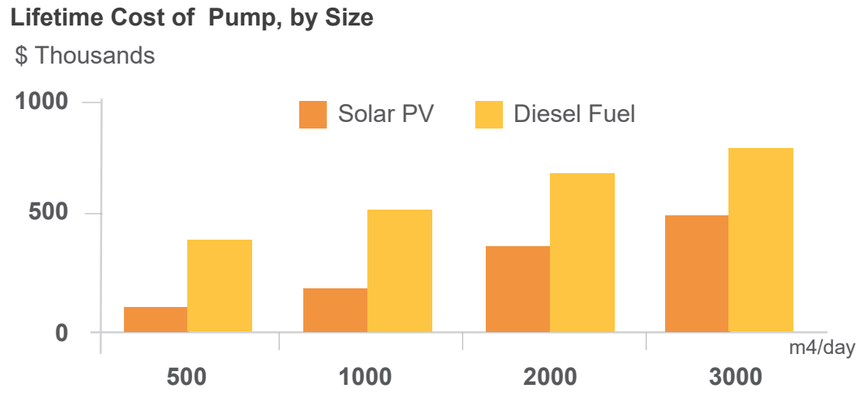

Figure 2 Cost comparison between solar PV and diesel pumps

thus providing a powerful avenue for social and economic impact.

Sustainable and affordable irrigation plays a key role in increasing productivity, however, most countries in sub-Saharan Africa (SSA), including Uganda, are yet to exploit their irrigation potential. In Uganda, the ratio of cultivated area under irrigation to the country's irrigation potential is even lower than the SSA average at only 0.5 per cent, whereas approximately 15 per cent of the country's surface area is covered by fresh water sources[5]. The land under irrigation in Uganda is almost exclusively under large-scale projects. However, the national focus is increasingly shifting towards smaller projects, driven by a combination of demographics and rural realities. Smallholder farmers manage approximately 80 per cent of the total farmland in SSA. As outlined below, there are some very clear benefits of solar irrigation for smallholder farmers.

Benefit 1: A cheaper alternative to diesel-run pumps

Solar pumps are emerging as a cost-effective, clean and sustainable technology in expanding irrigation to rural off-grid farmers[6]. The prices of solar PV have been decreasing dramatically over the last decade and are forecast to further decrease. The International Renewable Agency (IRENA) projects a 59 per cent cost reduction for electricity generated by solar PV by 2025, as compared to 2015 prices, further creating a case for solar water pumping[7]. While solar-powered irrigation systems have a higher initial cost averaging USD 1,000 to 3,000 per acre – depending on the type of land, crop water requirement and the irrigation system used – they are more cost-effective on a life cycle basis, compared to diesel pumps. As illustrated in Figure 2, diesel pumps have lower initial costs, but high maintenance costs, coupled with the possibility of erratic fuel prices and fuel shortages, especially in rural areas. Solar pumps, by comparison, have zero fuel costs, are often easier to maintain, and are less susceptible to global price fluctuations[8]. As a result, the costs are estimated to be between 22 and 56 per cent of diesel pump costs, with a possibility of payback in two years[9].

[5] Uganda National Irrigation Policy, https://www.mwe.go.ug/sites/default/files/library/Uganda percent20National percent20Irrigation percent20Policy.pdf

[6] Factsheet on Smallholder and Family Farmers, FAO, http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Factsheet_SMALLHOLDERS.pdf

[7] FAO, The Benefits and Risk of Solar-Powered Irrigation Systems (SPIS)

[8] "A Solar Powered Pump", Technology, Water & Pumps International, https://waterandpumpsint.com/a-solar-powered-pump/

[9] OCA analysis and interviews supported by Solar Electric Light Fund "A Cost and Reliability Comparison between Solar and Diesel Powered Pumps" https://www.self.org/SELF_White_Paper_-_Solar_vs_Diesel.pdf

Benefit 2: Increasing productivity and incomes for farmers

Through solar irrigation, rural farmers are not limited to specific growing seasons and can focus on producing diversified, high-value crops. As highlighted in the case study, early pilots in Kenya, Uganda and Tanzania by UOMA, E4I and CLASP show that solar irrigation systems enable farmers to have one or more additional growing seasons and improve productivity in the dry seasons.

As a result, farmers earn better margins as they take advantage of higher off-peak crop prices[10]. As summarised below, the benefits of solar irrigation are substantial for both farmers and the government[11].

Case Study: Research by the Low Energy Inclusive Appliances Programme show significant impact

Under DFID's Energy for Efficiency Coalition, CLASP and Acumen interviewed 400 farmers who owned a pump for 4– 5 months in Kenya, Uganda and Tanzania.

They were able to see significant impact:

- 91% reduction in expenditure – majority had converted from diesel or manual pumping; fewer cases of first-time irrigators given the initial capital cost
- 55% moved up the energy ladder – having previously had smaller lighting systems, they were now able to expand their use
- 81% felt it had improved their lives – increase in incomes and ability to count on extra harvest seasons.

Benefits for farmers

- Ready supply of energy and access to water for irrigation (if close to a source)
- Improved yield and increased incomes
- Reduced manual work and reduced time spent collecting water
- Enhanced crop resilience and security
- More income generating options by growing high value crops
- Improved health, education, and poverty alleviation

Benefits for the government

- Reduction in electricity and fuel use
- Savings on fuel import subsidies
- Creation of small businesses/ employment across the value chain
- Increased agricultural economic output, income and farmers' standards of living
- Reduced carbon emissions
- Increased consumption of other forms of energy due to increased income
- Increased affordability of electricity connections

[10] Uganda Off-Grid Energy Market Accelerator productive use pilots
[11] IRENA, Solar Pumping for Irrigation, https://www.sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/IRENA_Solar_Pumping_for_Irrigation_2016.pdf

2. Business Models for solar irrigation

There are a variety of business models in which operators are involved in one or more sections of the value chain. This is determined by the target clientele and type(s) of systems sold. This section explores in detail the different business models currently operating in Uganda and East Africa.

In Uganda, most operators of small-scale solar irrigation systems business are still in the pilot and initial launch phases and are yet to refine their business models for engaging small- to medium-scale farmers or operate at scale. There are no local manufacturers of small-scale water pumping systems, thus most operators import systems from China or India, and concentrate on the distribution and installation part of the value chain. See the Appendix 6.1 for more details on existing solar irrigation providers and details of their models.

