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The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Uganda

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LIGHTING AFRICA
Catalyzing markets for modern off-grid energy

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FOREWORD

As the world continues to be held in the grip of the COVID-19 pandemic, the difference between life with electricity versus life without has been placed in stark relief. Computers, radios, TVs, and phones have kept people connected maintaining social distance, and allowed to continue their studies or work from the safety of homes. This has not been true for the roughly 733 million people around the globe living without electricity.

For more than a decade the World Bank Group's Lighting Africa and Lighting Global programs have been leading the charge to expand off-grid electrification to those living without access to electricity in sub-Saharan Africa and around the globe. Initially the program's mission was to displace hazardous fuel-based lighting with clean, safe, solar alternatives. We worked to bring down costs, build consumer demand, promote quality, and help private solar companies access the finance they needed to build out distribution networks and make products more widely available. Today, 58.9 million people around the world are using off-grid products that meet Lighting Global Quality Standards to turn on their lights, and power typical household appliances such as cellular phones, fans, and TVs.

Now Lighting Africa and Lighting Global are expanding support into yet another new frontier: electricity for productive uses leveraging solar energy (PULSE) across the agricultural, industrial, commercial, and public sectors – appliances which can provide livelihoods and income-enhancing opportunities for off-grid households.

With one of the largest and most well-established solar markets in sub-Saharan Africa, and value chains that stand to benefit greatly from PULSE, Uganda has the potential to be a pioneer in growing a thriving PULSE market. Solar Water Pumps (SWPs) for example, would allow farmers to significantly increase their productivity. Solar Refrigeration Units (SRU) will allow shelf life of produce, all with potential to increase income. These and other solutions could drive job creation, economic growth, and improved resilience to climate change in agricultural communities. Coupled with attractive pay back cycles, the case for these PULSE appliances is extremely strong.

However, as with other off-grid products that came before, despite the clear benefits – affordability remains a real problem, with only 5–10% of rural households in Uganda able to afford PULSE products.

Thus, this report not only highlights the tremendous opportunities PULSE presents, but also looks closely at key barriers – and possible solutions. Issues such as affordability, access to finance, consumer awareness, and last-mile distribution will need to be addressed if the potential is to be reached. We hope the insights provided in these pages will help inform government strategy and excite development actors to grow the reach of PULSE in Uganda and maximize the benefits.

The Lighting Global program, with support from the World Bank and ESMAP donors, will continue to address these bottlenecks and help unlock the full potential and benefits of PULSE in Uganda, as they have done for off-grid products across the globe for more than 10 years.

Although it can be difficult at the moment to remember a time before COVID-19, let alone imagine the time 'after,' such a time will come. Our ongoing efforts to continue to work towards the ultimate goal of universal access to electricity are more important than ever.

Victoria Kwakwa
Vice President, Eastern and Southern Africa,
The World Bank

Lighting Africa is the World Bank Group's initiative to rapidly increase access to high-quality off-grid solar energy for the hundreds of millions of people in sub-Saharan Africa living without grid electricity. Together with our affiliated program, Lighting Global, Lighting Africa works with manufacturers, distributors, governments, and other development partners to build and grow the modern off-grid solar energy market. Our programs are managed by the World Bank with support from the Energy Sector Management Assistant Program (ESMAP), and funded by ESMAP, the Public –Private Infrastructure Advisory Facility (PPIAF), the Netherlands' Ministry of Foreign Affairs, the Italian Ministry for the Environment, Land, and Sea (IMELS), and the IKEA Foundation.

The Energy Sector Management Assistance Program (ESMAP) is a partnership between the World Bank and 18 partners to help low- and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank Group (WBG), ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) to ensure access to affordable, reliable, sustainable, and modern energy for all. It helps to shape WBG strategies and programs to achieve the WBG Climate Change Action Plan targets. Learn more at: ***https://esmap.org***

Economic Consulting Associates (ECA) specialises in advising on economics, policy and regulatory issues in the utilities industries, with particular expertise in the electricity, natural gas and water sectors. ECA has undertaken over 600 assignments in over 65 countries around the world.

African Solar Designs, Ltd. (ASD) is a leading Kenya-based renewable energy company that provides a range of engineering and advisory services. ASD specialises in helping clients complete off-grid solar projects and in providing in depth expertise that supports energy access and renewable energy sector development.

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The Lighting Africa team would also like to thank the companies, industry associations, aggregators, financial institutions, aid agencies, and non-government organisations that generously gave their time, and whose insights have made invaluable contributions to this report. A full list of these stakeholders can be found at the end of this report. We are especially grateful to the Ministry of Energy and Mineral Development, the Rural Electrification Agency, and the Uganda Energy Credit Capitalisation Company (UECCC) for their support.

ABBREVIATIONS AND ACRONYMS

A2EI	Access to Energy Institute
aBi	Agricultural Business Initiative
AC	Alternating current
ACE TAF	Africa Clean Energy Technical Assistance Facility
AFD	Agence Française de Développement
AfDB	African Development Bank
ASD	African Solar Designs
ATC	American Tower Corporation
BOS	Balance-of-system (see Definitions)
Capex	Capital expenditure
CASEE	Catalyzing Agriculture by Scaling Energy Ecosystems
DAFAN	Dairy Farmers Network
DC	Direct current
DDA	Dairy Development Authority
FCDO	Foreign, Commonwealth & Development Office
ECA	Economic Consulting Associates
ERA	Electricity Regulatory Authority
ERT	Energy for Rural Transformation
GOGLA	Global Off-Grid Lighting Association
FAO	Food and Agriculture Organization
FEI OGEF	Facility for Energy Inclusion, Off-Grid Energy Access Fund
HH	Households
IEC	International Electrotechnical Commission
IRR	Internal rate of return
kWp	Kilowatt-peak
LEIA	Low-Energy Inclusive Appliances (LEIA) program
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MEMD	Ministry of Energy and Mineral Development
MFI	Microfinance institution
MoFPED	Ministry of Finance, Planning and Economic Development
MWE	Ministry of Water and Environment
MT	Metric ton
MWp	Megawatt-peak
NAADS	National Agricultural Advisory Services
NPV	Net present value
NUCAFE	National Union of Coffee Agribusinesses and Farm Enterprises
NU-TEC	Northern Uganda, Transforming the Economy through Climate Smart Agribusiness

Opex	Operating expenses
PAEGC	Powering Agriculture: Energy Grand Challenge for Development Initiative
PAUESA	Power Africa Uganda Electricity Supply Accelerator
PAYG	Pay-as-you-go
PBP	Payback period
PFI	Participating financial institution
PSFU	Private Sector Foundation Uganda
PULSE	Productive Use Leveraging Solar Energy
PV	Photovoltaic
QA	Quality assurance
REA	Rural Electrification Authority
RBF	Results-based financing
SACCO	Savings and credit cooperatives organization
SHS	Solar home system
SME	Small and medium enterprise
SRU	Solar refrigeration unit
SUNREF	Sustainable Use of Natural Resources and Energy Finance
SWP	Solar water pump
TEA-POP	Transforming Energy Access, Powering Opportunities Partnerships
TOR	Terms of reference
UBOS	Uganda Bureau of Statistics
UCCCU	Uganda Crane Creameries Cooperative Union
UCDA	Uganda Coffee Development Authority
UECCC	Uganda Energy Credit Capitalisation Company
UGX	Ugandan Shilling
UHOA	Uganda Hotel Owners Association
UNCDF	UN Capital Development Fund
UNBS	Uganda National Bureau of Standards
UOMA	Uganda Off-Grid Market Accelerator
USAID	US Agency for International Development
USEA	Uganda Solar Energy Association
VAT	Value-added tax
WACC	Weighted average cost of capital
WB	World Bank

All dollar amounts are US dollars unless otherwise indicated.

CONTEXT AND KEY DEFINITIONS

This report provides an overview of the market for productive use leveraging solar energy (PULSE) in Uganda. The report seeks to inform the strategy of industry, government, and development partners going forward and to catalyze the market for PULSE applications. It was produced by the World Bank.

For the purposes of this report, we focused on small-scale applications that can be powered by standalone solar photovoltaic (PV) systems. The size of solar PV systems covered in this report ranges from as little as 50 watts to several kilowatts. Within this range, smaller PULSE units, which can be powered by solar systems of 1 kW or less, are targeted primarily to individual smallholder farmers and small businesses. Larger PULSE units serve commercial farms, farmer groups or cooperatives. These are often more viable solutions given the economies of scale that can be realized through aggregation.

While this report describes a wide variety of PULSE applications and market opportunities, we narrowed the scope of the detailed analysis to the more developed segments of solar water pumping and solar refrigeration. These technologies cover applications in agriculture, such as irrigation and cold storage, and commerce, such as retail cooling. They are the best-selling technologies among the broad spectrum of PULSE products covered in this report and were deemed the most likely to scale up rapidly in the short term.

This report is based on an extensive literature review and interviews with stakeholders in Uganda. We have had interactions with over 50 key informants including PULSE suppliers, end-users, industry associations, agricultural-sector aggregators, government institutions, and development partners. The list below provides an overview of key concepts and jargon that appear throughout this report.

Solar home system (SHS)	Solar home systems (typically ranging from 10 W to 350 W) usually include multiple lights, phone chargers, and often other appliances such as TVs and radios. Inverters to provide an alternating-current outlet are possible in larger systems, for example the Fenix International SHS, M-Kopa 600, and M-Kopa 6000.
Component-based SHS	These are SHS assembled from components (panel, battery, bulbs, wiring, and appliances) that have been bought separately as opposed to being bundled in a kit. The Lighting Global Quality Assurance Framework is not applicable to component-based SHS.
Plug-and-play SHS	Plug-and-play SHS are bought as kits that can be installed by a typical user without having to seek help from an electrical technician. All Lighting Global quality verified SHS are plug-and-play.
Balance-of-system (BOS)	All components of a photovoltaic system other than the photovoltaic panels are BOS.
Pay-as-you-go (PAYG)	PAYG is a system of paying costs or charges as they arise, i.e. a company rents SHS (typically plug-and-play) to consumers, with the option to own. This enables consumers to pay for products over time. PAYG is also available for certain stand-alone solar products for productive use.
PULSE product	"PULSE product" refers to a set comprising both a stand-alone solar PV system and the appliance or equipment used in productive applications, such as a water pump or fridge. Other tems used interchangeably for PULSE product throughout the report are PULSE unit, PULSE appliance, and PULSE equipment.
Small PULSE	Small PULSE products are targeted primarily to individual smallholder farmers and small businesses and have a solar PV capacity of less than 1 kW. In particular, small SWPs are designed for the needs of smallholder farmers irrigating up to 2 acres of crops and having around 20 head of cattle. Small SRUs have under 200 liters of capacity.
Medium PULSE	Medium PULSE products have a solar PV capacity above one kilowatt. In particular, medium SWPs are typically custom-designed for commercial farms. Medium SRUs cater for the needs of cooperatives or groups of users, for example, milk-chilling facilities (capacity 2,000–10,000 liters) for farmer groups or ice-making equipment (3–5 tons per day) supplying fishers.
Lighting Global Quality Assurance framework (VeraSol)	Lighting Global maintains quality standards that set a baseline level for quality, durability, and truth in advertising to protect consumers. Conformance with the quality standards is evaluated based on results from laboratory testing according to the Quality Test Method as defined by IEC/TS 62257-9-5. The tests are conducted at an approved, third-party test center using randomly procured samples. Products verified by Lighting Global are listed on the program's website: https://www.lightingglobal.org/products/

Smallholder farmer	A farmer with under 5 acres of land or fewer than 50 head of cattle. Smallholder farmers typically have mixed crops, cattle, and poultry within the same farm. Part of their production is consumed. Smallholder farmers represent the majority of agricultural output across all value chains reviewed in this study.
Cooperative	An association of agriculturalists in which farmers pool their resources in certain areas of activity. Most cooperatives mentioned in this text are secondary or tertiary, i.e. umbrella organizations or cooperative unions.
Aggregator	An entity that pools together groups of farmers and thus can provide an attractive point of sale for PULSE, aggregate demand for financing, and channel capacity-building activities. These include cooperatives, off-takers, public authorities providing agricultural extension services, and businesses providing commercial services.
System integrator	A solar PV supplier (typically small) with the capacity to design larger and more complex solar PV systems tailored to the needs of specific customers.
Donor	A bilateral or multilateral development agency or financial institution, NGO, or similar. The term is used interchangeably with "development partner."
Results-based financing (RBF)	In the context of this report, RBF refers to grants from donors or governments to solar PV suppliers, linked to achieving predetermined results (e.g. solar PV systems installed and operational at customer's premises), with payment made only upon verification that the agreed results have actually been delivered.
Productive Use Leveraging Solar Energy (PULSE)	Off-grid solar PV systems used to power productive applications such as agricultural transformation (threshing, milling), water pumping, or cooling. For the purpose of this report, PULSE products are defined as those that (a) serve a single customer, which may be a household, small business, or cooperative (as opposed to a mini-grid, which serves multiple customers); and (b) boost productivity and income-generation activities, contributing to economic growth. In this report, the following classification of PULSE is used:  *Solar water pumping (SWP) and irrigation:* systems used to pump water for a variety of productive uses, such as for agriculture and livestock. In the case of agriculture, these systems may include irrigation equipment (sprinklers, drip irrigation).  *Solar refrigeration units (SRUs) and ice-making:* coolers and ice-making machines that allow additional revenue to be generated or reduce waste of food products in agricultural and commercial markets.  *Solar milling* includes a variety of mechanical processing applications of agricultural produce, e.g. milling maize or cassava into flour, rice husking, and coffee hulling.  *Medium-sized systems:* applications that require several kilowatts of power and must be specifically designed for the application, e.g. powering an off-grid telecoms tower or tourism lodge.  *Other (niche) productive use:* less common productive applications in farming and fishing, such as power for milking machines, egg/chick incubation, and night lights for fishing.  *Commerce (SMEs) and connectivity applications:* power for small-scale businesses in rural areas, e.g. kiosks, phone charging, and barbershops).

UNITS, EXCHANGE RATE AND OTHER USEFUL CONVERSIONS

1 USD ($) = 3,700 UGX (Ugandan Shilling)

1 acre = 0.405 hectare (ha)

1 metric ton (MT) = 1,000 kg

1 household (HH) = 4.7 people (national average). Based on the most recent household survey (UNHS 2016/17), the average household size in rural areas is 4.9 and in urban areas 4.1. The total population according to that census was 37.7 million (76.5 percent rural, 23.5 percent urban).

Unit of solar PV capacity (Watt-peak, or Wp): The unit Wp and its multiples (kilowatt-peak or kWp, and megawatt-peak or MWp) are used throughout the report to refer to the capacity of solar PV systems (in individual or aggregate terms). For simplicity, the unit of power Watt (W, see below) is sometimes used for the same purpose.

Unit of power (Watt, or W): The unit W and its multiples (kilowatt or kW, and megawatt or MW) are used to designate the power demand of electrical equipment and appliances or the power capacity of electrical generators.

Unit of energy (Watt-hour, or Wh): The unit Wh and its multiples (kilowatt-hour or kWh, and megawatt-hour or MWh) are used to refer to the energy demand of a specific process or appliance (or energy-supply potential of a solar PV system) over a certain period.

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EXECUTIVE SUMMARY

Important note regarding COVID-19:

This market assessment was concluded prior to the COVID-19 crisis. All sales forecasts presented in this report, especially in the short term, are likely to decrease as a consequence of lockdown measures. Information on market opportunities, products, and stakeholders remains relevant, as does the analysis of barriers and recommendations for the scaling-up of the market. The report includes boxes providing additional insight on the impacts of COVID-19 in the off-grid solar industry in Uganda.

To date, the off-grid solar sector has primarily focused on consumption-related energy needs, such as household lighting and appliances. Productive use leveraging solar energy (PULSE) represents the next frontier in providing income-generating opportunities for off-grid households and businesses.

PULSE refers to off-grid solar PV systems coupled with equipment or appliances used in productive activities, such as water pumping for the irrigation of crops, chilling of milk or fish, and milling of cereals.

The market for PULSE appliances in Uganda is nascent, fast growing and focused on small solar water pumps (SWPs) and solar refrigeration units (SRUs). Most companies have introduced PULSE products commercially as recently as 2019. The market for small PULSE appliances[1] is by far the largest segment, with 1,400 small SWPs and 1,000 small SRUs sold in 2019, amounting to $1.9 million in sales revenue.

Sales of medium-sized[2] SWPs and SRUs accounted for just under $1 million in 2019[3]. In total, sales of SWPs and SRUs in Uganda represented almost $3 million. Three companies dominate sales of these PULSE products: solar home system (SHS) specialists SolarNow and M-Kopa, and water-related equipment distributor Davis and Shirtliff. Other PULSE products, such as solar grain mills, have only been tested as pilots and haven't yet been sold at a commercial scale.

Our conservative sales forecast for 2020 – before the COVID-19 crisis – is in the order of $6 million, representing a doubling of the market size year on year. Table S1 presents the most common PULSE products in the Ugandan market, including their typical use, price range, main distributors, and sales volumes. Several companies entered the market or launched new PULSE products in mid- to late 2019.

The sales forecasts for 2020 by market segment show that the market is expected to continue to be dominated by small SWPs and SRUs, which constitute about two-thirds of the total.

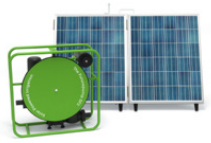
If support programs are implemented in a timely manner and aggressively address market challenges such as affordability, access to finance, consumer awareness, and last-mile distribution, the short-term sales forecast could double to **$97 million** for the four-year period.

1 Small SWPs are designed for the needs of smallholder farmers. For the purposes of this report, smallholder farmers are defined as having under 5 acres of land or fewer than 50 head of cattle. They typically have mixed crops, cattle, and poultry within the same farm, and consume part of their production. Smallholder farmers represent the majority of agricultural output across all value chains reviewed in this study. Small SRUs have under 200 liters of capacity. They are typically used in small dairy farms and in retail shops. Small SWPs and SRUs are well under one kilowatt of solar PV capacity.

2 Medium SWPs are above one kilowatt of solar PV capacity, typically custom-designed for commercial farms. Medium SRUs cater for the needs of cooperatives or groups of users. These may include, for example, milk-chilling facilities for farmer groups or ice-making equipment supplying fishers.

3 Commercial sales linked specifically to productive uses. Sales of medium SWPs in general are estimated to be $4–5 million per year, according to SWP suppliers. However, most of this is related to government procurement and/or not linked to productive uses.

Table S1: Most sold PULSE products in Uganda

Category	Typical use	Price range	Main distributors and sales volumes*
Small SWPs For example, Futurepump SF2 	Used by smallholder farmers for irrigation of crops (up to 2 acres) and other mixed uses, such as livestock watering and domestic use.	$700–1,600 (average $850), sold as a kit including solar PV system and irrigation tools.	Sales are estimated to be in the order of 3,000 units (worth $2.6m) in 2020. SolarNow has been a distributor for manufacturer Futurepump since 2017 and for SunCulture since 2019. New entrants in 2019 include Azuri and Tulima Solar. In addition, Davis & Shirtliff introduced a small SWP line in 2019. SolarNow, Azuri and Tulima Solar offer sales on credit or "pay-as-you-go" (PAYG).
Medium SWPs For example, Grundfos SQ Flex 2.5-2 	Mostly used in water supply projects sponsored by the government or donors, typically not related to productive activities. A commercial trend is emerging in irrigation of crops (especially horticulture), and in dairy and cattle farms.	Medium SWPs are custom sized and cost around $2,000 per kilowatt, not including the cost of drilling boreholes or irrigation equipment. A project in a commercial farm typically costs above $4,000.	SWPs imported from Europe (from manufacturers Lorentz, Grundfos, or Nastec) are distributed by specialists such as Davis & Shirtliff (the market leader), Aptech Africa, W.Water Works and Adritex. Sales are estimated at $4–5m per year but most of these are for government- or donor-sponsored projects. Sales related to productive use are estimated at $1.6m in 2020.
Small SRUs For example, M Kopa Solar Powered Fridge 	35- to 200-liter units used in milk chilling by small-scale dairy producers, and for cooling beverages and food in shops.	$500–900, including solar PV system.	Sales are estimated at 1,800 units ($1.4m) in 2020. Off-grid solar specialist M-Kopa introduced fridges in 2019. SolarNow has sold solar fridges since 2014 and solar milk chillers since 2019. Both M-Kopa and SolarNow provide consumer financing via PAYG or credit.
Medium SRUs For example, milk chillers of industrial capacity (2,000 to 8,000 liters) 	Chillers in off-grid milk collection centers, typically cooperative-owned. Ice-making for fish conservation. Businesses produce and sell ice to artisanal fishers at landing sites.	$25–100k per project, depending on size.	Limited penetration of PULSE in this segment, but growing interest for solar to replace diesel generators in hundreds of off-grid milk-collection centers. A few ice-making factories (for example, those operated by GRS Commodities) are connected to solar mini-grids in and around Lake Victoria. Stand-alone solar units could be considered in the future.

** Sales estimates were based on interviews with distributors prior to the COVID-19 crisis.*

The economics of SWPs and SRUs are overwhelmingly positive, with payback periods of between one and six years. SWPs allow farmers to increase their productivity significantly. There is growing evidence that the impact of irrigation is maximized in horticulture because of higher market prices and short cultivation cycles, among other factors.

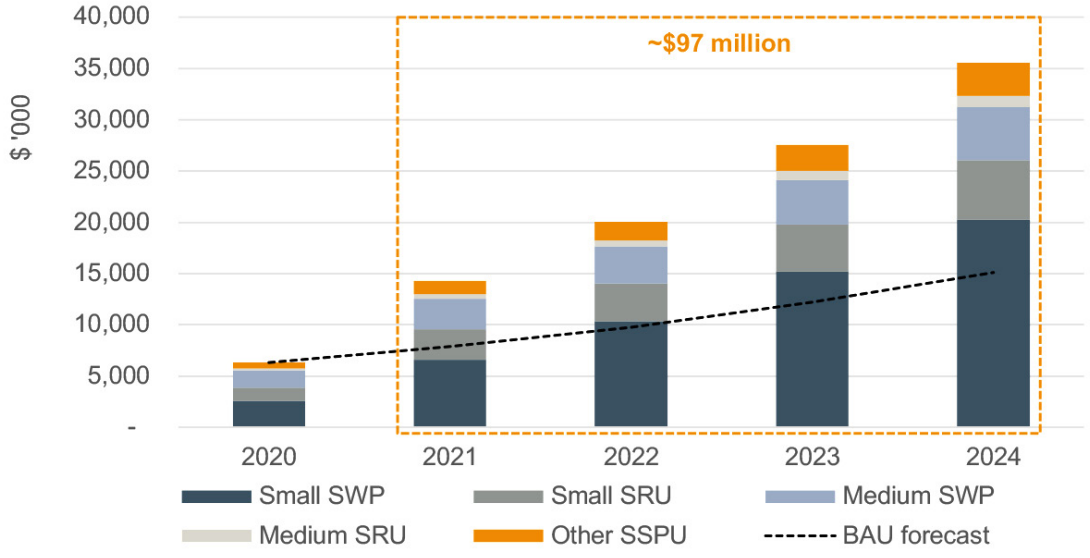
A payback period of less than a year is achievable for SWPs used in irrigation of vegetables and fruits, compared to rain-fed crops[4]. SRUs also provide significant gains, with chilling of milk or fish reducing post-harvest losses for farmers and fishers, and cooling of food and drinks allowing shop owners to double or triple their revenues. SWPs and SRUs are also viable compared to diesel-powered alternatives. The payback period of solar PV equipment replacing a diesel generator ranges from three to six years depending on the price of fuel and other variables[5].

SWPs and SRUs are expected to continue as the main PULSE products in Uganda in the medium term (next four years). Other PULSE products include (a) solar mills, which have been tested in Uganda by companies such as Agsol but are not yet being sold on a commercial scale; (b) medium-sized systems, of 10 kilowatt and above, such as power supply to off-grid telecom towers and hotels; and (c) small commercial solutions for rural SMEs, including phone charging, video cinemas, lighting and music for shops, and small-scale workshop tools.

The total market potential is estimated at around $100 million over the next four years if support programs are implemented. Projected sales in a business-as-usual (BAU) scenario if no support programs are implemented, based on the current level of sales and a conservative growth rate, range from $8 million in 2021 to $15 million in 2024, representing a total of $45 million for the four-year period.

If support programs are implemented in a timely manner and aggressively address market challenges such as affordability, access to finance, consumer awareness, and last-mile distribution, the short-term sales forecast could double to $97 million for the four-year period. Small SWPs and small SRUs together represent 70% of total projected sales in both scenarios. The support programs considered in the high scenario are presented below, under eight intervention categories.

Figure S1 Estimated projected short-term sales of PULSE appliances (high scenario)



4 The useful life of small SWPs is assumed to be longer than five years, based on manufacturer warranties (see Table 50).

5 The useful life of high-quality solar panel and inverters is beyond ten years.

Affordability, access to finance, consumer awareness, and last-mile distribution are some of the key barriers to market development. Currently, PULSE products are affordable for only 5–10% of rural households in Uganda, even considering financing options available. Most of those who can afford products will face difficulties in getting loans due to lack of credit history or collateral.

Distributors offering PAYG to customers also encounter difficulties in getting finance for their inventory and receivables accounts. Finally, given that PULSE products are substantially more expensive, more complex, and bulkier than SHS, the challenges associated with consumer awareness, capacity-building, last-mile distribution, and quality assurance are also much more significant. The risk of water-table depletion in association with SWPs is not of high concern in most of the areas in Uganda where agriculture is practiced.

We recommend eight different interventions to overcome the key barriers to market development. Several technical and financial support programs are being implemented or planned for implementation in the short term. A gradual and coordinated approach with long-term objectives will be needed to develop and scale-up the PULSE market, building on the many initiatives and institutions in place. The interventions proposed are:

- **Demand aggregation.** Smallholder farmers are scattered in rural areas, making the distribution of PULSE appliances difficult and expensive. The same applies to the delivery of interventions to support adoption of PULSE, such as enhancing access to finance, raising awareness, and building capacity. Supporting aggregators such as cooperatives, off-takers, and extension and advisory service providers, and encouraging partnerships between them and energy-sector stakeholders will help facilitate access to customers for PULSE products.

Affordability, access to finance, consumer awareness, and last-mile distribution are some of the key barriers to market development.

- **Access to finance.** A variety of interventions are needed to support access to finance, including (a) consumer finance through banks, SACCOs, and PAYG suppliers; (b) working-capital credit lines for PULSE companies; (c) financial incentives, such as results-based financing (RBF) for solar companies to cover the cost of developing distribution networks in rural areas. The total amount of financing needed to mobilize the $97 million of forecasted sales between 2021 and 2024 is estimated at about $48 million. About 20% of this amount could be disbursed as RBF and the remainder as loans. Financing institutions such as SunFunder and Stanbic Bank are already providing working-capital loans to suppliers of PULSE equipment in Uganda. The Uganda Energy Credit Capitalization Corporation (UECCC), with support from the World Bank, also operates a working-capital facility for partner financial institutions to provide loans to solar companies. Additional financing is, however, still needed in the sector.

- **Technology and innovation.** Technical and financial assistance to support product development is needed to increase functionality and/or reduce costs of PULSE products. Active programs supporting technology and innovation include CleanStart by the United Nations Capital Development Fund (UNCDF) and Low-Energy Inclusive Appliances (LEIA) funded by the Foreign, Commonwealth & Development Office (FCDO)[6].

- **Consumer education.** An intervention targeting consumer education should include **(a) training of end-users** in technical aspects and business concepts linked to PULSE equipment, and **(b) awareness campaigns** targeted at specific value chains. Organizations that are actively engaged in consumer education for PULSE include cooperatives and agricultural extension services. Additional financial support and coordination is needed to scale-up their activities.

- **Market intelligence.** The Global Off-Grid Lighting Association (GOGLA), the Energy for Access Coalition, and Lighting Africa are among the organizations producing market intelligence on an international level. A local industry association such as the Uganda Solar Energy Association (USEA) would be well placed to produce more detailed intelligence on the development of the market for PULSE products in Uganda.

6 NB FCDO merges with the Foreign & Commonwealth Office (FCO) to become Foreign, Commonwealth & Development Office (FCDO) in September 2020.

- **Business development support.** A recent survey conducted by USEA among its members suggests that their main weaknesses are sales and marketing, leadership, and organizational structure. Additional support in this field could be channeled through and coordinated by an industry association, such as USEA or the Private Sector Foundation for Uganda (PSFU).

- **Quality assurance (QA).**[7] A QA program for PULSE technologies needs to be developed in a way that is light-handed, low-cost, easily managed and, after an exacting application and approval process, self-enforceable by companies and consumers and verified by an independent agency. This QA framework should build on existing standards and players in Uganda, such as the Uganda National Bureau of Standards (UNBS), the Rural Electrification Agency (REA), USEA, and the LEIA program (Global LEAP Awards in particular).

- **Policy development.** Some of the most important issues at the policy level are (a) coordination of policies and strategies for PULSE among the ministries responsible for energy, water, and agriculture, their affiliated institutions and their development partners; and (b) considering reductions in VAT and import duty for solar products used in high-quality PULSE appliances. Donor-funded programs that are already active in creating an enabling environment for PULSE equipment include the FCDO-funded LEIA and Africa Clean Energy Technical Assistance Facility (ACE TAF), and the Uganda Off-Grid Market Accelerator (UOMA).

Over **80%** of respondents indicated they were unable to meet new product orders or provide customer service due to the lockdown measures put in place by the government in March.

COVID-19 has impacted the market significantly in early 2020, but has also accelerated the development of digital ways to do business. In April and May 2020, USEA ran a survey among its members to assess the challenges resulting from the pandemic. Over 80% of respondents indicated they were unable to meet new product orders or provide customer service due to the lockdown measures put in place by the government in March. Collection of payments for off-grid solar products sold on credit has also decreased. As a consequence, about half of USEA members are facing liquidity challenges. Businesses are increasingly turning to solutions such as e-commerce, mobile money, and call services to make sales and to maintain relations with existing customers.

Uganda has the potential to be one of the first countries in Africa to build a thriving off-grid PULSE market. In doing so it stands to benefit tremendously from job creation, economic growth, and improved resilience of rural communities in the face of climate change. We call upon all stakeholders to work together to take advantage of this exciting opportunity to advance a range of national development goals.

7 Since this report was written, VeraSol - an evolution of Lighting Global Quality Assurance - has begun testing off-grid appliances and productive use equipment to generate consistent, comparable performance data to fill critical information gaps. Learn more: *https://verasol.org/solutions/appliance-testing*

01

INTRODUCTION

This market assessment is focused on the next four years, 2021 - 2024. The study takes into consideration PULSE equipment of different capacities, from about 50 Wp (the capacity of solar PV systems powering small fridges) to systems up to several kilowatts in size.

1.1 Objectives

The objectives of this market assessment are to:

- Understand and estimate the size of the current and potential market for PULSE products, such as SWPs and SRUs;
- Identify high-potential value chains and productive-use applications in specific locations, including potential investment opportunities in line with the sector's absorptive capacity;
- Analyze the main barriers to market growth;
- Undertake stakeholder mapping to understand the current capabilities, priorities, activities, and plans of actors in the sector; and
- Provide recommendations for how market barriers might be overcome.

1.2 Sources and methodology

This market assessment was conducted on the basis of:

- Extensive literature review. About 70 recent publications in the field of study were reviewed. These are cited throughout this document. Some of the most relevant references include the "Assessment of Farmer-led Irrigation Development in Uganda" (World Bank Group, 2019), the "Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa" (World Bank Group, 2019), a report from the Productive Uses of Electricity Program Initiative (by NRECA International for USAID, 2018), a variety of market assessments produced by the Uganda Off-grid Market Accelerator (UOMA), and several technology-specific outlook documents published by the Energy for Access Coalition.
- Interviews with stakeholders. About 50 stakeholders in the Uganda PULSE market were interviewed, including suppliers, end-users, industry associations, agricultural-sector aggregators, government institutions, and development partners. Interviews were conducted through phone calls, meetings, and focus groups. Where citations for data in this report are not provided, specific data was obtained from stakeholders through interviews.

Our literature reviews and stakeholder interviews allowed for the collection of data to estimate the size of the PULSE market, identify high-potential value chains and productive-use applications, and analyze market barriers. Figure 1 shows our approach to linking market barriers with the different stakeholder groups consulted during our research.

Only a limited number of end-users were interviewed (farmers, agribusinesses, and other related SMEs). No extensive survey using representative samples was conducted. Recent surveys by other parties (e.g. "Use and Benefits of Solar Water Pumps" (Energy for Access Coalition) and "Grid-powered Refrigeration for Productive Use" (Energy for Impact)) were used for this purpose.

1.3 Limitations

There is a very wide variety of productive value chains in which solar energy technologies could potentially add value to and/or reduce costs to off-grid farmers and businesses. In order to keep this assessment focused, the following limitations apply:

- *Focus on stand-alone solar PV technologies.* Whereas the report (specifically section 2.1) acknowledges the importance of solar thermal applications in drying (grains, fruits, coffee), water heating, and, potentially, cooling, these are not explored in detail. This report does not cover applications powered by grid-connected solar PV systems.
- *Focus on most attractive technologies.* While the report presents a wide range of PULSE applications in the first two chapters, the deep-dive analysis (chapters 3–5) only covers the technologies deemed most attractive (and likely to represent most of the PULSE market) in the short term: solar water pumping and solar refrigeration. The rationale behind this choice is presented in the report.

1.4 Structure

Following this introduction, the report is structured as follows:

- Chapter 2 presents an overview of the market for PULSE from different perspectives: **a demand-side assessment** (section 2.1), which explores different productive value chains (e.g. grains and

staple crops, horticulture, coffee, and dairy) and the potential of PULSE to add value and/or reduce costs in each; and a **supply-side assessment** (section 2.2) presenting PULSE currently available in the Ugandan market. Finally, section 2.3 presents a quick prioritization analysis in order to focus the remainder of the report on the most attractive value chains and PULSE.

- Chapter 3 presents an estimation of the **potential market size** for PULSE in Uganda in the short term. This is based on sales projections and financial analyses for different PULSE applications.
- Chapter 4 maps **stakeholders in the Ugandan PULSE market,** including PULSE suppliers, market aggregators, public-sector organizations, financing institutions, and so on.
- Chapter 5 provides a list of challenges and **barriers to the development of the PULSE market,** based on the interviews with stakeholders and the literature review.
- Finally, chapter 6 provides **high-level recommendations to address the barriers** presented in chapter 5.

Figure 1: Market barriers and stakeholder groups

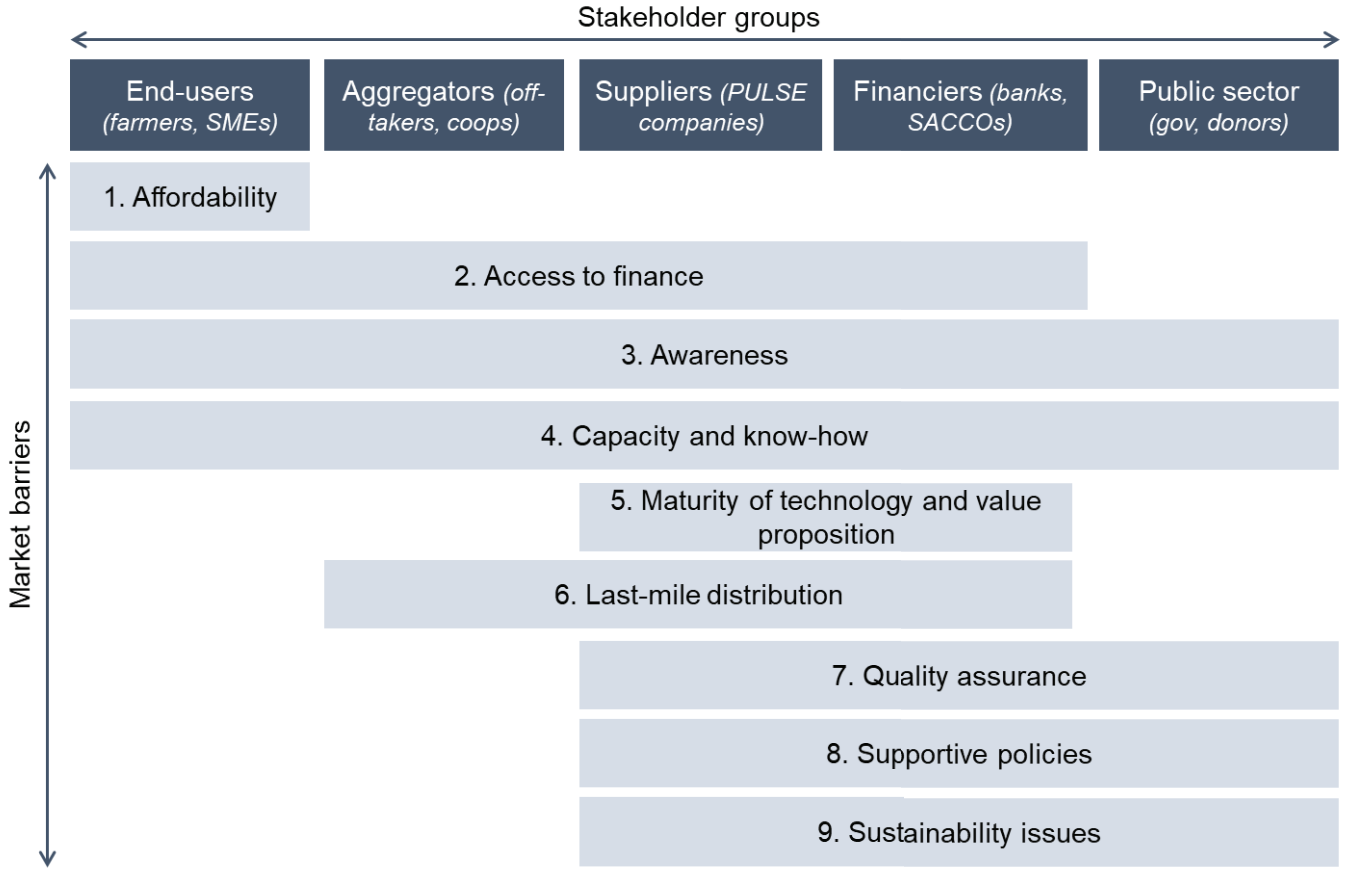
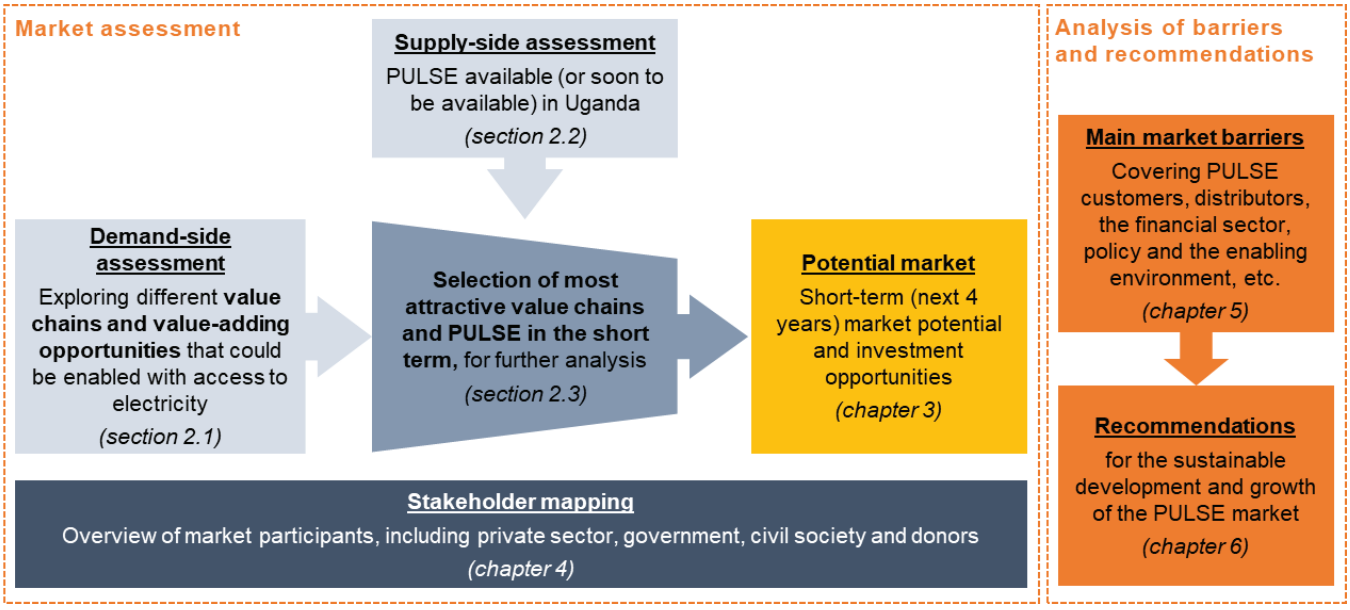


Figure 2: Structure of report



02

CURRENT MARKET

The Ugandan off-grid solar market is one of the most active in Africa. By 2020, at least 40 percent of off-grid households were estimated to have small solar devices[8] and the market is still growing. Although accurate data on the total size of the market is not available, a fairly clear picture of the supply side can be drawn based on available evidence and interviews with members of the Uganda Solar Energy Association (USEA).

