PRODUCTIVE USE OF ENERGY IN UGANDA

LEARNINGS FROM THE UGANDA OFF-GRID ENERGY MARKET ACCELERATOR (UOMA)

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ABBREVIATIONS & ACRONYMS

DC	Direct Current
GOGLA	Global Off-Grid Lighting Association
GoU	Government of Uganda
kW	Kilowatt
kWh/day	Kilowatt hours per day
M&E	Monitoring and Evaluation
NGO	Non-governmental organization
PAYG	Pay-As-You-Go
PUE	Productive use of energy
SHS	Solar home systems
SSA	Sub-Saharan Africa
SDGs	Sustainable Development Goals
UBOS	Uganda Bureau of Statistics
UNCDF	United Nations Capital Development Fund
UOMA	Uganda Off-Grid Energy Market Accelerator
USAID	United States Agency for International Development
USD	United States Dollar
W	Watt
Wh/day	Watt hours per day

EXECUTIVE SUMMARY

Off-grid solar energy has become a major success story, accelerating energy for millions of Ugandans. Over the last decade, off-grid solar products have become commonplace in Uganda, with over 4 million products currently in the market.[1] They provide not only clean and modern energy for lighting, but also mobile phone charging and household appliances such as radios and televisions. In Uganda, the sector has attracted one of the highest concentrations of private sector providers of solar products, resulting in a vibrant and active sector today.

Productive use of energy (PUE) technology, powered by standalone solar systems, is emerging as a new market in the off-grid solar sector and a major opportunity to drive energy demand and increase income levels. PUE is any agricultural, commercial, or industrial activity involving energy services as a direct input to the production of goods, or provision of services, to increase income or productivity.[2] Standalone solar implies a system that uses solar photovoltaic cells to directly power appliances or charge rechargeable battery banks, as opposed to hybrid-solar or mini-grid systems. The sector is now looking to appliances, for example solar water pumps, refrigerators, and mills, as a way for off-grid rural households to increase their incomes while stimulating energy demand. Given that 70% of the working population in Uganda is employed through agriculture, income-generating assets can have massive impact in the country.

Despite the potential for impact, little traction has been made in the sector to date. The sector is still very nascent, with few examples of standalone small-scale PUE applications in the region. Solar water pumps are one of the most commercially viable PUE appliance currently on the market, but GOGLA reported that only approximately 5,000 small-scale solar water pumps (less than 3kW) had been sold in all of East Africa during the first half of 2019, with 395 of those pumps sold in Uganda.[3] Though this only represents a portion of the overall water pump market, it is evident that there is still substantial room for growth in PUE.

To better understand the challenges of and opportunities for scaling PUE technology, the Uganda Off-Grid Energy Market Accelerator (UOMA) has looked back across its body of work. Productive use has been a key focal point for UOMA since founding. The team has provided targeted pilot support to companies to identify scalable business models, and commissioned research to better understand high-impact value chain opportunities. This work covers a broad cross section of companies representing several value chains and a wide geographical cross-section of the country.

We found that there are several key challenges that cut across technologies:

- **End users, particularly smallholder farmers of staple crops, have low affordability and willingness to pay.** Despite recent increases in efficiency and declines in component costs, many customers still cannot afford the high upfront costs for these systems. Consumer financing is difficult to obtain, and PAYG companies have struggled with repayment rates.
- **Companies are still tailoring products for consumer demand, and other products require heavy customization that prevents scalability.** Solar refrigeration is unpopular for rural households as it is often seen as a luxury good, while cultural preferences lean towards fresh food. Solar mills are currently unable to produce the right type of end product or process

[1] Lighting Global, GOGLA, Open Capital Advisors, and Vivid Economics, *Off-Grid Solar Market Trends Report 2020*, https://www.lightingglobal.org/wp-content/uploads/2020/03/VIVID%20OCA_2020_Off_Grid_Solar_Market_Trends_Report_Full_High.pdf

[2] GiZ, Productive Use of Energy Services – An experience form GiZ, 2013, https://www.unescap.org/sites/default/files/Session_10_Pooja_Sharma_0.pdf;

[3] UOMA productive use of energy pilots; GOGLA, *Off-Grid Solar Market Report H1 2019*, https://www.gogla.org/sites/default/files/resource_docs/global_off-grid_solar_market_report_h1_2019.pdf [pg. 76 and 77]

sufficient volumes. With solar irrigation, kits often require customization to meet the needs of the end users' farm.

- **There is limited access to finance for PUE companies.** Many businesses are in the pilot and early development stages with a lack of demonstrated success in generating revenues, cashflows, and customers, resulting in businesses being perceived as high risk to financial institutions. Local debt to PUE companies has been limited to date, and even impact investors who would typically be able to deploy patient equity still see too much technology risk and too little traction to make a bet on most PUE companies.
- **Limited consumer awareness means that customers don't yet fully appreciate the potential benefits of PUE technology.** Customers are often dissuaded from purchasing PUE technology due to the large investment costs of a system, until they are aware of the benefits either from demo sites or by word of mouth from other farmers utilizing the technology.
- **Market spoilage due to low quality products on the market has discouraged consumers from purchasing quality systems.** The solar water pump and refrigeration unit markets are flooded with poor quality systems which persuade customers based on price, however such systems break quickly which creates a negative impression for potential customers.

We believe that PUE, despite current challenges, has potential to scale. So far, solar irrigation is the most developed use case, with a strong economic case for farmers cultivating high value crops and with access to quality water sources. Refrigeration and milk cooling solutions are still relatively expensive, though companies are selling products commercially, albeit at low volumes. Agro-processing units such as solar mills are still in the pilot stage requiring increased efficiency and reduced costs to justify use cases and compete with alternative milling options. Each of these technologies requires a unique approach, given the variation in stage of commercial development.

A coordinated effort among stakeholders can help to unlock the potential impact of PUE. Recommendations to accelerate PUE in Uganda include:

- **Private companies can accelerate PUE by continuing to develop scalable business models and relevant technologies.** Companies are constantly modifying their business model to target more customers, whether by broadening their range of services across the agri-energy spectrum or creating new partnerships to reach last-mile customers. Given the significant affordability barrier, companies can incorporate seasonality into consumer finance models to incentivize uptake for farmers and continue to translate the increased wealth of consumer insights to design and manufacture more efficient products that are relevant to smallholder farmers' needs.
- **Donors and investors can promote PUE by providing the right forms of finance to scale early stage business models.** Grants tied to measurable objectives can de-risk the sector and pave the way for commercial investors, and grants for R&D can ensure that technology continues to develop to the point where appliances can be scaled. PUE companies also require patient equity to build their internal capabilities so they can grow their business through this phase of the sector's development.
- **Development partners and government are critical to developing the right enabling environment so that PUE companies can flourish.** Consumer awareness is a major barrier to growth. Demo sites and consumer education on the benefits and appropriate use of PUE products can increase willingness to pay for quality products. Demand mapping can better help companies with limited resources to understand potential demand across regions in Uganda. Government can support PUE companies with the development of quality standards to promote the adoption of quality products and streamlined tax policy and enforcement to lower the cost of

PUE systems which can boost affordability. Finally, they can also catalyze demand by including off-grid applications into national development plans.

We believe the recommendations outlined in this paper can help in scaling up the PUE space. The content in the paper is specifically focused on Uganda, but the key recommendations can also be applied across the off-grid solar PUE sector.

INTRODUCTION

Off-grid solar has proven to be a viable path to clean and modern energy access in Uganda, with the market penetration of off-grid products in the country reaching 40% of the potential market in 2019.[4] With almost 4 million products currently in use in the country—consisting of solar lanterns, multi-light systems, and solar home systems—Uganda has emerged as one of the leading countries in this sector in terms of market penetration and volumes sold. The market has attracted one of the highest concentrations of companies that provide quality lighting products, in addition to a plethora of unbranded products that often provide lower cost solutions to the market. Despite progress, there is still significant room for growth: the 2030 potential market based on electrification needs alone is estimated to be 7.1 million households, requiring additional products and innovative business models to reach unserved populations with affordability constraints.