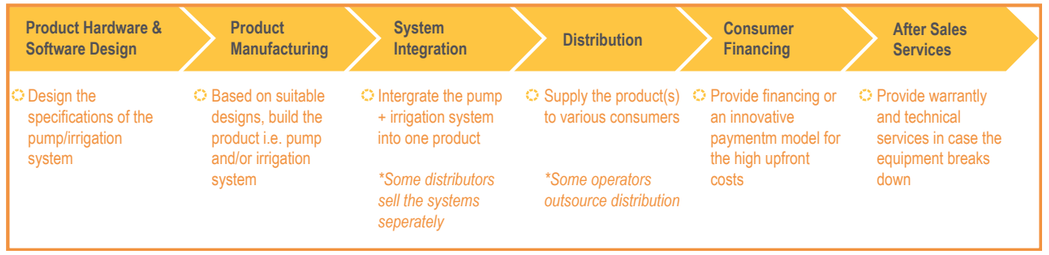

Figure 3 Solar powered irrigation value chain

2.1 MANUFACTURING ONLY

There are operators who are only active in the design and manufacture of the solar water pumps and irrigation systems. They then sell their products to distributors and other solar energy companies, and do not provide consumer financing or last mile after-sales services.
These companies are typically more established manufacturers who were already engaged in large-scale irrigation systems and have now developed products for small-scale irrigation. These include firms like Lorenz, ENOS and Davis & Shirtliff, who are well known globally.

A number of programmes and pilots have identified the preferred quality from these types of businesses as they understand the technical aspects of the industry and the needs of the end customer better. However, these players are focused on the business to business (B2B) model and do not see the business case to directly interface with small-scale farmers.
More recently, some manufacturers like Future Pump started providing end to end services, including consumer financing and developing software for remote monitoring and tracking of farmer usage.

2.2 DISTRIBUTION AND AFTERSALES SERVICES ONLY

Several of the newer entrants in the market who are targeting small-scale farmers are operating a model where they purchase products from manufacturers and use their own distribution channels to reach the last mile. They include specialised businesses that are branding products sourced from manufacturers and providing last mile distribution and services, for example SunCulture in Kenya. Other companies are vertically integrated into already existing businesses, for example:

- Agricultural appliances providers: These are businesses that were already providing agricultural appliances to rural farmers and have integrated solar water pumps into their product offering. These include operators like Simusolar and Water Pumps International. In the case of international companies operating in local markets, the most cost-effective option has typically been collaborating with local distributors to sell the product. Based on experience in other markets, this type of partnership is likely to continue until sales volumes justify the company coming into the market to carry out its own distribution. Many operators in Uganda are partnering with grassroot structures such as saving groups, farmer cooperatives and women groups that reach the last mile and often have deep trust with the consumers.

- Solar home system companies: These are businesses that were already providing energy products to rural populations and have integrated solar water pumps into their product offering. These include operators like Azuri Technologies, Aptech Africa and SolarNow. They are typically utilising their existing agent networks to bundle and sell solar water pumps. Sales agents are deployed in different communities to distribute products and offer technical assistance. The main concern with this model is the lack of technical capacity to support farmers given that most energy providers are not irrigation experts or agronomists, Solar irrigation technology is unique, and operators cannot typically rely on existing technician networks.

Given the rural and distributed nature of most solar irrigation consumers, operators and distributors must find cost-effective distribution channels that increase uptake while maintaining the affordability of technologies. Similarly, these channels must be coupled with ongoing technical and consumer after-sales support to ensure they continue to function. To address these needs, operators in Uganda are experimenting with different channels, financing and service models.

2.2.1 CONSUMER FINANCING

Most of the products offered include the solar water pump and other components like controllers, water storage tanks, sprinklers, and pivot and drip irrigation accessories as an integrated unit. Pilots run by UOMA, E4I and CLASP revealed that the controllers, storage tanks, sprinklers and drip irrigation kits are three times the cost of the solar water pump alone. Due to the significant upfront cost to rural farmers, most smallholder farmers require consumer financing.

Some operators are providing the solar irrigation systems on credit to farmers, with the system acting as collateral. Farmers begin with a down payment and a fixed monthly fee. Interest is charged on the declining principal balance. After the balance is paid in full, the customer owns the equipment. This is more common with the rent-to-own or pay-go/pay grow model where operators collect payments via mobile payment and use remote monitoring to disconnect when customers default.

Operators have also explored partnerships with banks and microfinance institutions to offer asset financing to farmers. However, the financial institutions have been reluctant to consider the system as collateral given the complexity of the systems and the protocol for removal in case of default. Further, from UOMA pilots run in 2018, it was noted that farmers in Uganda are largely averse to credit from formal financial institutions. From the pilots run, it was also noted that products were most effective when farmers received technical training on how to use the pump combined with business training on how to manage the enhanced output. In such instances, farmers understood the benefits of the product and were willing to increase uptake or refer community members.

2.2.2 AFTERSALES SERVICES

Aftersales services play a key role in influencing farmers to purchase solar water pumping solutions. Due to the remoteness of the farms, farmers may be deterred from purchasing the equipment for fear of not receiving assistance if the equipment breaks down.

One-on-one guidance when choosing appliances is necessary to assess consumer needs. For farmers to appreciate and derive value from a solar water pump, they require advice from energy experts (e.g. on the system size), agriculture experts (e.g. advice on high yield crops and best practices) and water specialists (e.g. to help with proper installation of the pumps on their farms).

3. Challenges in Scaling Solar Water Pumps for Irrigation

Despite recent innovations in technology and business models, there are several challenges that have limited the uptake of solar water pumps for irrigation in Uganda.

3.1. CHALLENGES

3.1.1 SYSTEM CONFIGURATION IS NOT STANDARD

Solar irrigation consumers are keen to have quality products with low maintenance and suitable features like autonomy, flexibility and low energy consumption. In Uganda, there are two main types of solar water pumps for small-scale farmers: surface pumps and submersible pumps. Depending on the use, scale and other factors (see Annex 7.2), the systems can have several modifications. This makes it very hard for businesses to develop standard product and pricing models to manage their operations. Some businesses have tried segmenting customers according to use case but have not been successful.

3.1.2 LIMITED CONSUMER AWARENESS ON THE AVAILABLE PRODUCTS AND BENEFITS

Due to the large investment cost, especially to smallholder farmers, many farmers are not willing to purchase the technology unless they witness the benefits through demonstration sites or other consumers' success stories. However, it is typically prohibitively expensive for private operators to provide such heavy investment in consumer awareness campaigns or in setting up demonstration sites.