8 Off-Grid Solar Market Trends Report 2020, Lighting Global. NB: This study focused especially on Lighting Global and PAYG segments of the market and did not provide information on the so-called "grey market," which plays a key role, especially in sales of larger systems.

The market can be divided into the following segments, although there is considerable overlap between these categories:

- Formal Solar Home System (SHS) companies offering small (typically below 60 Wp) solar PV systems, primarily to rural households. These players mostly offer devices meeting Lighting Global Quality Standards on a financed basis.
- System integrator companies. These tend to be small companies that supply larger systems (over 200 Wp) for special consumer needs, tenders, or projects.
- Over-the-counter traders that offer a wide variety of equipment through shops on a cash basis. This market provides solar components (modules, batteries, controls, and balance-of-system (BOS) to do-it-yourself buyers.
- Specialized companies that offer niche products (e.g. solar pumps) or services for developing market needs.

With the growth of the commercial market has come increased interest in productive uses of solar PV. Traders of PV products are aware of the demand for productive-use applications and increasingly adjust their offerings for this market.

Some of the productive-use PV system developments have been "spontaneous," i.e. developed based on attempts by small players to meet existing demand by providing end-use solutions for retail, communications (e.g. phone charging), and cottage-industry applications (see examples pictured below). Other productive use solutions (e.g. pumping and refrigeration) are being developed or assembled by formal and specialized companies to serve key segments of the market.

Examples of informal solar PV systems in productive-use applications

A hairdressing shop and general store on Buvuma Island (Lake Victoria) with solar PV systems used for hair-clippers, a sound system, and refrigeration of drinks. Photo credit: ASD.

This chapter explores the current market for PULSE. Section 2.1 presents an overview of productive value chains (demand-side analysis), while section 2.2 provides an assessment of existing PULSE products in the Ugandan market (supply-side analysis). Finally, section 2.3 assesses the most attractive PULSE technologies in terms of their development potential in the short term.

2.1 Overview of productive value chains

This section provides an overall analysis of the most important off-grid value chains. It seeks to identify those value chains with the highest potential for the use of off-grid solar PV to increase production, reduce costs, and add value to products.

While the primary focus has been on agriculture-related uses, other value chains such as fishing, services/SMEs, connectivity, tourism, and other typical village applications (e.g. phone charging and hairdressers) have also been explored. The value chains, along with the relevant solar applications covered in this report, are summarized in Figure 3.

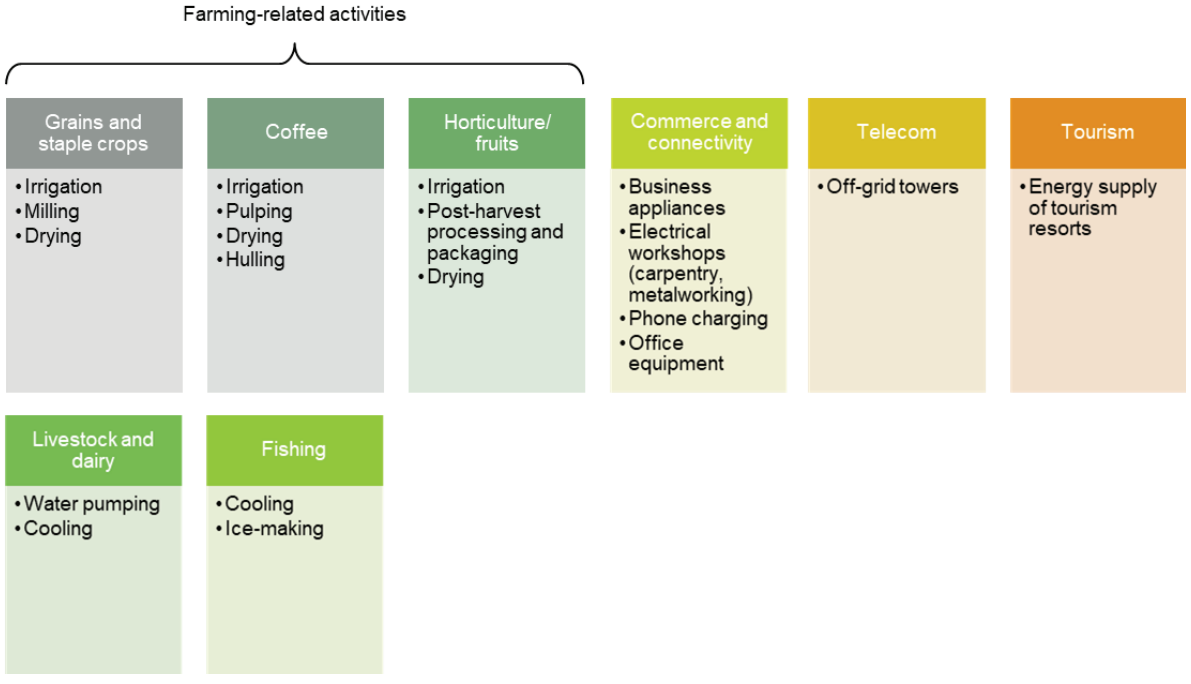
2.1.1 Grains and staple crops

This subsection considers how PULSE devices can assist in the production, harvesting, and processing of major food crops. Ugandan staple foods include plantains, cassava, dry beans, sweet potatoes, rice, millet, and sorghum.[9] Staple food crops account for 12 percent of GDP.[10] Maize is produced as both a staple food and a cash crop which is exported to various markets. Annual maize production doubled between 2003 and 2017, and exports have almost tripled over the same period.

PULSE appliances have the potential to improve production of staple crops, particularly when they help address primary constraints in production such as irrigation and processing:

Low output levels coupled with a high risk of pest or disease infestation, a weak market information system, limited market access, limited processing and value addition, poor post-harvest management, and disregard for quality and phytosanitary standards constrain the performance of staple foods markets nationally and regionally.[11]

Figure 3 Value chains covered in this report



9 National Household Surveys, UBOS, 2010 and 2014.

10 World Bank, 2018. Uganda Economic Update: Developing the Agri-Food System for Inclusive Economic Growth.

11 Chemonics International Inc., 2017. Uganda staple food market fundamentals.

Current production and growth potential

Table 1 presents major crop outputs and estimated areas of farmer production.

Table 1: Crop production volumes, retail value, and cropping areas

Crop	Average production ('000 MT/y)	Estimated area under production (acres '000)	Est. retail value, unprocessed ($'000/year)	No. of HH cultivating ('000)	Average yield (MT/acre/y)	Cultivated land/HH (acres)
Maize	2,707	2,505	764,547	3,657	1.1	0.7
Beans	937	1,525	663,776		0.6	
Sorghum	379	986	127,916		0.4	
Plantains	4,570	1,992			2.3	
Cassava	2,866	2,152		3,110	1.3	0.7
Millet	247	617			0.4	
Rice	234	185			1.3	

Source: UBOS, 2014; UBOS, 2010[12] ; FAO, 2012; USAID, 2017.

Maize farmers stand to benefit most from mechanization, in both irrigation and milling.[13] This is because maize is a widely traded commodity, it is consumed in most rural areas, and, unlike plantains, it is most useful as a product after being milled.

Maize makes up around 20 to 40 percent of Uganda's daily calorie consumption and is the most common food crop (it is also used as an animal feed). It is reasonable to assume that 90 percent of all farmers plant maize.[14] Conversely, over 90 percent of Uganda's maize is produced by smallholders (farm size under 5 acres), and about 60 percent of that is consumed directly on the farm (i.e. not sold).

Most small-scale farming in Uganda relies on two rainy seasons. Rainfall below expectations has a major impact on farming outputs. PULSE irrigation systems can help farmers to ensure production in the case of insufficient rainfall and even increase production by enabling additional crop cycles per year.

The seasons also affect the drying of the produce, and subsequently affect the final yield. Some 50–60 percent of the crop yield is lost due to poor post-harvest handling.[15] Technologies to improve the drying of crops can help in this regard.

High maize production areas include Kapchorwa, Iganga, Masindi, Mbale, Mubende, Kasese, Kamuli, Jinja, and Kabarole districts. Figure 4 shows the geographic distribution of smallholder farmers cultivating maize. The map is based on livelihood data collected by the Uganda Bureau of Statistics (UBOS) at the sub-county level in the 2014 census. The electricity network is also mapped, showing that areas with a significant number of farmers remain off-grid.

All staple crops can benefit from increased irrigation in smallholder farms. In addition to maize, other crops that can benefit from mechanization of milling and post-harvest processing include:

- **Cassava.** 13.2 million households farm cassava[16]. It is widely planted and can be made into flour through milling or sliced and packaged into "chips" for frying.
- **Rice.** Government programs are pushing expansion of rice cropping in many parts of the country, where conditions are suitable for dryland and paddy production.

With the growth of the commercial market has come increased interest in productive uses of solar PV.

12 Data obtained through the Global Yield Gap Atlas.

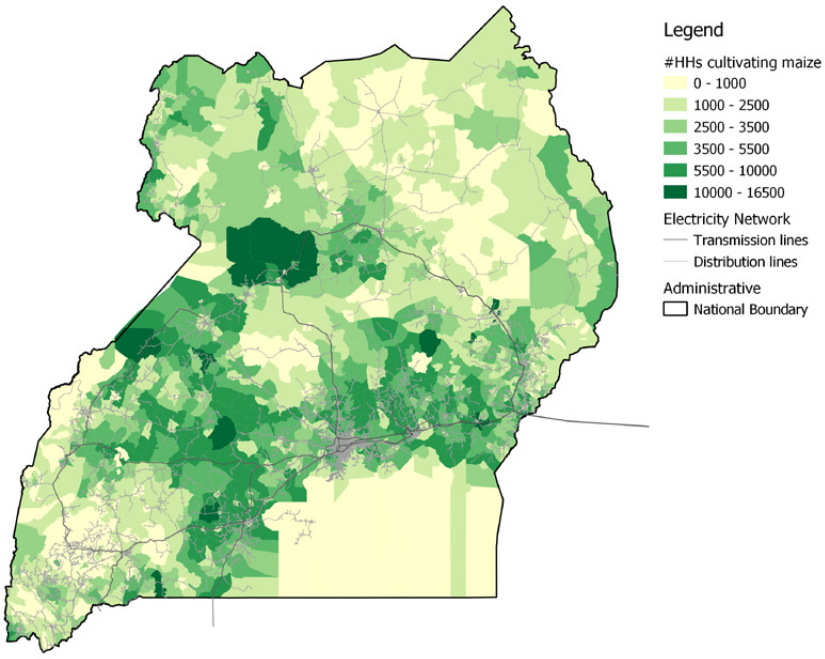
13 NRECA, 2018. Productive Uses of Electricity Program Initiative.

14 Ibid.

15 FAO, 2018. FAO's value chain support for Uganda.

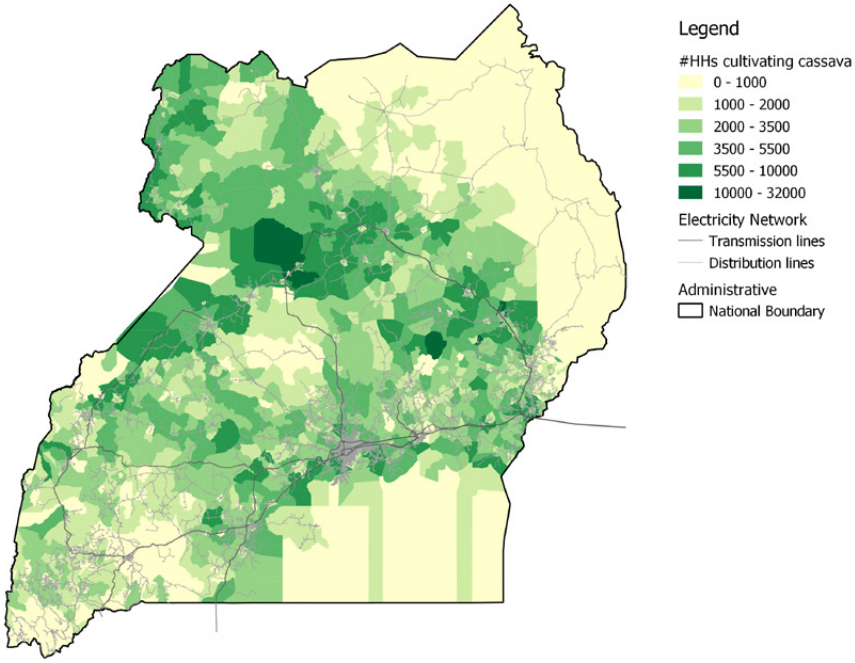
16 NRECA, 2018. Productive Uses of Electricity Program Initiative.

Figure 4: Geographic distribution of maize farmers vs electricity grid



Source: UBOS data collected during 2014 census; Energy Sector GIS Working Group Uganda.[17]

Figure 5 Geographic distribution of cassava farmers vs electricity grid



Source: UBOS, data collected during 2014 census; Energy Sector GIS Working Group Uganda.

17 Transmission lines from UETCL, 2017; distribution lines from UMEME and REA, 2018. Source: Energy Sector GIS Working Group Uganda.

Sector organization

Some 80 percent of farmers in Uganda are small-scale.[18] More than 90 percent of maize production is driven by smallholders. Although there are organizations that lobby for and support farmers (e.g. the Uganda National Farmers Federation), the majority of small-scale farmers are not organized the way cash-crop farmers or dairy farmers are. Regional producers of staples are not organized into formal groups. Small-scale staple farmers generally consume most of their production and sell the excess harvest to local markets.

Most rural farmers are not connected to grid electricity and rely on manual power or off-grid sources. Over 80 percent of smallholder farms are not connected to the grid. Over 70 percent of grain millers are not connected to the grid.[19] Off-grid mills use diesel- or petrol-powered hammer mills to grind farmed products. Mills are usually located in the vicinity of farms. As explained below, there are a variety of off-grid mill sizes depending on the intensity of grain production in the area.

Over **90%** of Uganda's maize is produced by smallholders (farm size under 5 acres).

About **60%** of that is consumed directly on the farm.

Locally milled and packaged maize is mostly used by households. Small-scale milling opportunities are mostly for service providers that work with end-users who require their own grain to be milled for household and home consumption. Solar-powered mills would not enable small-scale farmers to compete with much larger, industrial-scale millers. Milled maize is worth more than triple the value of the raw produce.[20]

Energy use and potential for PULSE applications in the production of maize and other staple crops

Irrigation. A large proportion of small staple food farmers in Uganda rely on rain-fed agriculture for their production cycles. There is large potential for the introduction of smallholder irrigation to expand the production of staple foods.

Milling. Consumers based in local markets close to the harvest location, including individuals and households, are the largest purchasers of maize flour processed in all regions (83 percent of all milled maize is consumed within the locality where it is produced[21]). There is also potential for milling cassava flour.

Current maize milling capacity (255 MT per day[22]) amounts to less than 10 percent of overall maize production, indicating a relatively large market for milling services. In addition, most milling services are carried out by relatively small players responding to local demand in their villages.

- Most maize millers produce between 1 and 5 MT of milled flour per day (46 percent of all maize millers surveyed).
- 27 percent have a production capacity of less than 1 MT per day.
- Only 3 percent mill more than 20 MT every day.
- The remainder is shared between millers producing 6–19 MT per day.

Within the staple food value chain, there are two primary activities that this report looks at that require additional power. (Drying is often also required for staples, but is not covered in this report.[23])

18 World Bank, 2018. Uganda Economic Update: Developing the Agri-Food System for Inclusive Economic Growth.

19 UOMA, 2019. Productive Use of Energy Market Map.

20 One kilogram of raw maize costs between UGX 300 and UGX 500. One kilogram of processed (milled) maize costs UGX 1,500–1,800. Source: Market Assessment for Solar Powered Milling Project, UOMA on behalf of Power Trust Solar, July 2018.

21 USAID/SPRING, 2017. "Uganda: Mapping of Maize Millers, A Road Map to Scaling Up Maize Flour Fortification".

22 Ibid.

23 Drying of grain is an important activity for two main reasons. First, it reduces the risk of aflatoxin poisoning, which presents a major health hazard and export barrier. Second, drying reduces crop losses, which are extremely high in Uganda (over 35 percent loss is common). However, to be solar powered, drying would rely mostly on solar thermal energy, not the PV power associated with PULSE. Although off-grid electricity can contribute to solar thermal device operation, the bulk of the energy would come from solar thermal collectors. Finally, it is worth mentioning that, although solar drying technologies exist and are relatively mature, they have not achieved scale in most agricultural processing markets. First, the quality requirements of dried products mean that the processes must have strong controls that solar drying equipment cannot meet. Second, mismatched variability of solar radiation with harvesting seasons can force processers to rely on other drying technologies.

- Irrigation. Most staple food production is carried out on rain-fed smallholder farms. Droughts and variability in rainfall greatly reduce overall output. Solar-powered water pumping and irrigation have the potential to increase production on small and medium farms where staple crops are cultivated. Water scarcity and the risk of water-table depletion are mentioned repeatedly in association with water pumping. However, this is not of high concern in most of the areas in Uganda where agriculture is practiced. Section 5.9 of the report addresses this issue.

- Milling. Solar-powered milling of grain products has viable potential to contribute to the milling of small-scale farmer products in off-grid areas. Milling maize is of primary interest, but solar-powered milling of cassava, millet, sorghum, and small-scale rice for smallholders also holds potential.

2.1.2 Coffee

Current production levels and growth potential

Uganda is the eighth largest coffee producer in the world[24]. In 2017, total coffee production in the country amounted to 280,000 MT, an increase of roughly 16 percent over the previous year[25] and 47 percent as compared to 2012. Most of the production is Robusta.[26]

Local consumption only accounts for 3 percent of production, while coffee accounts for about 30 percent of the country's total export revenue.[27]

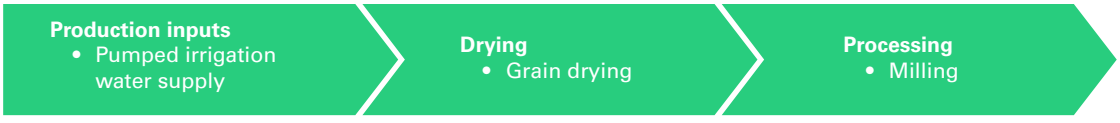
In 2017, a total of 250,000 MT, worth $490 million, was exported to 38 destinations. This represents an increase of 17.7 percent in quantity and 39.3 percent in value as compared to the previous year. Around 80 percent of that volume was exported by 10 companies[28], out of a total of 33 registered coffee exporters in the country.

Coffee is a major source of employment and income generation, particularly for smallholder farmers.[29] According to the Uganda Coffee Development Authority (UCDA), over 3.5 million households are employed in the coffee sector, including production and sales activities.[30]

The rapid increase in coffee production can be partly attributed to the replanting program implemented by UCDA, which aimed to increase yields by replacing coffee trees that were old or affected by disease and by expanding coffee production into additional suitable areas . As part of this effort, UCDA supplied 181 billion seedlings, benefiting 514,400 households.[31]

According to the Coffee Roadmap launched by the government in 2017, it is expected that total annual production will increase to 1.2 million MT by 2020. According to current projections, the average price of both Arabica and Robusta will increase from an average of $1.50 per kg and $1.20 per kg, to $3.00 per kg and $1.90 per kg, respectively, by 2021.[32]

Figure 6: Productive uses of electricity in the maize value chain



24 Statistics from the International Coffee Organization, data as of July 2020. http://www.ico.org/prices/po-production.pdf.

25 UCDA Annual report 2018.

26 World Bank, 2019. "Assessment of farmer led irrigation development."

27 UCDA Annual report 2018.

28 World Bank, 2019. "Assessment of farmer led irrigation development."

29 Verter, Nahanga, Bamwesigye, Dastan and Darkwah, Samuel A. 2015. "Analysis of Coffee Production and Exports in Uganda." Proceedings of the 10th International Conference on Applied Business Research, 14–18 September 2015, Madrid: 1080–93.

30 This includes the entire value chain, not only farming. World Bank 2018. "Developing the agri-food system for inclusive growth."

31 UCDA Annual report 2018.

32 World Bank, 2018. "Developing the agri-food system for inclusive growth."

Both coffee prices and yields vary significantly depending on the season. Between February and March yields are approximately 1.0 MT per acre, while between July and September they increase to 1.9 MT per acre, reaching around 3.8 MT per acre between October and December.[33] The price of unprocessed coffee varies from $0.40 per kg between February and March to $0.50 per kg between October and December.

Coffee is grown in five areas, spread across almost the entire country: the central, western, south-western, northern, and eastern regions. Arabica is grown at high altitudes, especially on the slopes of Mount Elgon on the border with Kenya and on the slopes of Mount Rwenzori on the border with the Democratic Republic of Congo. The predominant Robusta variety is grown in the rest of the country.

Sector organization

Following the liberalization of the coffee sector in the 1980s, several local investors, as well as multinational companies, have emerged.

There are currently around 1.7 million households engaged in coffee production. Most of them are involved in cultivation. Only 537 households are involved in processing, and a mere 17 in roasting.[34] Two main production systems are considered: smallholder farms and estate farms (see Table 2).

Most of the coffee (85 percent) is produced by small-scale coffee farmers, who own less than 5 acres of land each.[35] For instance, Kyagalanyi Coffee Ltd, one of the ten largest coffee companies, currently buys from 15,000 coffee-farming households. Commercial farmers are responsible for 10 percent of total production, while the remaining 5 percent of coffee is produced by plantations.

According to the Uganda Coffee Alliance, there are currently around 1,600 coffee associations and cooperatives. One of the most important umbrella organizations is the National Union of Coffee Agribusinesses and Farm Enterprises (NUCAFE). The sector is regulated by the Uganda Coffee Development Authority (UCDA), a public agency under the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF). The mission of UCDA is to "to facilitate increase in quality coffee production, productivity, and consumption."[36]

Table 2: Coffee production systems

Production system	Description	Number of HH	Land (acres)	Yield
Smallholder farmers	Responsible for 85% of coffee output. Mean plot size <1 acre (intercropped with bananas and beans) Unsophisticated. Only 0.1% of farms use irrigation.	1.7 million	874,000 acres in total (i.e. 0.5 acres per farm)	Varies widely between 0.2 and 0.9 MT/ acre, depending on practices.
Estate farms	A few large plantations, e.g. Kaweri Coffee Plantation in Mubende District (6,200 acres under Robusta) and Dr Ian Clark's farm in Kabarole District (320 acres of Robusta)	n.a.	~47,000 (5% of the total area under coffee)	1.5 MT/acre
Total (land)/ average (yield)			921,000	0.3 MT/acre (given annual national output of 280,000 MT)

Source: Uganda coffee country profile (UCDA, 2019).

Coffee is a major source of employment and income generation, particularly for smallholder farmers.

Over **3.5 million** households are employed in the coffee sector, including production and sales activities.

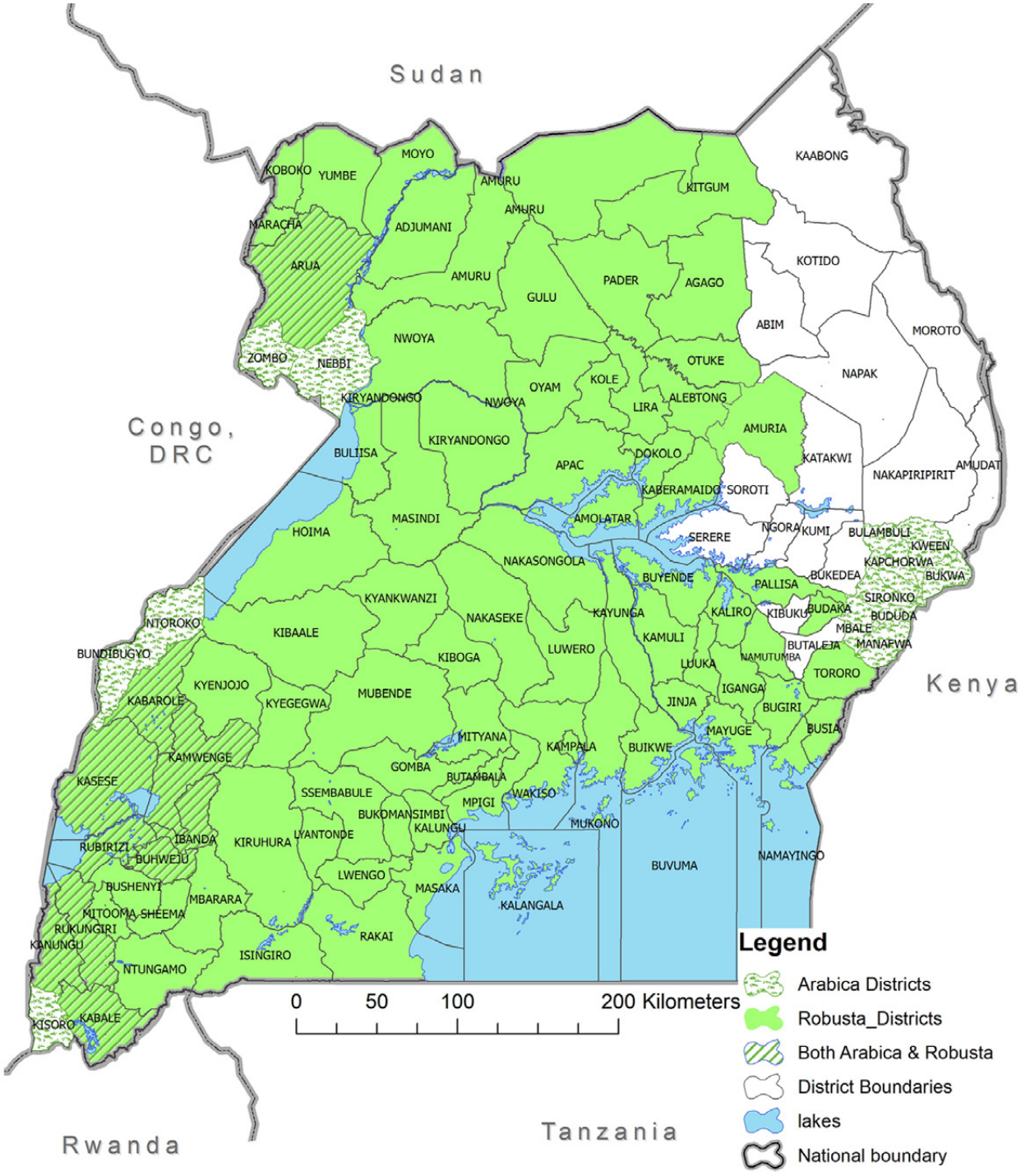
33 PAUESA, 2018.

34 UCDA, 2019. Country Coffee Profile: Uganda.

35 World Bank, 2019. "Assessment of farmer led irrigation development."

36 For more information, visit UCDA's website: https://ugandacoffee.go.ug/.

Figure 7: Coffee production areas in Uganda



Source: UCDA, 2018.

UCDA works in close collaboration with a number of government agencies, including the Ministry of Trade Industry and Cooperatives (MTIC), the Ministry of Finance, Planning and Economic Development (MoFPED), the Ministry of Water and Environment (MWE), and the National Planning Authority. While the coffee industry has been completely privatized, UCDA remains responsible for conducting quality control of all export shipments.[37]

Energy use and potential for PULSE applications in coffee production

Most small-scale coffee farmers are not connected to the grid and rely on off-grid energy sources. Larger commercial farms and coffee processing facilities are grid-connected. Within the coffee value chain, the main activities that require power are irrigation, pulping, and drying (see Figure 8).

Irrigation

Drip irrigation using pumps to move water from a well to an above-ground storage tank is the most effective method of coffee irrigation[38] and can lead to a yield increase of 15–20 percent.[39] However, in Uganda, only 8–10 percent of coffee production is currently irrigated. The power demand for drip irrigation is around 0.4 kW per acre.

A recent study[40] on the impact of irrigation on the agricultural sector in Uganda found that irrigation can lead to an increase in the gross margin (cash per acre) of between 87 and 92 percent (Figure 9).

Figure 8: Productive uses of electricity in coffee value chain

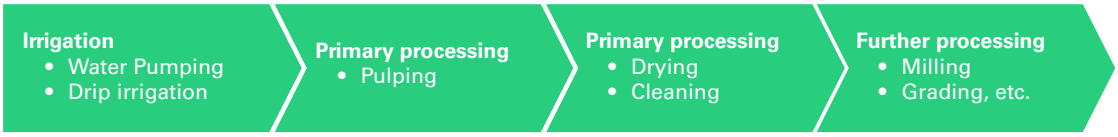
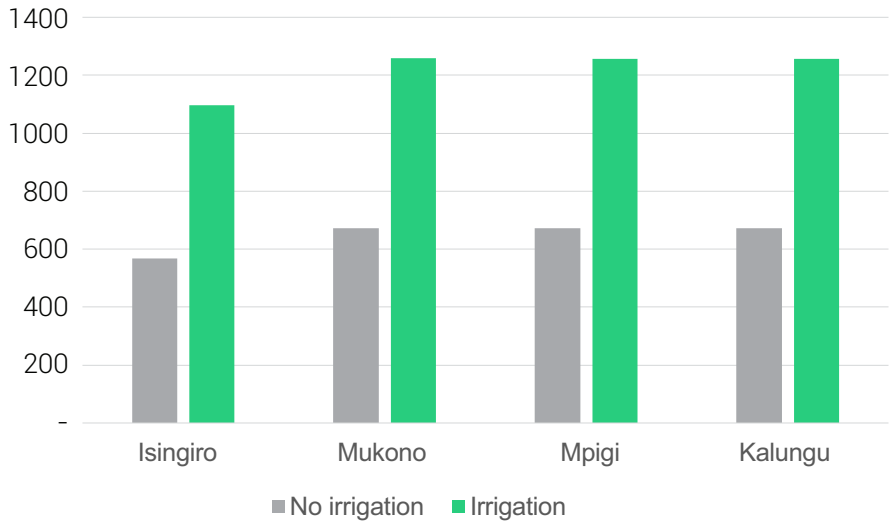


Figure 9: Impact of irrigation on gross margins for coffee production



Source: USAID, 2018.

37 Overview of the Uganda coffee industry from the Uganda Coffee Federation.

38 NRECA, 2018. Productive Uses of Electricity Program Initiative.

39 David Peasley and Chris Rolfe, 2003. Developing irrigation strategies for coffee under sub-tropical conditions.

40 World Bank, 2019. "Assessment of farmer led irrigation development."

Pulping

Both dry-processed and wet-processed coffee is produced in Uganda. Wet-processed Arabica, usually grown by smallholder farmers, is considered of higher quality compared to the dry-processed product. Pulping is part of the wet processing of Arabica coffee.

Pulping consists in processing coffee cherries and separating the bean from the skin and pulp. Most coffee farmers currently pulp coffee beans using hand-pulpers. These comprise a rotating drum and breastplate on which the beans are separated using gravity.

Solar - powered pulping machines are much more efficient and can result in significant time savings. A small pulping machine can process around 300–800 kg per hour, as opposed to 90 kg per hour manually, and has a power rating of between 0.5 and 3 kW[41]. These machines are not widely available on the market and their price can vary between $2,300 and $8,000, depending on size. Cooperatives that use these machines can then sell their produce at a price of $1.50 per kg, or more than 1.5 times the price of unprocessed coffee.

Solar-powered coffee-pulpers present attractive opportunities to promote local value addition in Uganda. On average, households engaged in coffee-growing activities are significantly less poor than other households. They are therefore in a better position to invest in technologies that would increase their productivity and consequently their income. Investments in solar power for irrigation and processing can also be used for other crops, enabling smallholders to diversify while increasing the volume and quality of their coffee product.

Drying

Most of the coffee grown in Uganda is the indigenous Robusta, which is dried in the sun instead of being wet-processed. In the dry process, coffee needs to be dried from an initial moisture content of about 30 percent at harvest to about 12 percent before being sold or further processed. The drying requirements tend to be largely at the farm level, where the entire cherry is placed in the sun for about 12 days using sun-drying floors or mats.

Solar dryers with polypropylene stackable trays and venting airflow are sometimes used in rural areas that are not connected to the grid. However, the process of drying is less capital intensive, and there is, thus, little potential for investment in solar-powered dryers.

Other value-adding activities

Further along the coffee value chain are milling, roasting, grinding, and packaging. However, most Ugandan coffee is exported after primary processing (pulping and drying). Local processing is only carried out by 17 roasters with a total market size estimated at 216 tons of roasted coffee per year, predominantly for domestic consumption[42]. Local processing is carried out in both private and cooperative-owned factories. NUCAFE owns and operates processing facilities for cleaning, drying, grading, roasting, grinding, and packaging.

The scale of these activities favors factories supplied by grid electricity. However, NUCAFE is currently installing an industrial solar plant in order to sell eco-friendly coffees in specialty markets that offer higher prices for farmers.[43]

Solar - powered pulping machines are much more efficient and can result in significant time savings.

A small pulping machine can process around **300–800 kg** per hour.

2.1.3 Horticulture and small-scale mixed farming

Current production levels and growth potential

Transition from rain-fed and subsistence agriculture to cash-based mixed farming (especially in areas around urban centers) is playing an important role in modernizing farming in Uganda. As families grow and farm sizes shrink as land is divided among more people each generation, farmers focus on higher-value, more intensive crops, and develop better methods to add value and get the products to market, especially in central, eastern, and western regions.

41 Access to Energy Institute (A2EI), 2019. Evaluation of Solar Powered Agricultural Technologies for Productive-Use Applications: A Modeling Approach.

42 UCDA, 2019. Country Coffee Profile: Uganda.

43 Channing Fisher, Kiva blog posts, n.d. "NUCAFE revolutionizing the supply chain in Uganda."

Much of the growth of smallholder, market-oriented farmers is being driven by national companies and investors, as opposed to international investors. Most high-value horticulture takes place on small farms. A large proportion of farmers are engaged in some type of commercial horticultural production of fruit or vegetable crops.

Uganda is currently the second-largest producer of fresh fruit and vegetables in sub-Saharan Africa after Nigeria, producing about 1.1 million tons per year.

Horticultural crops fall into two general categories:

- **Non-staple market vegetables:** tomatoes, okra, kale, carrots, green peppers, cabbages, French beans, chilies, onions, and a variety of other indigenous vegetables. These crops are actively grown in market gardens, to be sold in urban and peri-urban markets.

- **Fruits:** citrus, pawpaws, mangoes, pineapples, watermelons, avocados, passion fruits, jackfruit, and sweet bananas. Fruit production is driven by smallholder farmers. Pineapples are the most widely grown fruit, typically on monoculture plots or intercropped with bananas. In Luwero and Kayunga, production is estimated at 12,000 acres on 2,500 smallholdings.

Worth at least $35 million per year in exports[44], the horticultural sector – including flowers, plant cuttings, fresh fruits and vegetables, vanilla, cocoa, and papain – has high potential for increased productivity, especially with better irrigation, implementation of value-adding processes, and better farmer connectivity and linkages to markets. Total horticultural exports could rapidly scale up to a value of over $90 million if these type of solutions are implemented.[45]

Prices for fruits and vegetables vary by season. Farmers irrigating their crops benefit not only from increased yields but also from extending their growing seasons into periods during which they can sell their produce for more. Prices for fresh vegetables are prone to increase in the dry season, when rain-fed farms are unable to produce enough to meet urban demand.