Beyond providing access to energy, off-grid solar solutions coupled with household appliances can unlock income generation for entrepreneurs. They use of off-grid products comprises mainly consumptive energy use through lighting, TVs, fans, and radios for private use. Recent research, however, now shows that more and more households are using lighting products and household appliances to start new businesses or boost existing ones. A social and economic impact study of off-grid solar in East Africa showed that 28% of sampled households with solar home systems (SHS) generated additional income of approximately US $46 per month, on average, through use of the product in businesses such as TV halls, phone charging, etc., or simply because lighting allowed them to engage in business activities for longer each day.[5]

Dedicated productive use of energy (PUE) solutions are also emerging as a promising segment in the off-grid solar sector, with the potential to boost income levels and improve energy access. PUE is any agricultural, commercial or industrial activity involving energy services as a direct input to the production of goods, or provision of services, to increase income or productivity.[6] These solutions present a way for rural off-grid households in Uganda to boost their low-income levels and low energy consumption rates, increasing energy demand and ability to afford connections or off-grid solar home systems (SHS).

PUE technologies have existed for decades, but smaller scale applications (under 1kW) powered by off-grid solar systems have emerged to meet the significant potential energy demand in Sub-Saharan Africa. Larger, kilowatt-scale systems mainly targeting large scale applications such as water pumps with capacities of 4kW+ have dominated the PUE segment to date. However, the off-grid sector is now increasingly looking at smaller scale PUE appliances such as solar water pumps, solar refrigerators, solar mills etc., with capacities of less than 1kW that are being enabled by standalone solar solutions in the off-grid space. These appliances are enhancing incomes for households and enterprises, mechanizing activities that were previously performed manually or with less efficient equipment.[7]

The Uganda Off-Grid Energy Market Accelerator (UOMA) was set up in 2017 as a dedicated and neutral intermediary to reduce market barriers to energy access, and PUE has been a major priority area since then. UOMA was borne out of a partnership between the Shell Foundation, DFID and USAID / Power Africa under their Scaling Off-Grid Energy: Grand Challenge for Development (SOGE) partnership. The

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[4] Lighting Global, GOGLA, Open Capital Advisors, and Vivid Economics, *Off-Grid Solar Market Trends Report 2020*, https://www.lightingglobal.org/wp-content/uploads/2020/03/VIVID%20OCA_2020_Off_Grid_Solar_Market_Trends_Report_Full_High.pdf

[5] GOGLA, *Powering Opportunity in East Africa*, https://www.gogla.org/sites/default/files/resource_docs/powering_opportunity_in_east_africa.pdf

[6] GiZ, Productive Use of Energy Services – An experience form GiZ, 2013, https://www.unescap.org/sites/default/files/Session_10_Pooja_Sharma_0.pdf;

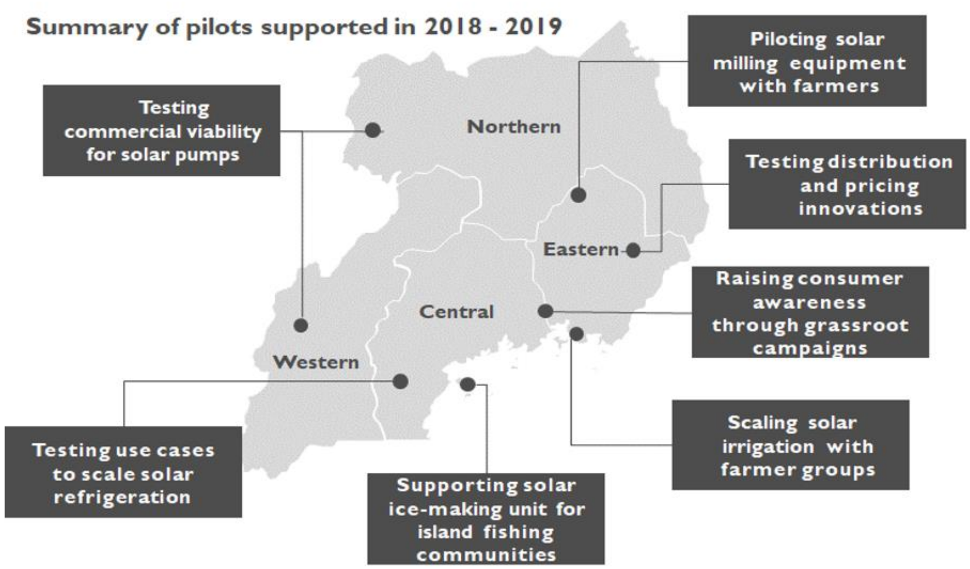
[7] UOMA, *Promoting Productive Use of Energy*, 2017, https://shellfoundation.org/app/uploads/2018/10/SF-OCA-Uganda-Accelerator-_-Productive-Use-Technology.pdf; GiZ, Productive Use of Energy Services – An experience form GiZ, 2013, https://www.unescap.org/sites/default/files/Session_10_Pooja_Sharma_0.pdf

organization is managed by a team of technical experts with experience across many areas of off-grid energy, finance, business, policy & regulation, and development economics. One of the core initiatives since UOMA was started has been to test and validate business models for productive use technologies that can achieve economic benefits for off-grid Ugandans while growing energy demand. Through this initiative, UOMA has undertaken the following activities:

- Supported companies to refine their growth strategy and operationalize pilots that introduce innovative products and business models to the market
- Published research including a demand mapping for productive use and an assessment of potential opportunities in the dairy value chain[8]
- Facilitated introductions between companies and relevant investors
- Held matchmaking events to convene stakeholders across productive use value chains, particularly in solar irrigation

The pilots with productive use companies provided insights of the realities on the ground, including the opportunities and challenges that companies face. The pilots cut across different value chains and use cases focusing mainly on applications in agriculture, including horticulture, dairy, and fishing where use cases have gained the most traction; however, UOMA has also supported companies in expanding off-grid lighting solutions and household appliances, which also support income generation through, for example, phone charging, hair salons, video halls, and restaurants. This work covers a cross section of business types, from locally based early stage companies to established international distributors, and a wide geographical reach across Uganda.

Figure 1: Locations of pilots supported by UOMA in 2018 - 2019



[8] UOMA, *Market Map of Off-grid Energy in Uganda*, Productive Use Section, https://uoma.ug/wp-content/uploads/2019/07/UOMA-Market-Map_PUEVersion-1.pdf

Table 1: Description of UOMA productive use pilots

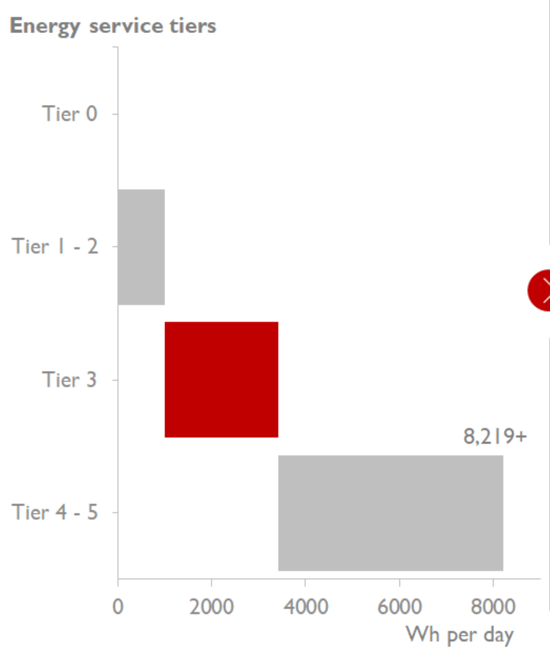
Pilot #	Use case	Description of pilot support
1	Irrigation	• Assessment of consumer demand for large-scale submersible and surface water pumps, and assessment of highest potential distribution channels, target regions and customer types. • Developed pricing tool to help assess the final cost to the consumer • Provided strategy recommendations for company's pilot project
2	Irrigation	• Developed strategy to scale business based on company's pilot results, in addition to customer consultations and focus groups
3	Milling	• Segmented potential customers for solar milling machine in Eastern Uganda through end user focus groups • Provided strategy recommendations for pilot program • Developed unit economics calculator to compare the economics of solar-powered milling to fossil fuel-powered alternatives
4	Milling	• Conducted market research to inform initial site selection for new solar-powered business hub in refugee settlements that incorporated milling • Provided direct implementation support to convene key stakeholders in the refugee settlement to mobilize the project
5	Ice making, fish drying, water purification	• Provided investment readiness support to mini-grid developer • Updated financial model, prepared investor memorandum, and developed list of potential investors
6	Refrigeration	• Research macroeconomic and customer demographic and usage trends in Uganda to better understand impact on sales and inform future strategy
7	Ice making	• Assessed business model using ice making as the anchor load for solar-powered mini-grid • Developed financial model and investor memorandum for revolving fund designed to finance mini-grid connections
8	Irrigation	• Developed flexible payment product to be piloted over 12 months, aimed at alleviating constraints from seasonal income.