3.1.3 LIMITED TECHNICAL EXPERTISE TO SUPPORT FARMERS TO MAXIMISE PRODUCTIVITY

Often, distributors and field staff may not have the technical capacity to select the appropriate pump based on farmer needs and land characteristics. As a result, consumers end up with the wrong pumps for their farms and limited knowledge on how to operate and maintain the pumps, thus diminishing the potential return on investment. From the pilots run under the Low Energy Inclusive Appliances Programme (LEIA) by Efficiency for Access Coalition, 55 per cent of the farmers involved had technical issues or had different expectations of the system's capacity at point of sale.
Many farmers also require additional training on inputs, market linkages and business training to maximise productivity and realise return on investment. Most operators lack in-house expertise to support the farmers holistically.

3.1.4 LOW AFFORDABILITY AND LIMITED ACCESS TO FINANCE FOR FARMERS

Solar powered water pumps and irrigation systems have high upfront costs. These costs are higher than most farmers' ability or willingness to pay for such products. Further innovation on the system configuration and pricing is required.

Additionally, there is room to explore consumer financing models that support farmers. It is important for operators to consider the seasonal nature of farmers' earnings and create flexible financing structures. There is also need to innovate in credit management models. For example, system disconnection as used in pay-as-you-go (PAYG) for lighting is ineffective given that it cuts off the farmer's livelihood and ability to pay back. Further information from the pilots run under LEIAP showed that only 25 per cent were base-of-pyramid users, implying that only middle class or wealthy farmers were able to afford the appliances with this model. Some operators have explored shared models or community models to make it easier for farmers to cost-share the initial capital costs of obtaining the system. However, shared models require a consideration of socio-cultural norms, land tenure laws, existing water user associations, operation and management of the systems, and other technical aspects related to the system.

While the above options provide more access to farmers, solar water pump providers need a lot of capital to be able to operate a credit model. Today, most existing working capital facilities and grants provided by the government and other development partners for the off-grid or agriculture sectors do not focus on solar irrigation or pumping.

3.1.5 UNAVAILABILITY OF DATA ON ACCESS TO WATER

The solar water pumps available are either surface pumps or submersible pumps. It is currently unclear to providers what is most relevant for specific geographic regions or types of farmers in Uganda. Providers need to be better equipped with data on water levels in specific regions to be able to determine the relevance of their products and add-ons like storage tanks.

3.1.6 MINIMAL GATHERING OR STANDARDISATION OF IMPACT MEASUREMENT

Metrics to measure the value from solar water pumping for smallholder farmers in Uganda should be developed to clearly show how farmers' incomes or productivity have improved. These metrics will be important in increasing awareness to farmers and financiers.

3.1.7 ACCESS TO INPUTS AND CROP MARKETS

The effectiveness of irrigation to improve crop yields is dependent on the availability of complementary inputs such as fertilisers, improved seeds and extension services. This emphasises the need for convergence between solar irrigation programmes and market linking or extension programmes.[12]

3.1.8 LACK OF A FRAMEWORK FOR QUALITY

Many consumers are uninformed about solar irrigation products and unable to distinguish between high-quality and sub-standard systems. While the market may currently be too young to set standards given the diversity in configuration, it is important to develop a framework and metrics to assess quality.

3.1.9 INCONSISTENT AFTERSALES SUPPORT

Even if a consumer purchases a high-quality system, they require training and maintenance throughout the life of the system. The scarcity of solar irrigation technicians affects the economic viability of the systems. A few days of system unavailability during peak growth can influence crop yield, and consequently the ability to pay off any loans or other financial obligations with the supplier.

3.1.10 EXISTING POLICY ENVIRONMENT DOES NOT HAVE TARGETED INTERVENTIONS FOR SMALL-SCALE FARMERS

There are no clear strategies advocating the promotion of solar water pumps for small-scale farmers. The private sector needs better tax incentives and subsidies from the government to increase affordability of the systems.

[12] https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/Agrawal_et_al-2018-Wiley_Interdisciplinary_Reviews_3A_Energy_and_Environment.pdf

4. Public Sector Interventions to Promote Solar Irrigation

4.1. PUBLIC SECTOR INTERVENTIONS AND POLICIES

Many of the challenges highlighted can be partially or wholly addressed through public sector interventions as well as strategies targeted at promoting private sector innovation in solar water pumping for irrigation. This section highlights potential interventions for the GoU to consider. A summary of the recommendations is also found in the Annex 7.5 and 7.6.

4.1.1 INCREASE COORDINATION WITHIN GOVERNMENT AGENCIES AND OTHER STAKEHOLDERS

Several changes in the policy framework could be favourable in creating an enabling business environment for farmers and private sector irrigation providers, thereby solving some of the challenges in scaling solar water pumping in Uganda. As highlighted in the previous section, consumers require high quality, affordable products regulated and approved under clear guidelines. Operators require clear policies and implementation plans for promoting private sector investment.

In recent years, the **MEMD** has increasingly focused on promoting off-grid renewable energy access. For example, the draft Off-Grid Strategy acknowledges that many agricultural and industrial activities are currently facilitated primarily by biomass and fossil fuels. However, it does not outline specific interventions or targets on how to increase access to off-grid renewable energy for productive use. MEMD is currently updating the Energy Policy. While it is yet to be released, early previews and consultations with government indicate that promoting productive use of electricity is listed as one of the strategies in the document, though the document does not spell out specific mechanisms to do so, nor make specific reference to solar irrigation.

The **Ministry of Water and Environment (MOWE)** developed and is responsible for the National Irrigation Plan, in line with Uganda's Vision 2040. The plan's main goal is to "transform agriculture from subsistence to commercial agriculture through mechanisation and introduction of modern irrigation systems".[13] The plan, however, mostly focuses on support to large irrigation schemes through drainage canals. It does not include specific initiatives to support smallholder farmers, or articulate potential off-grid sources of energy for irrigation. The government, through the National Agricultural Advisory Services (NAADS), is piloting large-scale solar water pumping irrigation projects in certain areas. However, other projects being implemented are privately owned.