Sector organization

The vast majority of fruit and vegetable production is consumed locally and sold at markets close to the farms where it was grown. Though informal market organization of the sector is occurring, there is still little formal structure. Some private companies have signed production agreements with fruit-farming organizations (e.g. buyers of dried pineapples and mangoes).

Given the relatively small volume of fruit and vegetable exports (170 exporters, 8,000 farmers[46]), horticulture is not as well organized as other sectors (e.g. coffee). The Horticultural Exporters Association of Uganda (Hortexa) is a small organization that represents exporters.

Energy use and potential for PULSE applications in horticulture

Most horticultural players are off-grid, with very little energy input. Farmers typically manage very small plots (less than 1 acre) and use manual systems (watering cans) to water their crops. Larger farms and cooperatives increasingly use petrol- or diesel-powered irrigation systems (sprinklers, drip) to better manage production during dry periods.

Processes with a high potential to increase productivity of farms include:

- Irrigation of high-value horticultural crops
- Cooling of high-value fruits and vegetables
- Drying of fruit (e.g. pineapple, mango, pawpaw, banana)
- Production of fruit juice and pulping of products

Irrigation

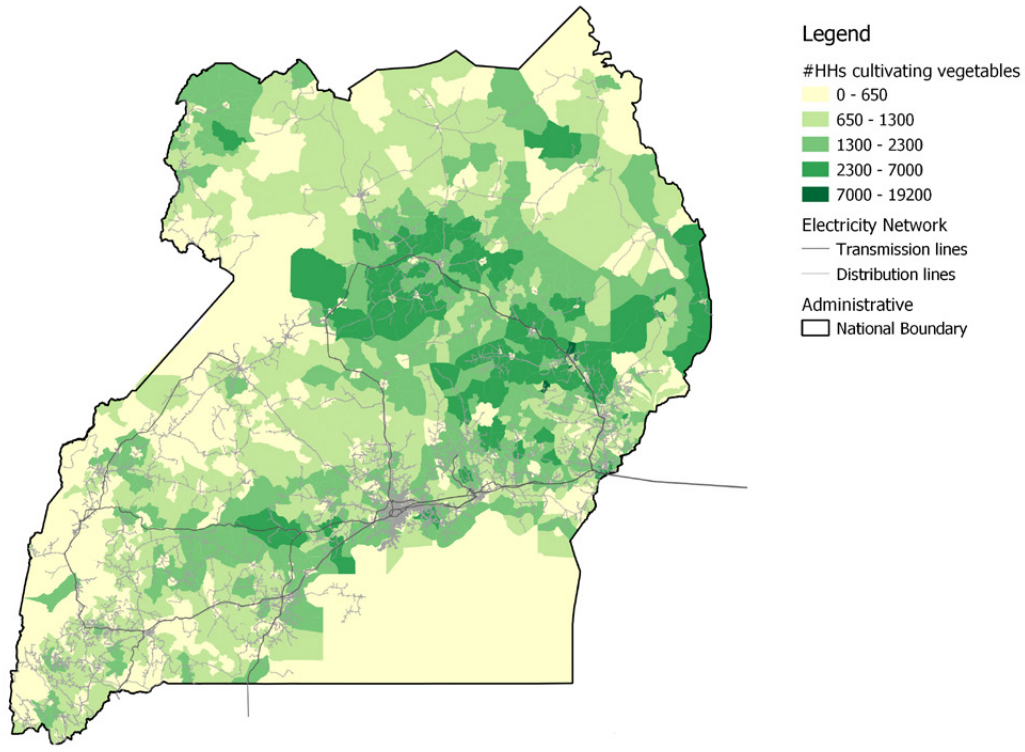
For vegetable crops (tomatoes, onions, leafy vegetables), drip and sprinkler irrigation systems would have an approximate power demand of between 0.2 and 0.4 kW per acre. Farmers would typically use irrigation systems in the dry season as a supplementary water source, irrigating once a week for up to five months. A 1-acre plot might need 100 hours of irrigation, or some 20–40 kWh per acre per week.

44 ICTSD, 2010. Horticulture Production and Biodiversity in Uganda.

45 World Bank, 2004. "Uganda Hortifloriculture Development Study."

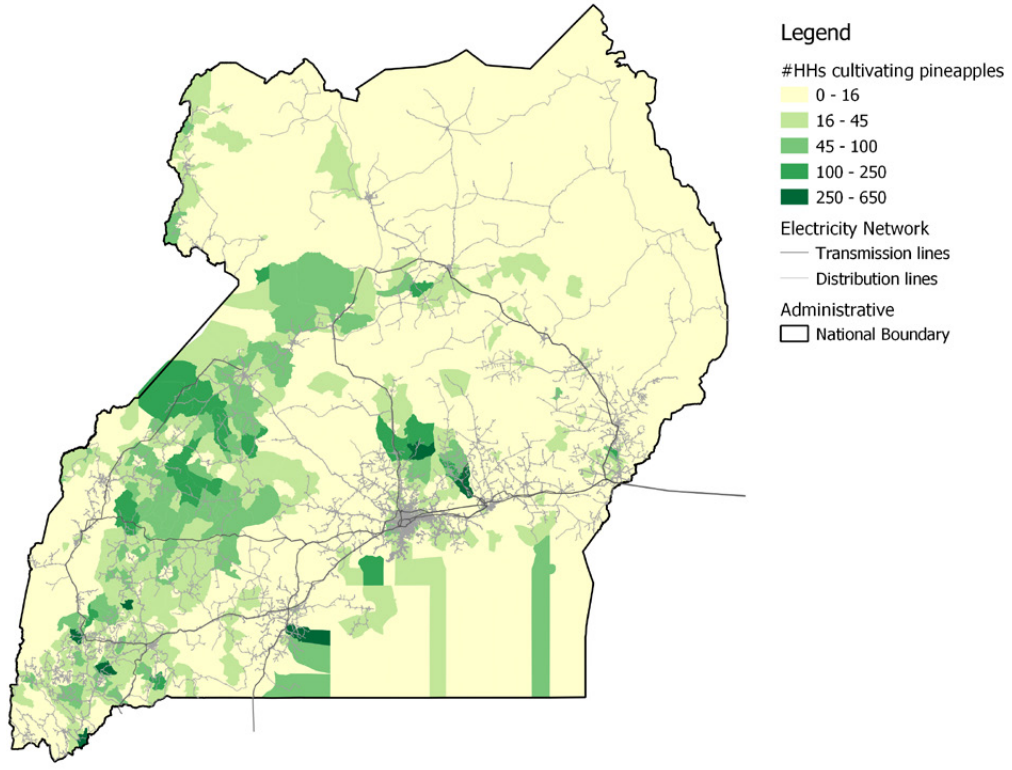
46 This may include flower farmers. See article from FarmBizAfrica on Uganda's horticultural exports.

Figure 10: Geographic distribution of vegetable farmers vs electricity grid



Source: UBOS, data collected during 2014 census; Energy Sector GIS Working Group Uganda.

Figure 11: Geographic distribution of pineapple farmers vs electricity grid



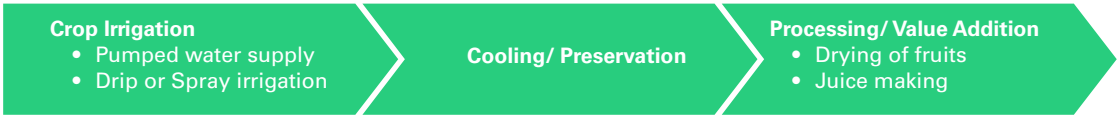
Source: UBOS, data collected during 2014 census; Energy Sector GIS Working Group Uganda.

Emerging experiences with irrigation pumps on smallholder mixed farming plots in Uganda (and Kenya) are demonstrating that an investment in an over-the-counter $750 solar pump can repay the investment in less than one year.[47]

A recent study on the use and benefits of SWPs in East Africa[48] (see Box 1) highlights that the impact of irrigation is maximized in horticulture by:

- making it possible to grow fruits and vegetables during the dry season, allowing for more than three crop cycles per year;
- farmers achieving higher market prices for fruits and vegetables produced during the dry season; and
- smallholder farmers get more opportunities.

Figure 12: Productive uses of electricity in horticulture value chain

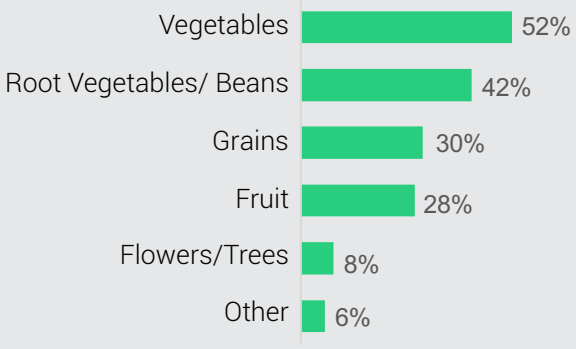


Box 1: SWP user profile and impacts

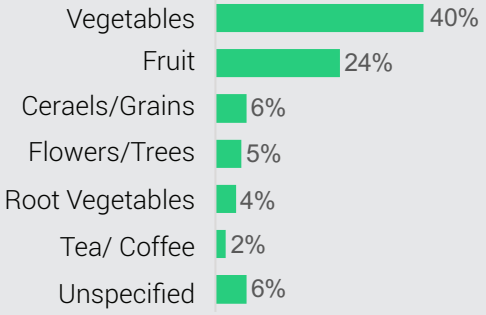
A recent publication by the Energy for Access Coalition presents the results of surveys of SWP users in Kenya, Uganda, and Tanzania, providing insights into the profile of customers and impacts of the technology. Some of the valuable insights include:

- Most SWP users have higher incomes relative to the average off-grid consumer. One explanation for the income gap relates to the SWP market being nascent. Existing consumers are likely innovators and early adopters who have a relatively high appetite for risk, and more disposable income.
- Ninety-two percent of SWP customers farmed crops. On average, each user had a farming area of approximately 5.2 acres, of which he/she irrigated 1.6 acres. Those who kept animals had an average of 22 head, kept on 1.5 acres.
- Top previous irrigation methods (i.e. before investing in a SWP) were manual use of buckets or watering cans (47 percent) and pumps powered by fuel or generator (43 percent).
- Vegetables and pulses were farmed most frequently. Among vegetables, tomatoes (20 percent of farmers), spinach/kale (16 percent), and cabbage (10 percent) were the most frequently farmed. Among root vegetables and pulses, beans (19 percent of farmers), potatoes and gourds (12 percent) and onions (8 percent) were the top choices.

Most commonly farmed crops



Most commonly irrigated crops



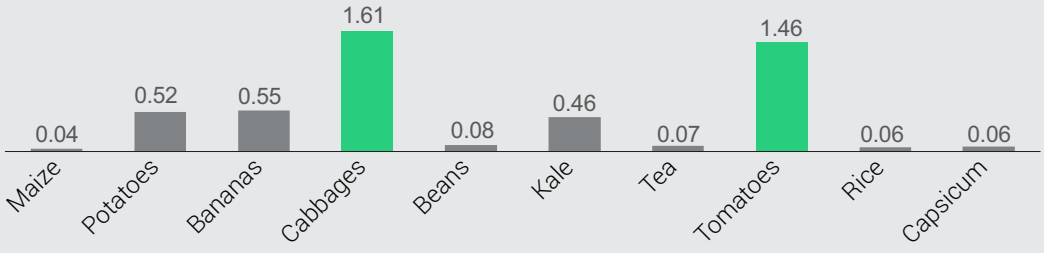
47 Lighting Global, 2019. "The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa."

48 Energy for Access Coalition, 2019. "Use and Benefits of Solar Water Pumps."

- Most SWP customers reported increases in their productivity, most often mentioning increased yields and a lack of seasonality in their produce as the drivers behind the change.
- There is growing evidence that the impact of irrigation is maximized in horticulture because of higher market prices and short cultivation cycles, among other factors.
- Increased yields and water requirements are also important factors. Lighting Global's report, "The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa"[49] presents some insights about this (see chart below). The relationship between yield uplift from irrigation and water requirements is highest for some of the most commonly grown horticultural products (tomatoes and cabbages – highlighted). The analysis below excludes market prices, which are also an important element in the equation and may explain why beans, kale, and capsicum are also frequently irrigated despite their lower yield uplift per unit of water requirement.

Yield uplift vs water requirement

(percentage yield uplift vs water requirement in cubic meters per ton of output – based on data for Kenya)



- Half of the customers interviewed identified specific challenges they had experienced with their SWP, mostly equipment breakdown or malfunction.
- However, overall, customers are relatively satisfied with their SWP. Satisfied customers talked about time savings, decreased intensive physical labor, and cost efficiencies in comparison to their previous irrigation method.

Source: Energy for Access Coalition, 2019 "Use and Benefits of Solar Water Pumps"; Lighting Global, ESMAP and Dalberg, 2019 "The Market Opportunity for PULSE in Sub-Saharan Africa".

Value addition for fruit products

Harvests of fruit, especially mango, typically result in high losses because the fruits rot before they can be sold. To overcome this, fruits – and some vegetables – can be converted to juice or dried and packaged.

- **Drying of fruits** has been carried out by partnerships between rural cooperatives and dry-fruit exporters in Uganda for over a decade. Simple indirect or direct solar thermal driers are used, sometimes with small (100 Wp) solar electric fans for forced convection. For example, Fruits of the Nile – a fruit export business – has promoted solar drying among their ~700 farmers of fair trade organic sun-dried pineapple and banana in southern and central Uganda.[50] Fruits of the Nile grades and packs all fruit for export at its factory in Njeru.
- **Production of fruit juice.** In East Africa, most juice production is undertaken by large players in grid-connected plants with sophisticated pulpers, pasteurizers, mixing tanks, and cooling tanks. The energy intensity of such processes is about 300 to 500 Wh per liter of juice produced. However, juice-making activities can be carried out profitably in restaurants or retail shops at much smaller scales with lower energy intensity and simpler equipment.

49 Lighting Global, 2019. The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa.

50 For more information, see the website of Tropical Wholefoods (Fruits of the Nile).

Cold storage of high-value crops

Perishable vegetable products such as French beans and sweet peas often need to be kept in cold stores before transportation to market. In Kenya, horticultural buyers maintain coolers fairly near farms so that exportable produce is kept at non-perishable temperatures.

Walk-in cold stores – typically around 10 cubic meters – use compressors running at about 3–4 hp (approx. 2.2–3 kW). Running 24 hours a day for five months, they use around 11 MWh per year. Typically, this type of cold storage is not viable for smallholders. However, cooperative investment or businesses could aggregate demand for these services.

2.1.4 Other crops with limited potential for PULSE

Table 3 presents other types of crops that are widely produced in Uganda but not covered in detail in this report. The main reason for omitting these value chains is that high-level research suggests that they present limited opportunities for PULSE applications (in irrigation and other types of processing).

Table 3: Other crops with limited potential for PULSE

Crop	Prevalence	Potential role of PULSE
Sugarcane	Uganda is the largest producer of granular brown sugar in the East African Community.	• **Irrigation.** Sugarcane is typically grown on commercial estates rather than the small-scale operations suited for PULSE. As a water-intensive crop, surface irrigation methods not requiring water pumps are most common. • **Processing** of sugar is mostly done at a large scale. Sugar factories typically generate their own power from bagasse. There is little potential for PULSE.
Cotton	Major export crop grown in many parts of the country (West Nile sub-region, Jinja, and Northern Region) which raises considerable foreign currency. The crop is grown in large plantations or with out-grower schemes[51].	• **Processing.** It is virtually all processed in large grid-connected ginneries. There is little potential for small-scale ginneries powered by PULSE. • **Irrigation.** Potential use of PULSE for irrigation of small-scale cotton farms is of interest to increase acreage of smallholders and to reduce dependence on rain.
Tobacco	Significant export crop grown in many parts of the country (east, south-west) by out-growers.	• **Curing and processing.** Tobacco is cured in large facilities that maintain carefully controlled atmospheric conditions and is then made into cigarettes in centralized grid-connected factories. Most facilities are grid-connected but there is some limited potential to use PULSE for off-grid ventilation of curing. • **Irrigation.** Potential use of PULSE for irrigation of small-scale tobacco farms is of interest to reduce dependence on rain.
Upland rice	Increasingly important export and food crop grown in many parts of the country. Grown by large and small players; requires energy-intensive milling.	• **Processing.** Like maize, rice is milled by specialized machines that utilize several processes (threshing, polishing, packaging). Milling machines are grid-connected or diesel-powered. With existing technology, there is little potential for small-scale PULSE for rice milling. • **Irrigation.** Potential use of PULSE for irrigation of small-scale farms is of interest to reduce their dependence on rain, if no other source of water is available.
Sunflower	Significant food crop grown in many parts of the country.	• **Processing.** Milling machines for sunflower must thresh, crush seeds, extract oil, and create sunflower cakes. Machinery available for sunflower is specialized and mostly designed to be grid-connected or grid-powered. There is little potential for PULSE. • **Irrigation.** Potential use of PULSE for irrigation of small-scale sunflowers farms is of interest to reduce their dependence on rain.

51 Out-grower schemes, also known as contract farming, are broadly defined as binding arrangements through which a firm ensures its supply of agricultural products by individual or groups of farmers.

2.1.5 Livestock and poultry[52]

Current production levels and growth potential

The Agriculture Sector Strategic Plan (2015/16–2019/20) targets beef and chicken as priority commodities for development and supports policies to build the sector.

Cattle are the most important source of meat in the country, with production estimated at over 200 MT per annum. Predominately indigenous varieties of cattle are raised, with the majority on smallholder farms. About one-quarter of the total Ugandan population depend partly or entirely on cattle for their livelihoods. In particular, over 8.5 million people (1.7 million households) live in households keeping cattle and producing some beef. Table 4 provides a summary of the sector.

Table 4: Types of cattle-production

Production system	Number of HH owning cattle	Description of system	Potential energy investments
Ranching	Not available (fewer than 1,400 farms)	500–3,000 cattle per holding in fenced enclosures or paddocks. Major product is beef, with milk as by-product. (10% of national herd, but low number of farms). The ranching sub-sector only employs few people, precise figures are not available. This production system is prevalent in the Kigezi, Ankole, Central 1 and Central 2 sub-regions[53].	Investments mostly large-scale and related to meat production Water pumping Chilling Abattoirs
Pastoral	0.5 million	Free grazing system. 5–100 indigenous cattle per household moved through open areas in search of pasture. Products are beef, milk, blood, and hides Relatively low investment. Average income per head of cattle: $41/year. 19% of the income of pastoral households comes from cattle. This system is prevalent in the Karamoja and Teso sub-regions.	Little investment in pastoral systems
Agro-pastoral	1.16 million	Cattle grazed on public and private farms. Beef and milk, hides, manure, and horns; also provide draught power. Small-scale subsistence. Relatively low investment. Average income per head of cattle: $90/year. 12% of the income of agro-pastoral HH comes from cattle. This system is prevalent in the Bukedi, Elgon, Busoga, Central 2, Toro, Bunyoro, West Nile and Acholi sub-region.s	Small-scale nature of sector prevents investment, potential for micro-credit Water supply Feed
Semi-intensive	0.08 million	Zero-grazed cattle kept in confined stalls, provided with water and feed. Significant investments. Milk is most important product. Average income per head of cattle: $129/year. 45% of the income of HH operating semi-intensive production comes from cattle. This system is prevalent in the Central 1, Central 2, Kigezi and Ankole sub-regions.	Intensive nature of operations features numerous investments: Water pumping Biogas Feed production/chaff-cutting Chilling Milking machines

Source: Adapted from FAO ASL2050 National expert consultation, 2017.

52 FAO, 2018. "Livestock and livelihoods spotlight: Uganda: Cattle and poultry sectors."

53 Reference to the 15 sub-regions defined by the Uganda Bureau of Statistics (UBOS) in the National Household Survey 2016/17 on the basis of common socio-demographic characteristics.

Uganda's greatest concentration of livestock is found in the "cattle corridor", which stretches from the south-west of the country through the center to the north-east.

Poultry: Chickens and other poultry are ubiquitous in all parts of Uganda, with 45 million domestic poultry in the country[54]. Over 80 percent are managed in free-range conditions and are indigenous varieties. Chickens supply both meat and eggs for household consumption and sale. About 16.8 million people (3.4 million households) are involved in poultry keeping, which contributes an average of 8 percent of income for those households.

This rapidly growing sector is especially important in peri-urban areas where demand for protein is high and where high profits can be made even from small-scale farms with improved production systems. Table 5 outlines how the sector is organized into three different categories.

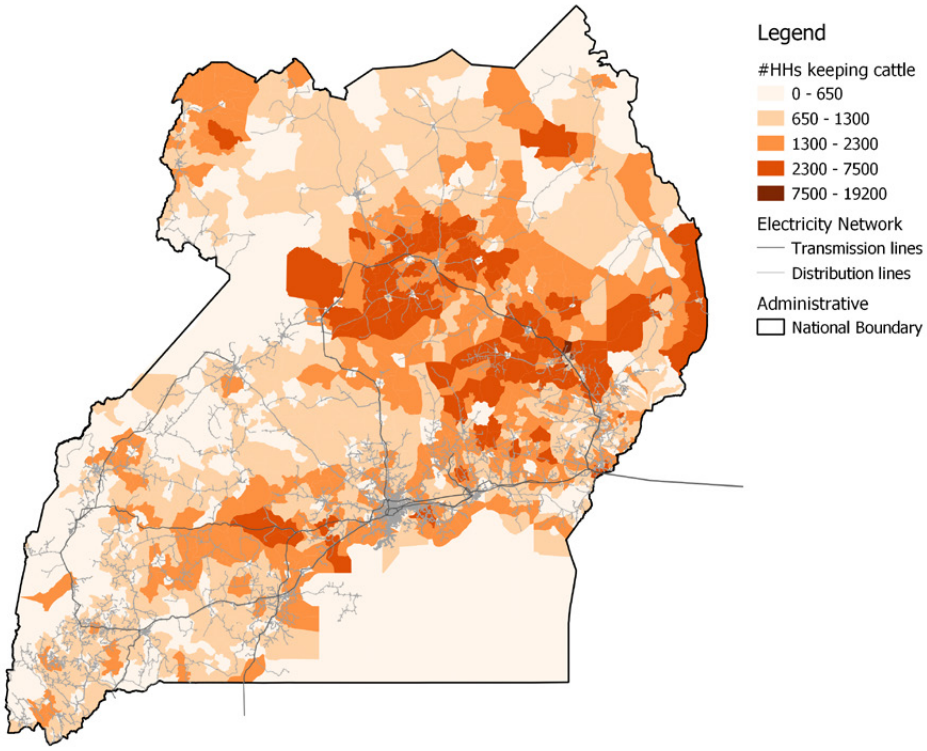
Table 5 Types of poultry production

Production system	Number of HH	Description of system	Potential energy investments
Free-range	2.86 million	Up to 20 indigenous birds that scavenge for food. Eggs and meat production for HH consumption and market sales (egg production 51% of sales value). Rural and peri-urban. This production system is prevalent in the West Nile, Kigezi and Ankole sub-regions. Average annual income: $2 per bird. 7% of HH income from poultry.	There is little investment in subsistence household systems
Semi-intensive	0.46 million	Hundreds of birds, commercially kept for eggs and meat in permanent structures (egg production 49% of value). Located in peri-urban areas. This system is prevalent in the Central 1, Central 2 and Busoga sub-regions. Average annual income: $7 per bird. 11% of HH income from poultry.	Small (and larger-scale) poultry and chick production businesses benefit from: • Water pumps • Heat lamps • Temperature control lighting and ventilation • Chillers
Intensive	0.12 million	Thousands of exotic birds commercially kept for eggs and meat in permanent structures. Sale of birds is main value (82%). Located in peri-urban areas. Prevalent in the Central 1, Central 2 and Busoga sub-regions. Average annual income: $14 per bird. 18% of HH income from poultry.	

Source: FAO ASL2050 National expert consultation, 2017.

54 UBOS, 2014. Statistical abstract.

Figure 13: Geographic distribution of cattle farmers vs electricity grid



Source: UBOS, data collected during 2014 census; Energy Sector GIS Working Group Uganda.

Semi-intensive poultry systems are a key growth sector in Uganda, because:

- There is growing demand for chicken meat in the country; and
- Small-scale poultry farms require relatively little investment to set up.

Sales of day-old chicks is a low-input business that is often carried out by off-grid smallholders in rural areas. In East Africa, and especially Kenya, off-grid egg incubators are a key productive use application targeted by solar energy companies.

Sector organization

Beef and poultry production is largely carried out by smallholders. The beef sector is not well organized (though dairy production is better organized), and most beef is consumed in households or sold to local abattoirs. The poultry sector is even less organized, as most participants are subsistence farmers or small-scale players.

The Meat Producers Cooperative Union facilitates dialogue between larger private-sector players and the public sector. Established in 2008 with support from MAAIF, it provides a voice for 2,600 beef farmers (mostly ranchers), working to enhance beef production, productivity, and quality assurance.

Quality standards are overseen by MAAIF and the UNBS. Various NGOs and cooperatives work with farmer and pastoralist groups to build their linkage to markets and provide technical support.

About **16.8 million people (3.4 million households)** are involved in poultry keeping, which contributes an average of **8%** of income for those households.

Energy use and potential for PULSE applications in the poultry sector

Energy production needs for cattle-raising are explained in subsection 2.1.6 (Dairy), as milk represents the main output of the agro-pastoral and semi-intensive cattle keepers, which constitute the most interesting groups for off-grid energy products.

Energy supply for poultry production is primarily demanded by semi-intensive and intensive players, though the latter are often able to connect to the grid. Energy demand is focused on:

- Supply of drinking water for poultry
- Heat production, lighting, and ventilation for egg-laying, incubation, and chicken coops, and
- Chilling and preservation of poultry meat and egg products.

Water supply

In general, drinking water supply for poultry production operations would be considered together with other power needs (e.g. incubation) and other parts of small-farm operations. Laying hens require about 0.5 liters of water per day. Growing meat chickens may require as much as one liter per day. Therefore,

- Semi-intensive chicken operations would require hundreds of liters of water per day, and
- Intensive operations would typically require thousands of liters per day.

Provided that water is easily accessible, at surface or low water-table depth, water pumps for such operations would require relatively small power systems – less than 1 kW of solar power – but the energy would have to be available on a consistent basis.

Power for chicken coops and egg incubation

Egg incubation and the raising of chicks can be done as small-scale businesses and are, thus, of particular interest to small players. The energy needs of chicken coops and egg incubation are for heat lamps, lighting, and temperature control, but they are relatively scalable according to the size of production (semi-intensive or intensive).

- In semi-intensive operations a 200-Wp solar energy system provides enough power for incubation operations of more than 100 chicks.
- An intensive 1,000-bird egg-laying business in a temperature-controlled hen house requires around 8 to 10 kWh per day to power egg incubation, ventilation, and lighting.

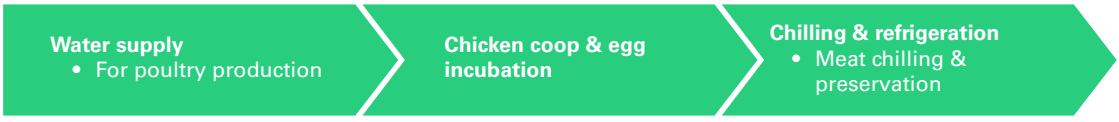
Chilling

As with chicken coops and egg incubation, power requirements for chilling vary greatly depending on the scale of the business, and intensive operations are more energy intensive. In general, however, egg-laying businesses require much less energy for chilling than meat operations.

Small-scale semi-intensive off-grid operations are likely to be mixed with other productive activities, such as dairy and crops, and would be able to use off-grid power systems for a variety of purposes.

- Semi-intensive operations in off-grid farms with mixed activities would be likely to use super-efficient refrigerators with capacity between 50 and 100 liters.
- An intensive 1,000-bird meat production business would require chiller space for 50 to 100 chickens per day, i.e. 200 to 500 liters of capacity.

Figure 14 Productive uses of electricity in poultry value chain



2.1.6 Dairy

Current production levels and growth potential

Dairy production is a fast-growing industry that makes up well over 4 percent of Uganda's GDP[55]. Annual milk output has grown steadily from 1.8 billion liters per year in 2012 to 2.2 billion in 2016 to 2.4 billion in 2018. Exports currently bring in over $100 million per year.[56]

Sixty percent of rural households in Uganda keep cattle, with an estimated 700,000 people participating in the dairy value chain. The national cattle herd was over 11 million head in 2008,[57] and small-scale farmers accounted for about 90 percent of cattle-rearing. With increased production has come sustained increases in milk consumption, with average national per capita consumption of 62 liters per year in 2017.

Development of the dairy value chain has led to employment creation and income generation not only for dairy-farming households, but also for farm input dealers, feed providers, dairy equipment dealers, and makers of value-adding products.

Nevertheless, there is ample potential for rural players to gain a greater share of their outputs. In 2018, only 20–30 percent[58] of milk output was processed on the farm and most milk is marketed "raw" to milk-processing companies.

Uganda has about 100 operational milk-processing companies (large-, medium-, and small-scale) with a total installed processing capacity of about 2.7 million liters per day.[59] With the growth of the dairy industry the opportunity for the manufacture of higher-value products has grown, including milk powder, ultra-heat treated (UHT) milk, yogurt, butter, ice cream, cheese, ghee, and casein. Though most of these opportunities are taken up by urban industries, mid-sized farms can significantly increase their income with small-scale production of such higher-value products.

Dairy sector organization

The industry is governed by the Dairy Industry Act of 1998, which created the industry's regulator, the Dairy Development Authority, an autonomous government organization. The National Dairy Corporation, a virtual monopoly, was privatized in 2006, creating room for other players to enter the market. Hundreds of cooperative societies work with dairy farmers throughout the country. The number of milk processors has grown from five in 2003 to about 100 today.

Dairy farming is a major activity in the Central, Kigezi, Ankole, Teso and Karamoja sub-regions.

Energy use and potential for PULSE applications in the dairy sector

A large majority of dairy operators are small-scale, possessing 5 to 50 head of dairy cattle. Most small-scale players are un-mechanized and deliver their daily milk output to nearby milk collection centers and processers that have chilling facilities.

Large private companies and cooperatives have set up chillers and processing plants in milk-producing areas. There are about 500 milk collection centers equipped with chillers in the country. For example, the Uganda Crane Creameries Cooperative Union (UCCCU), the biggest dairy cooperative in Uganda, owns a cold chain of 100 chillers in the proximity to farmers, most of them off grid.

Most small-scale farmers sell their product to these milk collection centers, either private- or cooperative-owned, who are able to chill it immediately upon milking and store it for later distribution and marketing. Some small-scale farmers invest in equipment for their dairy operations. For example, in a field visit to three dairy farms, organized by the Dairy Farmers Network (DAFAN) during the fieldwork for this report, the farmers had invested in biogas digesters, chaff cutters (for fodder production), water pumps, and small chillers. While many of these were running on fuel, a conversion to solar energy could be envisaged.

55 World Bank, 2018.

56 Halima Abdallah. "Uganda Dairy Sector Performing Below Full Potential." The East African (Nairobi), June 19, 2019.

57 The most recent full count.

58 NRECA, 2018. Productive Uses of Electricity Program Initiative.

59 Statements attributed to the Uganda Dairy Development Authority in article by Samson Okwakol, "Milk production in Uganda hits 2.08 billion litres" (EABW News, Kampala, 25 June 2018). Figures vary, however. According to Jonathan Adengo and Mark Keith Muhumuza in "Firms scale up investment in milk processing" (Daily Monitor, Kampala, 2 August 2017), it is 1.4 million liters per day.

Potential PULSE products in dairy farms include:

- Pumps for water supply, for cattle watering and irrigation of feed
- Chaff cutters for preparation of feed
- Milking machines
- Milk chillers: These range from very small on-farm refrigerators to cooperative-scale units that can chill thousands of liters
- Processing equipment to enable production of value-added products

Milk chillers and refrigerators

Two types of chillers and refrigerators would make sense for Ugandan dairy players. They are:

- Small chillers to enable short-term storage of milk (50- to 200-liter units). Such refrigerators would enable farmers to store evening milk for single delivery/pick-up, and to store other farm products and value-added products such as meat, poultry, and yogurt.
- Medium-sized chillers with 1,000- to 10,000-liter capacity for larger farms or cooperative groups to enable longer-term storage and possibly added capacity to store milk so that it can be converted into batches of value-added products. Such chillers would have to be designed to maintain large volumes of milk at a carefully controlled temperature (4° C).

Chaff cutters

Chaff cutters are found on farms with more than a few head of cattle. They chop grass and other organic feeds into a form that can be easily stored and fed to cattle in troughs. In medium-sized farms (four to eight cows), chaff cutters are operated for a few hours per day.

In East Africa common chaff cutters are assembled in workshops or imported from China and India. Typically, their motors are 10–15 kVA and turn blades using belts. Solar-powered chaff cutters are not yet readily available on the market, though operating a motor from a stand-alone solar system with batteries would be viable in principle.

Water supply pumps

Mixed-use small farms with small herds of dairy cows (up to four head) require water both for the cattle and for growing feedstock. Additionally, such farms will typically grow staples, horticultural outputs, or some type of cash crop (e.g. coffee) that also require water. Dairy farms with a larger number of cattle often have a small petrol- or diesel-powered pump to move water from the source to the cattle pens. Cows require a minimum of 60 liters of water each, per day, and the size of any required pump would depend on the dynamic head count and the pumping distance.

Milking machines

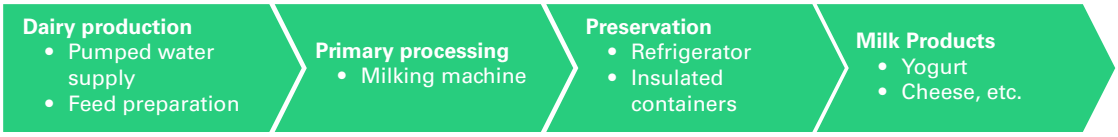
Milking machines significantly reduce the amount of manual work for farmers. Dairy farmers interviewed during field visits all mentioned that they had seen small portable milk machines in use on regional farms, and that obtaining such machines was a "high priority."

The smallest milking machines, powered by electric motors, use 0.5 kW and can milk 10 cows per hour. Purpose-designed solar-powered machines have not yet appeared on the market, but small portable electric machines could feasibly be powered by solar PV.

Value-added product machines

Value-added products include milk powder, UHT milk, pasteurized milk, yogurt[60], butter, ice cream, cheese, ghee, and casein. Processes involved in making these products include heating/pasteurization, mixing/agitation, chilling, and packing. Although most actors involved in value-added products are on-grid and relatively large-scale, there are examples of artisanal and women's groups engaging in the

Figure 15: Productive uses of electricity in dairy value chain



60 See the business case for yogurt in NRECA, 2018 "Productive Uses of Electricity Program Initiative."

production of cheese and yogurt.[61] Although solar PV is not suited for heating, it can be scaled to meet the chilling and mixing needs of small-scale production.

2.1.7 Fishing[62]

Current production levels and growth potential

About 1.1 percent of Uganda's GDP[63] is based on fishing from five inland lakes (Victoria, Kyoga, Albert, Edward, and George). Lake Victoria contributes over half of the annual catch. The total fish catch in 2018 was 543,000 tons,[64] with three species making up most of the catch: Nile perch, tilapia, and mukene (mukene is traded in the immediate Great Lakes region). Fish are traded locally, in regional markets, and exported; the most important market is the European Union (EU).

The fishing industry is Uganda's second-largest foreign exchange earner after coffee, contributing to the livelihoods of about 1.5 million people. The annual value of exports in 2013 totaled $126 million.

In the mid-2000s, national fish yields began to slow due to overfishing, capture of immature fish, and pollution. Government measures to protect the lakes have helped their recovery. Although the government has encouraged diversification into aquaculture fisheries, fish-farming from constructed ponds is still relatively undeveloped (104,000 tons in 2018).

Generally, fish product is delivered from boats and sold to traders at landing sites on lake shores or islands. As shown in Figure 16, about 30 percent of fish is purchased by intermediaries that process the frozen product for export. Seventy percent is sold into domestic and regional markets. The fishery industry has created a variety of jobs, especially in the processing industries and trade sectors. Landing sites, especially on the islands of Lake Victoria, tend to be unelectrified and lacking basic infrastructure and services. Refrigerated vehicles (with ice) travel to sites to collect fish products on the islands and deliver them to processors.

Post-harvest fish losses are as high as 35 percent. Common causes of loss are related to inadequate handling and processing methods – particularly poor access to energy and non-availability of water, ice, and cooling services on the islands. Fish spoils quickly in high ambient temperatures while awaiting pick-up.

Fish exports to EU markets have, in the past, been stopped due to salmonella contamination of fish product and the inability of landing sites to meet minimum EU quality and safety requirements. Efforts to bring storage and processing facilities – which require electricity – closer to fishing communities are therefore prioritized and supported by the government.

Sector organization

Virtually all fishing activities are small-scale and carried out by single boats owned by families or businesses. The lack of industrial or larger fishing boat operations, is the result of a deliberate policy by government to sustain communities of fishermen whose livelihoods depend on the lakes.

The Association of Fishers and Lake Users of Uganda (AFALU) represents fishers with the mission of "Promoting fishing and presenting it as a living and a coherent development activity in Uganda, as well as encouraging the attitude of positive change among fishers." Quality and standards of fishing output are managed by the Department of Fisheries Resources and the UNBS.

Energy use and potential for PULSE applications in fishing

Lack of access to energy in the delivery and marketing stages of the value chain results in delayed delivery of fish to customers and spoilage of a considerable proportion of product. Off-grid electricity could significantly improve cash incomes for fishing communities.[65]

61 A women's group, a member of DAFAN, made yogurt for urban markets using manual labour, biogas, and solar chillers. The product was unsuccessful because of a "lack of market" in Kampala.