The objective of this paper is to share learnings from UOMA's work in PUE for standalone solar. Findings from the pilots have been aggregated to maintain company confidentiality. We hope this will be useful for development partners who are looking to further catalyze the sector, for investors who are looking for opportunities in Uganda, and for existing companies as well as new entrants to the Uganda productive use landscape.

UOMA Productive Use Focus Areas

PUE applications exist across energy tiers ranging from low- to high-powered equipment. Impact data shows that solar home systems allow for productive use applications such as lighting, phone charging, and small productive use appliances that are classified as Tier 1 – Tier 2 based on energy consumption.[9] Tier 1 to Tier 2 products, by definition, require low energy and thus provide low organic consumer energy demand growth (Table 1).[10] Tier 3 productive use applications, typically used by SMEs, have a higher energy demand, and they have the potential to generate significant energy demand due to the appliances' energy requirement and the additional income generated from utilization. Tier 4 – Tier 5 applications require large power draws typically enabled by large solar PV installations for commercial and industrial uses or mini-grids. They are focused in major cities with a few use cases among rural off-grid Ugandans.

Figure 2: Productive use applications and technologies across various energy tiers



Productive use applications	Productive use technologies
Not applicable	
• Lighting, phone charging and powering appliances in local shops	• Lights, TVs, phone charging • Hair clippers/ salon driers
• Irrigation, agro-processing, cold chains solutions and refrigeration in crop farming, dairy and fishing value chains; • Refrigeration in retail shops	• Solar water pumps • Solar mills • Solar oil press/ pulpers • Solar refrigeration/ cold storage units
• Powering off-grid telecom towers, industrial plants and large business units	• Tailored solar PV systems • Mini-grids

Source: Tier definition based off of SEforALL and World Bank ESMAP, Beyond Connections: Energy Access Redefined, 2015

UOMA pilots largely focused on applications in the agriculture sector within Tier 3 energy use cases given the potential for impact across a wide range of value chains. This emphasis is also significant for Uganda, where agriculture employs 70% of the workforce.[11]

Tier 3 applications in this sector present a higher impact potential on energy demand stimulation and income compared to Tier 1 lighting applications as the technologies consume more energy and are more

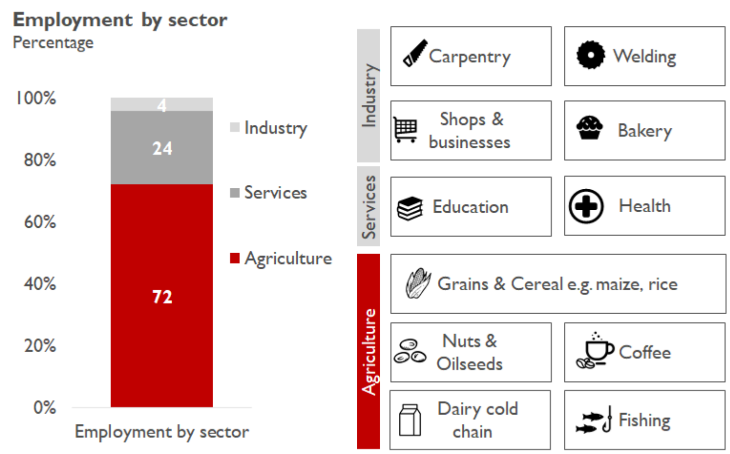
[9] Tier definition based off of SEforALL and World Bank ESMAP, *Beyond Connections: Energy Access Redefined*, 2015, https://www.worldbank.org/content/dam/Worldbank/Topics/Energy%20and%20Extract/Beyond_Connections_Energy_Access_Redefined_Exec_ESMAP_2015.pdf [page 6]

[10] Tier definition based of off SEforALL and World Bank ESMAP, *Beyond Connections: Energy Access Redefined*, 2015; UOMA, *Promoting Productive Use of Energy,* 2017, https://shellfoundation.org/app/uploads/2018/10/SF-OCA-Uganda-Accelerator-_-Productive-Use-Technology.pdf

[11] Uganda Bureau of Statistics, Statistical Abstract, 2018, https://www.ubos.org/wp-content/uploads/publications/01_2019STATISTICAL_ABSTRACT_2019.pdf

business-oriented given they can be widely used to generate income.[12] It is estimated that productive use equipment in agriculture could potentially increase household incomes by 30%.[13] UOMA pilots focused on how to better scale these productive use solutions to achieve this potential impact.

Figure 3: Share of productive use applications by sector



Source: Uganda Bureau of Statistics, Statistical Abstract, 2018

The learnings in this paper largely focus on standalone solar for three main use cases within agriculture: solar irrigation, solar refrigeration, and solar agro-processing. In late 2017, UOMA conducted a demand mapping for productive technologies.[14] Technologies for these use cases, if properly supported, have the potential to impact the majority of off-grid Ugandan farmers practicing agriculture, dairy, and fishing. Companies working with these use cases have the most traction in the market and are therefore good candidates for support in scaling their business, compared to those in very early-stage product testing. Though not a core focus, this paper also highlights a few examples of productive use powered by mini-grids, where learnings are applicable, from other countries, since the mini-grid sector in Uganda is very nascent.

[12] UOMA, Market Map of Off-grid Energy in Uganda, Productive Use Section

[13] UOMA, Promoting Productive Use of Energy in Uganda, National Survey and Segmentation of Smallholder Households in Uganda

[14] Open Capital Advisors, Promoting Productive Uses of Energy in Uganda: Status and Potential for Growth, 2017, https://uoma.ug/wp-content/uploads/2016/02/Promoting-Productive-Use-Technology.pdf

Productive Use Landscape in Uganda

The productive use space in Uganda is still very nascent, as in other countries, particularly for smaller scale applications in agriculture. Beyond the frequent usage of Tier 1 – 2 appliances such as solar lights and solar home systems to run retail shops, charge phones, and power other low energy appliances such as TVs for entertainment halls, few examples exist across the region and even fewer cases in Uganda. [15] The bulk of medium powered (Tier 3) appliances have high-impact potential but have limited traction in the market. High powered productive use technologies (Tier 4 – 5) such as off-grid telecom towers are commercially viable and have existed for a while but have very few use cases in rural off-grid areas.

In Uganda, the few small-scale use cases in agriculture that are gaining traction are solar water pumps for irrigation, solar refrigeration and cold storage, and solar milling. Companies in this space have leveraged declining technology costs and business model innovations to reach last-mile customers. They have also received support including grants for innovating, product testing, and market penetration to help expand their businesses, such as those provided by USAID's Powering Agriculture Grand Challenge program. Solar irrigation has seen the most traction, with a strong economic case for medium to large scale farmers and even small-scale farmers growing high value crops. Refrigeration and milk cooling solutions, particularly small-scale units being piloted for individual households and smallholder farmers, are still expensive and require modifications to fit various customer segments. Agro-processing units such as solar mills are still in the infancy stage with initial pilots suggesting they require increased system efficiency to reduce component costs, and modifications to produce an end product that meets consumer demand in Uganda.[16]

Figure 4: Productive use appliance value chain

Source: UOMA analysis

The business models for standalone solar productive use appliances vary, with stakeholders involved in one or more stages of the value chain from manufacturing to after sales services. Some companies specialize in the design and manufacture of products; some focus on distribution, system integration, and after sales support, while some provide services across the entire value chain. There aren't any vertically integrated players across the entire value chain in Uganda but there are some in the neighboring country, Kenya, that also distribute to Uganda, such as SunCulture and Azuri. Many product design companies are still testing the products for markets like Uganda, and this testing explains continued need for grant funding. Several operators provide consumer financing through PAYG models, or micro-finance institutions (MFIs) such as FINCA that are designing products to target microenterprises as well as farmers. Aside from MFIs, a few asset financing companies such as Cycle Connect and EnerGrow are emerging to provide smallholder farmers with consumer financing only, though they are still proving their model for productive use.