The **Ministry of Agriculture, Animal Industry and Fisheries (MAAIF)** holds the specific mandate of implementing any agricultural interventions, including those around irrigation projects and technical assistance to farmers. There has however been a lack of coordination, with MAAIF running parallel and sometimes competing programs with MOWE, leading to inefficiency due to duplicated efforts in the implemented programmes. MAAIF is working closely with the MOWE in promoting productive use of energy in irrigation. Government engineers are playing a supervisory role in developing some of the necessary policies in collaboration with the private sector who are leading the way in productive use technology.[14]

Given the inter-related mandates and roles for solar irrigation, the GoU must improve coordination. This will help to implement strategies that promote solar irrigation – combining awareness building with additional initiatives on law and standards enforcement, fiscal policies, financing mechanisms, stakeholder collaboration and capacity development as seen in other markets. A working group, incorporating relevant stakeholders from public and private sector, can be established to identify collaborative interventions and synchronise strategies and targets.[15]

4.1.2 CREATE A FRAMEWORK OR ADAPT METRICS FOR QUALITY AND STANDARDS

The government can support more research and testing of off-grid productive use appliances through bodies like Uganda National Bureau of Standards (UNBS) to define or adopt metrics for quality in the industry. As highlighted in Annex 7.5, Mexico presents a good case for a market protection strategy. The Mexican government implemented a certification scheme for solar powered irrigation system suppliers and installers to enhance consumer confidence and trust in private operators and weed out non-qualified suppliers in the market[16]. See Annex 7.5 for additional examples of governments using laws and standards enforcement to promote solar powered irrigation.

4.1.3 DEVELOP FISCAL POLICY INTERVENTIONS TO SUPPORT THE SECTOR

While solar generation components like solar panels are tax exempt in Uganda, the government should consider interventions such as tax breaks and other incentives for the remaining components. This approach can bring down the cost of the systems, making them more accessible to the market. For example, in Ethiopia, solar pumps and other modern off-grid energy products are exempt from customs duty, excise tax and surtax. Additionally, in the past couple of years, solar pumps have been exempted from 15 per cent VAT and 2 per cent withholding tax on the condition that the inputs are not directly used for commercial purposes[17]. This approach has significantly reduced the overall cost of the pumps, making them more affordable to farmers.
Further, the government should consider smart subsidies to the market to further incentivise uptake without distortion. The Government of India, for example, instituted an 80 per cent subsidy on irrigation pumps where the operator is not tied to the customer for service and maintenance. It is important that subsidies are structured in a way that incentivises operators to provide holistic support to the market. In Mexico, the government supported solar powered irrigation in specific areas through two different schemes: 1) highly productive provinces received 50 per cent subsidy on solar irrigation systems, up to a maximum amount of USD 6,000 and 2) rural arid areas received up to 70 per cent subsidy for solar-powered irrigation, up to a total amount of USD 22,000. The subsidies increased productivity and had a considerable impact where arid land was reclaimed for agriculture.
Additional examples on fiscal policy interventions are included in Annex 7.5.

4.1.4 CREATE AWARENESS AND PROVIDE MORE TRAINING TO BUILD CAPACITY

Given the high cost of awareness and capacity building campaigns, coupled with dispersed benefits, the government and development partners are best placed to manage these campaigns. Such programmes can increase farmers' and private sector's knowledge and skills needed to install and manage solar powered irrigation systems effectively. Capacity development will also provide farmers with information on the benefits of venturing into solar powered irrigation systems. Similar programmes are already in place, with the GoU promoting sustainable land management, effective conservation and sustainable use of available water through programmes that encourage use of trenches and tree planting, water harvesting, irrigation and storage.
Additionally, the government can leverage grassroot structures such as extension workers at the local government level, as well as cooperatives and savings groups to deliver information and increase awareness on the benefits of solar water irrigation. These channels can also be used for business training to enable farmers fully maximise productivity.

[13]Ministry of Agriculture, Animal Industry and Fisheries and Ministry of Water and Environment, National Irrigation Policy, November, 2017, https://www.mwe.go.ug/sites/default/files/library/Uganda percent20National percent20Irrigation percent20Policy.pdf
[14]OCG interview with the Ministry of Agriculture
[15]Ernersto Stein, "Coordination: Key to the Success of Public Policies", Inter-American Development Bank (IDB) (blog), March 15, 2017, https://blogs.iadb.org/ideas-matter/en/coordination-key-success-public-policies/

[16]Hans Hartung and Lucie Pluschke, The benefits and risks of solar-powered irrigation – a global overview, FAO and GIZ, 2018, page 26, http://www.fao.org/3/i9047en/I9047EN.pdf
[17]Miriam Otoo, Nicole Lefore, Petra Schmitter, Jennie Barron and, Gebrehaweria Gebregziabher, Business Model Scenarios and Suitability: Smallholder Solar Pump-based Irrigation in Ethiopia, IWMI, 2018, http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub172/rr172.pdf

5. Conclusion and Recommended Next Steps

5.1. CONCLUSION

As highlighted throughout this paper, small-scale off-grid solar irrigation systems provide a compelling solution to electrify rural households while also providing increased productivity and income. Despite the perceived attractiveness of these systems, there are insufficient private sector players and service delivery models to reach many smallholder farmers. The GoU can leverage several strategies and policies to encourage innovation in the sector, including:

- Increasing coordination within government agencies and other stakeholders
- Creating a framework or adapt metrics for quality and standards
- Developing fiscal policy interventions to support the sector such as tax incentives and subsidies
- Providing more awareness and training to build capacity to improve farmers' knowledge and access to resources needed to maximise productivity.

In so doing, the GoU can increase the uptake of off-grid solar irrigation systems and consequently provide energy access to unserved rural and agriculture households. These strategies will therefore help the government achieve its mandate of universal electrification and national development.