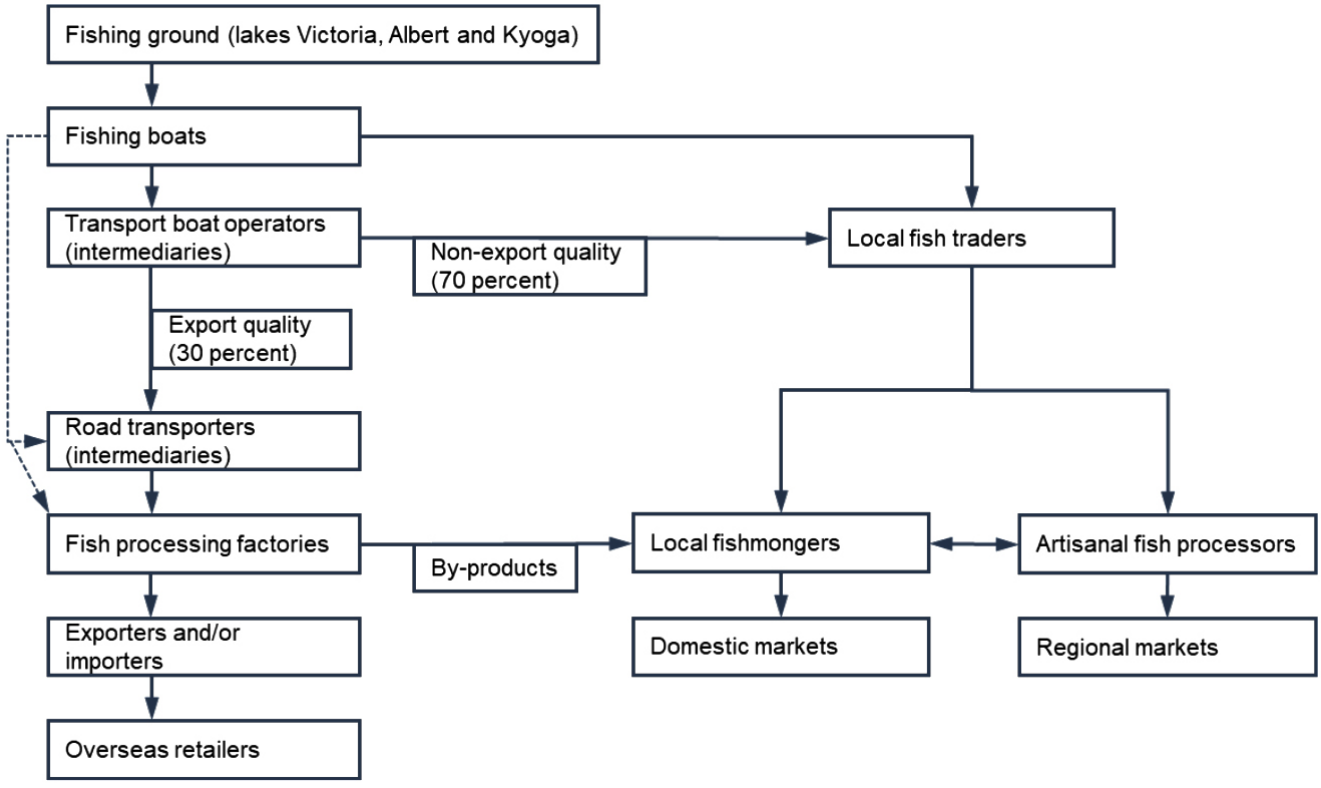
62 Much of the information in this section is taken from "Fishery Exports and the Economic Development of LCDs" (UNCTAD, 2017).

63 FY 2017/18. World Bank. Others estimate the value at closer to 3 percent.

64 FAO Fishery and Aquaculture Country Profiles: Uganda

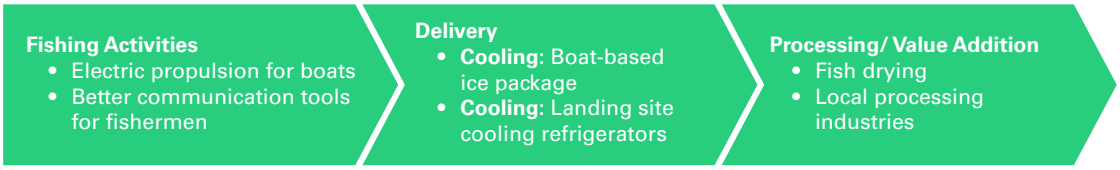
65 Fish preservation is an important local industry. It uses a variety of simple technologies including solar drying, oven drying, and smoking. It is not considered in this section because solar PV electricity is not competitive as a source for heat for the traditional drying methods currently in use.

Figure 16 Overview of fishing value chain and participants



Source: World Bank, 2006.

Figure 17: Productive uses of electricity in fishing value chain



Off-grid energy could potentially power:

- Fishing activities, such as electric propulsion for boats
- Cooling of fish, through the production of ice for short-term storage of fish catches and refrigerators at landing sites
- Fish processing

Electric propulsion

Fishers typically spend around $20 to $40 per day to power 5–10-kW diesel or petrol engines on fishing boats. Battery-powered electric motors have considerable potential to replace petrol- or diesel-powered boats, and pilot projects are already underway on Lake Victoria to field-test electric motors.[66] Batteries could be charged in solar-powered charging stations. Given the rapid development of electric batteries and transport, electric propulsion of fishing boats is something that should be regularly re-evaluated.

Ice for short-term storage

Availability of cooling equipment can enable fishermen to preserve their daily catch and increase their marketing opportunity window. Although individual refrigerators are probably too big an investment, ice packs delivered to fishermen on boats and carried in cooling chests could provide a cost-effective way for fishermen to preserve their catch on the boat and/or transport it to a better sales location. Ice-making at a commercial scale to supply dozens of boats would require an investment in stand-alone solar arrays (with batteries) in the order of 5–10 kW in size.

Local fish processing

Processing, packaging, freezing, and production of fish by-products (e.g. fish meal) for export or distribution to local markets is normally carried out in urban areas with access to relatively low-cost electricity. Though there are benefits of local production on site, setting up processing facilities involves a variety of equipment including ice-makers, chillers, processing buildings, transport, and cutting tools.

The fishing industry is Uganda's second-largest foreign exchange earner after coffee, contributing to the livelihoods of about **1.5 million people.** The annual value of exports in 2013 totaled **$126 million.**

Powering an operation of sufficient size to generate a return would likely require well over 50 kW of continuous power. Setting up this equipment in an off-grid location would need to have a strong return in order to justify such a level of investment, or be part of a planned investment in a fishing community. For example, Equatorial Power has set-up a "mini-industrial park" powered by solar-hybrid mini-grid on Lolwe Island on Lake Victoria, which includes ice-making and basic processing facilities.[67]

2.1.8 Commerce and connectivity

Current economic activity and growth potential

Connectivity

As in the whole of East Africa, mobile voice and data services drive Uganda's telecommunications market. Mobile networks carry most voice traffic and account for most internet connections. Investment in cellular infrastructure is dramatically expanding the reach of mobile broadband services. This has led to a range of social benefits, including the ability for individuals to make use of banking and m-commerce services.[68]

- **Mobile phone.** There are almost 25 million users of mobile phones in Ugandan (almost 70 percent of the population). Smartphone ownership is growing fast, largely because of decreases in price and increased demand for internet services.
- **Internet.** In June 2018, penetration rates for internet use in Uganda stood at 47.4 percent (18.5 million users).[69] Rural take-up of internet apps for business and social media (e.g. WhatsApp, Facebook) is also increasing rapidly.

66 Heartbeat Investments' blog. "Electric boats for African fishermen."

67 Information from Equatorial Power's website on their Lolwe Island project.

68 BuddeComm, 2018. "Uganda – Mobile Infrastructure, Operators and Broadband – Statistics and Analyses."

69 Following the introduction of a new tax on internet use, the number of users dropped to 13.5 million (35 percent) later in 2018.

Connectivity (i.e. mobile phones and internet) cuts across all value chains and drives income and opportunity growth in agriculture, tourism, commerce, fishing, and other sectors. For example:

- Fishing communities can link directly with sales outlets and restaurants using phone and internet connections.[70]
- Farmers can check prices for commodities and make informed decisions on where to sell their harvests.
- Small-scale regional tourism operators can build strong linkages with clients, decreasing reliance on hotel chains.
- Businesses can build their reputation, target consumers, and market products directly over the internet.

Although statistics are not available for rural/urban and on-/off-grid breakdowns of mobile phone and internet use, the penetration of both is much higher than the country's electrification rate of 27 percent[71], suggesting significant adoption of mobile phones and internet in off-grid areas.

Commerce

There were well over 500,000 SMEs in Uganda in 2010,[72] employing 1.1 million people. Seventy percent of these businesses were outside Kampala in peri-urban and rural areas, with 61 percent engaged in trade and 14 percent in hotels and food services. Typical businesses are small – 90 percent have fewer than four employees – and engaged in trade or services with annual turnover of less than UGX 5 million ($1,350) per year. In 2010 over 95 percent of businesses did not have a computer and only 3 percent used the internet for business operations. This trend is now changing, driven by the expanded use of smartphones and cellular networks.

Small-scale businesses in off-grid rural areas that have particular promise to increase production with off-grid electricity include:

- Food processing
- Tailoring
- Carpentry, electrical, or automotive repair
- Hospitality
- Transport – bicycles and boda (bicycle and motorcycle taxis)

NB: Solar energy sales and installation is also prioritized as a business by the Ugandan government.

Sector organization

Businesses are generally small scale and family-run. They have limited access to credit and tend not to have associations that represent them directly.

The Uganda Small Scale Industries Association (USSIA)[73] is a not-for-profit business association of micro, small, and medium industries (MSMIs) with a registered membership of about 5,000.

Energy use and the potential for PULSE applications

Relatively small amounts of electricity in connectivity and commerce applications can enable small businesses to gain significant incomes. In East Africa, the charging of cell phones using solar PV systems is worth tens of millions of dollars in revenue for off-grid businesses. M-Kopa, a PAYG solar energy provider, calculates that in 2018 more than 140,000 of its customers directly generated income through small businesses.[74]

70 Coastal fishermen in Kenya sell high-value fish directly to restaurants in Nairobi using smartphone communication.

71 Statistics available for 2016 at the Sustainable Energy for All Africa Hub.

72 UBOS, 2011. "Report on the Census of Business Establishments, 2010/11."

73 Information from the website of Uganda Small Scale Industries Association (USSIA).

74 For example, local phone-charging services, hosting movie screenings, barbershops, and using solar lighting in businesses. See O'Brien Kimani, "M-Kopa advances Ksh 23B in credit to customers in eight years." KBC, October 9, 2019.

Many of the small-scale commerce and connectivity applications have developed spontaneously on their own. In particular, solar-powered phone charging, video cinemas, and barbershops are extremely common in rural off-grid towns. Use of other applications is developing more slowly, partly because DC appliances are more expensive and sometimes difficult to source.

These opportunities may be best developed by local companies, possibly in partnership with international equipment suppliers or impact investors. Local players are better placed to develop suites of opportunities because:

- The applications are too small, dispersed, and niche for international players which focus on single products and hardware;
- Local players are closer to the market, understand specific opportunities better, and are in a position to stimulate demand; and
- They can better work with and cluster the end-user groups that may help to drive demand.

In the analysis below, small-scale developing opportunities are presented. These opportunities do not include a single application but instead show how "suites" of two or more applications can enhance traffic and productivity at a retail vendor, restaurant, or workshop. Rather than providing opportunity through a single technology– like water pumping and refrigerators – sets of high-impact, low-energy-use equipment can help transform certain microenterprises. The opportunities outlined below are of interest because they are:

- Low investment
- Widely demanded
- Replicable
- Suitable for development of targeted businesses
- Relevant to microfinanciers

Connectivity-related productive uses

Connectivity applications support off-grid information technology and the development of consumer cellular communication networks. Rural consumers are finding ways to make use of the wide array of low-cost devices which process information and facilitate communication. Note that services presented below can be "mixed and matched" and tailored to support specific value chains – such as dairy, maize, and fishing – in a selected geographic area.

Table 6 Connectivity-related productive uses

Application	Opportunity, applications, and scope of development	Solar equipment required
Phone and HH battery charging	Widely established business niche. Potential for players to expand services offered from charging phones to also charging tablets, laptops, and batteries	50—500 W PV systems with batteries and inverters to charge 20–500 phones per day
Office services	Rural people demand printing and office services for household and small business needs, such as printing, photocopying, lamination, and data transfer (music downloads, CD printing).	1–2 kW PV systems to power off-grid office services
Wi-Fi and connectivity	Proliferation of smartphones has reduced demand for internet cafes; whereas Wi-Fi demand is growing rapidly Shop connects mobile devices (e.g. smartphones, laptops, tablets) to Wi-Fi	1–2 kW PV off-grid office/entertainment space. Wi-Fi equipment
Mobile money and banking	Rural banks and mobile money providers require connectivity and electricity for data-based equipment. Banks and mobile money providers are investing in rural rollouts, especially in cash-crop areas	Off-grid PV systems of several kilowatt to provide power to banks in off-grid areas. Smaller systems (under 1 kW) needed for mobile money kiosks

SME and cottage industry applications

This subsection outlines applications that support traders and light industries that are increasingly powered by solar PV in off-grid villages. Efficient low-voltage appliances are increasingly available. This market is developing dynamically due to local and international innovations. Companies such as SoloGrid[75] are seeking to exploit small-scale productive niches like the ones outlined below.

Table 7: SME and cottage industry applications

Application	Opportunity and scope of development	Solar equipment required
Kiosks and shops	Availability of display lights, music, connectivity, fans, and other low-intensity electrical equipment greatly increases traffic and improves flexibility of operating hours and working conditions in small shops	20 W–1 kW solar PV system with battery
Bars and entertainment	Entertainment is a high priority for rural people and low-cost quality options are increasingly demanded. A good entertainment space will have: • Video cinema • Music system • Refrigeration (for cold drinks) • Good lighting and displays	100 W–1 kW solar PV system with battery Wi-Fi or satellite dish system
Barbershops and hair salons	Extremely common low-cost village application found in most off-grid villages. Power required for: • Clippers • Music • Phone charging • Lighting	20–100 W solar PV system with battery
Tailoring	Tailors and seamstresses are ubiquitous in off-grid areas. Manual sewing machines are still more common than electric units. Power required for: • Sewing machine • Cutters/shears • Lighting	100 W–1 kW solar PV system with battery
Electrical workshop and repairs Woodworking shop	Demand for woodworking craftspeople and repair of electrical devices is common in off-grid areas. Most small towns have workshops where technicians are based. Power required for: • Soldering irons • Drills and saws • Woodworking	100 W–1 kW solar PV system with battery Inverter with 240 V power supply

75 For more information, visit SoloGrid's website.

In unelectrified towns, tens of thousands of solar PV systems are placed in front of shops during the day (see photo). Systems are used by shops for SME applications, mostly phone charging, music and PA systems, video cinemas, and small tools, as elaborated below. In virtually every small town in farming areas of Uganda, informal SMEs assemble do-it-yourself systems purchased from over-the-counter players that supply these markets. Direct education of consumers – e.g. shops and farmers – can help them better construct and configure PULSE.

Informal stand-alone solar PV systems used by SMEs in rural Uganda

On the other hand, international companies operating in the formal SHS market – such as M-Kopa, Fenix International, and SolarNow – are increasingly offering appliances as an addition to their SHS. These include TVs, hair clippers, and fridges.

Emerging applications

Several off-grid applications have been identified and are quickly becoming economically viable. However, they are unlikely to develop spontaneously and require investment and technological development to spread into rural areas.

Electric transport is a rapidly developing potential PULSE category that has only recently become viable. Electric-vehicle (EV) and battery-storage technology is mature. The proportion of EVs in global automotive sales is increasing. Rapid take-up is driven by better availability and increasing choice of vehicles from suppliers. This in turn is driven by falling prices for lithium ion batteries and rapidly increasing energy density of EV batteries. Technological innovations will probably be driven by emergent production in Asia.

Electric transport is interesting as an emerging productive use application in Uganda for a number of reasons:

- First, a wide range of vehicles is likely to be electrified in Uganda. There are several categories of transport entry points, including bicycles, boda bodas, tuk tuks, small cars, buses, tractors, drones, and outboard motors. Transport applications will serve all value chains and there are a variety of business models linked to value chains.

- Second, for off-grid PULSE-powered vehicles, system sizes vary considerably and include both small- and large-scale businesses. Systems could be below 1 kW for solar-powered bicycles and as large as 100 kW for boda boda rental businesses. Niches exist for solar charging stations, as well as electric vehicles themselves.

However, solar-powered electric transport is still in the extremely early stages in Uganda and mature products and business models are not yet in place.

Table 8: Emerging applications

Application	Opportunity and scope of development	Solar equipment required
Small-scale food processing and packaging	Value chains for horticulture (fruit and vegetables) and dairy highlight the potential of value-added products such as yogurt, cheese, dried fruit, and juices. Small-scale cottage industry can be facilitated with, for example: • Blenders/mixers • Cutters • Refrigerators	1–5 kW solar PV system with battery Inverter with 240 V power supply
Automotive, metalworking	In small towns metalworking is a growing business, mentioned as important by a number of stakeholders. Although the energy demand is higher for the type of equipment this requires, there may be a niche for equipment that is modestly powered: • Compressors • Spot-welding • Pumps	>5 kW PV off-grid system battery and control applications
Transport	Electric vehicles (tuk-tuks, scooters, and bodabodas) are already beginning to appear in African market[76], which present an opportunity for solar-powered battery-charging stations.	Designed according to application

2.1.9 Telecommunications (off-grid telecom towers)

PULSE equipment used in telecommunications can range from phone charging for individual homes to the powering of off-grid telecom towers. The first category is well covered by lanterns and SHS, which are not the focus of this market assessment.

There are some 3,800 telecom towers in Uganda, of which 27 percent are located in off-grid areas,[77] powered by diesel generators. Solar PV and battery storage therefore present an opportunity to significantly reduce fuel costs. Most telecom towers in Uganda are owned by third-party operatorAmerican Tower Corporation (ATC).

ATC owns about 3,000 sites, of which approximately 1,000 are off-grid. Fuel for off-grid and weak-grid sites is a major component of the operating expenses of telecom tower companies. With the objective of reducing fuel costs, ATC has started converting off-grid sites from diesel to solar PV-diesel hybrids. Assuming an installed capacity of 4 kWp per tower, this represents 4 MWp in total.

While this is a significant market for off-grid solar PV, the involvement of local companies in providing solar PV infrastructure or mobilization of local finance is likely to be limited. ATC and Eaton are large international corporations, likely to procure this kind of infrastructure centrally outside the region, using their own financial resources.

76 Sauti tech article "Ugandan startup Bodawerk converts gas engine bikes to electric ones." February 2019.

77 Matt Edwards, "Why the Eaton deal works for American Tower," TowerXchange, June 20, 2019. ATC completed the acquisition of Eaton towers in January 2020.

2.1.10 Tourism (off-grid hotels)

According to UBOS, Uganda received 1.8 million tourists in 2018, up from 1.4 million in 2017, when they injected about $1.4 billion into the economy. This contributed about 10 percent of GDP and makes the sector a significant foreign currency earner.

There are some 3,800 accommodation facilities throughout Uganda, representing 384,000 beds.[78] About 1,000 of these facilities are located in Kampala, while many of the rest rely on weak-grid and off-grid energy, using diesel gensets as their back-up or main power source. Solar PV systems ranging between 10 and 100 kWp, depending on the number of beds and level of service, could be designed for the specific needs of off-grid tourism resorts. As a recent example, Serena Hotels – a group present in Uganda – recently commissioned a 307-kWp off-grid solar PV system for a 56-room lodge in the Tsavo West National Park in Kenya. There are also examples of solar PV projects in tourism resorts in Uganda – e.g. those installed by local company UltraTec[79] – but these are very few in number.

In contrast to Kenya, however, Uganda's tourism destinations attract lower-end tourism[80], making the number of off-grid lodges and hotels that could potentially afford solar PV comparatively low. According to a report by the Uganda Investment Authority, Uganda has limited "high-end" accommodations along the basic tourist circuit of Murchison, Kibale, Queen Elizabeth, and Bwindi, which together have 400 rooms in the 2-star-plus range.

An interview with the Uganda Hotel Owners Association (UHOA) revealed a number of important challenges for the take-up of solar PV by hotels:

- **High level of indebtedness.** Hotels in Uganda are heavily indebted. They are built with loans, which are difficult to repay due to low margins (high overheads and taxation). Ninety percent of UHOA's membership (of 520 hotels) claims to be in financial distress. In 2016, UHOA had to lobby for a government bailout for the sector.
- **Low level of awareness.** The benefits of solar PV in reducing costs (and potentially increasing revenues if this is complemented by eco-tourism practices) are not well known in the sector. The World Bank program "Energy for Rural Transformation phase II" (ERT-II) (2009–15) promoted solar water heating in the hospitality industry by offering cost-sharing grants, but take-up was low. UHOA notes that application procedures were burdensome but also that there was not enough awareness.
- **Lack of incentives.** Other than the ERT-II cost-sharing grants mentioned above, there has been little support for the sector to take up alternative sources of energy or energy-efficiency measures. Two recent initiatives/prospects were, however, mentioned:
  - The EU-funded "SWITCH Africa Green Program" includes a component to promote sustainability in the tourism sector. Energy audits in hotels are currently being conducted and promoted.
  - The Tourism Act is currently being reviewed to include incentives for energy efficiency and clean energy, such as a tax rebate for accredited resorts.

Despite signs that this sector may be promising for solar PV in the future, given the current status of market development and the difficulties mentioned above it is unlikely that solar PV in hotels represents a significant opportunity for PULSE in the short term.

2.1.11 Summary of productive value chains and PULSE technologies

Table 9 provides a summary of the productive value chains explored in section 2.1 and the PULSE technologies that are relevant for each value chain. Each of these technologies is presented in more detail in section 2.2.

78 Interview with Uganda Hotel Owners Association (UHOA), October 2019.

79 4-kWp PV system and solar water heating systems at Volcanoes Kyambura Gorge Lodge at Queen Elizabeth National Park and solar refrigerators and solar-home systems for a lodge beside Lake Mihingo.

80 Based on a report "Tourism sector profile" by the Uganda Investment Authority, 2009.

Table 9: Summary of productive value chains and relevant PULSE technologies

Value chain	Number of HH involved*	Energy access / importance of value chain	Most relevant PULSE technologies
Grains and staple crops	3.7m HH cultivating maize and another 3.1m cultivating cassava	Maize production is over 90% driven by smallholder farmers, more than 80% of them are off-grid. Over 70% of grain millers are located in off-grid areas, using diesel- or petrol-powered hammer mills.	 Small SWPs to upgrade from rain-fed irrigation or replace diesel pumps  Solar mills in trading centers or farmer cooperatives
Coffee	1.7 million	Off-grid smallholder farmers with less than 1 acre are responsible for most (85%) of the raw coffee production. Further processing (hulling, roasting, grinding) is done at larger (aggregated) scale in grid-connected factories.	  SWPs and irrigation kits of different sizes help increase yields by ~30%. Most motorized pulping and hulling takes place in grid-connected factories, and therefore opportunities for PULSE are limited.
Horticulture	>1.5–2 million farmers involved in fruit or horticulture production	Uganda is a major African producer of fresh fruit and vegetables. Most farms are small (under 5 acres) and off-grid. Smallholder farmers are increasingly involved in horticultural activities for export, local sale, and household consumption.	   Irrigation for high-value fruits and leafy vegetables (yield increase factor of up to four times) Cooling/chilling of produce for delivery to market (reduces wastage by ~30%) Juice-making, drying, packaging
Livestock and poultry	1.7m HH keep cattle 3.4m HH keep poultry	Meat and poultry production are transitioning from pastoral-ist and free-range to semi-intensive production methods. Poultry is the most common livestock type in the country.	   Cooling and water supply are critical inputs for meat-supplying cattle farms. For poultry, cooling (for meat storage) and heat/ventilation (for egg/chick incubation) are critical for farm operations.
Dairy	1.25 million farms engaged in semi-intensive or intensive dairy farming opera-tions	Dairy farming brings in over $100m per year from exports. Most farmers are smallholders with fewer than 30 head of cattle. Peri-urban semi-intensive dairy farmers are largely unelectrified.	   Chilling of milk to prevent losses (~20–40% is spoiled without chilling) and enable better market linkages Water supply for cattle Power needed for feedstock cutting, milking machines, and other farm equipment
Fishing	~250,000 artisan fishers (136,000 on Lake Victoria)	Energy access is low on and around Lake Victoria. However, there are commercial/industrial scale refrigeration and ice-making units connected to mini-grids.	 Ice-making facilities for fish conservation, reducing wastage

Value chain	Number of HH involved*	Energy access / importance of value chain	Most relevant PULSE technologies
Commerce and connectivity	500,000 SMEs employ 1.1m people 25m people own cell phones and 18.5m use the internet	Lack of energy access in small businesses is a primary constraint to expansion and productivity. Connectivity is a key driver of modernization of businesses; in off-grid populations small amounts of electricity are vital for mobile phone and internet service.	 Cottage industry applications for lighting, workshop tools, and entertainment Connectivity services for communities, businesses, offices, and banking
Other medium-scale busi-nesses (e.g. telecoms, tour-ism)	n.a.	Over 1,000 telecom towers are off-grid and over 2,000 hotels and accommodation facilities are off-grid or weak-grid. Other potential users are off-grid banks and fuel stations.	 Tailored solar PV systems >1 kWp displacing diesel gensets for power supply

** Households involved in activities relevant to PULSE, i.e. cultivating, basic processing, etc. Actors involved in the further value-adding stages (such as transport, factories, and commercialization) are not included.*

2.2 Current market for PULSE technologies

Section 2.1 presented a demand-side analysis for PULSE, i.e. an exploration of different value chains and value-adding opportunities that could be enabled with access to electricity. This section presents a supply-side assessment, focusing on PULSE products available (or soon to be available) in the Uganda market.

2.2.1 Solar water pumping and irrigation

Two SWP manufacturing companies – Grundfos (Denmark) and Lorentz (Germany) – dominate the international market, including Uganda. However, their products (with capacities in the kilowatt scale) are predominantly used in projects sponsored by the government, donors, or NGOs. They typically relate to water pumping for consumption (e.g. domestic water supply for a village or refugee camp) rather than productive activities, with a few exceptions. Examples of distributors of this type of SWP system in Uganda are Davis & Shirtliff, Aptech Africa, and W.Water Works.

For applications in irrigation, a typical SWP project (20 cubic meters per hour, 3–4 kWp of solar PV[81]) would make sense for plots of land of 10 acres and above. But as this is bigger than the typical smallholder farm, it would require farmers to associate, which is a complex process.

A new generation of SWP systems is targeting the needs of smallholder farmers in Uganda, with specially designed systems that meet their technology and finance needs. With pump capacities under 1 kW and much easier installation, they are better suited for individual farmers. Examples of this type of pump are from SunCulture, Tulima Solar, and Futurepump.

It is therefore important to differentiate between the two SWP types in Uganda:[82]

- Medium-to-large SWPs – kW-scale, tailored design/ turnkey projects
- Small SWPs – for individual farmers, easy (guided) installation and operation.

Medium-to-large SWPs

Products and suppliers

Lorentz and Grundfos products are distributed by Davis & Shirtliff and Adritex, among others. In addition, solar pumps made by Nastec (Italy) are sold by local distributors W.Water Works and NSI.

SWP and irrigation systems are composed of (a) pumps, which can be surface or submersible, AC or DC, solar or hybrid; (b) the solar PV system; and (c) irrigation systems (e.g. sprinklers, drip irrigation). These products and components can be sold either individually or as a set.

81 Typical (average) project of distributor W.Water Works. Interview, October 2019.

82 The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa report published by Lighting Global classifies the market for irrigation pumps into four categories: very small (less than 2.5 acres), small (less than 5 acres), medium (5 to 12 acres) and large (over 12 acres). For simplicity, this market assessment only refers to two groups: small (which also encompasses very small) and medium to large.

Table 10: Examples of medium-to-large SWP products and projects

Product		Technical parameters	Examples of application	Cost
	Lorentz PS2-4000 C-SJ8-15 (available at Davis & Shirtliff)	Submersible pump Brushed DC motor Head: 80 m Max flow: 60 m3/day Nominal power: 4 kW Solar PV: 5 kWp	High-flow borehole applications. Specific example: a project completed by Davis & Shirtliff for drinking water for the community, animals, and water treatment in Bidibidi, north-west Uganda	Project cost (estimate): $10–20k (turnkey)
	Grundfos SQ Flex 2.5-2 (available at Davis & Shirtliff)	Submersible pump AC motor Head: 120 m Max flow: 2.9 m3/hr Nominal power: 1,400 W Solar PV: 1,750 Wp	Davis & Shirtliff used this pump to install systems for NAADS for agriculture, livestock, and dairy farmers.	Retail price for pumping system: $2,170 Cost of turnkey projects under NAADS: approx. $27,000 per farm (15 sites completed for $400,000)
	Nastec 4HS Multipower 4HS 08/03 MP (available at W.Water Works)	Submersible pump AC motor Head: 45 m Max flow: 11 m3/hr Nominal power: 1,800 W	Average W.Water Works project needs 20 m3/hr, i.e. two pumps with 3–4 kWp of solar power. Most projects are for NGOs, but there are examples of farmers, e.g. a coffee farm in Zirobwe, doing drip irrigation.	Retail price for pumping system: $2,020 Irrigation kit of 20 m3/hr including 3–4 kWp of solar PV: $7,000–8,000.

Source: company websites; interviews with Davis & Shirtliff, NAADS and W.Water Works.

Figure 18: Overview of SWP distributors and products

	Market leader (~70% of sales)	Other prominent distributors			
Distributor	DAVIS & SHIRTLIFF	W. WATER WORKS	AptechAfrica	Adritex Complete Water Solutions	NSI.WATER SMART WATER & ENERGY SOLUTIONS
Brands and products sold*	GRUNDFOS, LORENTZ, DAYLIFF	NASTEC > we move it faster >	Soleil Power, GRUNDFOS, LORENTZ	GRUNDFOS, LORENTZ	GRUNDFOS, NASTEC > we move it faster >

** International manufacturers represented by each distributor*

Pricing

The price of a medium-sized SWP system is around $2,000 per kW of pumping capacity, including tailored installation. This does not include the cost of drilling boreholes or irrigation equipment. The cost of a complete SWP project can differ substantially from project to project, depending not only on the size and capacity of the system but also on the nature and scope of the project – for example, whether a borehole needs to be drilled and, if so, to which depth;[83] the remoteness of the site; the scale of civil works required; the type of irrigation system; and the extent of training needed.

83 According to a 2011 study by the British Geological Survey ("An initial estimate of depth to groundwater across Africa"), across much of Uganda, where the climate is seasonally wet and basement geology predominates, natural groundwater levels are generally shallow (approximately 0–25 meters below ground).

Sales

Based on interviews with SWP companies, an initial estimate of the market size is 2–2.5 MWp per year, measured in terms of total solar PV capacity deployed. About 70 percent of these sales are realized by Davis & Shirtliff. Other key players include W.Water Works (~10 percent), Adritex, Aptech Africa, and NSI (~5 percent each). It is important to highlight that most sales are for government- and NGO-sponsored projects rather than individual farmers and private businesses.

Business models, supply chain, and types of customer

As mentioned, established companies in Uganda act as distributors of European SWP products. Davis & Shirtliff also has its own brand, DAYLIFF, manufactured in China to European standards. In addition to acting as distributors, these companies carry out system integration – i.e. matching pumps with solar PV modules and irrigation kits from different sources and installing them as a complete project. According to Davis & Shirtliff, most (70–80 percent) of its SWP projects are turnkey and the main client is the government. Services will include drilling (if needed), system design, supply, and installation. O&M contracts are offered, but take-up is low. Most projects are not linked to productive uses but, rather, water for domestic consumption. Davis & Shirtliff has implemented various projects for MWE, ranging in size from 2.2 to 55 kWp, to pump water for communities in areas of water scarcity. Water Works has implemented a number of water supply projects for refugee camps.

SWPs are also sold **over the counter** (i.e. without installation), but this is rare for high-quality products – less than 5 percent of sales, according to Davis & Shirtliff. Installation is seen as the most sensitive and risky step to proper functioning and durability of the SWP. The warranty of these products can be cancelled if installation is performed by unqualified technicians. Examples of projects highlighted by distributors as having productive use applications are summarized in Table 11.

Table 11: Examples of medium-scale SWP projects linked to productive use

Type of project	Description	SWP system
Projects implemented by the government (NAADS)	NAADS supported the implementation of SWP systems for agriculture, livestock, and dairy farmers on a cost-sharing basis. Units deployed: ~120	SWP systems range from 1.5 to 5 m3/hr. Davis & Shirtliff implemented 27 sites on a turnkey basis in 2018 and 2019 (see examples pictured below).
Projects implemented by the government (MWE)	MWE works with farmers to promote associations (15 farmers combining their plots to total 15 acres) with support from sociologists. They receive advice from agronomists and on business practices. They also receive support for the procurement of SWP irrigation systems and corresponding training.	Suppliers provide and install SWP and irrigation systems for associations with farms ranging from 12 to 15 acres. Most farms are horticultural and are fitted with drip-irrigation systems and SWP systems ranging from 3 to 30 kWp each.
Projects on private cattle and dairy farms	W.Water Works supplies surface pumps for dairy farmers (typically 2 kW surface pumps). SolarNow has sold solar pumps to dairy farmers under a subsidy scheme from the Dutch government (Milking the Sun). These are, however, small pumps (supplied by Futurepump).	Small pumps (e.g. Futurepump – see next section) and medium (2 kW) surface pumps for animal consumption
Irrigation of private farms growing high-value crops (e.g. coffee, organic horticulture, vanilla)	According to W.Water Works, this is a new market opportunity that started within the last three years. Half of these farmers upgrade from rain-fed agriculture and half replace diesel pumps.	Example: Visited a coffee farm of 50 acres in Zirobwe that bought a SWP with a capacity of 1.9 kW and an output of 60 m3 per day for drip irrigation. The project cost UGX 28 million ($7,600).

Source: Interviews with NAADS, Davis & Shirtliff, W.Water Works and SolarNow.

Financing

Interviews revealed that the main distributors of medium SWPs do not take significant loans for stock or working capital and do not provide consumer financing. Short-term loans are taken out to finance equipment for, and operation of, large projects during construction, i.e. before full payment upon commissioning (cash conversion cycle less than six months).

- In the case of Davis & Shirtliff, whose main client is the government, projects are paid 30–50 percent in advance. The company receives supplier credit and borrows about 30 percent of the project cost over three to four months until they complete the project and receive payment. A large government project could be worth over $1 million.

A working capital facility may be more relevant for Davis & Shirtliff's new line of small SWPs (Sunflo), designed for the mass market, which it began selling in July 2019 (see next subsection, on small SWP).

- W.Water Works keeps around $100,000-worth of its best-selling pumps in stock, representing about $230,000 in sales (including design, transport, installation, and so on). Solar PV modules are locally sourced. Clients typically pay in cash and lead time to installation is short (a few weeks).

W.Water Works says it would welcome competitive financing in order to expand its business and be able to dedicate more budget to marketing. It estimates financing for the next three years of operation at $500,000.

Other issues

Other frequently mentioned issues affecting the market for medium-scale SWPs are:

- Consumer awareness and know-how. Consumer awareness is needed on the benefits of solar irrigation. Building capacity of SWP installers and technicians is also needed. Engineers Without Borders USA is working on manuals for the design, operation and maintenance of SWP systems (projected completion in 2020) intended for practical use by field engineers, technicians, and system operators. In partnership with MWE the manuals are being reviewed for adoption by the Ministry. Training is being provided with support from the industry, Makerere University, the Center for Renewable Energy and Energy Conservation, and others.
- Quality assurance. Stakeholders report an increasing penetration of low-quality products in the market. Clear standards for, and regulation of, imports are needed to keep consumer confidence high and to avoid market spoilage.
- Sustainability of water resources. Water table depletion is a risk in water-stressed areas, such as northern Uganda. It is, however, not seen as a problem in most of the agricultural areas where PULSE are relevant.

Cattle farm SWP project implemented by NAADS and Davis & Shirtliff

These challenges are presented in more detail in chapter 5.

Small SWPs

The market for small and very small SWPs, which cater to the needs of smallholder farmers, is at an early stage of development. Yet, there is already a variety of products available. Companies are attempting to prototype, package, market, and scale business models. Cheaper units are sold at a retail price of $700. Some suppliers are introducing a PAYG mechanism.

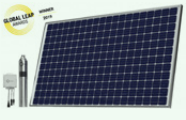
Products and pricing

The 2019 Global LEAP Awards Solar Water Pump Buyer's Guide lists 27 SWPs designed for smallholder farmers of 1 to 5 acres. Several of these products were only recently (between 2017 and 2019) introduced in Uganda. These include products by the following manufacturers:

- **Futurepump** manufactures surface water pumps designed for farms of up to 2 acres, distributed in Uganda through SolarNow. Its SF2 model (see Table 12) sells for $715 (complete kit including solar panels). Futurepump launched its entry-level SE1, for farms of up to 1 acre, in February 2020 in Kenya. This retails at $330 (pump only) but is not yet available in Uganda.
- **SunCulture,** a Kenyan manufacturer, produces submersible pumps and irrigation systems with solar panels and with and without batteries. It currently sells in Uganda through SolarNow and Tulima Solar. In Kenya, SunCulture has introduced a PAYG ("pay-as-you-grow") model.
- **Lorentz** has recently introduced solar-powered submersible pumps for low-head, low-flow applications to cater for the smallholder-farmer market. Its products remain significantly more expensive than those mentioned above.
- **Davis & Shirtliff** recently introduced small standard solar water pumping kits branded as Dayliff Sunflo. These come in a variety of sizes (150 W, 300 W, 600 W and 1 kW).
- **Azuri's** GrowFast, the PAYG solar irrigation solution from Azuri Technologies (whose PS2-100 AHRP-23S model is manufactured by Lorentz), is among the winners of the Uganda Renewable Energy Challenge Fund launched by the UNCDF CleanStart program.
- **Tulima Solar** (known as Simusolar outside Uganda) is initiating several partnerships with agricultural organizations to supply SWPs and irrigation systems.

Examples of products in this category are summarized in Table 12.