Table 2: Landscape of productive use companies in Uganda (List not exhaustive)

[15] Shell Foundation, UOMA, Promoting Productive Use of Energy

[16] Lighting Global, The Marketing Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa, https://www.lightingglobal.org/wp-content/uploads/2019/09/PULSE-Report.pdf

	Productive use landscape in Uganda		
Value chains	Solar irrigation pumps	Refrigeration + cold storage	Agro-processing (solar milling)
Hardware manufacturers	GRUNDFOS, LORENTZ, NASTEC, Soleil Power, Futurepump	UltraTec, SunDanzer, youmma, embraco	AGSOL
Distribution & system integrator specialists	DAVIS & SHIRTLIFF, Simusolar, Aptech Africa, solar now, W. WATER WORKS, Adritex, NSI.WATER	Aptech Africa, solar now	POWER TRUST
Consumer/asset financing specialists	FINCA	CYCLE CONNECT, EnerGrow	
End to end integrators	sunculture, azuri	M-KOPA SOLAR, SUNami	

Source: UOMA analysis

Several different players have emerged to deliver productive use appliances for standalone solar applications, resulting in a diverse set of actors in the market. The predominant players are established global manufacturing companies that work with local distributors. However, new market entrants and solar home system companies diversifying into the space are providing new products tailored to smallholder farmers and microenterprises. These actors are detailed as follows:

- **Established global companies:** These companies are mainly manufacturing companies such as Lorentz and Grundfos. Though these manufacturers have produced solar-powered water pumps for many years, they are now also producing smaller scale appliances to target the large potential off-grid market. These manufacturers, based outside Uganda, are partnering with local distributors to supply products to the Ugandan market.
- **Established distribution companies**: Established distributor companies such as Aptech Africa, Davis & Shirtliff, and Adtritex are distributing small-scale appliances from global manufacturers. Some of these companies also integrate the systems with other use cases, for example offering solar water pumps with other components such as irrigation kits, tailored to the needs of the end user.
- **SHS operators**: PAYG SHS operators such as M-Kopa and Azuri are diversifying their product range to include productive use appliances such as solar refrigeration units and solar water pumps. Income-generating potential of these appliances could imply better repayment rates on the PAYG models since consumers are incentivized to continue paying installments in order to keep generating income.

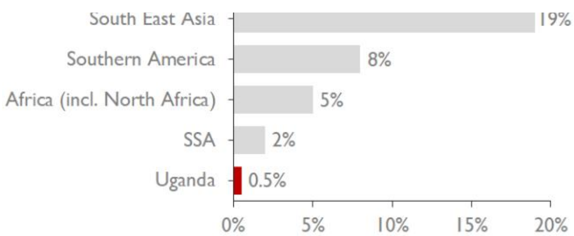
- **Specialized productive use companies**: Specialized companies have emerged to focus entirely on small-scale productive use technologies. Companies such as Futurepump (distributing through SolarNow in Uganda), and other key players such as SunCulture in Kenya have developed solar water pumps targeting the needs of smallholder farmers.

Lessons Learned in Productive Use

Solar Irrigation

INTRODUCTION

Figure 5: Irrigated land as a % of cultivated land



Source: FAO, The State of the World's Land and Water Resources for Food and Agriculture

Like many other countries in Sub-Saharan Africa (SSA), Uganda is yet to exploit its irrigation potential due to high set up costs and limited energy access.[17] The ratio of cultivated area under irrigation to the country's irrigation potential is very low, at 0.5%, whereas its fresh water sources such as lakes and rivers cover 15% of the total area. Only 1% of these sources are used for irrigation.[18] Increased instances of erratic weather patterns including drought, heavy rainfall, and shifts in seasons reduce productivity, are now prompting the government and private sector to shift focus to initiatives that can provide sustainable and affordable irrigation for off-grid rural smallholder farmers, who make up 80% of farmers in Uganda.[19] With decreasing capital costs, solar water pumps are beginning to provide a clean, cost-effective, and sustainable technology for off-grid farmers to reduce reliance on rain-fed agriculture and diesel alternatives. For solar irrigation, solar water pumps need to be coupled with additional components such as irrigation systems, solar panels, inverters, controllers, and at times storage tanks and batteries.[20]

Small-scale solar water pumps are presenting a solution to meet the irrigation needs of smallholder farmers, however sustainable use cases vary depending on type of agriculture, size of operation, availability of water, and depth of water table, as well as type of irrigation system. These factors influence the level of upfront investment that farmers need to make to equip their farms with solar irrigation. Small-scale solar water pumping systems are relatively more affordable for smallholder farmers that grow higher value crops and/or have larger farm plots but are still expensive for the majority of smallholder farmers, especially those growing staples, or farming on less than one hectare of land. Additionally, solar water pumps are dependent on available water infrastructure such as boreholes, wells, rivers, and lakes. In the absence of readily available surface water, farmers need to set up boreholes and wells depending on the level of the water table which drives up the irrigation costs making use cases typically only viable to medium to large scale commercial farmers or higher-income households. The irrigation system also adds costs, for example, properly setting up drip irrigation can reach up to approximately $1,500 per acre. Sprinkler irrigation is slightly cheaper but costs up to $500 assuming a farmer is using five quality sprinklers per acre of land.[21] These all-in costs can be prohibitively expensive for smallholder farmers.

Pilots did show that solar water pumps for irrigation provide a strong business case for horticultural crop farmers. Horticultural crops such as tomatoes, kale, cabbage, beans and onions. have shorter-term growing cycles that utilize the high temperature of dry seasons, allowing farmers to have three harvest

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[17] FAO, *The State of the World's Land and Water Resources for Food and Agriculture*, http://www.fao.org/3/i1688e/i1688e03.pdf [page 44]; International Food Research Policy Research Institute, "Irrigating Africa", July 21, 2010, http://www.ifpri.org/blog/irrigating-africa

[18] Uganda National Irrigation Policy, https://www.mwe.go.ug/sites/default/files/library/Uganda%20National%20Irrigation%20Policy.pdf [pg 4]

[19] Uganda Bureau of Statistics, Statistical Abstract, 2018, https://www.ubos.org/wp-content/uploads/publications/01_2019STATISTICAL_ABSTRACT_2019.pdf

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

[21] Analysis done during UOMA productive use pilots

cycles in a year when using irrigation. Furthermore, regular, consistent watering with an irrigation system can improve yields, and allows farmers to capitalize on higher market prices that occur during dry seasons.[22] As a result, operators to date have mainly sold to medium to large scale farmers or to smallholder farmers that grow high value horticultural crops as opposed to smallholder farmers that grow staple crops such as maize.

OPERATORS AND BUSINESS MODELS

A commercial market for solar water pumps has existed for years in Uganda, specifically for medium to large scale pumps, and smaller pumps for smallholder farmers are increasingly viable. Pumps in the kilowatt scale have been sold to government, NGOs or donors implementing projects to pump water, often for domestic water consumption. Global manufacturers and innovative startups are now opening up the market to serve smallholder farmers. Global manufacturers have developed solutions for smallholder farmers, and companies such as Futurepump and SunCulture are now increasingly providing solutions that match the energy demand of smallholder farmers (less than 1 kW) and are easy to install and operate. These solutions are also providing SHS operators such as Azuri and SolarNow an opportunity to diversify their product range to higher margin productive use appliances.

All the operators in Uganda have established distribution networks for targeting consumers. Some operators import systems from China and India, brand them, and focus efforts on distribution and after sales services. Aptech Africa, for example, has established distribution partnerships with cooperatives and local farmer groups, while also selling B2B to other distributors in Uganda who purchase a large number of systems to on-sell to consumers. Davis & Shirtliff has a large network of retail stores distributed around the country, and new market entrants such as Simusolar are also evaluating distribution partnerships with existing businesses.

As part of the distribution model, some operators of small-scale solar water pumps provide consumer financing to increase affordability. PAYG reduces the upfront payments as payment is spread over time. The PAYG technology is integrated into the systems with a run-stop function based on whether or not payment has been made.[23] An issue with the traditional PAYG model, however, is that payments are required regularly whereas farmers' incomes are received seasonally, creating a mismatch between when payments are required and when farmers have income to spare. Several companies, as a result, are experimenting with flexible payment plans that spread clients' payments over a year or two years, into seasonal or monthly payments that better match farmers' income and expenditure patterns.

Private operators are also combining sales with technical training and farm design to ensure proper utilization of solar water pumps for irrigation. Use of the equipment is improved when a farmer receives technical as well as business training on how to manage their system. However, agronomical expertise is in very low supply which requires companies to invest heavily in hiring or upskilling their human capital, particularly if a company is diversifying from the solar sector into the productive use space.