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7. Annex

7.1 KEY PLAYERS PILOTING SOLAR PUMPING SOLUTIONS

Company	Description of solar pumping solutions
solar now	○ SolarNow was one of the first players to pioneer a portable solar powered surface pump with a pilot run in 2016. ○ System can be utilised with drip, surface and sprinkler irrigation.
Aptech Africa	○ Aptech Africa is a distributor of solar submersible and surface pumps from leading brands such as Grundfos, Soleil Power, DAB etc. ○ Offers farmers solar water pumps coupled with an irrigation system (either drip or sprinkler) depending on the customer's needs and ability to pay.
azuri	○ Azuri is a major provider of PayGo solar home systems operating in 12 countries including Uganda. ○ Has piloted solar irrigation systems called 'GrowFast' for rural farmers offered on a pay-as-you-go basis.
Village Energy	○ Village Energy offers ground and surface water pumps from leading international brands for a variety of needs, including irrigation and domestic consumption, with installation customised according to clients' needs and backed by a two-year service and maintenance offer. ○ Provides financing for qualifying clients through PAYG technology and partnerships with financial institutions.
Water & Pumps International	○ Water & Pumps International offers solar irrigation pumps in remote off-grid villages where alternative sources such as wind do not provide sufficient energy. ○ Supports smallholder irrigation through finance and technical assistance aimed at improving productivity.
sunculture	○ SunCulture manufactures and finances solar powered water pumping solutions and irrigation systems. ○ Offers additional services such as soil sampling and runs a financing platform know as 'Pay-As-You-Grow'. ○ Product slightly more expensive than others as it comes with a battery that can extend pumping up to six hours on a cloudy day and has a wireless controller with weather and soil sensors.
Futurepump	○ Kenyan-based company that manufactures and distributes solar irrigation systems. ○ Partnered with SolarNow, a local Ugandan solar distributor, for its portable solar irrigation pump. ○ Offers a financing plan which requires a 24 per cent deposit with the remaining amount being paid in monthly payments of at least USD 20.
Davis & Shirtliff	○ Davis & Shirtliff are a major supplier of water pumps in East Africa, sourcing their products from leading manufacturers such as Grundos, DAB, Davey etc. ○ Product offering for water pumps includes solar powered water pumps.
Water Brick	○ Water Brick provides solar pump systems in both urban and rural areas with no access to water. ○ Offers water exploration, water well construction, Water, Sanitation & Hygiene (WASH) solutions, agricultural purposes and implementation of entire projects for governments, NGO and CSR activities.

7.2 DIFFERENT CONFIGURATIONS AND TYPES OF SOLAR WATER PUMPS

Solar surface pumps are above ground installations that pull water from a water body and push it forward to be used for irrigation or in the household. These systems are suitable if the water table is within a depth of 10 meters. Solar submersible pumps are submerged in the water body to pump water to the surface from an underground source with a depth of more than 10 meters[18].

Depending on the purpose of the solar water pump, there could be a few installed modifications such as:

- Controllers that use Maximum Power Point Tracking (MPPT) technology to match the solar panel model output to that of the motor. This ensures maximum output throughout the day. The controllers also provide inputs for real-time monitoring of parameters such as borehole water levels, storage tank levels, pump speed etc., which can be used for water measurements and remote switching of the pumps[19]. Prices of controllers and pumps have decreased over time, with a 30 per cent reduction in prices between 2009 and 2017[20].
- Inverters to convert the power generated by the solar panels from direct current (DC) to alternating current (AC) in case the pump requires AC.
- Storage tanks that solve the problem of energy storage because solar systems only operate during daylight and are less efficient on rainy or cloudy days (no sun days). The size and dimensions of the tank are determined based on the required number of storage days.
- Back up batteries/generators that can be incorporated in the design to allow for prolonged periods of 'no sun days' that will eventually empty the water storage tank. These are also useful if large storage tanks are impractical.

Once set up, the solar water pumps are then connected to an irrigation system. Common irrigation systems include flood, sprinkler, pivot and drip irrigation. The system can also include filtration or fertigation equipment for injecting fertilisers into the irrigation equipment. The type of installed pump and its required capacity depends on various factors including:

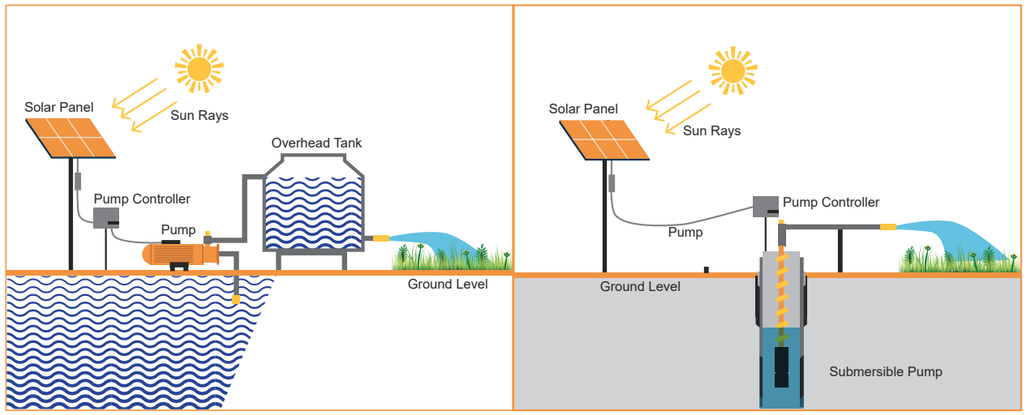

Figure 4 Surface pump and submersible pump

[18]India Water Portal, https://www.indiawaterportal.org/articles/frequently-asked-questions-faqs-solar-water-pumps
[19]FAO, The Benefits and Risk of Solar-Powered Irrigation Systems (SPIS)
[20]FAO, The Benefits and Risk of Solar-Powered Irrigation Systems (SPIS)

- Peak daily water requirement: The higher the peak daily water requirement, the larger the system used hence the higher the capital expenditure (capex). The peak daily water requirement can be optimised with the use of micro-irrigation solutions such as drip or sprinkler irrigation systems that can be easily combined with solar pumps, and they utilise water more efficiently.
- Depths or distance from water source: The capacity of the solar pump is determined by the head of the pump, which is dependent on the distance from or the depth of the water source. The higher the capacity, the higher the capex needed.
- Utilisation factor: This determines the number of times the farmer crops in a year. The returns on the pump can be enhanced by increasing utilisation by assisting farmers to grow multiple crops in a year, particularly high value crops. Excess water can be utilised within the household or sold to neighbours for an extra income.
- Solar irradiance: The lower the levels of solar radiation, the higher the number of solar PV cells required to pump the water, which increases the initial costs of the pump and irrigation systems.
- Scale of farming: The scale of operation determines the capacity of the pump required, revenue from cultivation, purchasing power of the farmer as well as his/her ability to access credit services. In Uganda, as per MOWE's categorisation, an over 100ha farm is considered medium scale, and over 1000ha is considered large scale. However, many farms are less than 1ha and are run by smallholder farmers.
- Crop value chain: In East Africa, emphasis has been put on the horticulture value chain due to its shorter harvest cycles, making it easier to realise returns and the resulting impact of the irrigation system.

Solar pumps need to be carefully calibrated at the design stage since capacity cannot be easily augmented and may require replacement of the solar PV panels to re-install a pump with higher capacity.