Table 12 Examples of small SWP products

Product	Technical parameters	Examples of application	Cost
 Futurepump SF2 (distributed by SolarNow and Davis & Shirtliff)	Surface pump DC motor Head: 15 m Max flow: 3.6 m3/hr Supplied with 3x40 W (120 W) solar panels	Small-scale agricultural uses using low pressure spray, hoses, and drip applications (up to 2 acres)	Retail price for pumping system (with solar PV, irrigation kit, and installation): $715
 SunCulture Rainmaker 2 irrigation kit (with ClimateSmart Direct)	Submersible pump Brushed DC motor Head: 30 m Max flow: 1.1 m3/hr Solar PV: 310 Wp	Typical farmer has 1–2 acres plot. Water for mixed uses including domestic needs, irrigation of staple crops, livestock watering, and kitchen garden	Retail price for pumping system (with solar PV): $850

Product		Technical parameters	Examples of application	Cost
	Lorentz PS 150 HR-04S3 (available from Davis & Shirtliff)	Submersible pump Brushed DC motor Head: 60 m Max flow: 0.77 m3/hr Nominal power: 300 W Solar PV: 400 Wp	Small-scale water supply from boreholes and wells for livestock watering, irrigation, and general water supply applications	Retail price for pumping system: $1,500
	Sunflo S-150 (bigger sizes available) (distributed by Davis & Shirtliff)	Submersible pump Brushless DC motor Head: 60 m Max flow: 0.35 m3/hr Nominal power: 120 W Solar PV: 200 Wp	Multi-purpose water pump (agriculture, livestock, and domestic use)	Retail price for pumping system (with solar PV): $750

Source: company websites and interviews with SolarNow, SunCulture and Davis & Shirtliff.

Lighting Global's Market Opportunity for PULSE in Sub-Saharan Africa report assumes an 11 percent reduction in small SWP costs between 2018 and 2030, i.e. 1 percent per year.

Sales

With suppliers having introduced small SWPs very recently, data on sales volumes is limited. GOGLA's and Lighting Global's biannual Global Off-Grid Solar Market Report presenting semi-annual sales[84] started publishing data for solar PV appliances (including SWPs) in 2018. Its latest report, for the second half of 2019, only recorded 395 units sold in Uganda in the six-month period, although the report acknowledges that there is insufficient data and therefore actual sales are likely to be higher. SolarNow said in an interview that it sold **900 small SWP units in 2019.** Davis & Shirtliff, having introduced their Dayliff Sunflo line as recently as July 2019, estimate that annual sales will be in the thousands of units starting 2020.

Business models

The key players in the market are made up of:

- **Early-stage innovators,** specializing in small SWPs, such as **Tulima Solar, SunCulture,** and **Futurepump,** the last two currently operating in Uganda through distributors.
- **Established appliance manufacturers** such as **Lorentz,** which is now starting to look at small-scale applications within an affordable range for smallholder farmers.
- **Established SHS** firms like **SolarNow** and **Fenix International,** leveraging on their distribution networks and payment platforms to sell SWPs from international manufacturers.
- **Distributors of water-related equipment,** such as **Davis & Shirtliff,** leveraging on their established network of outlets into rural areas (both owned stores and retailers) to sell SWPs.

Table 13 provides an overview of the business models of suppliers mentioned above. It is important to note that business models are evolving quickly. For example, SunCulture operates under end-to-end integration in Kenya – from manufacturing to distribution, installation, consumer financing, and training – but in Uganda only sells products through distributors. Fenix International, an end-to-end integrator of SHS, is considering expanding its product offering to PULSE, but only by providing its distribution and payment platform to manufacturing partners. Both these market approaches may evolve and change.

84 Every six months, GOGLA and The World Bank Group's Lighting Global program publish the Global Off-Grid Solar Market Report, a market intelligence series on sales and impact of off-grid solar lighting products, sold by GOGLA and Lighting Global affiliates. Since H2 2018, the report also includes sales numbers of off-grid appliances, in partners hip with the Efficiency for Access Coalition.

Table 13 Business models for small SWPs in Uganda

Business model	Activities	Examples in Uganda
End-to-end integration	Azuri buys submersible (low-head, low-flow) pumps from Lorentz and partially assembles irrigation kits which are marketed under the brand name GrowFast. Azuri offers a PAYG solar irrigation bundle that includes a smartphone with the GrowFast app, as well as agronomy services. Tulima Solar (known as Simusolar outside Uganda) operates as a full-service business, offering financing, design, installation, and after-sales service directly to end-users. It also works through partnerships such as NUCAFE and other agricultural associations to reach and educate large numbers of smallholder farmers.	azuri Simusolar
Hardware manufacturer	Futurepump and Lorentz are focused on manufacturing, with factories in India and Germany, respectively. They rely on partnerships with local distributors for sales and customer service (through SolarNow and Davis & Shirtliff, respectively). SunCulture is vertically integrated in its country of origin (Kenya) but operates through distributors in Uganda.	Futurepump SunCulture LORENTZ
Distribution specialist	SolarNow (almost 50 branches) and Fenix International (30 service centers) leverage their established distribution networks and SHS customer bases to sell solar water pumps. Davis & Shirtliff, an established player in water pumping projects, is now distributing its smaller SWP products through its six branches in Uganda, and doing marketing and distribution at the village level in hardware stores.	solar now D&S DAVIS & SHIRTLIFF fenix intl AptechAfrica

Source: company websites and interviews with Azuri, Tulima Solar, SolarNow and Davis & Shirtliff.

Financing

Similar to business models, financing models for small SWP are expected to evolve rapidly as the market develops. Table 14 summarizes the types of financing available to suppliers and end-users. In regards to financing for PULSE suppliers, it is important to note that, in addition to debt and equity, significant grant money has been injected into the sector by development institutions such as USAID and FCDO.

Table 14 Examples of financing of small SWP

Company financing	
Debt	• **SolarNow** has benefitted from three syndicated loans arranged by SunFunder[85] and funded jointly with Oikocredit[86] and responsAbility[87], totaling $19 million.[88] This is a tailored receivables financing structure, designed by SunFunder, for solar companies deploying systems through PAYG and leasing. Terms are typically around 10 percent interest in hard currency with a tenor of 24–36 months. • **Fenix International** has ample access to financing through its parent company, ENGIE.

85 SunFunder is a solar energy finance business with a mission to provide debt financing for solar assets in emerging economies.

86 Oikocredit is a Netherlands-based international cooperative and worldwide social impact investor.

87 responsAbility Investments AG is a private Zurich-based asset manager in the field of development investments.

88 SolarNow news item of January 9, 2019.

Company financing	
Grants	• There is a significant amount of grant funding flowing to international companies in the sector, from e.g. USAID, FCDO, the Shell Foundation, AECF, and REEEP. • More specific to SWP in Uganda, **Azuri** and **Aptech Africa** were awarded cost-sharing grants from the UNCDF CleanStart program's Renewable Energy Challenge Fund (RECF) to develop their PAYG SWP businesses. Grants are in the order of $100,000–$500,000. • Global LEAP-RBF incentives will be available for best-in-class SWP and for off-grid refrigerators that were identified as winners or finalists in the 2019 Global LEAP Awards. This includes many of the products mentioned above. The request for funding from suppliers in Uganda totals nearly $250,000 for an estimated 2,000 pumps to be sold to end-users by the end of August 2020. The funds available are, however, lower than this amount (based on an interview with CLASP).
PAYG	• **Azuri** offers a PAYG solar irrigation bundle inclusive of installation and agronomist support. • **Fenix International** has a partnership with Tulima Solar to sell SWPs on a PAYG basis. • While not strictly PAYG, **SolarNow** provides credit over 24 months.
MFIs/ SACCOs	• Despite experience in financing SHS, MFIs and SACCOs are not currently providing financing for solar pumps. The maximum amount of loans offered (e.g. $1,000 with tenor of one year for **EBO SACCO**) could, however, cover the cost of an entry-level SWP.
Grants	• The World Bank is preparing a $50m project (Micro-scale Irrigation Program) to subsidize micro-irrigation schemes based on SWP.
Other	• Aggregators (off-takers of crops and cooperatives) could be well placed to provide financing to smallholder farmers. However, no examples were found in Uganda during this market assessment. **NUCAFE** (a vibrant umbrella organization for coffee-farmer cooperatives reaching over 1 million individual farmers) promotes and demonstrates solar irrigation among its members, but this does not yet include a financing scheme.

Source: company websites and interviews.

Other issues

The quality and awareness issues mentioned under "medium SWP" also apply to smaller products. In addition, and with regard to quality, the CLASP-managed 2019 Global LEAP Awards have focused on SWP among other technologies. Award recipients are considered best-in-class products and will be eligible for results-based financing incentives. With regard to awareness, it is interesting to highlight that NUCAFE promotes and demonstrates solar irrigation with Futurepump products.[89]

2.2.2 Solar refrigeration and ice-making

Similar to solar water pumping, the market for cooling and ice-making equipment can be divided into two groups, according to size:

- **Medium-scale equipment to cater to the needs of cooperatives or groups of users.** This may include, for example, milk-chilling facilities (capacity 2,000–10,000 liters) for farmer groups, or ice-making equipment (3–5 tons per day) supplying multiple fishers.
- **Small refrigeration units (under 200 liters)[90]**, which include milk-chilling units for small-scale dairy producers located far from collection centers, and refrigerators originally conceived for domestic use, but mostly used to generate income by cooling beverages and food in shops.

89 Kiva blog posts, "NUCAFE revolutionizing the supply chain in Uganda."

90 Lighting Global's "Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa" report labels this size range as "very small." No examples of solar refrigeration equipment in the range 200–2,000 liters, which the report labels "small," were encountered during this market assessment.

Medium-scale solar refrigeration and ice-making

Milk chilling

It is estimated that 20–40 percent of milk production in Uganda is wasted due to lack of timely cooling.[91,92] Solar cooling technologies can provide consistent cold storage for areas with no or unreliable energy access, offering a significant reduction in losses.

In areas with a high density of dairy farmers, the cooling and chilling of milk is carried out at a cooperative-owned cooler very close to the farmers. Milk is collected from the farmer within one hour of milking and delivered to the cooling station. Cooling takes place in industrial coolers with capacities ranging from 2,000 to 8,000 liters. Most of these are off-grid and powered by diesel generators.

No industrial milk coolers powered by solar PV were found in Uganda during this market assessment, but they exist in other countries and are technically and financially feasible. Table 15 presents examples of industrial milk coolers in Uganda and elsewhere.

According to an interview with NAADS there are about 100 off-grid medium-scale milk collection centers, with capacity ranging between 2,000 and 8,000 liters per day. The "low-hanging fruit" in terms of solar medium-to-large-scale refrigeration would be to convert diesel-powered units to solar PV. However, greenfield units are also feasible.

An analysis of market potential and financial feasibility is presented in chapter 3.

Table 15 Examples of industrial milk coolers in Uganda

Product description		Manufacturer	Presence in Uganda	Financial feasibility
	Milk cooler of industrial capacity (2,500 liters)	Mueller, distributed in Uganda by Inndigo Ltd.	Mueller/Inndigo have set up about 100 milk collection centers in Uganda, to which farmers bring milk for it to be cooled, and stored under conditioned circumstances.[93]	Based on a modelling exercise (subsection 3.2.2), coolers running on diesel are found to be financially feasible if they allow loss of milk due to waste to be reduced by at least 15%.
	Stand-alone milk chiller developed by ILK Dresden (1,000 liters)	German industrial research institute ILK (Dresden)	Not commercially available in Uganda. 1,000-l cooling container with stand-alone solar PV system of 3.4 kWp, estimated cost $25,000.[94]	The financial performance of a solar-powered cooler is similar to that of the diesel-powered unit.

Source: UOMA, Mueller, ILK Dresden, ECA financial model.

Ice-making for fish conservation

Fish product is delivered from boats and sold to traders or intermediaries at landing sites on lake shores or on islands. Landing sites, especially on Lake Victoria's islands, tend to be unelectrified and lacking basic infrastructure and services.

The exceptions are a few ice-making factories at landing sites selling ice to fishers:

- **GRS Commodities** on Bugala Island (Mwena landing site) – a 3.5-ton-per-day ice-making machine originally constructed by the district government

91 Tijanni, K.I. and Yetisemiyen A. 2015. "Dairy Cattle and Dairy Industry in Uganda: Trends and Challenges." Research Journal of Agriculture and Forestry Sciences 3(10): 14–18.

92 Uganda Off-grid Energy Market Accelerator (UOMA) 2019. "Productive use of off grid energy: The business case in Uganda's dairy value chain."

93 Mueller's website, information on milk-collection center development.

94 UOMA. "Productive use of off-grid energy: The business case in Uganda's dairy value chain." August 2019.

and then taken over and rehabilitated by GRS Commodities, a private company.

- **GRS Commodities** on Bukasa Island – a 5-ton-per-day greenfield site (under construction).
- **Equatorial Power** on Lolwe Island - a "mini industrial park" consisting of machines for water purification, ice-making, and basic fish processing (under construction).[95]

It is important to note that all three of these projects are, or will be, connected to solar hybrid mini-grids rather than stand-alone solar PV units. The first unit is connected to the grid operated by Kalangala Infrastructure Services (KIS).[96] The second will be connected to the solar mini-grid developed by Absolute Energy (but run as a separate business), and the third will be connected to Equatorial Power's own mini-grid.

Figure 19: Ice-making factory at Mwena landing site

GRS Commodities at Mwena site

Infrastructure and equipment

GRS took over and rehabilitated a district government site in 2017. The factory is connected to the KIS mini-grid at 33 kV, 3-phase. It has a 100 kVA transformer.

The ice-making machine has a capacity of 3.5 tons per day (i.e. in a full 24 hours of operation).

Production and services

The machine currently produces between 1 and 2 tons of ice per day (running between 7 and 14 hours per day) and caters to about 10–20 fishers per day.

The factory produces ice flakes sold by the sack (approx. 90 kg per sack) at 25,000 UGX ($6.80) each. Revenues are, therefore, in the order of 270,000 UGX ($73) per ton of ice.

Costs

Electricity, according to GRS accounts for 90% of the operating expenses. The retail tariff is 825 UGX ($0.22) per kWh plus VAT of 18%. The machine draws 23 kW of power during ice production. Other operating costs include staff – 1.5 full-time equivalent employees – and maintenance work.

GRS operates under a 10-year revenue-sharing agreement with the district government, to which 12 percent of revenue is given, in exchange for the right of GRS to use the facilities.

95 Information from Equatorial Power's website on their Lolwe Island project.

96 KIS is a mixed utility company that has developed 1.6 MW of hybrid solar-diesel power and has recently taken over operation of the Kalangala Town Council (KTC) grid.

Financials

The factory currently has a modest operating margin of about 10 percent of revenue (net of revenue shared with the district government). The company has no significant assets or debt to repay (assets belong to the government). Higher electricity costs (for instance from a diesel-powered generator) would make the business unviable.

Planned investment and expansion

For new sites, GRS plans to invest in new equipment with higher output and greater efficiency. This makes a more attractive business case. The new ice-making equipment for Bukasa Island has a capacity of 5 tons per day and a power draw of 17.5 kW, which would significantly decrease the impact of electricity costs.

The total capex including the ice-making machine, civil works, and cooling container is $50,000. This machine was procured and installed with a cost-sharing grant provided by one of GRS's partners.

Assuming current (30 percent) or similar levels of factory utilization and similar staff wages, electricity prices, and revenue-sharing arrangements with the government (assuming 10 percent of revenue for use of the landing site), revenue would be double operating expenses ($30,000 vs $15,000, on an annualized basis), which would determine a **healthy IRR for the capex investment of 26 percent** (not considering the grant).

If the new investment were to operate as via PULSE instead of buying electricity from a mini-grid, the additional investment in solar PV equipment would be around $63,000. The total investment in this case would yield a lower IRR (17 percent).

More details on the financial analysis are provided in subsection 3.1.3.

In addition to the investment on Bukasa Island, further expansion plans for GRS Commodities could include:

- Increasing output in existing sites to supply intermediaries – increasing the capacity of the ice-making equipment to supply ice to transporters (intermediaries) in addition to boats. Trucks currently buy ice in Kampala in large quantities, between 2 and 10 tons per order.
- Expanding to more sites – expand to 5–10 landing sites in the near future, both by taking over derelict government infrastructure – as at the Mwena site – and by investing in greenfield projects. In principle, these would be sites with availability of electricity and water rather than utilizing PULSE. GRS is considering partnerships with other mini-grid companies, to expand ice production as a productive-use component of their mini-grid.

Source: Interview with GRS Commodities, site visit and ECA financial model.

The main advantages of being supplied by a mini-grid vs stand-alone solar PV include: not having to incur the capital cost of solar PV, cheaper electricity (many of these mini-grids integrate subsidies), and only paying for the electricity actually used (i.e. no risk of idle capacity). Mini-grid-connected ice-making machines could be seen as the low-hanging fruit, but the concept could be replicated as PULSE, in areas where no grid or mini-grid electricity is available.

Other cooling applications

In addition to the refrigeration of dairy and fish, cooling and chilling can also be applied to horticultural products. There are no examples of companies or cooperatives providing this type of technology and service at a commercial scale in off-grid Uganda. Table 16 includes an example of a company piloting this technology in neighboring Kenya. More examples of cold-chain technologies used in other countries can be found in Annex A2, which provides the results of the 2018–19 Global LEAP Off-Grid Cold Chain Challenge (OGCCC). Most of these solar technologies are at a very early (pilot) stage in sub-Saharan Africa.

Another example of the application of cold storage is UltraTec's ice-pack plant for beverage companies in Uganda, a concept that could be replicated in other value chains and businesses.

According to an interview with NAADS there are about 100 off-grid medium-scale milk collection centers, with capacity ranging between **2,000 and 8,000 liters per day.** The **"low-hanging fruit"** in terms of solar medium-to-large-scale refrigeration would be to convert diesel-powered units to solar PV. However, greenfield units are also feasible.

Table 16 Examples of other cold storage applications

Company/Country	Features	
(Kenya) SOLAR FREEZE	• Mobile cold storage units powered by solar PV for smallholder farmers (pilot phase) • Would help reduce the 30–40% of food production that is usually lost before it reaches the market (FAO estimate) • Cold storage as a service: Through mobile apps and mobile money transactions, farmers and traders can find, use, and pay for the nearest cold storage. • Holistic approach: Solar Freeze integrates transportation of fresh produce via energy-efficient trucks. • Works with 3,000 farmers in Kenya	
(Uganda) UltraTec Energy Solutions For All	• UltraTec has designed and implemented ice-pack plants for beverage companies. These consist of several Steca freezers inside a repurposed shipping container fitted with a stand-alone solar PV system. • Specs: each container houses 14 166-liter Steca refrigerators converted to freezers and ~1 kWp of solar PV with batteries. • Estimated price per container: $25,000. • Approx. 500 freezers (i.e. 30–40 containers) have been sold to beverage companies and are spread over several locations in their distribution networks. • Ice packs produced in the containers are provided to retailers together with bottles to keep drinks cold. • Sales of drinks are reported to have increased by 700 percent since cooling became available.	(containerized refrigerators with stand-alone solar PV) 

Sources: Solar Freeze website, Brookings Institution,[97] interview with UltraTec (October 2019), UltraTec website.

Business models and financing

Medium-scale refrigeration of fresh produce relies on **aggregators,** which either buy from a group of smallholder farmers or provide services to them. In the examples shown above, cooperative-owned milk-chilling units serve 20–30 dairy farmers each. The ice-making factories cater for 15–30 fishers.

Each of these investments is in the range $25,000–$100,000 and has a useful life of more than 10 years. This type of investment will require longer-term project finance as opposed to the working capital loans required by companies selling small PULSE products.

Both public and private players can leverage a variety of models to introduce off-grid cooling technologies. Some of the business and financing models to be considered in this market segment are:

- **Private investment by a service company** (fee for service), as is the case of GRS Commodities in Uganda and Solar Freeze in Kenya. These models either charge customers for the ice sold (ice factory), or by the day for an allotted space within a cold storage unit, typically some type of reusable tray or crate.

  GRS Commodities received a grant allowing expansion to one additional site. Loans could be considered for further scale-up.

- **Cooperative-owned schemes,** as is the case of the milk-collection centers run by dairy cooperatives. Many of these cooperatives have received cost-sharing grants and technical support from the government (through NAADS) and cooperative unions (like UCCCU). A mix of loans and grants could support the conversion of diesel units to solar PV or new greenfield investment in stand-alone solar coolers.

97 Kibiti, B. and Strubenhoff, H. "How off-grid cold storage systems can help farmers reduce post-harvest losses." Brookings Institution, October 16, 2019.

- **Public investment operated by a private company** on a revenue-sharing basis. This is the case with GRS Commodities taking over the district-government-owned Mwena landing site, rehabilitating it, operating it, and sharing revenues. A similar model has been used in Kenya to introduce solar milk-chilling plants. County governments invest and then hand the facilities over to dairy associations.[98]

Other issues

Other issues affecting the medium-scale solar refrigeration market that are often mentioned by stakeholders are:

- **Awareness and know-how.** Awareness is needed across consumer groups (medium and large farms, cooperatives, and so on) about the potential benefits of solar-powered refrigeration. In addition, suppliers and financiers could also be made aware of the market opportunity to design, supply and finance medium-scale milk-chillers for large farms and cooperatives (~1,000 liters), and for horticulture, which is yet to be exploited.
- **Sustainability.** There is a limit to the amount of fishing that Lake Victoria and the other main lakes can sustain, which limits the size of the market opportunity for PULSE in fishing.

Small-scale solar refrigerators

Smaller (50–200-liter) solar chillers and refrigerators for multiple uses are currently sold in Uganda. These solar refrigerators have a significant market potential in the country, enabling short-term storage of milk and other fresh produce such as meat, poultry, and fish, and for use in retail shops to cool drinks.

Products and suppliers

Several suppliers have recently begun selling high-quality small solar refrigerators. Examples include:

- **M-Kopa.** Started selling small (100-liter) solar refrigerators with a stand-alone 60 W solar module in June 2019, targeting the residential market but also used in shops to cool drinks. Refrigerators are sold on a cash or PAYG basis.
- **SolarNow.** Began selling refrigerators in 2014 (two different sizes available) and solar milk-coolers in 2019.
- **SunDanzer.** US manufacturer of high-quality stand-alone solar refrigerators (50–225 liters) and freezers (50–390 liters), commonly for use in households, small-scale retail, and hospitals in rural areas. The distributor in Uganda is Aptech Africa, which markets the product primarily for NGO and health applications.
- **UltraTec.** Distributes Steca (German) refrigerators to NGOs or larger projects such as the ice-pack production facilities mentioned above.

Refrigerators from local company ADH are relatively common in rural areas. They are not sold as stand-alone solar units, but ADH also sells solar modules and batteries that could be coupled with their refrigerators. Unlike the solar refrigerators of the suppliers mentioned above, ADH solar refrigerators have not been quality-verified.[99]

Table 17: Examples of small SRUs

Product		Technical specs	Applications	Pricing
	M-Kopa Solar Powered refrigerator	100-l capacity 60 Wp solar PV Includes lightbulb and phone-charging ports Full warranty (two years) Designed by Youmma and manufactured in China Winner of Global LEAP Award in 2019	Domestic use and retail shops	Cash price: UGX 2.999m ($810) PAYG price: Deposit: UGX 499,000 ($135) Daily rate: UGX 5,500 ($1.49) for 650 days

98 Kagondu Njagi. "Milking it: solar coolers heat up earnings for Kenya's dairy farmers." Sun-Connect, September 3, 2018.

99 "Fake solar batteries flood market." UNBS, March 13, 2017.

Product		Technical specs	Applications	Pricing
	SunDanzer (distributed by Aptech Africa)	Various sizes SunDanzer DC 165 has a volume of 160 liters 100 W solar PV module 2 USB ports Made in US Winner of Global LEAP Award in 2017	Aptech Africa markets refrigerators primarily for NGOs and clinics for vaccine and medication storage	SunDanzer DC 165: $1,700
	SolarNow refrigerators (distributed by SolarNow)	35-l (100 Wp) and 112-l (150 Wp) units Both finalists in Global LEAP Awards in 2019	Various uses (domestic, commercial, overnight milk-chilling for individual small-scale dairy farmers, etc.)	$500 (35-l) and $700 (112-l) Payable in instalments
	Steca high-efficiency solar refrigerators (distributed by UltraTec)	166 liters 70 Wp solar PV and battery Configurable as refrigerator or freezer Made in EU Winner of Global LEAP Award in 2019	These refrigerators are used for the ice-pack production facility and NGO projects. They are also suitable for the mass market.	$1,800

Source: Manufacturers' and distributors' websites, Global LEAP, and interviews.

Lighting Global's "Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa" report assumes a 10 percent reduction in the cost of small SRUs between 2018 and 2030, i.e. 1 percent per year.

Sales

So far, off-grid solar refrigeration units have a very low penetration rate. The latest reports in the Lighting Global / GOGLA Global Off-Grid Solar Market report series presenting semi-annual sales recorded a relatively small number of sales in Uganda – 298 units in the first half of 2019 and 666 units in the second half – but even this represented an impressive increase over the second half of 2018, which recorded only 87 units. However, the reports acknowledge that in the case of Uganda there is insufficient data to provide fully accurate figures.

The H1 2019 report in the Global Off-Grid Solar Market report series also states that the largest commercial market for refrigeration units is for the medicine and vaccine cold chain, which is dominated by bulk purchases for institutional use. Established companies and new arrivals like M-Kopa are evolving and adapting current designs to meet the needs of the mass market and to leverage both the off-grid solar systems themselves, and also the distribution, sales, finance, and after-sales infrastructure to accelerate access.

M-Kopa and SolarNow are currently the only companies in Uganda selling high-quality small solar refrigerators for the mass market at affordable prices. M-Kopa refrigerators were introduced to Uganda in June 2019, and 250 units were sold over the first three to four months (i.e. likely to sell about **1,000 units per year,** representing about $800,000).

Further growth of this segment is expected to be fostered by the 2019/20 Global LEAP RBF incentives for the procurement of best-in-class solar off-grid refrigerators. Products from M-Kopa (Youmma), SolarNow, SunDanzer, and Steca were identified as winners or finalists of the 2019 Global LEAP Awards and are therefore eligible for RBF.

Business models and financing

SolarNow and **M-Kopa** are both SHS/PAYG firms that are successfully integrating household appliances and PULSE. They are well positioned to leverage their customer profile and credit repayment data to target high-potential PULSE customers with PAYG financing.

Both companies operate an **end-to-end integration** approach for their products. They design and brand refrigeration units as their own – although manufacturing is outsourced – and then specialize in distribution, customer acquisition, sales, financing, and customer service.

With regard to financing sources:

- M-Kopa received an $80m syndicated loan from Stanbic, CDC, Norfund, and Dutch development bank FMO, in local currencies (KES and UGX) in 2017.
- In addition to the three syndicated loans mentioned in Table 14, SolarNow has also received various loans from crowdfunding platforms Trine and Lendahand. All of these were in foreign currency but deemed by SolarNow to be more competitive than loans from commercial banks in Uganda. SolarNow would prefer loans in local currency if interest rates and overall terms are improved .

Other issues

Other important issues shaping the market for small SRUs are:

- **Affordability and willingness to pay.** A survey by Energy for Impact conducted in rural Uganda in 2017 highlights affordability as a challenge. According to the survey, the cost of a standard non-solar-powered refrigerator of 100 to 150-liter capacity is in the range of $230–270 (see Annex A3). On the other hand, the cheapest solar units currently available cost $500 and may therefore not be affordable for the rural population. Refrigerators supplied by M-Kopa and SolarNow are helping address this barrier. Their energy-efficient products are helping reduce costs and, most importantly, PAYG and credit options will make products more affordable. RBF incentives linked to the Global LEAP awards will also be helpful in increasing affordability.
- **Awareness.** Solar refrigerators – as opposed to regular refrigerators connected to solar PV but not originally designed for this purpose – represent a new market of which there is little awareness.
- **Last-mile distribution.** Solar refrigerators are bulkier than SHS or SWPs, resulting in more complex and costly distribution logistics.
- **Quality.** As with most solar products, there are claims that the market is being flooded with sub-standard solar PV and battery product[100]. Cheap refrigerators can be coupled with inverter-based SHS at a lower price than energy-efficient solar refrigerators. The Global LEAP Awards address this by testing solar refrigeration units in accredited laboratories for energy performance, quality, and reliability, and include an evaluation by a panel of off-grid market experts.

2.2.3 Solar milling

Milling of grain and staple crops

Typically, milling machines used in villages and trading centers are made by local fundis (handymen) and depend on low-speed diesel engines, making their functionality extremely variable and energy inefficient.[101]

Solar PV power can be used to operate a motor that powers a mill. Technological progress coupled with rapidly falling solar PV costs has made solar milling an increasingly viable in economic terms[102] and the technologies are rapidly progressing beyond pilot and start-up stages. Solar-powered mills can process coconut, cassava, maize, rice, and other cereals.

A typical solar-powered mill with a power requirement of around 1 kW can mill 25–30 kg of produce per hour and costs approximately $3,250. While these units are small, they are still larger than the requirements of an average smallholder farmer.[103] For this reason, these units will mostly be used commercially rather than on individual farms. There are no branded solar mills currently available in Uganda. A product developed by Agsol (see Table 18) was only tested as a pilot in 2019, and has not yet been introduced commercially.

The units piloted by Agsol in Uganda were hammer mills powered by a 1.5-kWp solar PV system with batteries. Units were considered expensive by potential customers. In addition, the pilot equipment did not include a maize huller, which is deemed essential in Uganda to obtain pure ugali (a type of maize flour porridge). Agsol's grain mill is therefore still at the product development phase and not ready for scaling-up.

100 "Fake solar batteries flood market." UNBS, March 13, 2017.

101 GIZ, 2016. "Photovoltaics for Productive Use Applications: A Catalogue of DC-Appliances."

102 Ibid.

103 Eighty-three percent of farmers have plots of less than 5 acres. Five acres would only yield 15 kg of maize a day on average.

The main lessons learned from the Agsol pilot were:[104]

- For millers of staple foods, margins are very thin, which makes affordability a significant concern. Solar PV panels in the first pilot were oversized, leading to overcapacity that millers could not afford.
- In addition, the units were not equipped to supply energy to alternative activities. Adding a socket for other appliances, which could be used for additional income-generating activities – e.g. phone charging/barbershop/video cinema – and potentially deliver a higher margin than the essential staples, could help maximize utilization of the unit.
- For this reason, the next version of the product is likely to be introduced not only as a maize mill but as a unit that can power a number of complementary activities.

Agsol is planning to carry out additional pilot tests in Kenya, Uganda, and Tanzania in 2020. Its target customers are farmer cooperatives and SACCOs.

An alternative model for solar maize milling would be the government-sponsored cooperative mills recently implemented in Zambia with support from China. Two thousand units have been rolled out in 2018, coupled with 25-kWp solar PV systems, costing about $70,000 each. It is, however, too early to draw lessons from this project.

Table 18: Milling: Examples of PULSE products available in Uganda

Product	Product description	Presence in Uganda	Cost and financial feasibility
Universal mill (battery-coupled solar mill) 	Mill for flour production from cereal grains and dried tubers (32 kg/hr). Can be used as a hammer mill, pin mill, disk mill, or flaking mill. The machine can also be used as a rice mill, oil expeller, mincer, or pelletizer.	Manufacturer Agsol ran a pilot test (6 units) in 2019 with local distributor Power Trust and with support from CLASP/UNCDF.	~$2,500. First pilot showed that adjustments in product and value proposition are needed.

Source: Agsol website and interview, UNCDF.

Other mechanical processing

This type of machine can also be used for other agricultural products, e.g. coffee pulping and hulling. The main limitation of solar PV in this case is seasonality. Unlike staple foods, demand for coffee processing is not consistent throughout the year. Other than during post-harvest periods, the machines would remain idle.

Coffee hulling is, therefore, better suited for large-scale processing (e.g. at a cooperative scale), where demand from several farmers can be aggregated and, ideally, electricity use shared with other value-adding activities.

An analysis by NRECA provides an overview of the financial performance of electricity use in a variety of value chains, including coffee.[105] Its analysis of a coffee-farmer cooperative using electrical water pumping and hulling results in a positive financial performance (IRR of 23 percent). This is, however, based on grid electricity and the hulling equipment (a 2.2 kW, 800 kg-per-hour huller) being used for only eight months of the year. A stand-alone solar PV unit would not be feasible if not used throughout the year.

NUCAFE is currently installing an industrial solar plant to produce eco-friendly coffee for specialty markets that offer higher prices for farmers. It is not clear whether this plant is off-grid or grid-connected. In any case, it is assumed that solar power output is used not only for hulling, but also for a variety of other activities – such as roasting, grinding, and packaging services – making consistent use of installed capacity.

104 A more detailed account of the Agsol solar mills test can be found in Energy for Access's recent publication "Solar milling: exploring market requirements to close the commercial viability gap" (January 2020).

105 NRECA, 2018. Productive Uses of Electricity Program Initiative.

2.2.4 Commerce, connectivity, and medium-sized systems

Solar energy plays an important role in the supply of power for off-grid commerce and connectivity applications. This growth is visible universally in off-grid areas and productive use is a key driver of ongoing growth. Much of the growth is driven by local solar companies attempting to provide energy solutions for off-grid customers with specific energy problems related to their SME activity and connectivity.

Niches for consumer SME off-grid electricity supply comprise a wide range of applications. A variety of companies work with SMEs to meet power demand. These include:

- Professional high-end local suppliers of solar equipment
- International companies that have identified specific problems and are attempting to address them systematically
- Over-the-counter suppliers using solar power to solve small-scale consumer problems.

System types fall into two broad categories: high-end and small-scale applications.

High-end applications

High-end applications are for established private consumers seeking to save money and improve performance by replacing generators. Such clients are also interested in "going green." Medium-sized businesses recognize that solar PV can meet off-grid energy needs and are often eager to replace generators with solar power. They typically approach local **solar integrator companies**[106] and contract them to design solutions.

Players in this segment tend to be small professionals, competent in system design and integration. Systems range in size from 500 W to tens of kilowatts. Applications vary with the consumer.

Table 19 High-end applications: Examples of PULSE suppliers and projects

Suppliers	Examples of PULSE projects
UltraTec Energy Solutions For All	UltraTec specializes in medium-sized niche applications for the off-grid needs of its customers. It has completed kilowatt-scale projects for a variety of commercial customers, including: • Off-grid hotels for boutique tourism sites • Telecom transmission towers for MTN and Airtel • Solar power for off-grid bank branches and ATMs (up to 25 kWp) • Ice-packing plants for beverage companies • SWP on farms around Kampala • Cooling containers for milk
D&S DAVIS & SHIRTLIFF	Davis & Shirtliff was approached to provide power for an off-grid fruit-processing (e.g. tomato extract) factory in Kayunga.
solar now	SolarNow is often asked to design kilowatt-scale solar PV systems for clients. These include large pumping systems, cold-store containers, and commercial rooftop systems for high-end clients seeking energy independence and green branding credentials.

Source: interviews with UltraTec, Davis & Shirtliff and SolarNow.

106 Many of these companies are members of USEA.

Examples of financing requirements expressed by these companies include:

- UltraTec is considering an ESCO-type model[107] for powering the off-grid facilities of banks and financial institutions. For 10 bank branches, the loan would need to be in the range of $250,000–500,000 for five to seven years at 7 percent in local currency.
- SolarNow is interested in a special financing facility which can be passed on to clients for larger projects, e.g. rooftop solar panels for petrol stations.

In addition to commercial projects, there is an opportunity for product development to cater to the various needs of rural farms (see Annex A4: Product development – Multipurpose platforms for farms).

Small-scale SME applications

Smaller SMEs seek to improve the performance of their business by using solar power to meet critical needs. Their interests lie in increasing service offerings and lowering energy costs. Typically, they have seen another SME using solar energy and, in the absence of plug-and-play solutions for their needs, they construct a solution from components obtained from an over-the-counter supplier.

Applications in this segment, which is a significant part of the overall market, include phone charging, barbershop tools, video cinemas, lighting and music for shops, and small-scale workshop tools. System sizes for small SMEs range from 50 W to several kilowatts. Although purpose-designed systems are available,[108] most systems are assembled from components available commercially. They tend to be inefficient and perform less than ideally.

Over-the-counter traders are a main driver of this market. Shops targeting off-grid customers prominently display solar modules and batteries and offer equipment to rural consumers directly. Equipment is often low quality and design services are weak, but consumers are often able to build acceptable solutions for their businesses.

For example, in a PAUESA survey of Buvuma District island fishing communities in October 2018, over 80 percent of households and businesses were using solar PV systems as a primary power supply. Respondents indicated they used PULSE applications ranging from retail shop power, lighting, and refrigeration (for cold drinks) to video cinemas, internet cafés and printing/scanning services, tourism resorts, phone charging, and barbershops. The systems were largely "designed" by over-the-counter traders who supplied directly to communities.

Professional companies in Uganda are increasingly addressing this niche market opportunity with high-quality plug-and-play products, some examples of which are shown in Table 20.

Table 20: Small-scale SME applications: Examples of PULSE suppliers and products

Suppliers	Examples of PULSE projects
solar now	SolarNow has introduced a "Solar Business Systems" line targeted at rural off-grid SMEs. The 50–500 W range is based on its SHS line but is marketed to power SMEs in villages.
SoloGrid	SoloGrid, a start-up based near San Francisco, is focused on developing a flexible "power platform," which enables a variety of small-scale productive uses including tailoring, barbershops, and phone charging.
BrightLife By FINCA International	BrightLife, a solar company spin-off social enterprise financed by non-profit microfinancer FINCA international, is introducing products designed by a US company (Amped Innovation). They focus on low-cost productive use systems such as power for pumps, ice-makers, and televisions.
fenix intl	Companies such as Fenix International and M-Kopa offer consumer products such as barber kits and phone chargers without really differentiating between the household and SME market segments.

Source: Company websites.

107 In this context, an Energy Service Company (ESCO) invests in and operates the solar energy project, in exchange of a fee paid by the end-user for the electricity received.

108 See GIZ catalogue of DC appliances for productive use (2016).

2.3 Relative attractiveness of PULSE technologies in Uganda

This section deals with the selection of the most developed value chains and PULSE product categories, i.e. those which are more likely to achieve scale in the short term. The objective is to provide a more detailed analysis of a subset of PULSE technologies for market-sizing purposes.