CHALLENGES IN SCALING SOLAR WATER PUMPS

UOMA pilots revealed that small-scale solar water pumps for irrigation were highly beneficial to farmers, though traction remains low. Solar-powered irrigation can provide farmers with higher yields, an additional growing season, and reduced reliance on rainfall. However, the sector has had low sales volumes to date. GOGLA reported that approximately 5,000 small-scale solar water pumps (less than 3kW) had been sold

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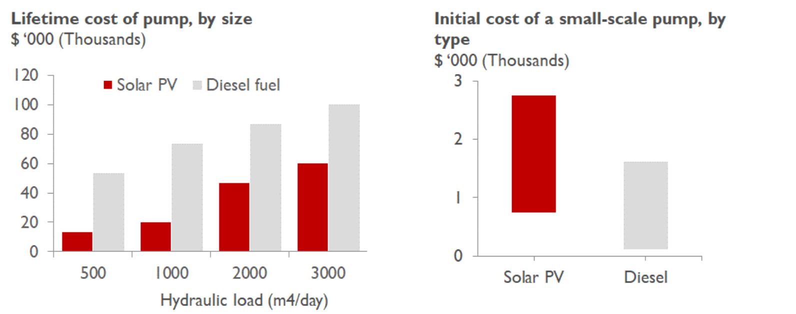
[22] UOMA productive use pilots; Efficiency for Access, 60 Decibels, Use and Benefits of Solar Water Pumps, Kenya, Tanzania and Uganda Consumer Research, https://efficiencyforaccess.org/publications/use-and-benefits-of-solar-water-pumps

[23] UOMA productive use of energy pilots

in all of East Africa during the first half of 2019 with only 395 attributed to Uganda in that period.[24] The main challenges affecting scale-up have been limited access to water infrastructure, limited access to finance, low ability and willingness to pay for the systems, limited consumer awareness especially in the remote locations, and limited technical expertise. This section discusses these challenges in scaling solar water pumping in Uganda in more detail.

Figure 6: Comparison of solar- and diesel-powered water pump life cycle and initial costs



Notes:

- Formula for hydraulic load: daily water (m3/day) * head (m)
- Lifetime costs based on an existing analysis done in Namibia in 2006 [1 USD = NAD 7.49 (2006 FX rate)] over a 20-year period; pump heads of 10m to 200m, daily flow rate ranging from 3m^3/day to 50m^3/day
- The initial costs are based on current prices for small-scale pumps with hydraulic loads of less than 500m4/day; pump heads of 15 – 60m; with daily flow rate of approximately 1m^3/day to 28 m^3/day

Source: 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

Solar irrigation is dependent entirely on the availability of quality water sources and water infrastructure, and a lack of access significantly decreases the potential market. In the absence of water sources such as lakes, rivers, existing boreholes or wells, or very shallow water, smallholder farmers really struggle, suffer from drought, or walk miles to the nearest borehole in the next community as they often do not have the dedicated resources needed for drilling wells or boreholes. Given the significant upfront investment needed, we found boreholes and wells are usually dug by the government or an NGO / grant provider and is not a service typically offered by solar irrigation providers. Many farmers invest in water storage for the home, and companies note that in very dry areas significant portions of land are not productive due to lack of water. Despite the benefits of solar irrigation, digging boreholes dramatically drives up the upfront costs of setting up a solar irrigation system – we heard this was often minimum of ~USD 100+ per meter, often going a couple hundred meters deep - reducing upfront affordability for many and increasing the questions around the business case for investing for a smallholder, rural farmer who has minimal savings and limited access to financing. Notably, where significant water tables and water pumping yield exists, and given the lifetime of a solar water pump (~7 years typically), we heard that the "cost per liter" of water becomes increasingly negligible, making the drilling cost more a question of availing upfront financing and less about future price implications. The pilots supported did not go into specifics on this so more dedicated research into this insight is required to validate the initial findings and better understand the granularities.

Additionally, smallholder farmers need training on sustainable land and water management to implement "zero operating cost methods" such as solar irrigation. Sustainable land and water management measures include soil and water conservation measures such as digging trenches and harvesting water in pits. We also found that more technical data is needed about water levels in different regions of Uganda since most providers we spoke with were unsure about how to best determine the relevance and applicability of products (like surface pumps or submersible pumps) and addons like storage tanks.

[24] UOMA productive use of energy pilots; GOGLA, *Off-Grid Solar Market Report H1 2019*, https://www.gogla.org/sites/default/files/resource_docs/global_off-grid_solar_market_report_h1_2019.pdf [pg. 76 and 77]

Even with access to water, affordability is still a major issue for a large portion of the potential market. When considering full lifetime costs of an irrigation system, solar water pumps present a cheaper option to diesel pumps. Lifetime costs for solar pumps are approximately 22 – 56% the lifetime costs for diesel pumps since solar water pumps require little maintenance and they have no fuel costs.[25] Initial costs of solar irrigation, however, can reach up to approximately $1,000 - 3,000 depending on available infrastructure, for example the type of land, water source, and the irrigation system. Diesel-powered pumps, on the other hand, cost from $120 – 1,000 upfront.[26] Comparatively, the upfront costs for solar irrigation are very high for smallholder farmers, unless they grow higher value horticultural crops.

Consumer finance that could potentially address the affordability gap is becoming more available in Uganda, however farmers do not have a positive attitude towards lending from banks and formal institutions. Even with guarantees, financial institutions have not been able to draw down on available loan facilities by selling productive use systems to rural farmers. Banks have struggled to lend to farmers due to their seasonal cashflows and varying crop cycles, and because they find it hard to use the solar irrigation system as collateral for asset financing since it is not easily recoverable, and it cannot be easily repurposed. Additionally, some smallholder farmers are in hard-to-reach areas with lower access to financial services and lower financial literacy. Even agency banking is often located in towns, not deep in rural areas. Some financial institutions have tried to penetrate more rural areas, for example BRAC and FINCA, and they have invested significantly in financial literacy training and partnerships with farmer groups. Where there is supply, farmers are reluctant because they feel like they may not understand all the financial terms, or they prefer to save informally. Smallholder farmers also prefer taking capital from grassroots structures such as cooperatives and SACCOs, given banks' strict collateral requirements and the ability of cooperatives to negotiate better rates for their members. Specialized finance providers are trying to close this gap with financing targeted directly for PUE appliances.

Companies have also encountered issues in using the PAYG financing model for smallholder farmers. PAYG business models are complex, and implementation requires an active on-the-ground sales agent to follow up with consumers for repayments, and robust credit assessment processes which are difficult to implement as farmers have little to no financial histories. Additionally, with solar water pumps the down payment can range from 14-33%, depending on the system size, or $100 on the lowest end, which makes it harder for smallholder farmers to afford. Based on results from UOMA pilots, willingness to make timely repayments varied across customer segments, with smallholder farmers showing the lowest performance. Companies provide leeway in switching off the pumps when repayments are not made, but they have occasionally had to turn off pumps or repossess systems, which presents a reputational risk to the company locally. As a result, some companies who were initially targeting smallholder farmers have shifted to focus on businesses and institutions since these customers make repayments more consistently, and, in a few instances, have opted to fully purchase systems upfront. For smallholder farmers, other household needs such as school fees, health, and funeral costs outrank the value add of the solar water pump. In addition, seasonality of income results in a mismatch between when payments are required and when customers have disposable income. There is room to further research the causes behind low repayment rates and factor that information into PAYG models.

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[25] 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 ; Emcon Consulting Group, sponsored by UNDP, Namibia Ministry of Mines and Energy, Global Environment Facility, *Feasibility Assessment for the Replacement of Diesel Water Pumps with Solar Water Pumps*, http://pubdocs.worldbank.org/en/511871475091277205/1-Replacement-diesel-GEF-UNDP-Namibia-2006.pdf

[26] 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 ; Emcon Consulting Group, sponsored by UNDP, Namibia Ministry of Mines and Energy, Global Environment Facility, *Feasibility Assessment for the Replacement of Diesel Water Pumps with Solar Water Pumps*, http://pubdocs.worldbank.org/en/511871475091277205/1-Replacement-diesel-GEF-UNDP-Namibia-2006.pdf

One potential driver for the limited uptake and low willingness to pay is limited consumer awareness on the benefits of solar irrigation. Despite significant initial interest in solar irrigation, few farmers have been willing to pay for it. Consumers with limited capital to invest in solar water pumps were more likely to make purchases once they saw the returns from demo sites. The cost to set up sites, however, is borne by companies which limits the number of demo sites that can be created and subsequently, the number of sales resulting from demo sites.

Finally, a lack of technical experience within companies also impacts scale-up of solar irrigation in Uganda. Currently, sales agents don't always have agriculture or agronomy experience, which makes it difficult to provide targeted support to consumers. Additionally, there has at times been limited knowledge transfer among trained agents and the farmers. Some leave their position without imparting the right training to farmers which limits the ability to optimize use of the system.[27]

[27] UOMA productive use pilots

Solar Refrigeration

INTRODUCTION

Solar refrigeration is an even more nascent subsector than solar water pumping with a wide variety of use cases in different stages of development. Uses range from household refrigeration, to small businesses such as small shops and retail, and refrigeration for agriculture. Within agriculture specifically, productive use refrigeration solutions currently provide potential for dairy and fisheries. For small businesses, one emerging opportunity is refrigeration for beverages in retail shops and restaurants.