Most common configurations are shown in Table 1.[21]

Table 1:Common solar water pumping configurations

Configuration	Pros	Cons
Direct pumping for irrigation and household uses	System can be used for irrigation as well as other water requirements.	May result in excess water withdrawal due to the zero operational costs nature of the systems.
Multi-use system for other on farm activities	When no pumping is required, the solar system is channelled into other productive uses such as milling, grinding, sawing, food processing, cooling etc.	• Since the controller is optimised for the needs of the pumping system, energy needs for the other appliances must logically follow the pump. • The motors for the other appliances should have the same voltage as the water pump as well as the AC/DC mode. • Reconfiguring the system for other uses may require special skills.
Pump feeding into the mini-grids	Excess solar energy generated can feed into the mini-grid and generate income if not required for other uses.	Requires proximity to mini-grids.
Hybrid systems with multiple sources of energy	Solar pumping system works in parallel with electricity grid and/or diesel pump to supplement solar power when the system is not producing the required amount of energy	• Requires adjustment of the controller. • A costly option given the need to rely on fuel-based options, such as diesel.

[21] FAO, The Benefits and Risk of Solar-Powered Irrigation Systems (SPIS)

7.3 ONGOING AND COMPLETED SOLAR WATER PUMPING PROJECTS IN UGANDA[22]

ONGOING PROJECTS

Project Name	Client	Contract Value
Construction of Solar Powered Mini Piped Water Schemes in Rural Areas in Uganda	Ministry of Water and Environment	USD 1,398,647
Construction of Solar Powered Micro Irrigation Systems in Lot 2: Northern Uganda Districts	Ministry of Water and Environment	USD 732,572
Construction of Piped Water Supply Systems (Installation of Solar Pumping System)	Ministry of Water and Environment	USD 82,455
Construction of Solar Motorised Water System at OmiyaAnyima/Nakamori Sub Counties	Kitgum District Local Government	USD 43,388
Supply and Installation of a Solar Powered Mini Piped System at Kyasonko Water Scheme	Ministry of Water and Environment	USD 19,513
Installation and Commissioning of Seven (7No.) Solar Photovoltaic (PV) Energy Packages for Water Supply Schemes	Ministry of Water and Environment	USD 1,194,223

COMPLETED PROJECTS

Project Name	Client	Contract Value	Completed
Design and Supply of a Solar Water System for Irrigation in Amudat	Mr. Christopher Kipterit Akorikimoi (Member of Parliament- Amudat)	USD 15,784	June 2018
Construction of Solar Powered Mini- Piped Water Schemes in Rural Areas in Uganda	Ministry of Water and Environment	USD 597,199.00	April 2017
Installation of Solar Energy Packages for Water Supply Schemes in Rural Areas	Ministry of Water and Environment	USD1,394,060.00	March 2013

[22] http://tass.co.ug/wp-content/uploads/2018/11/TASS-PROJECTS.pdf

7.4 EXISTING POLICIES IN UGANDA FOR ACCELERATING ACCESS

There are several policies promoting the use of renewable sources of energy and rural electrification which indirectly promote solar powered irrigation for the farmers. These are shown below.

The Energy for Rural Transformation (ERT) programme has been the main driver behind most of the direct public procurements of PV systems in the institutional market segment. Other international aid programmes and NGOs have similarly targeted the institutional PV market segment. For example, the Promotion of Renewable Energy and Energy Efficiency Programme (PREEEP) programme mentioned above was specifically aimed at electrifying government institutions (such as health centres, boarding schools, vocational training centres and local government offices) with solar PV systems by providing an 80 per cent subsidy for the procurement of a PV system while the receiving institution was responsible for providing the remaining 20 per cent. This segment is therefore still strongly influenced by donor support, although channelled through the REA[24].

Policy	Description
Renewable Energy Policy (REP), 2007	Aims to increase the share of "modern renewables" of total energy production to 61 per cent (2017) by: • Publishing standardised PPAs with feed-in-tariffs (creating REFiT) • Putting in place legislation and regulations to promote appropriate use of REs • Implementing innovative financing mechanisms through PPPs.
Rural Electrification Strategy and Plan 2013 – 2022 (RESP II), 2013	• Intends to increase rural electricity access to 26 per cent by 2022. • Addresses the shortcomings of RESP I by centralising rural electrification planning where the REA will be responsible. • Investment in small distributed power generation facilities as local sources of supply will be given increased priority and enhanced support.
National Development Plan II 2015 – 2020 (NDP II), 2015	• Aims to increase power generation capacity to 2,500 MW by 2020 for the national grid, largely through hydro and geothermal power. • Aims to increase overall access to electricity to 30 per cent and per capita consumption to 584kWh by 2020. • Intends to increase energy efficiency and public investment in the energy sector. • Remains silent on the government's stance on off-grid technologies.[23]

[23] DALBERG GLOBAL DEVELOPMENT ADVISORS, IMPROVING ACCESS TO ELECTRICITY THROUGH DECENTRALISED RENEWABLE ENERGY, https://www.dalberg.com/system/files/2017-08/off-grid percent20policy.pdf
[24] UNEP Risø Centre, Review of Solar PV market development in East Africa, http://pubdocs.worldbank.org/en/600611475093991341/Solar-PV-market-East-Africa-UNEP-2014.pdf

7.5 EXAMPLES OF POLICIES AND STRATEGIES IMPLEMENTED IN OTHER MARKETS

LAWS AND STANDARDS ENFORCEMENT EXAMPLES

Country	Description of Intervention	Objectives and Lessons Learned
Tunisia	Law on self-production allowed agricultural development groups (ADGs) in Kebili governate, a region which gets abnormal amounts of direct sunlight, to self-produce solar energy for solar pumps and irrigation and sell any excess energy back to the national Tunisian Company for Electricity and Gas (STEG). [25]	The government aimed to promote the productive use of solar energy among farmers thus enabling them to increase their agricultural production and at the same time become producers of energy.
India	• The government implemented a mandatory Renewable Purchase Obligation (RPO) for electricity distribution companies and some large power consumers if they wanted to access funds for financial restructuring of their utilities. • The RPOs specified the minimum percentages of the total power that needed to be purchased from renewable energy sources, which created a minimum market for renewables in the absence of pricing externalities for conventional power generation.[26]	The RPOs encouraged farmers to venture into productive use of solar energy. Farmers could thus install the solar pumps and have a market for the excess energy that was generated.
Mexico	It is one of the countries with a certification scheme for SPIS suppliers and installers which is a key step in creating confidence and trust and weeding out non-qualified suppliers in the market. [27]	This was key to providing farmers with confidence in the supplied solar products. Governments regulated suppliers through standard quality checks on the products.