Table 21 shows how the market has been segmented according to the different PULSE technologies presented in section 2.2. It also provides a summary of preceding subsections, describing the value chains and the active suppliers (i.e. market activity in Uganda) in each category.

Table 21: PULSE technologies and market penetration in Uganda

Product category	Relevant value chains	Market activity in Uganda
Solar water pumping and irrigation 	Agriculture (grain, staple crops, coffee, horticulture, livestock, dairy, etc.) Other uses: domestic, institutional	Several companies already active in Uganda, e.g. Davis & Shirtliff, SolarNow, Azuri, and Aptech Africa. **Key players entering the market:** SunCulture and Tulima Solar.
Solar refrigeration and ice-making 	Horticulture, livestock, dairy, fishing, other (e.g. small commercial, kiosks) Other uses: institutional (clinics) and domestic	SHS market leaders M-Kopa and SolarNow **recently introduced small SRUs.** Milk cooperatives are introducing off-grid industrial-sized diesel-powered chillers at milk-collection centers that could be potentially converted or replaced by solar units. GRS Commodities has introduced ice-making factories for fishing. While these units are powered by solar mini-grids, stand-alone units could be envisaged in off-grid locations.
Solar milling 	Milling of grain and staple foods (maize, cassava), rice husking, coffee pulping and hulling.	Power Trust piloted Agsol's universal mill. The technology and business model need adjustment. **No current commercial operations in Uganda**
Medium-sized systems 	Tourism (off-grid hotels), off-grid telecom towers, off-grid commercial systems (e.g. bank branches, petrol stations)	**A few companies** with capacity to design and install larger and more complex solar PV systems, with a few projects realized, e.g. UltraTec, Davis & Shirtliff
Other (niche) productive use 	Horticulture (drying of fruit), poultry (egg incubation), dairy (milking machines), etc.	**No established companies** addressing niche opportunities in farming or fishing-related activities. Examples of informal businesses in rural areas.
Commerce and connectivity 	Small-scale village applications (kiosks, phone charging, barbershops, etc.) Regular SHS could be used for these purposes.	Over-the-counter traders are a main driver of this market. **Established SHS companies** (e.g. Fenix International, SolarNow, Village Energy, SoloGrid) are **integrating appliances without differentiating commercial use from domestic.**

The more developed PULSE technologies in terms of market penetration are (a) solar water pumping and irrigation, and (b) solar refrigeration. Several international and local manufacturers and distributors are already pursuing these markets in Uganda and selling hundreds to thousands of units annually. Sales of SWPs and SRUs in 2019, both small and medium, are estimated at $3 million.

PULSE sales in the commerce (SME) and connectivity market segment are also significant but are led by informal over-the-counter traders, and are thus difficult to quantify. Established companies such as Fenix International, SolarNow, Village Energy, and SoloGrid are also selling appliances that can be used by SMEs, such as hair trimmers and phone chargers, but these sales overlap significantly with their SHS sales.

Further to the market penetration argument, Table 22 provides a comparison of PULSE technologies based on the additional broad criteria listed below. These also suggest that SWPs and SRUs represent the most attractive market segments, at least in the short term. A more detailed assessment can be found in Annex A5.

- **Presence of suppliers in Uganda.** The number of companies already operating in Uganda is a good indication of the degree of market development.
- **Market size,** measured in MWp (aggregated) or US dollars per annum.
- **Market potential and growth/scalability prospects.** The higher the potential growth of the market, the greater will be the demand for PULSE products within that value chain. Focus is on the short term (next four years).
- **Economic attractiveness of the technology.** This is based on the potential impact on farmers' income, or cost reductions, from the use of PULSE products.
- **Transformation potential.** The potential of a device or technology to shift value-added possibilities to rural and small-scale players, or to disrupt existing value chains to the benefit of rural and local players.

Table 22 Relative attractiveness of PULSE technologies

Category	Presence in Uganda	Market size (short term)	Growth prospect	Economic attractiveness	Transformative potential
Solar water pumping 	**High** Over 25 suppliers in Uganda	**High** ~$7m/y on average between 2020–24, excluding government/NGO procurement	**High** Leading companies are introducing new affordable products	**High** Two- to threefold increase in yields vs rain-fed irrigation, or 3-year payback period for solar offsetting diesel	**High** New products tailored for smallholders
Solar refrigeration 	**Medium** Small SRUs introduced by leading companies M Kopa and SolarNow	**Medium** ~$3m/y based on sales forecast for 2020–24	**Medium–high** Companies introducing new affordable products, positive early response	**High** Can significantly reduce waste of food products (milk, fish, horticulture)	**Medium–high** New products tailored for smallholder farmers (e.g. milk chillers) and small businesses
Solar milling 	**Low** No commercial operations in Uganda	**Low–medium** Commercial sales unlikely to be substantial in the short term	**Medium** Least mature technology and business model	**Medium** Staples have very low margins. Solar vs existing petrol/diesel engines is only moderately attractive.	**Medium** Targeted to commercial operators, not individual farmers

Category	Presence in Uganda	Market size (short term)	Growth prospect	Economic attractiveness	Transformative potential
Medium-sized systems, for example for off-grid telecom towers 	**Medium** Several companies with capacity to design and install	**Medium** Few projects, but of significant size (>$100k)	**Medium** Likely to grow given falling PV prices	**Medium** Solar vs diesel gensets off-grid/ weak-grid offer moderate payback periods	**Low** Unless PV systems cater for groups of smallholders
Other (niche) use 	**Low–medium** Only informal traders, no established operations	**Uncertain**	**Uncertain**	**Uncertain**	**Uncertain**
Commerce, connectivity 	**Medium–high** Sold by leading companies like SolarNow and Fenix International	**High** Already integrated in SHS offering by leading companies	**Medium** High-quality products face strong competition from informal market	**High** Revenues from small businesses in rural villages	**Medium** Market already reasonably served by informal market

The remainder of this market assessment focuses on the more developed market segments of solar water pumping and solar refrigeration.

03

POTENTIAL MARKET

This chapter provides further analysis on the two specific market segments which are more likely to achieve scale in the short term: solar water pumping and irrigation, and solar refrigeration and ice-making. Each of these is subdivided into small and medium-sized products.

This chapter provides:

- Estimates of the market size in the short term
- A financial analysis for the different technologies
- A summary of investment opportunities for donors, investors, and banks.

Box 2: COVID-19 and potential market estimates

Important note: estimations of market potential were made prior to the COVID-19 crisis

All sales forecasts presented in this report were concluded before COVID-19 was declared a pandemic in March 2020. Forecast sales, especially in the short term, are likely to decrease as a consequence of lockdown measures.

In April and May 2020, the Uganda Solar Energy Association (USEA) ran a survey among its members to assess the challenges resulting from the COVID-19 pandemic. Over 80 percent of respondents indicated they were unable to meet new product orders or provide customer service due to the lockdown measures put in place by the government in March. Collection of payments for off-grid solar products sold on credit has also decreased. As a consequence, about half of USEA members are facing liquidity challenges. Businesses are increasingly turning to solutions such as e-commerce, mobile money, and call services to make sales and to maintain relations with existing customers.

Source: USEA.

3.1 Potential market size

This section provides estimates of potential market size in each of the retained categories – small and medium SWPs, and small and medium SRUs. The potential market is measured in terms of projected sales of PULSE products in the short term, quantified in terms of units sold, aggregated MWp of solar PV capacity, and turnover in US dollars.

This is based on a bottom-up analysis of market opportunities across the different value chains and forecasts of existing PULSE suppliers. The approach to sizing the market opportunity therefore differs from the serviceable market estimations in Lighting Global's "Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa" assessment, which is top-down.

3.1.1 Solar water pumping and irrigation

Medium SWP

Sales in this market segment are estimated to be 2–2.5 MWp per year, according to SWP suppliers. However, most of this is related to government procurement and/or not linked to productive uses. Assuming 25 percent of sales relate to productive-use applications, the size of this market segment is approximately 560 kWp per year, representing about 160 projects and $1.1 million in sales annually[109].

Based on interviews with suppliers, existing and probable customers for medium SWPs include cattle and dairy farms (water pumping for consumption by animals) and farms growing high-value crops such as coffee, horticulture, and vanilla (water for irrigation). Given that SWP for productive activities is a nascent market, penetration in the short term has been estimated at a conservative 10–15 percent of the land where the technology is most promising. A first estimate of the potential market is summarized in Table 23.

109 Typical SWP project size in commercial farms is 3.5–4 kWp. The average cost of SWPs (installed) is $2,000 per kWp. More details on cost assumptions in Annex A1.

Table 23 Estimated market potential for medium SWP

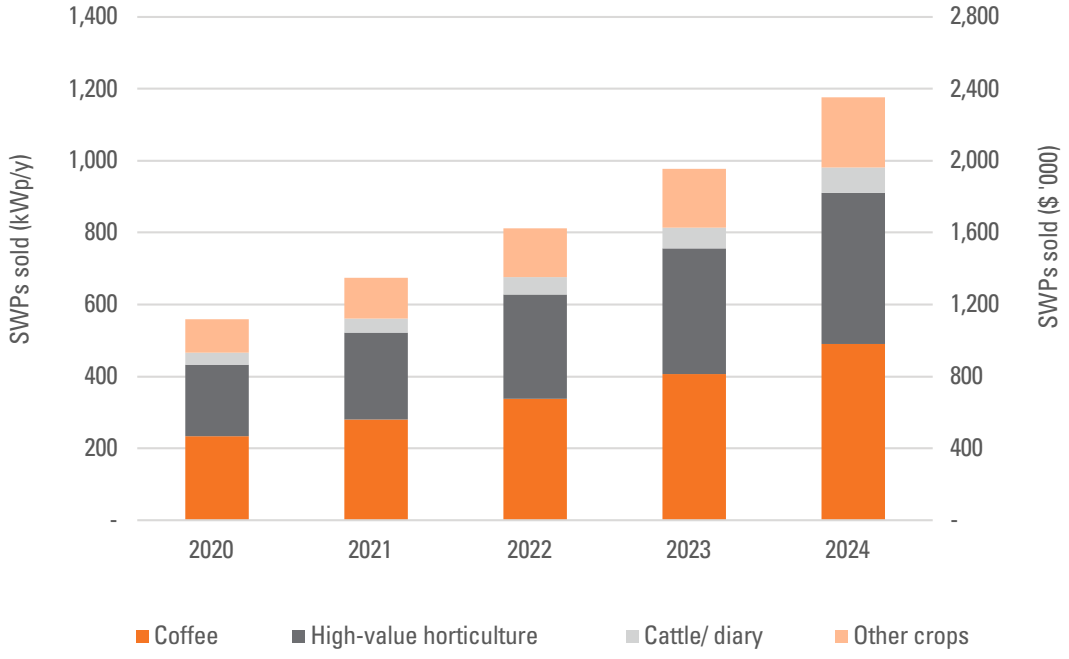
Customer category	Assumptions	Estimated potential demand (short term)
Coffee farms	~47,000 acres – 5% of the total area under coffee – is cultivated on commercial farms and plantations that would require medium or large pumping systems. Assume 10–15% of this land is converted to solar drip irrigation with a power demand of 0.2–0.4 kW/acre.	1.8 MWp ($3.5 million)
Horticulture farms	Most horticulture is done in smallholdings of under 1 acre. Larger farms and cooperatives could consider SWPs to increase yields or replace their diesel systems. Assume a small sample of farms (e.g. ~10–15% of the 8,000 horticulture farmers involved in exporting at 5 acres each) and solar drip irrigation with a power demand of 0.2-0.4 kW/acre.	1.5 MWp ($3.0 million)
Cattle/dairy farms	A 2-kW surface pump delivers ~80m3 per day, which could supply ~1,300 head of cattle at a water consumption rate of 60 liters per head per day. Only 10% of the national herd (i.e. about 1.1 million head) is kept on ranches of this size. Assume up to 10–15% of these would require solar pumping.	0.3 MWp ($0.5 million)
Other crops	Other irrigation and water supply applications not captured above	20% of total demand of the three categories above
Irrigation equipment	The costs above do not capture the costs of irrigation technologies (e.g. sprinklers, drip irrigation). Assume half of the SWP investments in coffee, horticulture, and other crops (cattle and dairy not relevant) also invest in new irrigation equipment.	~6,000 acres ($4.0 million)
Total	**4.2 MWp of SWP ($8.4 million for SWP, or $12.4 million including irrigation equipment)**	

Source: ECA analysis based on value chain information presented in section 2.1. Assumptions: average cost of SWPs $2,000 per kWp; average cost of irrigation equipment $600 per acre.

Assuming the above market opportunity materializes within five years, sales projections would evolve from 560 kWp in 2020 to 1,200 kWp in 2024, as shown in Figure 20. This represents a realistic growth rate of **20 percent per year.**[110]

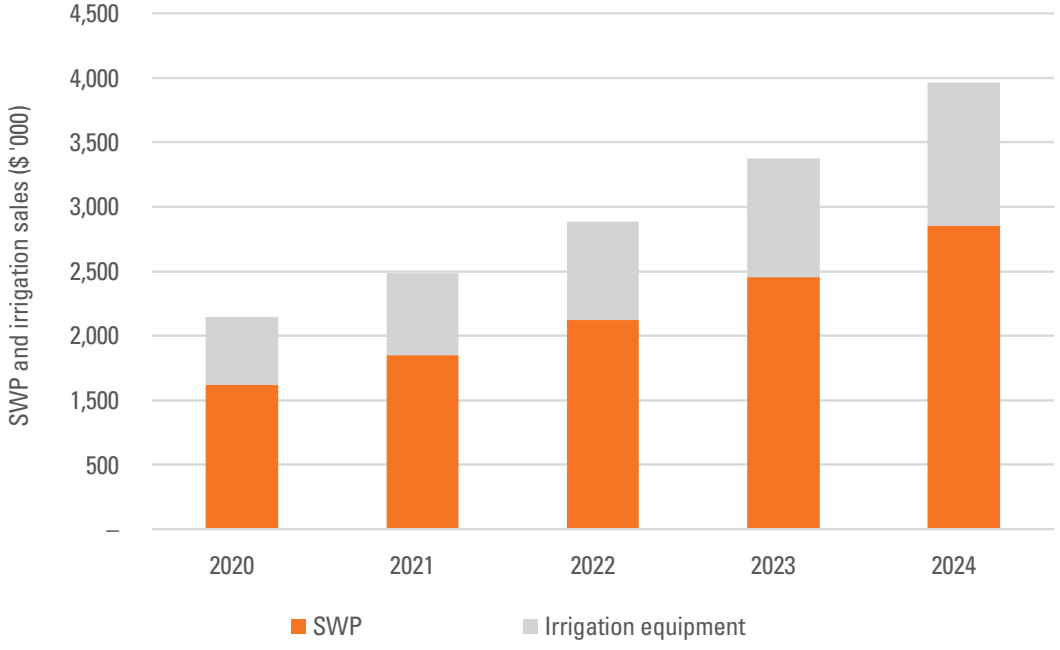
110 Commercial sales of medium SWPs for productive use are very recent and there is not enough data to assess the historical growth of the market. However, a rate of 20 percent per year can be considered realistic when compared to the growth of other relevant markets, such as the off-grid solar lighting industry (30 percent growth in annual revenue from 2017 to 2019; Lighting Global, 2020) and power supply capacity in Uganda (27 percent growth between December 2018 and December 2019; Electricity Regulatory Authority, 2020), and the evolution of solar PV capacity globally (29 percent growth annually over the last five years; REN 21, 2020). Finally, the resulting 4.2 MWp market opportunity for medium SWPs by 2024 represents only 7 percent of the potential take-up of captive solar PV in Uganda of 60 MWp, as estimated in a recent study by the GIZ (Uganda: Captive Power Developer Guide, 2019).

Figure 20: Estimated sales of medium SWPs



Assumptions: 25% of current sales of SWPs are linked to productive use, i.e. 560 kWp in 2020. A growth in sales of 20% year on year determines a total installed capacity of 4.2 MWp in 5 years. This corresponds to a 10–15% penetration in commercial coffee, horticulture, cattle, and dairy farms, which are the most likely customers for SWP according to suppliers in Uganda. Average cost of SWPs $2,000 per kWp.

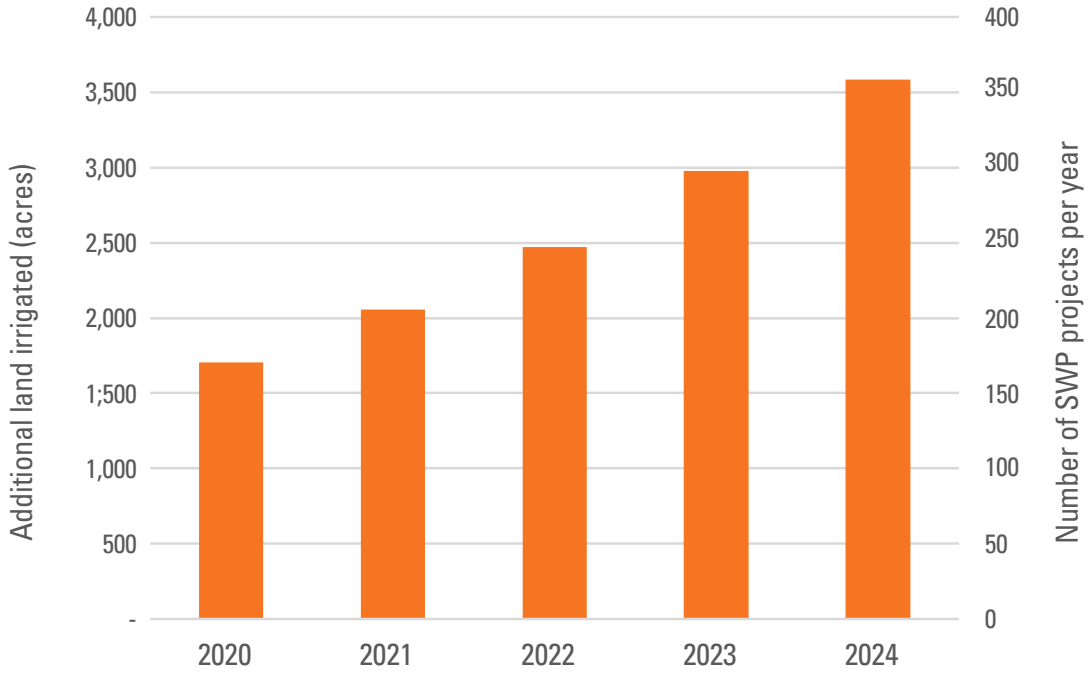
Figure 21: Estimated sales of medium SWPs including irrigation equipment



Assumptions: half of the SWP investments in coffee, horticulture, and other crops (cattle and dairy not relevant) include new irrigation equipment. Average cost of irrigation equipment is $600 per acre.

Given an average project size of 3.5–4.0 kWp and an irrigation power demand of 0.2–0.4 kW per acre, the market potential estimates above translate into the following number of projects and amount of land irrigated.

Figure 22: Estimated number of SWP projects and land irrigated



Assumptions: average project size of 3.5–4.0 kWp, according to SWP suppliers in Uganda. Irrigation power demand 0.2–0.4 kW per acre.

Small SWPs

According to the analysis in section 2.1, agricultural and livestock production is dominated by smallholder farmers across all value chains. Eighty-five percent of the country's coffee output comes from farmers with plots under 1 acre on average. A large majority of dairy operators are small-scale and have between 5 and 50 head of dairy cattle.

There is clearly a large market potential for small SWPs, but, due to significant constraints on access to water, and affordability, among other factors, the serviceable market today is likely to be small. The estimated sales for small SWPs illustrated in Figure 23 take into account the top-down approach to market sizing of Lighting Global's "Market Opportunity for PULSE in Sub-Saharan Africa" assessment and sales information provided by Uganda PULSE suppliers.

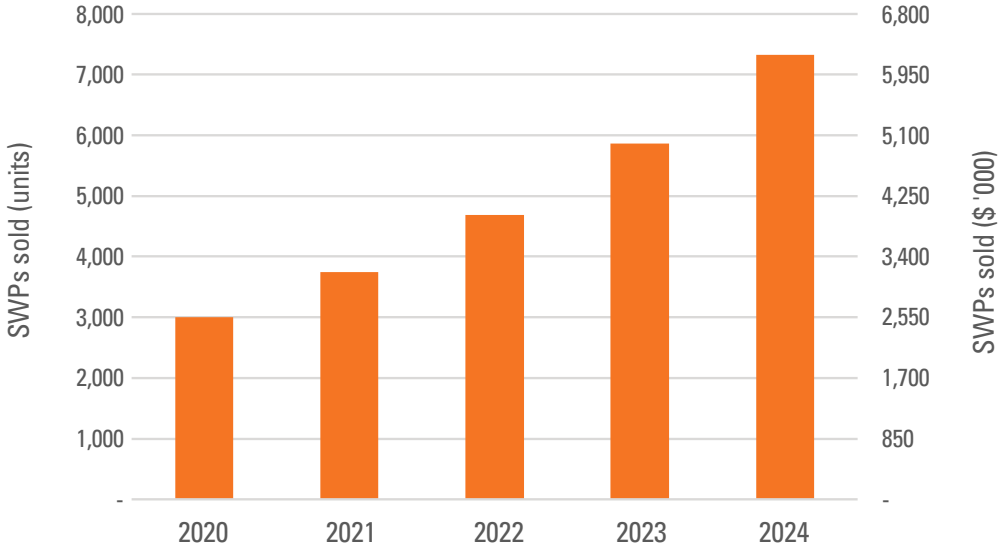
The main considerations behind this estimation are:

- **Current level of sales: 3,000 units per year.** Three leading distributors are (and will be) distributing affordable SWPs through their established and separate distribution networks. Lead distributor SolarNow (Futurepump and SunCulture products) reported selling 900 units in 2019. Davis & Shirtliff started distributing a low-cost SWP (Sunflo) in July 2019, of which it estimates it will sell thousands per year through its well-developed network of branches and retailers. In addition, Azuri and Tulima Solar – the latter in partnership with Fenix International – began distributing SWPs in 2019, making use of innovative distribution channels and providing PAYG services.

- **An annual growth rate of 25 percent is assumed.** This rate is between (a) the projected growth rate of the SWP serviceable market in sub-Saharan Africa (12.3 percent), as estimated in the Lighting Global "Market Opportunity for PULSE in Sub-Saharan Africa" assessment, and (b) the growth in turnover of the off-grid solar industry as a whole (30 percent, according to Lighting Global's 2020 Off-grid Solar Market Trends report[111]). Given an average price of $850 per unit, with these assumptions, sales would be in the range of $2–6 million a year between now and 2024.
- **Serviceable market[112]: 34,000 units today, growing at 12.3 percent a year.** Using the methodology applied in the Lighting Global "Market Opportunity for PULSE in Sub-Saharan Africa" assessment – quantifying eligible serviceable households based on issues of water access, off-grid population, and affordability – the current size of the serviceable market in Uganda would be in the order of 34,000 units, growing at 12.3 percent a year.

Figure 23: Estimated sales for small SWPs

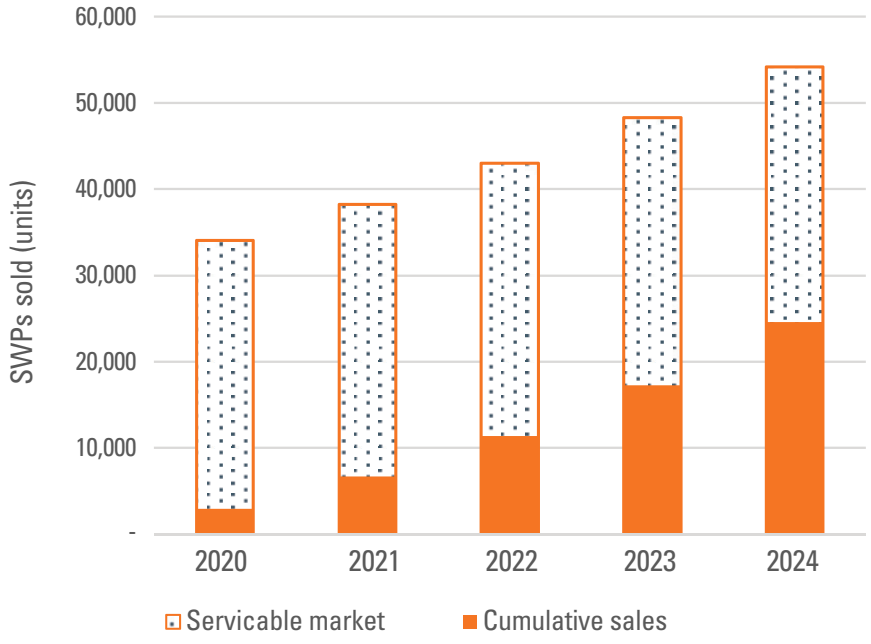
a) Projected volume of sales (number of units and $ '000)



111 Lighting Global, 2020. "Off-grid solar market trends report 2020".

112 The Lighting Global "Market Opportunity for PULSE in Sub-Saharan Africa" differentiates addressable market from serviceable market. The former refers to the total the number of smallholder farmers or production volumes to indicate total potential demand. The serviceable market results from discounting the total addressable market by market structure/physical constraints, grid access, and affordability. The serviceable market is then multiplied by the average unit price of industry-leading products to calculate market size.

b) Cumulative projected sales vs serviceable market (units)



3.1.2 Solar refrigeration and ice-making

Medium SRUs

Milk-cooling

While data from various sources differs, there are at least 100 off-grid medium-scale milk-collection centers (equipped with milk chillers with capacity ranging from 2,000 to 5,000 liters), each of them serving groups of 20–30 farmers.[113] Some of these were set up with financial and technical support from the Government of Uganda through NAADS, while others were set up by farmer groups without support. All of these chillers are currently powered by diesel generators, but according to an interview with NAADS, there is growing interest in solar PV alternatives.

Given that there are only a few examples of PULSE applications of this scale, a reasonable expectation for the short-term market potential would be:

- the conversion from diesel to solar of 20 percent of the existing 100 off-grid milk-collection centers, i.e. 20 units converted
- the development of an additional 20 percent of greenfield sites powered by stand-alone solar units, i.e. 20 new units).

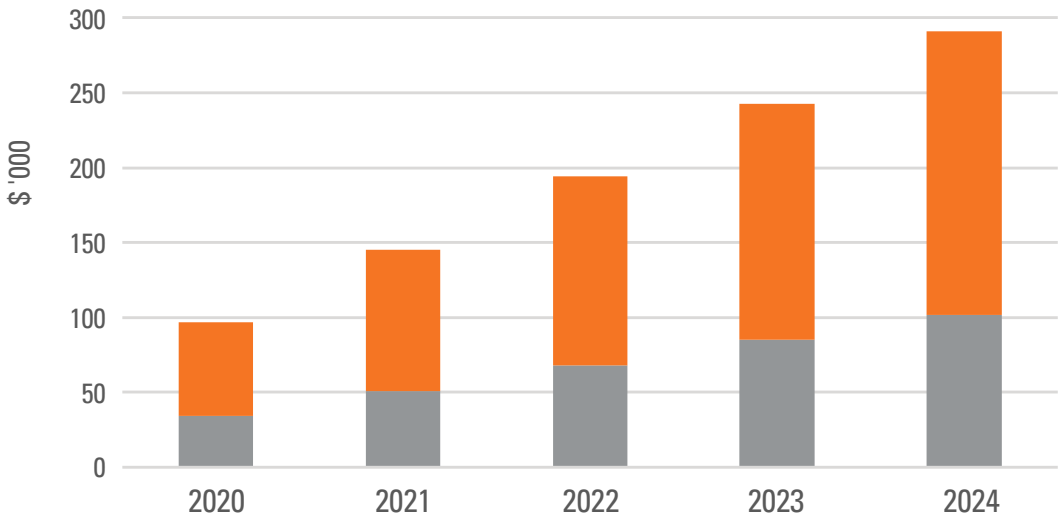
Assuming an average sized industrial stand-alone solar cooler of 2,500 liters, the 40 solar-powered units would allow processing of 100,000 liters per day, i.e. about 4 percent of the milk processed daily in the country. The cost of a new 2,500-liter milk chiller with an 8.5 kWp stand-alone solar PV system is about $31,500[114], this translates to $630,000 for 20 new units. The cost of the 8.5 kWp solar PV system alone is estimated at $17,000, so the cost of converting 20 diesel-powered units is about $340,000. The total investment of $970,000 represents an average annual investment of almost $200,000 from 2020 to 2024. This is shown in Figure 24.

Subsection 3.2.2 provides further insight into the costs and financial viability of this PULSE technology.

113 Based on interview with NAADS, October 2019.

114 UOMA, 2019. "Productive use of off grid energy: The business case in Uganda's dairy value chain"

Figure 24: Estimated investment in solar milk-chillers



Assumptions: cost of $31,500 for a new 2,500-liter milk chiller with an 8.5 kWp stand-alone solar PV system (source: UOMA). For the conversion of diesel units, only the cost of the solar PV system ($17,000) is relevant. More details in annex A1.

Ice-making for fish conservation

The business model presented in subsection 2.2.2 consists of ice-making factories located at fishers' landing sites in order to supply ice to fishing boats and, potentially, traders and intermediaries. GRS Commodities has set up factories to sell ice to fishers at only two landing sites, on Bugala and Bukasa islands. There are, however, 67 official landing sites in Kalangala District, where these two islands are located. For the whole of Lake Victoria, the number of landing sites is in the order of 200–300. Sites on the other smaller lakes in Uganda would add another 50 sites or more.

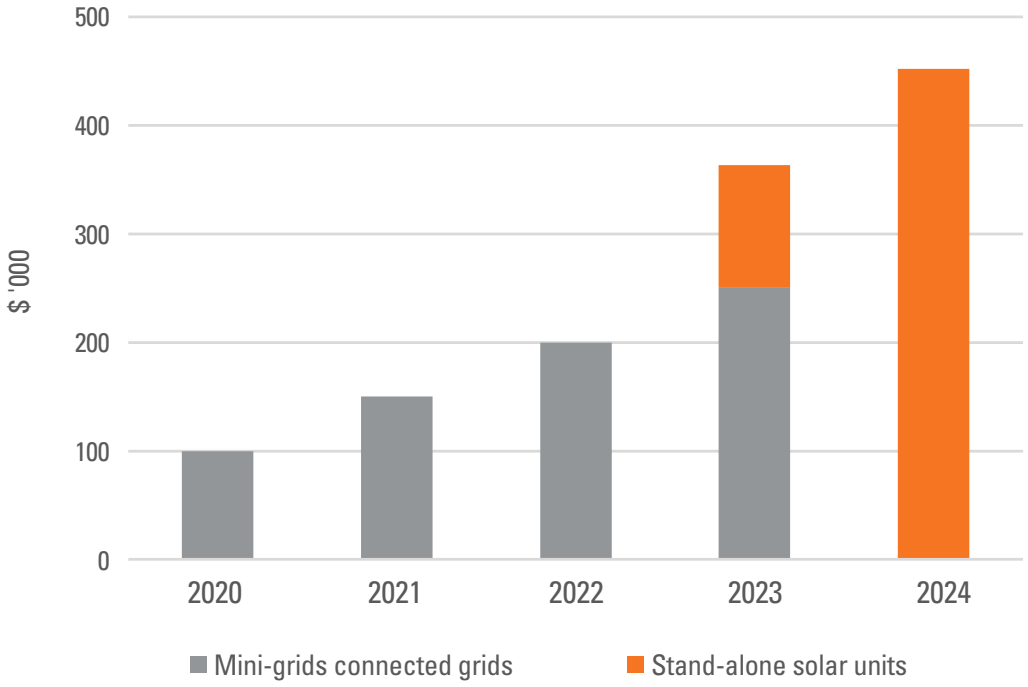
Maximum ice-making demand would, however, be constrained by the total production of Nile perch and tilapia, the species which require icing, which amounts to some 1,000 tons of fish per day.[115] According to GRS, one sack of ice allows 300 kg of fish to be kept fresh for two days. Based on this, overall demand for ice would amount to 300 tons per day. This translates to 200 units equivalent to GRS's investment in Bukasa Island (a 5-ton-per-day machine operating at 30 percent of capacity). Demand could, however, increase significantly if ice is sold to intermediaries, such as trucks transporting fish between landing sites and Kampala.

In the short term (the next four years), about 10–20 ice factories could be established in sites where electricity and water are available – connected to the main grid or in partnership with solar mini-grids. Another five stand-alone solar PV units could potentially be piloted after the sites with existing electricity supply have been utilized.

The cost of an ice-making factory connecting to an existing mini-grid is $50,000. A stand-alone system would require 31.5 kWp of solar PV capacity, representing an additional investment of $63,000. Figure 25 shows the estimated investment into 14 mini-grid-connected units and five stand-alone units, totaling $1.3 million over the five-year period.

115 Fishing catches in Uganda amount to 500,000 tons a year. Most of this (80 percent) is caught by artisanal fishermen who would benefit from ice-making facilities. Given that tilapia and Nile perch – which require icing, as opposed to silverfish, which is dried – account for 90 percent of total catch, daily production of fish requiring ice would amount to about 1,000 tons. Sources: FAO, 2018, "Fishery and Aquaculture Country Profiles;" C.T. Kirema-Mukasa & J.E. Reynolds, 1991, "Marketing and consumption of fish in Uganda."

Figure 25: Estimated investment in ice-making factories



Assumptions: cost of $50,000 for mini-grid connected unit (source: GRS Commodities). A stand-alone system would require 31.5 kWp of stand-alone solar PV capacity, representing an additional investment of $63,000.

Subsection 3.2.2 provides further insight into the costs and financial viability of this PULSE technology.

Other cooling applications

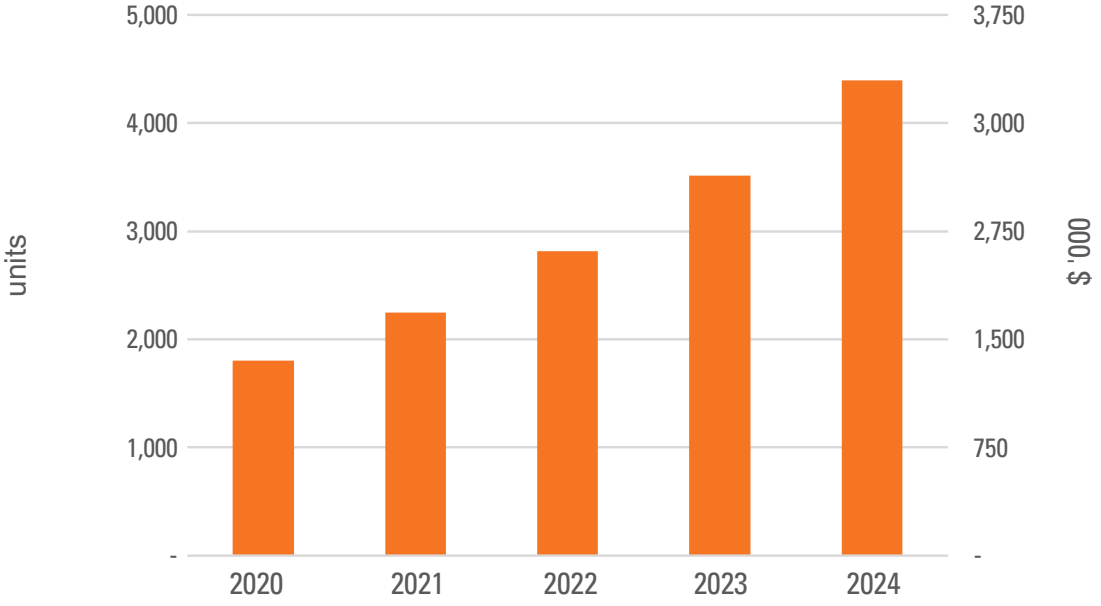
Solar cold rooms such as those offered by ColdHubs, Ecozen, and FreshBox in Nigeria, India, and Kenya, respectively (see Annex A2), are not yet commercially available in Uganda. For this reason, potential sales have not been quantified.

Small SRUs

The main suppliers of small solar refrigeration units – the only ones catering for the mass market in Uganda are M-Kopa and SolarNow, both of whom only introduced this product line in 2019. M-Kopa sales over the past three to four months indicate it will be able to sell over 1,000 units annually. SolarNow sales are lower, at about 200 units annually. The RBF facility linked to the Global LEAP Awards of 2019 could further support sales for both suppliers.

Sales of small SRUs in Uganda are assumed to grow at a rate of 25 percent a year for the first few years. This rate is between (a) the projected growth rate of the SRU serviceable market in sub-Saharan Africa (17.4 percent), as estimated in the Lighting Global "Market Opportunity for PULSE in Sub-Saharan Africa," and, (b) the growth in turnover of the off-grid solar industry as a whole (30 percent, according to Lighting Global's 2020 Off-grid Solar Market Trends report). Given an average price of $750 per unit, with these assumptions, sales would be in the range of $1.4–3.3 million a year between now and 2024.