Solar refrigeration unit sales reported by GOGLA for the whole of East Africa in the first half of 2019 stood at approximately 1,159 units with 291 units attributed to Uganda.[28] This was a 300% increase in the number of refrigeration units sold between the second half of 2018 and the first half of 2019, albeit from a very low base. Though these sales only represent refrigeration units of less than 200 liters sold by companies that report in the GOGLA data collection process, the total market sales for off-grid refrigeration products is undoubtedly low. The slow traction and use of refrigeration options limits growth in production and expansion of agribusinesses such as dairy to new areas due to spoilage.

OPERATORS AND BUSINESS MODELS

The market for refrigeration and cold storage units encompasses small-scale equipment to much larger systems. This segment includes refrigeration units both with and without freezer compartments, chilling options mainly for milk and dairy products, and ice-making equipment. Small-scale refrigeration equipment typically has capacity under 250 liters and is well suited for households, individual farmers, and local retail shops.[29] Some small fridges are sold as standalone appliances that can integrate with standalone solar systems, whereas others are connected to solar and are typically more expensive than standalone units. These different categories of equipment each present very different use cases. Large scale refrigeration and cold storage includes milk chillers, often operated by cooperatives, and ice-making plants with capacity of a few tons of ice per day. These require large amounts of power, often by diesel generation of mini-grid respectively, that cannot be efficiently generated with standalone solar.

One way that small-scale standalone solar-powered refrigeration units are reaching end users is through the distribution networks of solar home system distributors such as M-KOPA and SolarNow who are diversifying their product range. These companies design and brand their products (manufacturing may be outsourced) and then specialize on distribution, consumer financing and after sales services. To date companies have had success selling systems on PAYG to middle to high-income households and local shops and kiosks for cooling beverages and food. It is worth noting that this demand is largely from business owners rather than residential customers that have a lower willingness and ability to pay for refrigeration. The model of using sales repayment data to upsell refrigeration products to residential customers has not yet proven out in Uganda.

CHALLENGES IN SCALING SOLAR REFRIGERATION/COLD STORAGE

Similar to solar water pumping, a key challenge limiting uptake of refrigeration units is low affordability and willingness to pay. In addition, current product design can limit demand as it can differ from existing products on the market, and the relatively larger size of the units creates logistical issues for companies

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[28] GOGLA, *Off-Grid Solar Market Report H1 2019*, https://www.gogla.org/sites/default/files/resource_docs/global_off-grid_solar_market_report_h1_2019.pdf [pg. 72 and 73]; Note: Solar refrigeration units mean units with one or more fresh food compartment but no freezer compartment.

[29] UOMA productive use pilots

that are used to transporting smaller systems. This section outlines these specific challenges faced in scaling refrigeration units in Uganda.

Affordability and willingness to pay for small-scale refrigeration units is low, particularly at the household level. Off-grid households, particularly in rural areas, typically have lower incomes and thus lower ability to pay for units. Solar refrigeration units are considered a luxury item typically purchased by middle- to high-income households. Additionally, most rural households often have a bias towards fresh food and are accustomed to cooking only what will be consumed, thus, cost savings from using refrigeration to reduce spoilage are not highly justified among off-grid households. Many customers to date have been local retail businesses selling cold drinks. This customer segment has recorded better repayment rates than individual households as they are able to generate additional income from utilizing the solar refrigeration units. It may be worth investigating consumer preferences for cold beverages as this may further boost the economic case for solar refrigeration units in local retail shops.

In the retail segment, a key factor contributing to willingness to pay is seasonality. Customers have made fewer purchases of refrigeration units in the cold and rainy seasons when there is relatively low demand for cold drinks. Refrigeration unit distributors are also recording low sales at the beginning of the year as households are then focusing on school fees and other household costs.

Within the fishing customer segment, the current solar refrigeration units have limited freezing capabilities as they have no freezer compartments. Fishermen also have low willingness to pay due to other cheaper alternatives such as smoking and drying though methods are less effective. Fishermen and small enterprises are typically willing to buy a crate of ice to cool their produce, for example fish or local beverages, however the investment in an ice-making plant is typically high for an individual fisherman or businessman, and there are currently no small-scale ice-making technologies powered by standalone solar.

Box 1: Mini-grids providing fish farmers on Lake Victoria island with cheaper ice made by solar-powered ice-making plants

Localized ice-making plants powered by mini-grids are providing a cheaper alternative for fishermen on the Ssese group of islands in Lake Victoria by supplying them with readily available ice instead of expensive ice shipped from the mainland. GRS Commodities is a Ugandan mini-grid operator that has set up an ice-making plant in Bugala, the largest island, as an anchor load for its mini-grid, with plans to set up a new facility on the nearby island of Bukasa. Due to the high energy demand and capacity of ice-making plants, mini-grids provide a viable alternative to standalone solar. Mini-grids have the potential to unlock these productive use cases with high energy demand, while also providing electricity access to nearby households. Mini-grids, however, require a large capital investment and the process of acquiring licenses and permits is typically very lengthy and bureaucratic, often taking up to 18 months. Uganda's Rural Electrification Agency (REA) currently incentivizes the private sector to set up mini-grids by financing the distribution grid and connection costs and offering exemption licenses.

Product design has also proven to be an issue when introducing products into the Ugandan context. Consumers want to purchase products that are built in similar fashion to their expectations of how a refrigerator should look. These expectations are driven by market perceptions and consumer awareness on available options in the market. Some prefer the chest model (opened from the top) while others prefer the cabinet model (which opens from the side) based on available market options. For example, the chest model performs better among businesses since it has more space to fit products.

Given the size of solar refrigeration units, logistics also create a challenge for companies and agents moving the goods to consumers. Distributors must often navigate poor roads which become worse in rainy seasons. For active marketing strategies, sales agents are required to demonstrate how solar refrigeration units operate at consumer sites which necessitates moving from one area into another with the units. Operators are trying to centralize distribution to reduce the challenge presented by poor roads.

Solar Agro-processing

INTRODUCTION

Given the significant demand for milling services in Uganda, agro-processing presents a major potential opportunity if companies can provide relevant technologies and business models to the space. Maize and cassava constitute Uganda's top crops by tonnage due to high demand for milled products such as *posho* and porridge.[30] In a study conducted on a sample of smallholder farmers, 83% grew maize and 75% grew cassava.[31] Consumer demand for these end products results in high demand for affordable milling services in rural off-grid areas.

Compared to irrigation, which remains largely untapped by smallholder farmers, milling is well-established in the country with commercially viable alternatives to solar-powered solutions. Rural off-grid farmers mainly rely on diesel millers to process grain and staple crops. Smallholder farmers, however, currently face high costs due to transportation to millers at distant trading centers and limited to no access to reliable electricity which results in often expensive fuel-based milling options.[32]

Solar mills, if efficiently manufactured and distributed, can help rural farmers cut down on milling costs by reducing reliance on diesel-powered mills which depend on fuels whose prices fluctuate on the market. Specifically, standalone solar mills with capacities of less than 500kg per day could present an alternative for off-grid diesel millers providing services to off-grid households and smallholder farmers.[33] This would result in cost savings within the local communities where diesel is sometimes difficult to source. Beyond economic benefits, solar-powered milling can reduce issues of contamination of flour caused by diesel spills and air pollution.

In Uganda, solar mills are still being piloted to test commercial as well as technical viability. To better understand the current and potential landscape for solar-powered milling in Uganda, UOMA provided pilot support to evaluate the business case of milling grain and root tuber crops using stand-alone solar. The pilot provided indications of challenges with the existing technology that could hinder scale up of solar milling in Uganda, as detailed in the following section.