[25]FAO and GIZ, International Workshop: Prospects for solar-powered irrigation systems (SPIS) in developing countries, Italy: FAO and GIZ, 2015, page 11, http://www.fao.org/fileadmin/user_upload/faowater/docs/FAO_GIZ_SOLAR_FINALREPORT.pdf
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[27]Hans Hartung and Lucie Pluschke, The benefits and risks of solar-powered irrigation – a global overview, FAO and GIZ, 2018, page 26, http://www.fao.org/3/i9047en/I9047EN.pdf

FISCAL POLICY EXAMPLES

Country	Description of Intervention	Objectives and Lessons Learned
Morocco	• The government of Morocco is executing the national irrigational plan (PNEEI) under the Plan Maroc Vert, which looks to increase current area under drip irrigation and to double the value added per cubic meter of water by the end of the programme. • The PNEEI ultimately aims to convert surface and sprinkler irrigation to drip irrigation over an area of 920,000 ha by 2030, resulting in water savings of 2.4 billion m3/year. From a technical viewpoint, the coupling of solar pumps and drip irrigation has been identified as an optimal solution, potentially resulting in increased field application efficiency.[28]	Setting targets is crucial for achieving the SDG goal on affordable and clean energy. Targets provide a clear implementation strategy for promoting productive use of energy.
Chile	The National Irrigation Commission (NIC) supports small-scale farmers through building their capacity to better compete with large-scale farmers, with a spending budget from the national treasury.[29]	• The budgets enable the respective implementing bodies to function and deliver on set targets while scaling up total investments in irrigation. • They are also used to set up capacity development programmes to train farmers or operators on use of solar water pumps.
Ethiopia	Solar pumps and other modern off-grid energy products are exempt from duty tax, excise tax and surtax. Additionally, in the past couple of years, the importation of solar pumps has been included in the list of items that are exempt from 15 per cent VAT and two per cent withholding tax on the condition that the inputs are not directly used for commercial	The tax cuts reduced the overall cost of the pumps to the farmers, making them more affordable.

[28]Hans Hartung and Lucie Pluschke, The benefits and risks of solar-powered irrigation – a global overview, FAO and GIZ, 2018, page 49, http://www.fao.org/3/i9047en/I9047EN.pdf
[29]FAO and GIZ, International Workshop: Prospects for solar-powered irrigation systems (SPIS) in developing countries, Italy: FAO and GIZ, 2015, http://www.fao.org/fileadmin/user_upload/faowater/docs/FAO_GIZ_SOLAR_FINALREPORT.pdf
[30]Miriam Otoo, Nicole Lefore, Petra Schmitter, Jennie Barron and, Gebrehaweria Gebregziabher, Business Model Scenarios and Suitability: Smallholder Solar Pump-based Irrigation in Ethiopia, IWMI, 2018, http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub172/rr172.pdf

FINANCING MECHANISMS

Country	Description of Intervention	Objectives and Lessons Learned
China	• China subsidises up to 50 per cent of total irrigation capital costs. In remote areas without electricity supply and where diesel costs are high, a special fund was established for the application of solar irrigation systems while looking into other methods to scale up current efforts.[31] • 18 solar PV pilot areas were created in Northeast and Northwest China, as well as in other locations, for irrigating pasture areas and crops.	Subsidies help to set affordable prices for consumers. Governments offer the subsidies independently or in collaboration with national banks or other financial institutions.
Morocco	• The Moroccan government lifted all subsidies on diesel, gasoline and heavy fuel oil to encourage more efficient use of energy and free up resources to invest in the transition to a green economy. [32] • In 2013, the Ministry of Agriculture, the Ministry of Energy and the Ministry of Finance jointly rolled out a subsidy scheme, together with the government-owned bank Crédit Agricole, to help farmers transition from conventional to renewable energies. It was solidified in 2017 with a budget of USD 220 million.	The programme provides 50 per cent subsidy on the capital cost of the solar panels and 80–100 per cent for drip irrigation installation.
Mexico	The Ministry of Agriculture supports solar powered irrigation in specific areas through two different schemes: • Highly productive provinces receive 50 per cent subsidy on solar irrigation systems, up to a maximum amount of USD 6,000 • Rural arid areas receive up to 70 per cent subsidy for solar-powered irrigation, up to a total amount of USD 22,000.	The subsidies increased productivity and had a considerable impact where arid land was reclaimed for agriculture.
Nepal	An intergovernmental knowledge and sharing centre, the International Centre for Integrated Mountain Development (ICIMOD) offers farmers three grant financial models to set up irrigation schemes: • A grant model, covering around 60 per cent of total investment costs • A grant-loan model with a grant component as well as an additional 20 per cent loan at a five per cent interest rate per annum • A grant pay-as-you-go model, where farmers pay a monthly rental fee for use[33]	These are incentives for making the irrigation schemes affordable to local farmers.

[31]FAO and GIZ, International Workshop: Prospects for solar-powered irrigation systems (SPIS) in developing countries, Italy: FAO and GIZ, 2015, http://www.fao.org/fileadmin/user_upload/faowater/docs/FAO_GIZ_SOLAR_FINALREPORT.pdf
[32]FAO and GIZ, International Workshop: Prospects for solar-powered irrigation systems (SPIS) in developing countries, Italy: FAO and
[33]GIZ, 2015, http://www.fao.org/fileadmin/user_upload/faowater/docs/FAO_GIZ_SOLAR_FINALREPORT.pdf