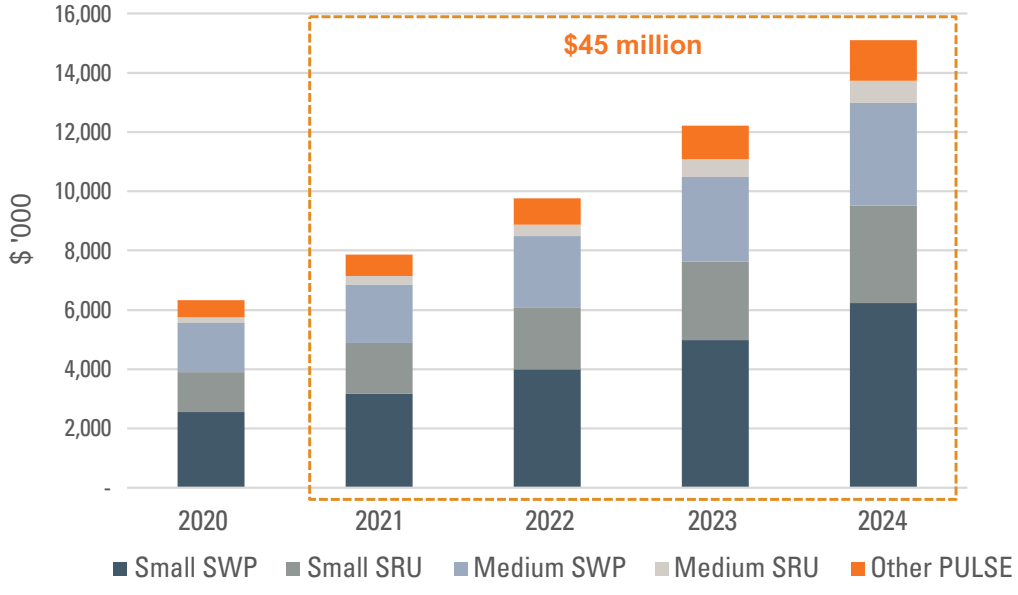
Figure 26: Estimated sales for small refrigeration units



3.1.3 Total potential market

Total projected sales across all PULSE categories analyzed above are shown in Figure 27. An additional 10 percent of sales has been included to cover other PULSE applications not presented above, such as solar milling, commerce, connectivity, and other medium-sized systems. Total projected annual sales across all categories range from $6.3 million in 2020 to $15.1 million in 2024. **This represents a total of $44.9 million for the four-year period 2021–24 and an annual growth of 24 percent.** Small SWPs and SRUs represent 63 percent of total sales.

Figure 27: Estimated sales of all PULSE applications



This is a conservative scenario, constructed based on current sales of PULSE products in Uganda and applying moderate growth rates. If support programs for the scaling-up of the market are implemented, sales are projected to be higher.

High scenario

PULSE products are creating a new market and facing multiple challenges – affordability, access to finance, awareness, logistics, and so on. If support programs are implemented in a timely manner and aggressively address these challenges, the short-term sales forecast could increase significantly.

Table 24 provides the assumptions behind a high sales scenario for each of the PULSE categories presented above. The programs mentioned in this table are explained in more detail in section 4.5.

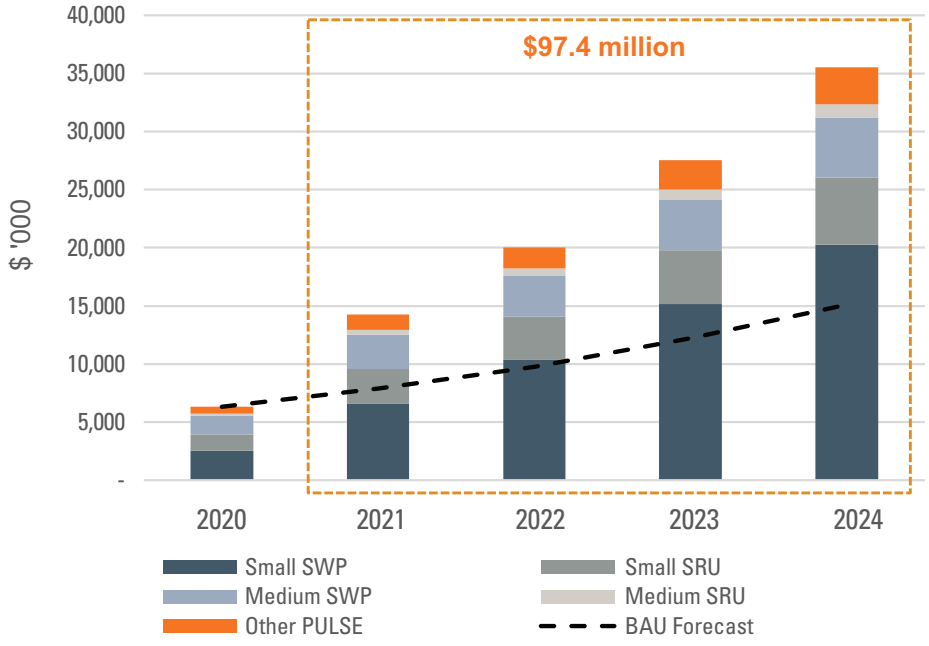
Table 24: Definition of high sales scenario

PULSE category	Assumption	Increase in sales (vs conservative forecast)	Total amount of sales in high scenario (2021–24) ($m)
Medium SWPs	A program supporting PULSE products in general provides concessional finance and facilitates market awareness and partnerships, in coordination with the Government of Uganda and other relevant programs in the energy, water, and agricultural sectors (e.g. LEIA, UNCDF's CleanStart, aBi).	~50%	16.0
Small SWPs	In addition to the above, a financial and technical support program targeted at smallholder farmers provides subsidies for SWPs as well as awareness-raising, outreach and training (see Government of Uganda's Micro-scale Irrigation Program in section 4.5). RBF is also made available to support last-mile distribution and to mitigate against affordability constraints.	An additional 40,000 units are rolled out in the four-year period.	52.4
Medium SRUs	A program supporting PULSE products in general provides concessional finance and facilitates market awareness and partnerships, in coordination with Government of Uganda and other relevant programs in the energy and agricultural sectors (e.g. LEIA, UNCDF's CleanStart, aBi). Note that LEIA is running a challenge specifically addressing off-grid cold-chain technologies.	~50%	3.1
Small SRUs	In addition to the above, RBF is made available to support last-mile distribution and to mitigate against affordability constraints.	~75%	17.0
Other PULSE	Other PULSE applications also benefit from a program supporting PULSE products in general.	Sales of other PULSE (estimated as 10% of the total of the above 4 categories) increase proportionally	8.9
Total			**97.4**

Source: ECA analysis.

Total sales of all PULSE equipment in the high scenario amount to almost $100 million in the short term, as shown in Figure 28. Annual sales range from $6 million in 2020 to $36 million in 2024, which implies an annual growth rate of 54 percent.[116]

Figure 28 Estimated sales of all PULSE products (high scenario)



3.2 Financial analysis

3.2.1 Solar water pumping and irrigation

Medium SWPs

The financial analysis for medium-scale SWPs was made on the basis of an irrigated plot of 20 acres, requiring ~6 kW of pumping capacity at a product cost of $12,000. Another $12,000 is estimated to be required for irrigation equipment (drip system), bringing the total to $24,000. Different types of crops were considered according to the following assumptions:

- Tomatoes, at a price of $500 per ton, a yield of 20 tons per acre without irrigation, a potential yield increase of 100 percent (conservative) with SWP, and the assumption that only 70 percent of production is sold (tomatoes are highly susceptible to spoilage)[117]
- Maize, at a price of $300 per ton (unprocessed), a yield of 1 ton per acre without irrigation, a potential yield increase of 50 percent with SWP and the assumption that only 50 percent of production is sold (the rest is consumed)[118]
- Coffee, at a price of $400 per ton (green coffee beans), a yield of 4.5 tons per acre without irrigation, a potential yield increase of 20 percent with SWP and the assumption that 100 percent of production is sold.[119]

The returns associated with SWPs are very high for tomatoes, moderate for coffee, and unviable for maize, as shown in Table 25.

116 This annual growth rate, while very high, is comparable to the annual growth rate in sales of off-grid solar products during the early years of market development (79 percent annual growth between 2012 and 2015).

117 Lighting Global, 2019. "The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa". The potential for yield increase of irrigated tomatoes is up to four-fold, making the assumption of a 100 percent (two-fold) yield increase conservative.

118 Own research (section 2.1.1) and Lighting Global "Market Opportunity for PULSE in Sub-Saharan Africa" assessment.

119 Own research (section 2.1.2) and NRECA productive uses study.

Table 25: Financial analysis for a medium SWP project

Type of investment	Key assumptions	Results
SWP vs rain-fed irrigation	Capacity: 6 kW Price: $24,000 (useful life: 10 years) Operating expenses: 10% of price p.a. (assumed to represent replacement of pipes and other components) WACC: 16% (80% debt at 15% interest) Irrigated land: 20 acres (tomatoes, coffee, maize) Yield: assumed increase in yields presented above	Investment is financially attractive for tomatoes (payback in one harvest) and coffee (payback period of five years). Investment not viable for maize
SWP vs diesel pump	Same assumptions as above regarding SWP, except that investment in irrigation equipment is not considered relevant (it would be the same regardless of source of power). Off-set investment and fuel expenses: Diesel genset: $3,000 Fuel consumption: 8 liters per day (supplementary irrigation needed only eight months of the year) Diesel price: $1.10 per liter (pump price plus transport) Total fuel and genset O&M costs: $2,500 per year	Investment is financially feasible Net Present Value (NPV): $4,200 Internal Rate of Return (IRR): 27% Payback Period (PBP): 3.6 years

Source: ECA analysis

Many medium-sized farms such as the one in this analysis are already being irrigated with motorized pumps powered by petrol or diesel. If this is the baseline, the benefits of SWPs consist in fuel savings (as well as small O&M savings) compared to those associated with the diesel engine, making solar pumps financially viable.

Sensitivity analysis

Some of the key assumptions made in the financial analysis will inevitably be different in reality, such as the market price for crops, the price of fuel that is being avoided with a SWP, and the cost of the SWP itself. A sensitivity analysis was conducted to evaluate the impact of these changes and to determine in what circumstances SWPs continue to be viable.

Table 26 shows the result of a sensitivity analysis testing the impact of different yield uplift, crop prices, and SWP equipment cost. Yield uplifts or output prices were assumed to vary by plus or minus 25 percent, increasing or decreasing farmer revenues from the baseline. For example, higher prices could result from selling products off-season and lower yields than expected could result from SWP equipment malfunctions. The costs of the SWP and irrigation projects were assumed to vary from –10 percent to +50 percent. The reason for the asymmetry in investment costs is that, depending on access to water and other considerations, investment could be much higher than foreseen if the project was not properly assessed (e.g. the need to drill a deeper borehole).

Total projected annual sales across all categories range from **$6.3 million in 2020** to **$15.1 million in 2024.** This represents a total of $44.9 million for the four-year period 2021–24 and an annual growth of **24%.** Small SWPs and SRUs represent **63%** of total sales.

Table 26: Sensitivity to yield uplift, product prices, and equipment cost

SWP and irrigation for tomatoes (PBP in years)					SWP and irrigation for coffee (PBP in years)				
		Project cost (capex and opex)					Project cost (capex and opex)		
		–10%	Base case	+50%			–10%	Base case	+50%
Yield uplift OR output price	–25%	0.2	0.2	0.4	Yield uplift OR output price	–25%	6.7	8.1	20.3
	Base case	0.2	0.2	0.3		Base case	4.3	5.0	10.1
	+25%	0.1	0.1	0.2		+25%	3.2	3.7	6.7

The conclusion of the sensitivity analysis is that changes in inputs do not have a significant impact on the profitability of solar irrigation for tomatoes – which could be extended to high-value horticulture more generally. On the other hand, unfavorable changes in project costs or revenues would render a coffee irrigation project much less attractive, with payback period increasing to well over five years. Solar irrigation of maize remains unviable regardless of the scenario.

As for SWPs replacing diesel pumps, sensitivity has been tested in relation to fuel costs (+/–20 percent) and SWP costs (–10 percent to +20 percent). The fuel price variation applies to the long term, i.e. to the assumed 10-year life of the SWP project. Short-term variations, like the recent collapse in fuel prices, are less relevant in this analysis. The upward change in investment cost is kept lower than in the previous case because the risk of underestimating the investment cost in an existing irrigation scheme would be lower. There are still variations to be considered due to price differences between suppliers and cost overruns during installation.

Table 27: Sensitivity to fuel cost and equipment cost

PBP (in years) of solar vs diesel				
		SWP capex		
		–10%	Base case	+20%
Fuel cost	–20%	3.9	4.6	5.8
	Base case	3.2	3.6	4.6
	+20%	2.6	3.0	3.8

Based on the result of the analysis, the payback period varies between 2.6 and 5.8 years, indicating that a SWP is financially viable vs. a diesel pump in most scenarios.

Small SWPs

Results for small SWPs (such as SunCulture or Futurepump) at an average cost of $850 to irrigate 1 acre of land are very similar to those presented above, i.e. very lucrative for high-value horticulture, moderate results for coffee, and unviable for maize.

3.2.2 Solar refrigeration and ice-making

Milk-cooling

The financial analysis for medium-scale stand-alone solar milk coolers was made on the basis of a 2,500 liter-per-day cooler. The key assumptions and results are summarized in Table 28. The analysis compares the performance of off-grid coolers powered by diesel with those powered by stand-alone solar. Despite the higher up-front cost, stand-alone solar allows for significant fuel savings (approx. 10 liters per day) and therefore has about the same financial performance as coolers powered by diesel generators.

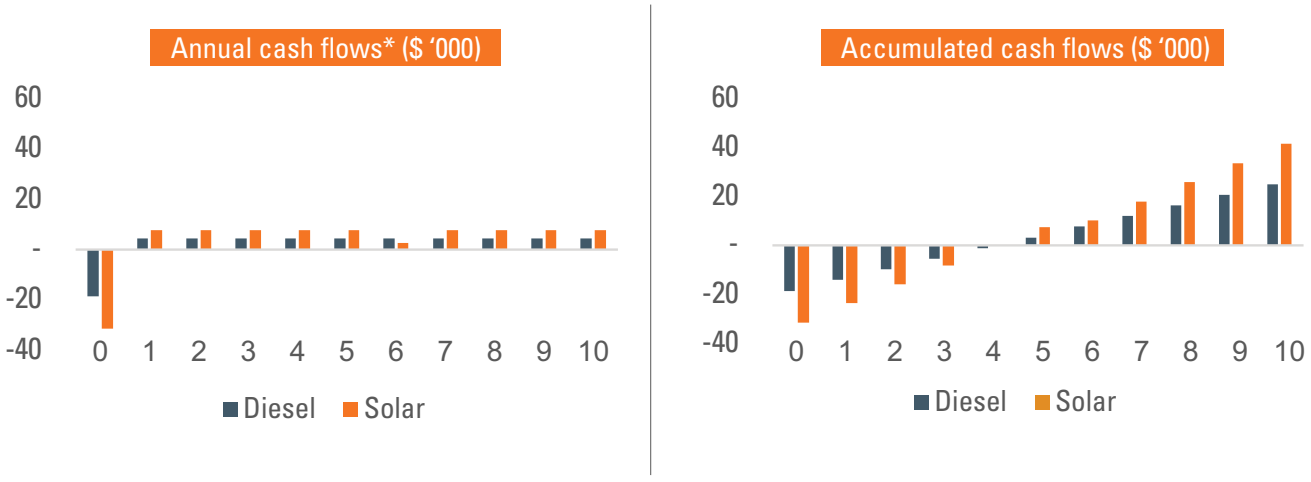
Table 28: Financial analysis for milk-cooling centers

Type of investment	Key assumptions	Results
Milk cooler powered by diesel 	Capacity: 2,500 liters (one batch per day) Utilization: 80% Milk price: $0.10/liter (conservative) Avoided waste of milk: 15% (conservative) Capex: $18,500 (including genset, useful life: 10 years) Energy consumption: 35 kWh/day Electricity cost: $0.34/kWh (fuel cost and maintenance, assumes efficient and properly sized genset) Other opex: $3,150 p.a. in staff and O&M costs WACC: 16% (80% debt at 15% interest)	The investment in a diesel-powered cooler to avoid waste of milk is financially feasible NPV: $2,500 IRR: 20% PBP: 4.3 years
Milk cooler powered by solar 	Same assumptions as above, except for power supply Solar PV capacity: 8.5 kWp Solar PV capex: $17,000 (of which batteries represent 30% and are replaced after six years) Total capex: $31,500 Opex: $3,150 p.a. in staff and O&M costs (10% of total capex)	The investment in a solar-powered cooler to avoid waste of milk is financially feasible, with a similar financial performance as the diesel-powered cooler NPV: $4,100 IRR: 20% PBP: 4.0 years

Source: UOMA, ECA analysis.

The analysis of cash flows, illustrated in Figure 29, compares the savings generated by avoiding wasted milk with the capex and opex of milk coolers, for the two different power sources. While the initial investment is higher for the solar-powered cooler, operating expenses are much lower than those of the diesel-powered cooler, resulting in similar financial performance indicators.

Figure 29: Results of financial analysis for milk cooler



**The negative cash flows in year 0 represent the initial investment in diesel- and solar-powered coolers. The positive cash flows thereafter are the net of (a) savings from avoided waste of milk, and, (b) operating expenses, for each type of cooler. Because of the high cost of fuel, net savings are lower for diesel-powered coolers.*

Looking at the financial analysis of the conversion from diesel to solar PV, therefore considering the $17,000 investment in a solar PV unit vs. fuel savings, the NPV is negative (–$2,400) and the IRR is 12 percent. This implies that incentives may be required to make these investments attractive. These could take the form of:

- Cost-sharing grants, reducing the investment cost by 10–20 percent;
- Concessionary financing, bringing the WACC to below 12 percent; or
- A combination of the above.

Sensitivity analysis

The financial viability of solar PV for milk-chilling is dependent on the assumptions regarding milk price, avoided milk losses, SRU investment costs, and diesel prices, among others. Sensitivity to these factors is shown in Tables 29 and 30. Milk price or avoided losses are assumed to vary between $0.8–1.2 per liter and between 12–18 percent of production, respectively. Capex is likely to decrease over time, but the higher cost represents the risk of having underestimated investment given that this is a new technology in Uganda. The results, with payback periods exceeding five years in some of the tested scenarios, confirm that financial incentives will need to be provided to encourage greenfield and brownfield (replacing diesel) investments in solar milk chillers.

Table 29: Sensitivity to milk price or avoided milk losses

PBP (in years) of SRU vs avoided milk losses				
		SRU capex		
		–10%	Base case	+20%
Milk price or avoided losses	–20%	4.8	5.6	7.6
	Base case	3.5	4.0	5.3
	+20%	2.8	3.2	4.0

Table 30: Sensitivity to fuel cost and equipment cost

PBP (in years) of solar vs diesel				
		SRU capex		
		–10%	Base case	+20%
Fuel cost	–20%	5.5	6.2	7.4
	Base case	4.4	4.9	5.9
	+20%	3.5	4.1	4.9

Ice-making for fish conservation

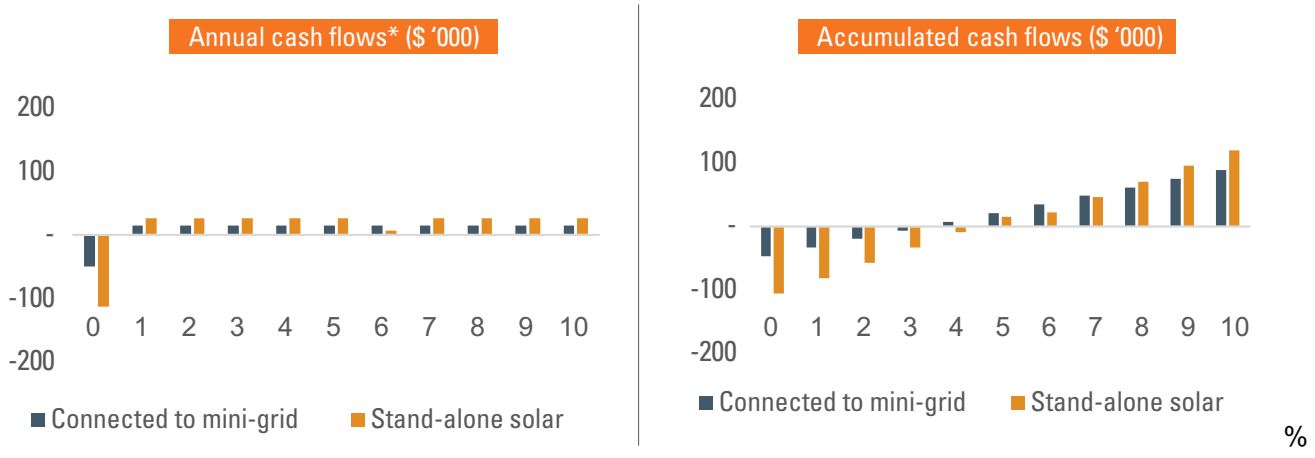
The financial analysis for the ice-making factory was made on the basis of the investment by GRS Commodities on Bukasa Island presented in subsection 2.2.2. The key assumptions and results are summarized in Table 31. Factories connected to mini-grids are more attractive financially than stand-alone units, and it is therefore likely that this type of investment will be mostly linked to mini-grids in the short term. However, stand-alone units are also financially feasible.

Table 31: Financial analysis for ice-making factory

Type of investment	Key assumptions	Results
Ice factory connected to mini-grid 	Capacity of factory: 5 tons of ice per day Utilization: 30% Ice losses: 20% Resulting output: 548 tons of ice per year Ice price: $75/ton Capex: $50,000 (useful life: 10 years) Power draw: 17.5 kW (i.e. 46 MWh/y) Electricity cost: $0.26/kWh (KIS mini-grid) Other opex: 10% of revenue to district government and $3,000 p.a. in staff and O&M costs WACC: 16% (80% debt at 15% interest)	Investment is financially feasible NPV: $20,000 IRR: 26% PBP: 3.4 years
Ice factory with stand-alone solar PV 	Same assumptions as above, except for power supply Solar PV capacity: 31.5 kWp Additional capex: $63,000 (of which batteries represent 30% and are replaced after six years) Solar PV O&M expenses: 1% of capex p.a.	NPV: 4,700 IRR: 17% PBP: 4.4 years Investment is financially feasible.

Source: ECA analysis.

Figure 30: Results of financial analysis for ice-making factory



Sensitivity analysis

The financial viability of solar PV for ice-making is dependent on assumptions regarding revenue – a function of the price of ice and sales volume – electricity tariffs (if buying power from a mini-grid), and solar equipment costs (in the case of stand-alone solar units). Sensitivity to these factors is shown in Tables 32 and 33.

Table 32: Sensitivity to electricity tariffs and revenues

PBP (in years) of mini-grid-connected ice factory				
		Electricity tariff		
		–10%	Base case	+20%
Revenue	–20%	5.1	5.8	8.1
	Base case	3.2	3.4	4.1
	+20%	2.3	2.4	2.8

Table 33: Sensitivity to solar investment costs and revenues

PBP (in years) of stand-alone solar ice factory				
		SRU capex		
		–10%	Base case	+20%
Revenue	–20%	5.3	5.6	6.3
	Base case	4.1	4.4	4.9
	+20%	3.3	3.5	4.0

Milk price or avoided losses are assumed to vary between **$ 0.8–1.2 per liter** and between **12–18%** of production, respectively.

The results show that financial viability is more sensitive to revenue than it is to the cost of electricity or the investment cost in stand-alone solar. A stand-alone solar ice factory with revenues 20 percent lower than expected due to either low demand or lower market price would result in an IRR of 10 percent and a PBP of 5.6 years. In order to make the investment financially viable in these circumstances, financial incentives should be provided, such as:

- Cost-sharing grants, reducing the investment cost by one-third.
- Concessionary financing, bringing the WACC to below 10 percent.
- A combination of the above.

Small refrigeration units

The case of a small dairy farmer chilling milk was modelled. A 50-liter unit is priced at $1,000[120] and can help avoid milk wastage of around 20 percent. At a conservative price of $0.10 per liter, the solution would increase revenues by $1.00 per day, with a PBP of 2.7 years.

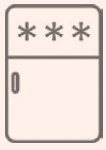
Sensitivity to investment costs and avoided milk losses is similar to the case presented in Table 29.

3.2.3 Summary of financial analysis

Results of the financial analysis are summarized below. Moderate and high returns were observed for all technologies. The returns for smaller PULSE products are higher, as PULSE allow smallholders to significantly increase yields or reduce spoilage of production. On the other hand, medium PULSE appliances typically replace diesel power and thus have a more competitive baseline.

120 A milk-chilling unit is considered more expensive than the SRUs presented in section 2.2.2, as it needs to chill milk to 4° C in a very short time.

Table 34 Summary of financial analysis

PULSE category	Subcategory	Results
Solar water pumping and irrigation 	**Small** ($850 SWP for 1 acre)	**Very high returns for horticulture** (e.g. investment in irrigation of tomatoes pays back in one harvest) and coffee (PBP of three years) given the high value of the commodities and the high potential yield increase with irrigation. ***Not financially feasible for maize,*** given low commodity value (part of production is consumed by the producer) and low yield increase.
	Medium ($12k SWP for 20 acres)	The above also applies for medium-scale irrigation, but in this case a comparison of solar pumps with diesel pumps is more relevant. SWPs have **moderate returns in comparison with diesel or petrol** (PBP 3.6 years, IRR 27%)
Solar refrigeration and ice-making 	**Small** (50-l milk chiller at $1,000)	Small SRUs used by individual dairy farmers to chill overnight milk production or in retail shops for cooling drinks and food have **moderate returns** (PBP 2.7 years)
	Medium (industrial milk chiller of 2,500 liters) (ice-making plant of 5 tons per day)	New stand-alone solar industrial milk cooler (investment vs reduced wastage of milk) yields moderate PBP of about four years (IRR 20%); **but solar PV unit replacing existing gensets** and thus reducing fuel consumption **has lower returns and pays back in five years** (IRR 12%). In the case of ice-making plants, **solar-mini-grid-connected factories have a PBP of 3.4 years (IRR 26%)**, while for **stand-alone solar units PBP would be 4.4 years (IRR 17%).**

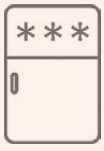
Source: ECA analysis.

Despite these favorable results, it is estimated that financial incentives – e.g. concessionary financing and/or results-based (grant) financing – would be needed to increase affordability for smallholders and to incentivize commercial operators to switch technologies. The issue of affordability is tackled in more detail in section 5.1.

3.3 Investment opportunities

This section aggregates the investment amounts presented in section 3.1 and provides a high-level view of types of financing required. Investment opportunities are summarized in Table 35.

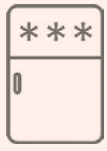
Table 35 Summary of investment opportunities

Category	Subcategory	Short-term sales/ investment (2021–24)	Type of financing
Solar water pumping and irrigation 	Medium (~$10k per project)	$10.7m (BAU scenario) $16.0m (high scenario)	• Concessional finance for capex investments (>$10k) granted to horticulture or coffee farmers operating medium-sized farms or to association of smallholder farmers combining plots. Long term (>5 years). • Loans to PULSE suppliers for financing SWP stock (6–12 months of sales) • Grants to end-users to incentivize conversion to SWP (~20% of capex)
	Small (~$850 per unit)	$18.4m (BAU) $52.4m (high)	• Working capital for PULSE distributors (six months) and receivables financing for companies operating PAYG (over more than 24 months) • Consumer financing through MFIs and SACCOs (12–24 months) • Grants to incentivize take-up (e.g. Global LEAP RBF facility) (~20% of cost) • The high scenario assumes subsidies to mitigate against the affordability barrier and unlock economies of scale, such as those planned under the Micro-scale Irrigation Program (see section 4.5).
Solar refrigeration and ice-making 	Medium (~$30–$100k per project)	$2.0m (BAU) $3.0m (high)	• Concessional finance for capex investments (>$30k) granted to entrepreneurs (such as GRS Commodities), cooperatives (e.g. running milk-collection centers), or off-takers • Grants to end-users to incentivize conversion to SRUs (~20% of capex)
	Small (~$750 per unit)	$9.7m (BAU) $17.0m (high)	• Working capital for PULSE distributors (six months) and receivables financing for companies operating PAYG (over more than 24 months) • Consumer financing through MFIs and SACCOs (12–24 months) • Grants to incentivize take-up (e.g. Global LEAP RBF facility) (~20% of cost)
Other PULSE	$4.1m (BAU) $8.9m (high)		• A combination of the above mechanisms
Total		**$44.9m (BAU)** **$97.4m (high)**	

Source: ECA analysis.

The projected amount of financing needed to mobilize almost $100 million in sales of PULSE equipment is estimated at about $48 million, given as a combination of project/corporate financing and working capital and receivables loans, as shown in Table 36.

Table 36 Financing requirements

Category	Sub-category	Sales (2021–24)	Type of financing	Amount of financing ($m)
SWPs 	Medium	$16.0m	Finance for end-user, long term (>5 years) Assumed gearing ratio: 80%	12.8
			Equipment financing for suppliers: ~6–12 months between buying equipment and commissioning projects/ receiving final payment*	3.0
	Small	$52.4m	Commercial sales ($18.4m): Working capital and receivables/consumer financing. ~6 months between placing order with manufacturer and installation at customer's premises + 24 months of PAYG/consumer financing. Sales on cash: 20%* Sales under government procurement ($34m**): Working capital ~6–12 months between placing order with manufacturer and installation at customer's premises, verification, and receiving payment*	16.0
SRUs 	Medium	$3.0m	Finance for end-user, long term (>5 years) Assumed gearing ratio: 80%	2.4
			Equipment financing for suppliers: ~6-12 months between buying equipment and commissioning projects*	0.6
	Small	$17.0m	Working capital and receivables/consumer financing ~6 months between placing order with manufacturer and installation at customer's premises + 24 months of PAYG/ consumer financing. Sales on cash: 20%*	8.9
Other PULSE		$8.9m	A combination of the above	4.4
Total		**$97.4m**		**48.2**

** Working capital and receivables financing requirements are calculated as annual average sales ($/year) multiplied by average financing period (in years). The latter is calculated as a weighted average of the financing period for cash sales (typically 0.5–1 year) and the financing period for PAYG/consumer credit (typically 2.5 years). ** Micro-scale Irrigation Program or a similar program. Government-assisted procurement removes the need for PAYG/consumer financing provided by suppliers.*

RBF has not been explicitly included in the requirements above. If RBF grants are given, the total amount of financing (loans) required will decrease by that amount.

The above financing requirement will be addressed by multiple players, many of them already present in the market, including the Government of Uganda, international and local financing institutions, and development partners. Many of these players are presented in chapter 4.

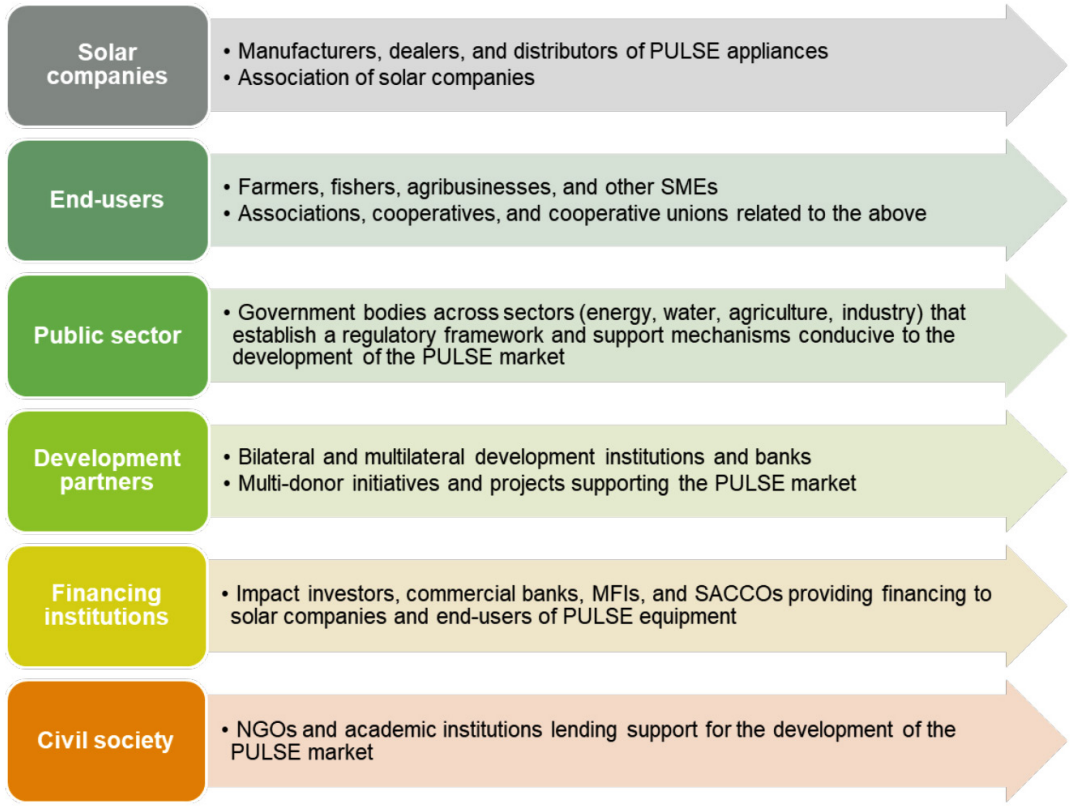
04

STAKEHOLDER MAPPING

The market for PULSE products involves various stakeholders with different objectives and roles in the sector. This chapter presents a map of the key players, to understand their current and future roles in the Ugandan PULSE market.

An overview of the key stakeholders is provided below.

Figure 31: Key stakeholders



4.1 Solar companies

The market for solar PV in Uganda has grown significantly from a few importers based in Kampala a decade ago to more than 200 companies today. Over 180 of these are members of the Uganda Solar Energy Association (USEA), which describes its membership as being composed of:

- **10 percent manufacturers or assemblers,** i.e. companies manufacturing solar products, with their own factories or outsourcing, e.g. Chloride, Exide, Davis & Shirtliff, M-Kopa, Fenix International, and Greenlight Planet.
- **70 percent distributors,** importing from manufacturers – some of them with contracts for official in-country representation – and selling through their distribution network, both wholesale and retail. Some of these companies also provide financing and customer service. Examples of distributors are Davis & Shirtliff, SolarNow, Village Energy, Village Power.
- **20 percent dealers,** exclusively involved in retail business (less specialized product lines than distributors).

These companies vary widely in the type of solar systems they sell and have the potential to support the expansion of the PULSE market by adopting business models that make PULSE products more accessible to smallholder farmers and other SMEs. Table 37 provides a non-exhaustive list of prominent companies selling and distributing PULSE products in Uganda.

Table 37: List of solar companies in Uganda focusing on PULSE

Company	Type	Description	Presence in Uganda	Product categories
Adritex	Dealer	Dealer in irrigation equipment, SWPs, boreholes, solar equipment, generators, etc.	Proprietary Distribution	
AgSol	Manufacturer	Sells solar powered agro-processing machines. Piloted its Universal Grain Mill in Uganda through Power Trust	Through local distributor Power Trust	
All-In-Trade	Dealer	Sells solar panels, solar charge controllers, SWPs, solar water heaters, refrigerators, and freezers	Proprietary Distribution	
Aptech Africa	Distributor	Sells solar applications such as SWPs, SRUs, solar water heating, office power supply, portable solar kits, solar street- and security lighting	Proprietary Distribution	
Azuri	End-to-end integration	Launched pilot of "GrowFast" PAYG SWP in Uganda in 2019. Product includes installation and agronomist support	Proprietary Distribution	
BrightLife (by FINCA)	Distributor	Partnering with manufacturers to bring solar appliances (water pumps, maize grinders, and ice-makers) to farmers	Proprietary Distribution	
Davis & Shirtliff	Distributor	Market leader for SWPs, sprinklers, drip kits, foot pumps, etc. Turnkey projects	Proprietary Distribution	
Energy Systems	Distributor	Stand-alone solar/hybrid energy solutions, solar medical refrigerators/freezers, SWPs	Proprietary Distribution	
Fenix International	End-to-end integration	Market leader for PAYG SHS and appliances (radios, TVs). Partnership with Tulima Solar for SWPs.	Proprietary Distribution	
Futurepump	Manufacturer	Portable solar irrigation pumps for smallholder farmers in East Africa	Through local distributors SolarNow and Davis & Shirtliff	
GRS Commodities	Manufacturer/ system integrator	Project development services, piloting commercial off-grid solar concepts, supporting plant installation through assembly of local teams	Proprietary Distribution	
Grundfos	Manufacturer	Leading manufacturer of SWP systems	Through local distributors Davis & Shirtliff, Aptech Africa, NSI	
Innovation Africa	Distributor	Designing and implementing SWP projects in rural areas, from concept to commissioning, and ongoing support	Proprietary Distribution	
ItalTrade	Distributor	Solar installations. Products include solar panels, solar charge controllers, and solar inverters	Proprietary Distribution	

Company	Type	Description	Presence in Uganda	Product categories
Lorentz	Manufacturer	Leading manufacturer of SWP systems	Through local distributors Davis & Shirtliff, Adritex	
M-Kopa	End-to-end integration	Leading PAYG SHS company, selling solar-powered appliances, including refrigerators	Proprietary Distribution	
Mueller	Manufacturer	Milk-cooling equipment (grid and off-grid) of different sizes	Through local distributor Inndigo	
NSI Water	Distributor	Supply and installation of pumps, solar systems, irrigation systems, water treatment systems	Proprietary Distribution	
Power Trust	Distributor	Supply, installation, and servicing of solar systems and solar water heaters, both domestic and commercial	Proprietary Distribution	
Solantis	Distributor	Diversified portfolio of SHS in different sizes, solar lanterns, and electrical accessories such as TVs and radios	Proprietary Distribution	
SolarNow	Distributor	Leading SHS company also providing solutions for small businesses and agriculture	Proprietary Distribution	
Solar Today	Distributor	SHS for businesses, including standard solar packages (e.g. hair salons and cinemas)	Proprietary Distribution	
SoloGrid	End-to-end integration	Focused on village-level small-scale productive use applications such as workshops, barbershops, and tailoring	Proprietary Distribution	
SunCulture	Manufacturer (end-to-end integration in Kenya)	Designs, manufactures, finances, and distributes solar-powered irrigation systems and services	Through local distributor SolarNow	
SunDanzer	Manufacturer	SRUs, serving a range from small dairy farmers and shop owners up to large projects	Through local distributor Aptech Africa	
Tulima Solar	End-to-end integration	Known internationally as Simusolar Launched PAYG SWPs in Uganda in 2019 as a full-service B2C business, offering financing, design, installation, and after-sales service directly to end-users	Proprietary Distribution	
UltraTec	Distributor and system integrator	Design, installation and maintenance services for SWPs and medium-sized installations	Proprietary Distribution	
Village Energy	Distributor	Solar for businesses and institutions (refrigeration, water heating, water pumping, office equipment, etc.)	Proprietary Distribution	
Village Power	Distributor	Provides a range of solar kits (system and accessories), supported by financing options	Proprietary Distribution	
W.Water Works	Distributor	Water engineering company selling SWPs and irrigation systems	Proprietary Distribution	

Note: Companies marked with the Ugandan flag are based in Uganda. Source: Company websites.