CHALLENGES IN SCALING SOLAR MILLING

Given current technology and business models, there is limited economic justification for an end user to purchase a solar-powered milling machine. The upfront capital expenditure to purchase a solar-powered machine—inclusive of the mill, solar panels, batteries, frames, and PAYG system—is very high. A solar mill costs roughly the same as a diesel mill, however, the solar mill's system component costs for solar panels, batteries, frames and PAYG systems cost nearly twice as much as the solar mill itself.[34] Solar mill operators do eliminate the need for fuel costs, and therefore ongoing operating expenditure, however, the capital cost is still too high and the return on investment comparatively less than on a diesel mill which limits the economic case. Our analysis found that operators could only recoup investments if the mill constantly operates at full capacity, which is unlikely due to both uneven demand for milling services and variable

30 Uganda Bureau of Statistics, *Statistical Abstract 2015*: http://www.ubos.org/publications/statistical-abstract/

31 CGAP, National Survey and Segmentation of Smallholder Households in Uganda, April, 2016

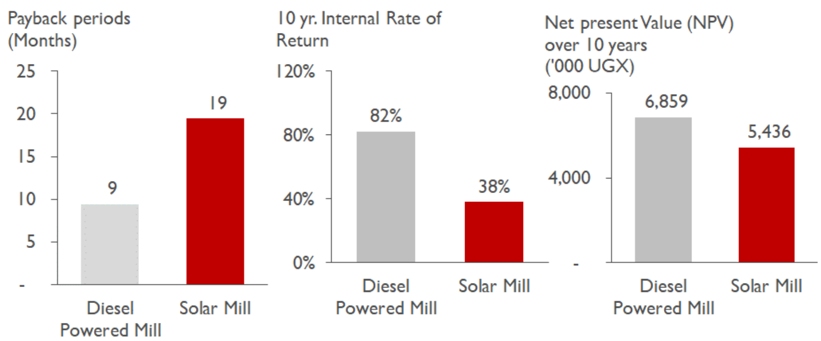
32 UOMA, *Promoting Productive Uses of Energy in Uganda*

33 UOMA, *Promoting Productive Uses of Energy in Uganda*

34 OCA analysis during UOMA productive use pilots

weather that reduces production from the solar mill. Currently, diesel mills are more competitive than solar mills given the cost of the required components for a solar mill as explained above.[35]

Figure 7: Investment return comparisons between diesel powered mill and solar mill



Notes:

- Average volumes milled: Diesel mill – 250kgs/day; Solar mill – 200ks/day
- Investment costs: Diesel mill + component costs – UGX 3.8m; Solar mill + component costs – UGX 13.5m

Source: OCA analysis

Beyond the limited economic justification, currently solar mills are perceived as technically inferior to other options on the market. For one, end users that already operate mills, perceive the output of solar-powered mills to be too low. Small-scale solar mills powered by standalone solar have a maximum capacity of 300kg per day whereas comparable diesel mills have maximum capacities of 1,000kg per day. In addition, the end product with currently available solar mills does not match that which is typically demanded by customers in Uganda. Current offerings do not have a 'huller' which removes the hull in the grain to provide very fine flour. In Uganda, consumers typically preferred very fine flour for *posho*. For the operator of such mills, therefore, demand for their flour would be much lower. Many other use case opportunities however exist in other value chains such as poultry, where the solar mills can be used to grind feed which is typically coarse in nature. Additionally, other end users such as institutions or organizations in refugee settlements where access to milling services is low may provide a potential market.

Box 2: What about mini-grids for milling?

There may be a case for high-efficiency AC-powered mills if they are being powered by a mini-grid, however mini-grid uptake in Uganda has been slow to date. With a mini-grid, solar mills may compete better with diesel mills, however mini-grids have very high set up costs. The milling component of the solar mill is priced similar to a diesel mill and given the mill operator could plug onto an already existing mini-grid, they would not have to recover the cost of electricity generation and storage. The operating costs will be lower for a solar mill powered by a mini-grid in comparison to a diesel mill.

[35] OCA analysis during UOMA productive use pilot

Summary Of Challenges in Productive Use

As with many nascent technologies, productive use presents a huge opportunity, but many companies looking to scale solutions across Uganda still face many challenges. Beyond the technology-specific challenges previously mentioned, there are several challenges that cut across all technologies that are preventing these solutions from scaling. They include affordability, product market fit, limited access to finance, awareness and technical expertise, and a general lack of quality standards in the market.

1. Low affordability and willingness to pay, particularly for smallholder farmers that grow staple crops relative to higher value crops

The bulk of the standalone solar appliances for the agricultural value chains are targeting the needs of smallholder farmers, however, this customer segment often cannot afford these products, despite recent price declines in solar panels and accessories. These products are imported, with high upfront costs due to both production and distribution. Reducing system costs could unlock large portions of the potential market. Additional costs of accessories and services such as installation and training also contribute to overall affordability. However, to further drive down costs to the end consumer, some solar water pump operators shoulder installation and training costs to create more brand awareness but in turn this significantly drives up their operating costs. Private operators are using PAYG models to increase affordability, but even with such models, repayments have been less than satisfactory due to low willingness to pay for the technology.

2. Product-market fit to meet the targeted customer segments is still under development

Some companies have found a strong value proposition for niche segments of the population, however across the board product-market fit is still under development for most productive use systems. For example, in the case of solar water pumps for irrigation, the systems are not very adaptable if the farmers do not have access to a water source such as a river or lake, or income to sink a well or borehole. This means that systems must be heavily customized to meet the required scale or type of farming practiced. In the case of solar refrigeration, the size of the units could ideally fit the needs of individual smallholders and off-grid households, however, most are not willing to invest in the product as they view it as a luxury item, or because of cultural preferences that favor the cooking and eating of fresh rather than refrigerated food. In milling, though there is a well-established market for milling services, solar mills currently are unable to produce the right type of end product or with sufficient capacity.

3. Limited access to finance for operators

Companies piloting PUE appliances have limited access to financing due to limited business traction and the high perceived risk in the sector. A lot of the businesses are in the pilot and early development stages with a lack of demonstrated success in generating revenues, cashflows and customers. Operators have typically required concessional and grant funding to be able to prove business models through running pilots and testing PAYG business models. Local debt to productive use companies has been limited to date, and even impact investors who would typically be able to deploy patient equity see too much technology risk and too little traction to make a bet on most productive use companies.

4. Limited consumer awareness

Due to a lack of familiarity with most PUE appliances, many potential customers of off-grid products do not understand their potential benefits. And given the large investment costs of these systems, this lack of familiarity dissuades many farmers from purchasing the technology until they are aware of the benefits either from demo sites or by word of mouth from other farmers utilizing the technology. Private operators have attempted to set up demo sites in various areas to promote consumer awareness, however many have had to shoulder such costs with no guaranteed return which diverts resources from other activities that can help grow their business. Building consumer awareness takes time, and this is partially a reason for lack of traction to date.

5. Market spoilage due to low quality products on the market

Many operators cited that sales are limited by sub-standard, cheaper systems that to end users are indistinguishable from higher quality systems. The solar water pump as well as refrigeration unit markets are flooded with poor quality systems which always present as cheaper, persuading farmers based on these lower costs. However, these systems break down after a short period of time which has a negative effect on the perception of these products across the market. There is an opportunity to properly define and enforce quality standards for each of the technologies whilst boosting consumer awareness of quality systems so that market spoilage does not occur.

Recommendations to Accelerate Productive Use in Uganda

Despite challenges in the productive use sector, commercially viable approaches have developed, and all players within the ecosystem have a role to play to ensure that the sector reaches its full potential. This section details the opportunities for private operators, development partners, financiers and governments to promote uptake of productive use appliances in Uganda.

1. Private operators

As the productive use sector in Uganda is still young, companies are constantly innovating new strategies and modifying products to target more customers and improve willingness and ability to pay. Private operators are broadening the range of services offered to consumers to include land assessments, design, supply, installation and after sales maintenance that can sufficiently assess farmer needs. For solar irrigation, best practice even relays information including required inputs, planting time, harvesting time, and route to market so that farmers can maximize their investment in a system. The need for this agronomy support is a key lesson to date, so that customers can increase incomes and improve system repayments.

To address the issue of seasonal income, private operators are also piloting flexible payment plans to cater to the varying repayment habits of different customer segments and match the seasonal income of smallholder farmers. To ensure that consumer finance models succeed, companies must dedicate resources to pilots. Defaults are expected during this process, so companies must generate learnings quickly during the pilot phase to ensure a successful launch post-pilot. All these measures, however, require working capital in the form of concessional funding or grant funding from donors, as many operators are not able to recoup some of these operating costs.

Private operators must translate learnings from the field into targeted R&D to develop more efficient and affordable systems that meet the needs of end users in practice. In particular for agro-processing, full-system costs for milling machines will need to decline and products will need to be tailored to better meet the market needs for milling services in Uganda. Increased machine efficiency would reduce the capacity of the solar panels and batteries required to power the system. Regarding product development, systems must also be designed in ways that result in a product that suits the cultural demands of end users, for example in incorporating a hulling component in a solar mill to produce flour demanded in the market. Equally, there remains an opportunity to improve the product-market fit for solar irrigation and refrigeration, and reduce product prices to overcome affordability barriers.