STAKEHOLDER COLLABORATION EXAMPLES

Country	Description of Intervention	Objectives and Lessons Learned
Egypt	FAO implemented solar-powered surface-irrigation water-lifting stations through the Ministry of Water Resources and Irrigation to irrigate crops in the Nile Delta as part of the Country Programme Framework Agreement between FAO and the Egyptian government.	• The project contributes significantly to reduced water losses caused by evaporation in the channels, provides a more sustainable source of energy for irrigation purposes, and reduces the negative impacts of diesel spills and greenhouse gas emissions on the environment. • The stations have so far provided energy to irrigate 120 feddans of land (50.4 hectares) out of the targeted 500 feddans (210 hectares).[34]
Mauritania	An IFAD-supported programme, Oasis Sustainable Development Programme, introduced solar powered water pumping for agricultural use in the oases, along with improved water storage and distribution systems to combat environmental degradation while reducing poverty.	A study in the oases found that revenue increased by up to 200 per cent for vegetable gardening, especially in carrots, and 27 per cent among households growing palm trees. An unexpected benefit was more sleep as families were no longer awakened by the deafening noise of fuel-based motor pumps.[35]
Nepal	• The NGO SunFarmer partnered with existing local cooperatives to offer affordable solar water pumping. • SunFarmer installs the pumps, provides affordable rent-to-own financing with three-year terms, and monitors/maintains the systems. The farmer cooperatives, in return, identify farms and collect monthly repayments on behalf of SunFarmer while retaining a collection fee. [36]	This increased traction and awareness of the pumps among the farmers, driving the campaign for use of SPIS.
Kenya	Banks such as Equity Bank, and microfinance institutions such as Juhudi Kilimo (owned by farmers), are working in partnership with farmer cooperatives to offer credit lines for solar powered irrigation. Different options for loan prerequisites and repayments are offered, for example, harvest cycle repayments.[37]	This has increased affordability of solar irrigation systems by giving farmers a way to cover the initial costs.
Morocco	The UNDP/GEF designed a project termed 'Promoting the development of photovoltaic pumping systems for irrigation' to run from 2016 to 2019 with an investment of USD 73.5 million (with 96.5 per cent national co-financing) to promote the adoption of solar powered drip irrigation pumping systems by creating a conducive framework for the implementation of the national renewable energy programme.[38]	This will go a long way in encouraging farmers to make use of solar water pumps as opposed to diesel pumps.

[35]IFAD, Sharing a vision, achieving results, IFAD, https://www.ifad.org/documents/38714170/39150184/Sharing+a+vision percent2C+achieving+results+-+Partnership+between+the+Netherlands+and+the+International+Fund+for+Agricultural+Development/0ee9639a-ef12-4ff4-abc1-83d69c1ea30d
[36]Hans Hartung and Lucie Pluschke, The benefits and risks of solar-powered irrigation – a global overview, FAO and GIZ, 2018, http://www.fao.org/3/i9047en/I9047EN.pdf
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[38]Hans Hartung and Lucie Pluschke, The benefits and risks of solar-powered irrigation – a global overview, FAO and GIZ, 2018, http://www.fao.org/3/i9047en/I9047EN.pdf

Rwanda	• The OPEC Fund for International Development (OFID) approved a USD 1 million grant for Energy 4 Impact to develop the small-scale solar irrigation market in Rwanda as a way of increasing farmers' productivity and the country's food security by increasing awareness, availability and affordability of appropriate solar irrigation technologies. • The programme will target 3,000 smallholder farmers across the country, as well as technology suppliers and lenders.[39]	Small-scale solar irrigation will contribute to improved food security and higher rural incomes. Agriculture employs 79 per cent of the total population.
Malawi	The government is implementing a programme funded by the African Development Bank (AfDB) to develop over 500 hectares using solar powered irrigation. [40]	The goal is to increase food production in the country.
Tanzania	Since 2014, a World Bank Technical Assistance Programme for Sustainable Rural Water Supply has been working to build capacities and awareness of solar water pumping in Tanzania.	Replacement of some water schemes in the country, from diesel to solar, has already registered up to 50 per cent reduction in the price of water from TShs 50 to TSh 25 per bucket. The technical assistance from the World Bank has also brought together two rural-oriented arms of government, the Rural Energy Agency and the Ministry of Water, for more efficient collaboration. This partnership was formalised through a memorandum of understanding in which the energy agency would raise funds for solar energy, while the Ministry of Water delivers the water infrastructure.[41]

[39]"Energy 4 Impact granted US$1 million to develop the small-scale solar irrigation market in Rwanda", Energy 4 Impact, January 9, 2018, https://www.energy4impact.org/news/energy-4-impact-granted-us1-million-develop-small-scale-solar-irrigation-market-rwanda
[40]Model Scenarios and Suitability: Smallholder Solar Pump-based Irrigation in Ethiopia, IWMI, 2018, http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub172/rr172.pdf
[41] "Using Solar Energy to Power Water Supply in Tanzania", THE WORLD BANK, December 7, 2015, http://www.worldbank.org/en/news/feature/2015/12/07/using-solar-energy-to-power-water-supply-in-tanzania

CAPACITY DEVELOPMENT EXAMPLES

Country	Description of Intervention	Objectives and Lessons Learned
India	There are solar power cooperatives that provide access to zero-carbon energy for agriculture and extra income from selling energy to the grid in Rajasthan and Gujarat.	Farmers have alternatives for energy use and the excess energy pumps water that is sold to neighbours, or fed into the grid.[42]
Zimbabwe	A solar water pumping project implemented in Zimbabwe has pumps that are used to fill a dam and localised storage tanks for commercial vegetable gardens[43].	Showed increased cropping seasons per year, resulting in increased incomes ranging from 47 per cent to 286 per cent, and improved dietary diversity through nutritious crops.[44]
Sudan	15 solar pumps were installed by the government to improve seasonal irrigation of *Jubrakas*, which are collective plots of land managed by groups of 10 to 12 women.	This helped to diversify household food crops particularly in the dry season, and supported women's increasing role as leaders of the community in managing and producing food.[45]
Benin	• The Solar Electric Light Fund's (SELF's) long-running solar drip irrigation project in Benin started in 2007 and has been built on a steady process of capacity building for both the 400+ women growers in their 11 half-hectare gardens and their local NGO partner, ADESCA. • From the beginning, SELF has provided training in solar and pump installation and maintenance while the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has provided training in the installation and use of drip irrigation systems as well as horticultural practices that optimise gardens to produce high value fruits and vegetables.[46]	SELF's project has resulted in improved productivity among the farmers.

[42]FAO and GIZ, International Workshop: Prospects for solar-powered irrigation systems (SPIS) in developing countries, Italy: FAO and GIZ, 2015, http://www.fao.org/fileadmin/user_upload/faowater/docs/FAO_GIZ_SOLAR_FINALREPORT.pdf
[43]Miriam Otoo, Nicole Lefore, Petra Schmitter, Jennie Barron and, Gebrehaweria Gebregziabher, Business Model Scenarios and Suitability: Smallholder Solar Pump-based Irrigation in Ethiopia, IWMI, 2018, http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub172/rr172.pdf
[44]Miriam Otoo, Nicole Lefore, Petra Schmitter, Jennie Barron and, Gebrehaweria Gebregziabher, Business Model Scenarios and Suitability: Smallholder Solar Pump-based Irrigation in Ethiopia, IWMI, 2018, http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub172/rr172.pdf
[45]"SOLAR EMPOWERMENT ACROSS COUNTRIES", UNDP, https://stories.undp.org/solar-empowerment-across-countries

7.7 INTERVIEWEES LIST

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