2. Development partners, financiers and government

Companies require concessional capital to support R&D, field pilots, consumer research, and strategic pivots to address many of the above-mentioned challenges. Grants tied to measurable objectives can de-risk the sector and pave the way for commercial investors. Grants such as the UNCDF and Global LEAP Results-Based Financing Program which provides a results-based financing grant to several private operators to promote PUE among smallholder farmers are necessary to reduce costs and support company expansion.

Productive use companies also require patient equity to grow their business through this phase of the sector's development. Companies, supported by grants and other high-risk capital, have the opportunity to continue identifying other potential business models for current products. They require equity to build their internal capabilities to manage growth at this stage, given the lack of consistently available debt for the sector.

One other main area of support from government and development partners is consumer awareness programs on the benefits of standalone solar PUE appliances, and customer finance options. Government could shoulder the creation of demo sites at the district level and provide consumer education on the benefits of utilizing PUE appliances in agriculture and how to efficiently operate and maintain the systems. Such programs could also educate end users on the benefits of quality systems, reducing potential market spoilage caused by uptake of poor-quality systems. Awareness programs can be coupled with financial literacy programs, to improve familiarity with consumer financing options and terms.

For successful scale up of productive use appliances, development partners can also support R&D as well as demand mapping for productive use products to improve business models in the field. Improved product design can increase product performance and reduce product costs, while demand mapping can better help companies with limited resources to understand potential demand across regions in Uganda. Developing a sound business case informed by market intelligence is a first step before investing in subsidies and guarantees that de-risk the sector and make capital readily available to suppliers.

Governments and development partners can also begin looking at quality assurance frameworks for appliances, given that markets for appliances such as solar water pumps and small-scale refrigeration units are still flooded by sub-standard products. There is an opportunity for the government to create standardized certification for quality products and to regulate the sector to avoid the sale of low-quality equipment that negatively impacts the end consumer. These regulations can be enacted alongside consumer awareness programs, mentioned above, to help consumers differentiate between low- and high-quality equipment.

Finally, targeted policies and government intervention strategies can help scale productive use appliances and improve affordability. Currently solar generation components such as solar panels receive duty waivers, however, some components and accessories such as batteries and controllers do not receive tax waivers, increasing cost to the end consumer. Streamlining tax policy in support of productive use, in conjunction with increased supply-side subsidies can help reduce costs and cater to those most in need of income-generating assets. The government of Uganda is considering productive use as a focus in the draft Energy Policy and in the third phase of the National Development Plan, and the World Bank is also including a component of its upcoming program that focuses on productive use. Such initiatives can further increase demand for PUE products, in line with government development objectives.

Conclusion

UOMA was set up in 2017 with the key aim of reducing market barriers and accelerating the push towards universal electricity access in Uganda. Since the beginning, productive use of energy has been a key initiative. Building on our initial demand mapping of productive use applications, we have been able to support businesses representing a wide variety of technologies and business models. Now, the sector is at an exciting point with a diverse set of well-established market players and commercially viable models making traction in the country.

To see the sector achieve its potential, we need to see a coordinated effort by stakeholders to overcome some key challenges in the space. Low end user affordability, suboptimal product-market fit, limited consumer awareness, little access to finance, and a lack of targeted policy for the sector stand in the way of uptake in the productive use segment.

Development partners, working with governments, can make a concerted effort to provide building blocks for the sector to expand, as was the case for the off-grid solar lighting segment. Consumer awareness programs can improve willingness to pay and reduce the use of low-quality products. Meanwhile, supportive tax policy and supply-side subsidies can make products more affordable while reducing company costs.

Investors too must support private sector companies by providing the capital needed to expand operations. Highly concessional capital is needed so that companies can continue to test products and business models, while patient equity is needed for companies to build internal capabilities.

Companies must also play their part to accelerate the segment and accelerate sales for productive use. Companies can develop strategies tailored to the realities of end consumers on the ground, efficiently using capital to test new products, business models, and consumer finance models to provide suitable and affordable income-generating solutions to the last-mile.

We believe the recommendations within this paper can unlock the potential of productive use in Uganda. These findings should be relevant for markets outside of Uganda that are also attempting to develop the productive use segment. If together we can scale productive use appliances, we can greatly increase incomes, improve livelihoods, and accelerate energy access for the millions of rural households across the country.

REFERENCES

Analysis done during UOMA productive use pilots

CGAP, National Survey and Segmentation of Smallholder Households in Uganda, April, 2016

Efficiency for Access, 60 Decibels, *Use and Benefits of Solar Water Pumps, Kenya, Tanzania and Uganda Consumer Research*, https://efficiencyforaccess.org/publications/use-and-benefits-of-solar-water-pumps

Emcon Consulting Group, sponsored by UNDP, Namibia Ministry of Mines and Energy, Global Environment Facility, *Feasibility Assessment for the Replacement of Diesel Water Pumps with Solar Water Pumps*, http://pubdocs.worldbank.org/en/511871475091277205/1-Replacement-diesel-GEF-UNDP-Namibia-2006.pdf

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

FAO, *The State of the World's Land and Water Resources for Food and Agriculture*, http://www.fao.org/3/i1688e/i1688e03.pdf

GiZ, Productive Use of Energy Services – An experience form GiZ, https://www.unescap.org/sites/default/files/Session_10_Pooja_Sharma_0.pdf;

GOGLA, *Off-Grid Solar Market Report H1 2019*, https://www.gogla.org/sites/default/files/resource_docs/global_off-grid_solar_market_report_h1_2019.pdf

GOGLA, *Powering Opportunity in East Africa*, https://www.gogla.org/sites/default/files/resource_docs/powering_opportunity_in_east_africa.pdf

International Food Research Policy Research Institute, "Irrigating Africa", July 21, 2010, http://www.ifpri.org/blog/irrigating-africa

Lighting Global, GOGLA, Open Capital Advisors, and Vivid Economics, *Off-Grid Solar Market Trends Report 2020*, [link to be added]

Lighting Global, *The Marketing Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa*, https://www.lightingglobal.org/wp-content/uploads/2019/09/PULSE-Report.pdf

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

Uganda Bureau of Statistics, *Statistical Abstract 2015*: http://www.ubos.org/publications/statistical-abstract/

Uganda Bureau of Statistics, *Statistical Abstract, 2018*, https://www.ubos.org/wp-content/uploads/publications/01_2019STATISTICAL_ABSTRACT_2019.pdf

Uganda National Irrigation Policy, https://www.mwe.go.ug/sites/default/files/library/Uganda%20National%20Irrigation%20Policy.pdf

UOMA, *Market Map of Off-grid Energy in Uganda, Productive Use Section*, https://uoma.ug/wp-content/uploads/2019/07/UOMA-Market-Map_PUEVersion-1.pdf

UOMA Productive Use Pilots

UOMA, Shell Foundation, *Promoting Productive Use of Energy*, https://shellfoundation.org/app/uploads/2018/10/SF-OCA-Uganda-Accelerator-_-Productive-Use-Technology.pdf

ANNEX I: PRODUCTIVE USE APPLICATIONS ACROSS VARIOUS ENERGY TIERS

Table 3: Productive use applications across various energy tiers

Energy tier	Daily Energy use (Wh/day)	Applications (*List not exhaustive*)	Specific productive uses	Productive appliances
Tier 0	X ≤12	Not applicable		
Tier 1 **Tier 2**	12≤ X ≤ 200 200 ≤ X ≤ 1,000	• Local retail shops	• Lighting • Phone charging • Powering appliances	• Lights, TV, phone charging • Hair clippers/ salon dryers
Tier 3	1,000 ≤ X ≤ 3,425	• Agriculture (grain & staple crops, horticulture, coffee, nuts/oil seeds) • Dairy • Fishing • Local retail shops	• Irrigation • Agro-processing, i.e. drying, milling, pulping; oil seed processing • Cold chain solutions & refrigeration	• Solar water pumps • Solar mills • Solar oil press/ pulpers • Solar refrigeration/ cold storage units
Tier 4 **Tier 5**	3,425 ≤ X ≤ 8,219 ≥ 8,219	• Telecom i.e. off-grid towers • Large business units e.g. hotels, corporate buildings • Industrial plants	• Off-grid telecom towers and industrial plants (substituting diesel run systems with solar or hybrid systems)	• Tailored solar PV systems • Mini-grids

Note: X – Energy use per day; ≤ Means less than or equal to; ≥ means greater than or equal to; Tier definition based off of SEforALL and World Bank ESMAP, Beyond Connections: Energy Access Redefined, 2015
Sources: UOMA, Shell Foundation, *Promoting Productive Use of Energy*