Relevant associations

Association of solar energy companies

The Uganda Solar Energy Association (USEA) was established in 2016 with a mandate to facilitate the growth and development of solar energy business in Uganda. The association comprises 180 members. Some of the association's activities include:

- Advocacy. USEA has recently published a booklet on solar product taxation. It does not, however, cover productive uses.
- Business & technical training. The association is working closely with donor agencies to design and provide capacity-building to its members.
- Market research
- Networking and linking members to potential business opportunities.

Private Sector Foundation Uganda

The Private Sector Foundation Uganda (PSFU) is Uganda's apex body for the private sector. It has 240 members, the majority of which are associations. PSFU runs government projects related to private-sector inclusion and provides capacity-building to its members to prepare them for taking loans.

Some of the relevant activities carried out by PSFU in the field of solar energy are:

- Support for a solar water heating project for the hospitality industry as part of the World Bank program ERT-II (2009–15), offering cost-sharing grants.
- Support for awareness creation campaigns as part of ERT-II.
- Support for USEA in the establishment of governance structures, and provision of start-up financial and technical support.
- Provision of capacity-building to members on a cost-sharing basis.

4.2 End-users

Potential end-users of PULSE products include farmers, dairy producers, fishers, and other businesses that could increase the value of their production and/or decrease costs by investing in stand-alone solar products.

Given that most end-users are small scale, aggregators that pool groups of farmers can provide an attractive point of sale for PULSE, aggregate demand for financing, and channel capacity-building activities. These aggregators include:

- **Cooperatives and associations.** These groups aim to promote the interests of their members – e.g. farmers or agribusinesses – in each value chain. They also facilitate access to financing and capacity-building for their members and can be important channels for the promotion of PULSE products.
- **Public authorities overseeing specific value chains,** e.g. the Uganda Coffee Development Authority and the Dairy Development Authority.
- **Off-takers,** i.e. purchasers of crops that source from many farmers, in some cases providing pre-harvest contracts to farmers with a set price. Examples are Fruits of the Nile and large coffee companies operating out-grower schemes, such as Kyagalanyi Coffee Ltd.

Table 38 provides a summary of selected cooperatives and umbrella associations under each of the value chains examined in this study. More information is provided in Annex A6.

The market for solar PV in Uganda has grown significantly from a few importers based in Kampala a decade ago to more than 200 companies today.

Table 38 List of end-users (and aggregators thereof) of PULSE products

Association	Type	Description
Grains and staple crops		
Uganda National Farmers Federation (UNFFE)	Umbrella organization	Largest private-sector farmers' organization in Uganda, comprising over 90 independent associations of farmers, agro-industrialists, and agro-commodity dealers. The core founding members are the 70 District Farmers Associations (DFAs). However, the UNFFE is not considered to represent the interests of smallholders effectively.
Coffee		
Uganda Coffee Development Authority (UCDA)	Public authority	Public body mandated to promote and oversee the coffee industry by supporting research, promoting production, controlling quality, and improving the marketing of coffee in order to optimize foreign exchange earnings for the country and payments to farmers.
National Union of Coffee Agribusinesses and Farm Enterprises (NUCAFE)	Union of cooperatives	NUCAFE is an umbrella national coffee-farmers' organization founded in 2003 as a successor to the Uganda Coffee Farmer's Association (UCFA). NUCAFE has become a vibrant private-sector-led farmer organization consisting of 213 farmer cooperatives and associations with 215,120 farming families in the five coffee-growing regions of Uganda.
Ankole Coffee Producers Cooperative Union Ltd	Union of cooperatives	Comprises 20 primary cooperative societies with some 10,000 individual farmers growing, packing, and transporting coffee
Kyagalanyi Coffee Ltd	Off-taker	One of the 10 large coffee companies controlling over 80 percent of the export market, currently working with 15,000 coffee-farming households
Horticulture		
Horticultural Exporters Association of Uganda (Hortexa)	Umbrella organization	HORTEXA represents Ugandan exporters of fresh fruit and vegetables. Its role is to organize growers and exporters of horticultural products in order to increase production of high-quality fruits, vegetables, and other products for export. The association has over 2,000 growers as members, linking them to exporters. It also runs practical demonstration gardens and provides training for growers.
Fruits of the Nile	Off-taker	Ugandan company exporting dried banana and pineapple, set up to link rural producers to export markets. The company has been popularizing solar drying equipment and techniques among farmers to preserve their fruits and add value. It buys Fairtrade organic sun-dried pineapples and bananas from five farmer groups in southern and central Uganda, which together form the Fruits of the Nile Growers Association.
Livestock and dairy		
Dairy Development Authority (DDA)	Public authority	Statutory body under MAAIF with a mandate to develop and regulate the dairy industry in a sustainable manner
Uganda Crane Creameries Cooperative Union (UCCCU)	Tertiary cooperative	Active in the 12 districts of south and mid-western Uganda. Membership stands at 18,506 in 140 primary cooperatives and societies and 10 district unions, producing over 700,000 liters daily and formally marketing 300,000 liters. UCCCU provided support for the investment of farmers in cooperative-owned milk collection infrastructure of 100 milk cooling tanks and 10 road tankers. In addition, they are supporting the investment in a farmer-owned dairy processing plant in Mbarara.
Uganda Meat Producers Cooperative Union (UMPCU)	Union of cooperatives	Owned by 34 grassroots primary cooperative societies bringing together about 2,600 beef farmers, covering 17 districts. The union was established to improve local livestock marketing and meat exports, seeking to establish and maintain best practices to produce meat and meat products.

Association	Type	Description
Dairy Farmers' Network Association (DAFAN)	Industry association	Involving over 200 dairy farmers and development partners, this organization promotes a practical farmer-oriented dairy-farming network geared towards the production of safe, quality-assured products in a sustainable manner that underpins the future of the dairy farming industry in Uganda.
Uganda Dairy Industry Association (UDISA)	Industry association	Organization of all stakeholders in the Ugandan dairy industry, one of the sectors with the greatest potential for the PULSE market.
Uganda Dairy Processors Association	Industry association	Membership is divided into three categories – large-, medium-, and small-scale. Dairy processing has been identified as a value chain with significant potential for solar-powered applications.
Poultry		
Association of Uganda Poultry Industry (AOUPIL)	Industry association	Provides assistance to local farmers on how to increase their income in the poultry sector
Fishing		
Uganda Fisheries and Fish Conservation Association (UFFCA)	Industry association	One of its mandates is to ensure the sustainable exploitation, utilization, and management of the fishery resource.
Telecoms		
American Tower Corporation (ATC) Uganda	End-user	Largest owner and operator of telecom towers in Uganda. Some of its off-grid sites are being converted from diesel to solar PV.
Tourism		
Uganda Hotel Owners' Association (UHOA)	Industry association	Trade and lobbying organization whose membership includes almost all the nation's hotels, lodges, and camps.

Sources: company websites and interviews.

4.3 Public sector

Relevant government bodies

The PULSE market in Uganda is governed by several institutions established by the Government of Uganda to focus on accelerating the market for solar PV:

- **Ministry of Energy and Mineral Development (MEMD),** the policy-making agency for the energy sector. Its Renewable Energy Department is responsible for implementing the renewables program in both the on-grid and off-grid space.
- **The Ministry of Agriculture, Animal Industry and Fisheries (MAAIF)** is responsible for policy formulation, regulation, and quality control of the agricultural sector. Agencies under the MAAIF that are relevant to the PULSE market include:
  - **National Agriculture Advisory Services (NAADS).** This statutory semi-autonomous body is mandated to manage the distribution of agricultural inputs to farmers that would secure their income. NAADS supported the implementation of SWP systems for agriculture and livestock and provided cost-sharing grants and technical support for dairy cooperatives running milk-collection centers.
  - **The Dairy Development Authority (DDA)** is a statutory body with the mandate to develop and regulate the dairy industry in a sustainable manner.
  - **Uganda Coffee Development Authority (UCDA)** is a public authority mandated to promote and oversee the coffee industry by supporting research, promoting production, controlling the quality and improving the marketing of coffee in order to optimize foreign-exchange earnings for the country and payments to farmers.

- **Ministry of Water and Environment (MWE).** The ministry's Water for Production (WfP) department has the objective to promote the development of cost-effective and sustainable water supply and water management solutions in the agricultural sector. The department is currently active in developing a quality assurance framework for solar pumps. MWE also worked with farmers to provide advice on agronomy, business practices, and training for the procurement and use of SWP irrigation systems.
- **Rural Electrification Authority (REA)** was established by an act of parliament in 2001 to operationalize the government's rural electrification policy. It is mandated with increasing access to electricity in rural and marginalized areas.
- **Uganda National Bureau of Standards (UNBS)** has a mandate to develop and enforce standards to protect the public's health and safety. In the light of the increasing penetration of low-quality products in the SWP market, UNBS played an important role in addressing quality issues through meetings with SWP suppliers.

Relevant policies

Rural Electrification Strategy

The latest Rural Electrification Strategy and Plan (RESP), covering the period 2013–22, is an integral component of the government's overall policy and program to promote national economic and social development and integration. As of 2018, nearly 20 percent of Ugandan households have access to electricity. The RESP aims to achieve an access rate of 26 percent by 2022, 51 percent by 2030, and 100 percent by 2040. By the end of the RESP period (2022), the government plans to have 1.28 million new grid connections and 138,500 new off-grid connections.

The systematic and informed promotion of productive uses will directly contribute to execution of the REA's mission. While PULSE is not explicitly mentioned in the RESP, the technology is very much aligned with the objective to expand electrification infrastructure to power small industry, commerce, and agricultural productivity.

Agriculture Sector Strategic Plan

The Agriculture Sector Strategic Plan (ASSP) is derived from the priorities in Uganda's second National Development Plan (NDP II) and covers the period 2015–20. Under the plan, sector investment over the medium term will be channeled to the specified priority and strategic commodities across their entire value chains, focusing on: research; extension; pest, vector, and disease control; provision of inputs; promoting sustainable land use and soil management; post-harvest handling; improving market access; and value addition. The investment strategy will target four objectives:

- Increasing agricultural production and productivity;
- Increasing access to critical farm inputs;
- Improving agricultural markets and value addition; and
- Improving service delivery through strengthening the institutional capacity of MAAIF and its agencies.

Increasing access to **water for agricultural production** and **promoting agricultural mechanization** are listed as strategic interventions under the second objective "Increasing access to critical farm inputs." The strategic interventions listed in the ASSP under each of the four objectives will mainly be focused on 12 priority commodities – bananas, beans, maize, rice, cassava, tea, coffee, fruit and vegetables, dairy, fish, livestock (meat) – and four strategic commodities, namely cocoa, cotton, oil seeds, and oil palm. The government has prioritized these 12 commodities and four strategic commodities based on their contribution to household income and food security, among others.

Some of the specific interventions to be implemented for these commodities that are relevant to PULSE are:

- Maize: "promoting mechanization …; supporting post-harvest handling through training traders and farmers on quality standards and post-harvest handling technologies; supporting processing and value addition including household cottage industries;"
- Coffee: "supporting acquisition and use of mechanization and irrigation technologies;"
- Fruit and vegetables: "interventions to boost production and exports of fruits and vegetables will include: … packaging and handling of fruits and vegetables … and support to processing of fresh fruits;"
- Dairy: "on-farm water harvesting infrastructure … and increased efforts to improve dairy market access and value addition;"

- **Fish:** "increased value addition to fisheries;" and
- **Meat and other livestock products:** "provision of adequate water for livestock production."

National Irrigation Policy

The National Irrigation Policy sets an ambitious target of 3.7 million acres of total irrigated area by 2040, compared to the current indicative area of 190,000 acres. This would require the establishment of 170,000 acres of newly irrigated land per year.[121] The Government of Uganda is embarking on numerous programs to expand and support the irrigation sector, some targeting individual smallholders to enable them to access micro-irrigation systems (solar pumps with hose-and-furrow or drip systems) from private-sector suppliers, and others that invest in schemes of various sizes for group irrigators.

Climate change: Uganda's Nationally Determined Contribution

Uganda's Nationally Determined Contribution (NDC) presents several activities for both climate-change mitigation and adaptation that are relevant to PULSE. Examples include:

- Expanding agriculture value addition, post-harvest handling and storage, and access to markets, including microfinance
- Expanding small-scale water infrastructure
- Extending electricity to rural areas or expanding the use of off-grid solar systems to support value addition and irrigation.

All of the above are listed under priority adaptation actions. The objective of adaptation actions in Uganda is to reduce the vulnerability of the population to climate change, with a focus on the following sectors: agriculture and livestock, forestry, infrastructure (with an emphasis on human settlements, social infrastructure and transport), water, energy and health.

Government budget allocations

Public expenditure in the agricultural sector (PEAS) was around 4 percent of the total in 2018. This is much lower than what has been suggested by the African Union (10 percent). The largest share of the agricultural sector budget (30 percent) is given to NAADS, while subsidies for the provision of inputs accounted for one-quarter of the total support budget (Figure 32). The irrigation budget more than doubled between 2013 and 2018, and now accounts for more than 12 percent of the total. The value chain that has benefited most from PEAS is coffee, with budget allocation to the UCDA quadrupling between 2015 and 2016.[122]

4.4 Financing institutions

Access to finance is one of the major challenges faced by the agricultural sector. Financing institutions are wary of lending to agribusinesses due to the high perceived risk of crop failure and the inability of the businesses to meet the requirements for collateral. As a result, the few commercial banks that provide financing to the sector are limiting their loans to larger agribusinesses that have steadier cash flows.

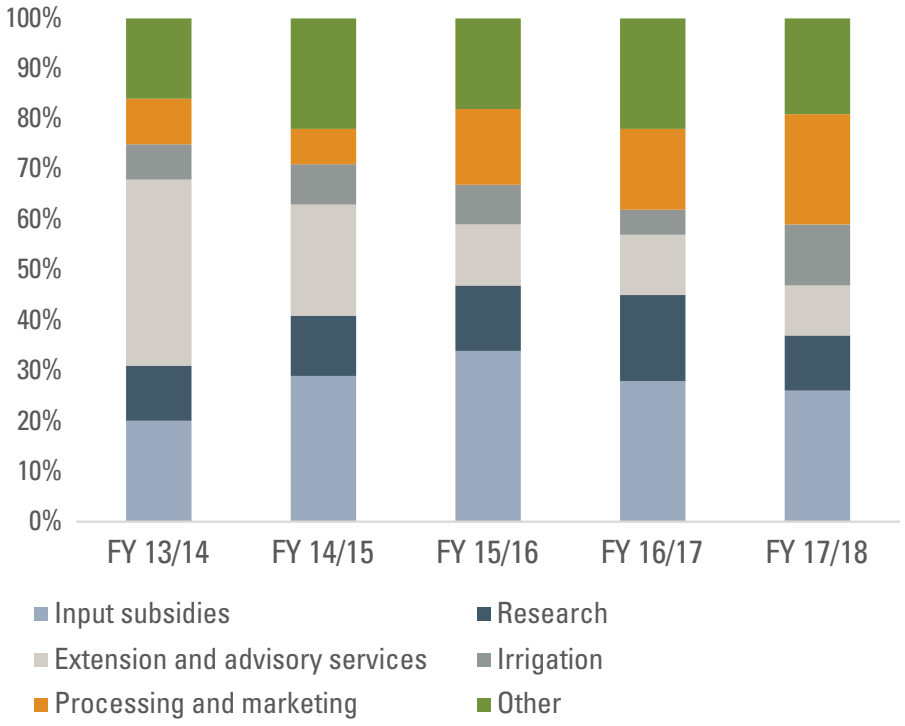
Financing institutions active in the off-grid energy and agriculture sectors in Uganda can be potential sources of credit for investment in productive use equipment and are, therefore, expected to play an important role in supporting the expansion of the PULSE market. The main categories of financing institutions are discussed in the subsections below. Section 5.2 (on access to finance) will discuss the potential roles that these institutions can play.

The National Irrigation Policy sets an ambitious target of **3.7 million acres of total irrigated area by 2040,** compared to the current indicative area of 190,000 acres. This would require the establishment of 170,000 acres of newly irrigated land per year.

121 The potential short-term market for small and medium SWPs is estimated to represent about 10,000 acres of newly irrigated land per year, i.e. ~6 percent of the irrigation target.

122 World Bank, November 2018. "Uganda Economic Update (12th edition): Developing the Agri-food system for inclusive economic growth."

Figure 32 Distribution of public budget between agricultural subfunctions



Source: World Bank 2018.[123]

4.4.1 Local commercial banks

A few commercial banks in Uganda currently provide loans to the off-grid sector, including for productive use. These include:[124]

- **Centenary Rural Development Bank:** The Bank was established in 1983 as a credit trust to support the rural poor. With a market share of 25 percent, Centenary is currently the second largest commercial bank in Uganda. It provides agricultural loans across the entire value chain and the collateral requirements are lower compared to other commercial banks. The majority of these loans are for production. The loans have a tenor of five years and interest rates range between 25 and 42 percent, depending on the risk profile of the business. Centenary, in partnership with the government funded program, Agricultural Credit Facility (ACF), also offers loans to farmers focusing on value addition at lower interest rates.
- **dfcu Bank:** Through its 67 branches, the bank focuses on providing credit to rural and agricultural customers. Agricultural loans, to both commercial and smallholder farmers, represent around 16 percent of the bank's portfolio, with processing accounting for 70 percent of that amount. The bank offers lower interest rates (18 percent for commercial farmers and 24 percent for smallholder farmers) compared to other financing institutions active in the agribusiness sector and has designed innovative products, such as the 'save for loan' targeting smallholder farmers who lack usable collateral. Like Centenary, dfcu has also partnered with ACF to offer loans with lower interest rates (12 percent) to agribusinesses.
- **PostBank:** The Bank is 100 percent owned by the Government of Uganda and its mandate is to facilitate access to financing for agribusinesses. PostBank offers a number of agricultural specific loans, including for marketing, equipment and

123 Ibid.

124 Information is sourced from NRECA International's report on the Productive Uses of Electricity Program Initiative.

inputs. The duration of the credit ranges between one and five years and interest rates are on average at 22 percent. Like Centenary and dfcu, PostBank has also partnered with ACF to co-finance loans for agribusinesses.

- **Stanbic Bank**: largest commercial bank in the country, by assets. Stanbic Bank is a division of Standard Bank, a member of the Standard Bank Group, based in Johannesburg, South Africa. Stanbic in Kenya was the arranger and book runner of the record-breaking $80 million local currency debt facility for M-Kopa in 2017 (see Table 39 below). Stanbic is also a participating financial institution in the credit line run by UECCC.

- **Opportunity Bank:** Commercial bank regulated by the Central Bank of Uganda, offering products and services for individuals, micro, small, medium, and large enterprises. Opportunity banks introduced affordable agricultural financing schemes for activities involving crop production, livestock, agri-processing, marketing and mechanization, and other agricultural value chain activities. The bank now provides loans to approximately 12,500 farmers and processes 50,000 loans at affordable interest rates to boost agricultural value chains.

- **Diamond Trust Bank Uganda:** Commercial bank, the seventh-largest in Uganda by assets. The bank partnered with AFD's SUNREF facility to provide credit to sustainable energy projects, including renewable energy and energy efficiency. They have provided, for example, financing for a 30 kWp rooftop solar PV project in the real-estate sector.

4.4.2 International financing institutions

International financing institutions that have facilitated financing for the off-grid solar sector in Uganda include:

- **Facility for Energy Inclusion's Off-Grid Energy Access Fund (FEI OGEF).** The FEI OGEF offers flexible financing solutions to companies in sub-Saharan Africa that provide off-grid renewable energy. The fund invests via a range of debt instruments, including receivables lending, inventory finance, other working capital lending, and unsecured corporate debt, to increase the availability of local currency debt and build the capacity of local capital markets. FEI OGEF is sponsored by AfDB, and received catalytic investments from a variety of donors and other public- and private-sector investors.

- **SunFunder.** A specialist debt-financing partner for solar companies active in off-grid residential, commercial, and industrial sectors in East and West Africa, focused on off-grid and solar-powered productive use technologies.

- **responsAbility.** A Zurich-based asset manager in the field of development investment. The company's investment solutions supply debt and equity financing, predominantly to non-listed firms in emerging and developing economies. It operates a working-capital debt facility targeted to off-grid solar.

- **Oikocredit** is a Netherlands-based cooperative society offering loans or investment capital for microfinance institutions, cooperatives, and small and medium-sized enterprises in developing countries.

- **Crowdfunding platforms** like TRINE and Lendahand. Both of these are European financial institutions providing crowdfunded loans to companies that have positive environmental and social impacts in developing countries. TRINE focuses specifically on solar energy.

Table 39 summarizes recent transactions relevant to off-grid solar. It is important to highlight that many of these are not specific to PULSE – although PULSE companies are included in the portfolio of recipients – and not specific to Uganda, as some of the companies also operate in several other countries in the region.

Table 39: Examples of recent transactions relevant to PULSE in Uganda

Investors and financiers	Company	Amount	Date	Comments
FEI OGEF	SunCulture	Not disclosed	2019	• Inventory working capital facility
SunFunder, Oikocredit, responsAbility	SolarNow	$9m	2019	• Syndicated loan structured by SunFunder to provide consumer credit for 17,500 of its off-grid solar systems in Uganda • SolarNow supplies PULSE products, but this facility is not specific to them. • This facility is SolarNow's third structured asset finance instrument and syndication arranged by SunFunder with Oikocredit and responsAbility, after a similar $6m facility received in 2017. • SunFunder arranged a total of $19m in investments in SolarNow.
ElectriFI, TRINE	Azuri	$20m	2018	• Azuri supplies PAYG SWPs in Uganda, but this facility is not specific to Uganda or PULSE (its focus is on sub-Saharan Africa)
SunFunder, Oikocredit, responsAbility	SolarNow	$6m	2017	• A syndicated receivables financing facility, structured as a bankruptcy-remote special-purpose vehicle, the facility will enable SolarNow to deploy SHS to a broad section of Uganda's off-grid population by offering credit to end-users.
Stanbic Bank, CDC, FMO, Norfund, Triodos, responsAbility, Symbiotics	M-Kopa	$80m	2017	• Syndicated loan for M-Kopa operations in the region • Not specific to Uganda or PULSE products • Loan provided in local currencies (Kenyan Shillings, Ugandan Shillings)
SunFunder	SolarNow	$2m	2016	• Working capital debt facility
Centenary Rural Development Bank	SolarNow	Not disclosed	2015	• No further details available

Source: UOMA analysis, press releases and company websites.

4.4.3 Government financing institutions

Uganda Energy Credit Capitalisation Company (UECCC)

UECCC was established to facilitate investment in Uganda's renewable energy sector by providing innovative financing products and technical assistance to firms and channeling project investments as the administrator of the Uganda Energy Capitalisation Trust.

UECCC operates a World Bank–funded solar working capital facility through participating financial institutions (PFIs), such as Stanbic, PostBank, and Centenary Bank. There is a pipeline of about $8 million in loans to seven solar companies to be disbursed by the end of 2020. UECCC financing in general is provided (a) directly, (b) through PFIs (see previous paragraph), and (c) to SACCOs.

Agricultural Credit Facility

The Agriculture Credit Facility (ACF) was established in 2009 by the Government of Uganda in partnership with several commercial banks. Its mandate is to provide financing to agribusinesses, mostly for value addition, on better terms than loans offered by commercial banks.

The agency is mandated to support the financing of agricultural equipment, including solar products for productive use. The maximum value of a loan is $600,000, but this can be increased up to $1.4 million if the proposed investment will add value to the agricultural sector.

The loan period is between six months and eight years, with a grace period of up to three years. Take-up of the facility has so far been limited, primarily due to lack of awareness among agribusinesses of the availability of the funds.[125]

125 NRECA International 2018. "Productive Uses of Electricity Program Initiative".

4.4.4 MFIs and SACCOs

Savings and Credit Cooperatives Organizations (SACCOs) are member-owned financial institutions mainly established under the Rural Finance Strategy (RSF) at sub-county level to deliver microfinance to those that lack access to credit resources. Members' savings and government subsidies are used to provide loans to agribusinesses at affordable rates.

There are currently more than 5,000 SACCOs in the country that provide lending to smallholder farmers unable to access credit from the commercial banks. By the end of 2013, SACCOs had extended $100 million in loans. Loans offered by SACCOs usually have a duration of six months to two years. One factor in their success is the extended network offering financial services in every sub-county of Uganda.

Another important characteristic of SACCOs is that they do not require collateral for a loan to be secured. Strict collateral requirements have been one of the main reasons why the agricultural loans offered by commercial banks cannot be accessed by smallholder farmers. SACCOs usually lend money to groups of consumers, where each member of the group acts as a guarantor for the others.

The following are some examples of SACCOs that could play a key role in promoting the PULSE market.

- **EBO SACCO** and **Buyanja SACCO** extend loans, including for the purchase of solar products, to smallholder farmers that have been excluded from the formal finance sector.
- **Rushere SACCO** focuses on improving access to finance in rural Uganda, where the majority of the population is involved in agriculture and agribusiness-related activities.
- **BRAC** is a microfinance institution that offers loans to farmers looking to invest in new equipment and increase their yield.
- **FINCA Uganda** is a microfinance deposit-accepting institution with extensive experience in promoting off-grid renewable energy in Uganda.
- **Pride Microfinance,** Hokofam Limited and Uganda Finance Trust collaborate with UECCC to provide loans for solar energy.
- **Tujijenge Uganda Ltd** is a microfinance institution with branches in eastern Uganda focusing on providing credit solutions to the poor for the purchase of personal assets or for investment in their business.

While SACCOs have been relatively successful in bridging the gap in provision of much-needed financing to those at the bottom of the pyramid by overcoming the need for collateral and establishing closer interaction with their clients, they still face several challenges. These mostly relate to a lack of managerial capacity and poor governance. Discussions with some of the SACCOs reveal that they will likely have a limited capacity to manage loan programs for financing productive use solar products.

4.5 Development partners

The Government of Uganda and development partners have taken important steps to stimulate the development of solar markets in off-grid regions, with positive implications for the PULSE sector. Development partners actively supporting the Ugandan solar sector include FCDO[126], the World Bank, GIZ, UNCDF, and USAID. Current donor-funded programs that support off-grid renewable energy solutions, including for productive use, include the following:

The World Bank Group

- **Energy for Rural Transformation (ERT III):** The objective of the Third Phase of the ERT project is to increase access to electricity in rural areas of Uganda. There are three components to the project, the first being on-grid energy access, the second is off-grid energy access. The off-grid energy access component includes the installation of solar PV systems for public institutions in rural areas; business development support; provision of credit facilities to enhance electricity access; and quality standards enforcement support. Finally, the third component is institutional strengthening and impacts monitoring. This last component will finance technical assistance and capacity development, required to accelerate electricity access.

126 NB FCDO merges with the Foreign & Commonwealth Office (FCO) to become Foreign, Commonwealth & Development Office (FCDO) in September 2020.

- The Government of Uganda's **Micro-scale Irrigation Program,** supported by the World Bank: The MAAIF and local governments across Uganda are preparing the Micro-scale Irrigation Program to support individual farmers (male and female) to buy and use micro-scale irrigation equipment. The program's matching grant scheme is part of the government's World Bank–supported Intergovernmental Fiscal Transfers Reforms Program (IFTRP). The Micro-scale Irrigation Program caps support to irrigation development at 2.5 acres per farmer, and thus it is expected to be of interest mainly to smallholder, mostly subsistence, farmers with potential to transform to more commercial agriculture.

  With a budget of about $50 million (of which roughly half is to support equipment purchase), a three-year implementation schedule starting in fiscal year 2020/21, and a phased approach initially targeting 40 Districts around Uganda before going nationwide in year 3, the program provides subsidies to support farmers to purchase individual micro-scale irrigation equipment.

  The size of subsidy varies based on the energy source, with a 75 percent subsidy for solar-powered systems and 25 percent for diesel- or petrol-powered systems. It is expected that about 22,000 acres will be equipped with irrigation over the three years of program implementation, corresponding to 9,000–18,000 farmers, depending of the size of the landholding of the applicants.

  The program puts the farmer at the center of the decision-making process: the individual farmer decides to apply for the program, chooses the preferred irrigation technology, provides co-financing, and owns the irrigation equipment once installed, being fully responsible for its operation and maintenance. Local governments lead activities of awareness-raising, outreach, training, and procurement of irrigation equipment on behalf of the farmer, while the MAAIF is in charge of general program coordination and the prequalification of irrigation equipment suppliers at the national level.

- **Lighting Global** is the World Bank Group's initiative to rapidly increase access to off-grid solar energy for the 733 million people living without electricity world-wide. Managed by the Energy Sector Management Assistance Program (ESMAP), we work with governments, the private sector, development partners, and end-users, continually innovating to unlock key market barriers and enable access and affordability to those that would otherwise be left behind. Our support has expanded to technologies that go far beyond lighting, including systems to power the needs of households, businesses, schools, and health centers. We operate with funding gratefully acknowledged from ESMAP and their donors.

  Lighting Global supports regional market transformation programs including **Lighting Africa,** which work along the supply chain to reduce barriers to market entry and first-mover risks.

- **Agriculture Finance Support Facility (AgriFin):** This facility co-finances innovative proposals from financial institutions in Africa and Asia and supports these institutions to expand their services to smallholder farmers and SMEs. In Uganda, AgriFin contributed $1 million to support Centenary Bank's agricultural portfolio. This initiative, which closed in 2014, aimed to increase the mix of products and services offered to smallholder farmers and improve staff skills, while targeting key agricultural value chains.

FCDO (UK Aid)

- **Low-Energy Inclusive Appliances (LEIA).** This UK-funded program aims to accelerate the availability, affordability, efficiency, and performance of a range of low-energy inclusive appliances particularly suited to developing-country contexts. LEIA will work to accelerate the availability, affordability, efficiency, and performance of four near-to-market products (refrigerators, televisions, fans, and SWPs) and five cross-cutting horizon and enabling technologies – brushless DC motors; advanced electric cooking; advanced refrigeration technologies; interoperability and compatibility; and connectivity and the internet of things (IoT).

  Key activities to stimulate the sector include:

  - Market stimulation and incentives, including the Global LEAP Awards
  - Testing and quality assurance, having developed testing protocols for SWPs, SRUs, and other appliances
  - Marketplace education, communications, and coordination
  - Market intelligence and technology road-mapping
  - R&D co-investments.

- **Transforming the Economy through Climate Smart Agribusiness (NU-TEC).** The purpose of this $58-million program is to supply agribusiness in northern Uganda with cheaper, more efficient, and more varied agricultural inputs and services, including PULSE products. It is expected that more than 250,000 households in the region will benefit from this program by adopting new practices and products, and by having better access to markets, which will make them more resilient to climate change, while also increasing their income.

- **Energy Africa campaign.** This initiative focuses on removing policy and regulatory barriers to solar PV market expansion and aims to improve cooperation between donors to provide more effective support to the sector.

- **Africa Clean Energy Technical Assistance Facility (ACE TAF)** is a four-year FCDO-funded program operating in 14 African countries including Uganda and aims to catalyze off-grid markets to facilitate energy access to vulnerable communities.

  As far as PULSE is concerned, the program activities in Uganda will be centered on policy and regulatory reform and quality standards, including:

  - Streamlining the SWP subsector through the formation and operation of a technical working group comprising three core ministries (MWE, MEMD, and MAAIF)
  - Drafting position papers on the inclusion of SWPs as a core element in the draft off-grid energy policy
  - Addressing solar-generated e-waste
  - Working closely with UNBS and REA to strengthen the standards agency's capacity to undertake import inspection in all types of weather conditions through potential equipment acquisition and laboratory training. This might evolve into providing support for defining quality standards for SWPs.

- **Transforming Energy Access (TEA).** This five-year project supports the scaling-up of innovative technologies, including SHS, aiming to accelerate access to affordable and sustainable energy services for poor households. *Powering Opportunities Partnerships (POP)* is a component of the TEA program, focused on the potential of the off-grid energy sector to stimulate local jobs and create local economic value. The *Productive Energy Use (PEU) challenge fund,* a component of the POP, is aimed at providing grant support to partnerships promoting productive energy demand in rural areas.

USAID

- **Power Africa Uganda Electricity Supply Accelerator (PAUESA).** This program focuses on support for generating capacity, access, and enabling environment through grants, transaction advisory support, short-term grants, and technical assistance.

- **Scaling off-grid energy enterprise awards.** This program provides seed funding to solar companies that provide innovative solutions to scale up the use of SHS to unelectrified areas.

Other bilateral and multilateral donors

- **UNCDF (CleanStart)** supports low-income households and SMEs to jump-start their access to clean energy through microfinance. It comprises four components: finance, technical assistance, knowledge and learning, and advocacy and partnerships. Relevant programs implemented by UNCDF are:

  - Clean Start Challenge Fund for solar PV and clean cooking. For solar, this provides grants ranging from $100,000 to $500,000 on a cost-sharing basis. Recipients have included M-Kopa, GRS Commodities, Power Trust (piloting Agsol mills), Aptech Africa (PAYG SWPs), Azuri (PAYG SWPs), and Village Energy (institutional systems for schools and clinics).
  - In addition to grants, UNCDF provides working capital in local currency and guarantees. Investees are All in Trade, Aptech Africa, SolarToday and BM Energy.

- **AFD (Agence Française de Développement) Sustainable Use of Natural Resources and Energy Finance (SUNREF).** A green credit line developed by AFD with a focus on clean energy. SUNREF's partner financial institution in Uganda is Diamond Trust Bank (DTB).

- **European Union (EU):** Scaling-up rural electrification using solar PV distribution model. The objective of this program is to increase the take-up of solar PV systems at schools, health clinics, and businesses by providing training to community-based organizations.

- **EU: Scaling up access to modern electricity services in sub-Saharan Africa through fee for service business model.** This aims to increase access to electricity via SHS and mini-grids in rural areas of Uganda, Cameroon, Mali, and Guinea-Bissau.

- **Austrian Development Agency and Nordic Development Fund: EEP Africa.** This provides early-stage and catalytic financing for innovative solar PV energy projects and solutions.

Multi-donor initiatives and projects

- **The Efficiency for Access Coalition,** coordinated by CLASP and the Energy Saving Trust (EST), is scaling up a number of support mechanisms to improve the efficiency and affordability of low-energy inclusive appliances for off- and weak-grid households and businesses. The coalition has a range of co-funders – the IKEA Foundation, Lighting Global, the Rockefeller Foundation, the Shell Foundation, SIDA, EnDev, and the Good Energies Foundation, amongst others. The coalition acts through market acceleration programs, primarily the UK-funded LEIA and the multiple-funder-supported Global LEAP program. In order to stimulate the growth of the PULSE market, Global LEAP is currently providing RBF to companies selling productive use appliances, such as SWPs and SRUs. Companies submit bids quoting the level of subsidy they require to achieve a certain number of sales, and those that offer the best value for money are selected. Regulator monitoring is conducted to verify the sales reported by the companies and to ensure the continuity and usefulness of the appliances through reports from end-users.

- **Global LEAP's** activities seek to transform the global market for off-grid energy products by harnessing the power of marketplace competition to drive technical and market innovations in the off-grid appliance sector. This unique program has evolved into a trusted global brand that serves as the de facto source of accurate, actionable information about the quality and energy performance of off-grid appliances.

The Global LEAP Awards competitions are coupled with RBF to help mitigate real and perceived financial risk associated with bulk procurement of highly efficient products. Global LEAP RBF incentives are allocated through a reverse auction process. Incentives claims submitted during the past two RBF rounds have significantly exceeded the amount of funding available. In the 2017 round, the auction window closed more than two weeks earlier than originally planned. In the 2019 round, the aggregate value of claims received (for SWPs and SRUs) exceeded available funding by 469 percent.

The Global LEAP program is implemented through the Efficiency for Access Coalition and managed by CLASP, with support from Power Africa, FCDO, Energizing Development, Powering Agriculture, and USAID. Program partners include Ideas to Impact, IMC Worldwide, Energy 4 Impact, Acumen, the Shell Foundation, and GOGLA.

- **Powering Agriculture: An Energy Grand Challenge for Development Initiative (PAEGC)** was launched by USAID, SIDA (Sweden), and the BMZ (Germany) to accelerate the development and deployment of clean energy solutions for increasing agricultural productivity in developing countries.

- **Shell Foundation.** A number of initiatives have been promoted by the Shell Foundation to catalyze sustainable and scalable off-grid solutions. An example is the Catalyzing Agriculture by Scaling Energy Ecosystems (CASEE) program, launched in partnership with FCDO, to fast-track access to renewable energy services for smallholder farmers.

- **Agricultural Business Initiative (aBi).** This multi-donor entity supports agribusiness development in Uganda by providing financing and technical support. The aBi Trust assists farmer organizations, NGOs, and SMEs in promoting agribusiness development, while aBi Finance provides lines of credit and loan guarantees to agriculture-based SMEs. More specifically, in partnership with USAID aBi provides 50 percent cover for loans provided to small and medium-sized agribusinesses.

- Access to Energy Institute (A2EI): This not-for-profit research-and-development institute seeks to advance the solar revolution in developing countries by delivering solar-powered solutions for small businesses and smallholder farmers, with a focus on productive use appliances.

- The Uganda Off-Grid Market Accelerator (UOMA) is a neutral intermediary founded on the Scaling Off-Grid Energy: A Grand Challenge for Development (SOGE) partnership between USAID's Power Africa initiative, FCDO's Energy Africa program, and the Shell Foundation, focused on accelerating the growth of off-grid energy in Uganda.

Table 40 provides a summary of the donor-funded support facilities relevant (but not exclusive) to PULSE in Uganda.

Table 40 Development partners' support (not exhaustive)

Development partner	Amount	Initiative / facility	Comments
World Bank	$8.5m to be disbursed to local banks	Energy for Rural Transformation Phase III (ERT-III)	• Considering expansion of both funding and technical assistance to support PULSE
World Bank	$50 million	Micro-scale Irrigation Program	• Grant financing and technical assistance to roll out solar micro-irrigation units for smallholder farmers
FCDO	$37 million	Northern Uganda: Transforming the Economy through Climate Smart Agribusiness (NU-TEC)	• Medium term credit fund: Delivery of medium-term credit to agribusiness through a local financial institution ($13m to Mercy Corps) • Long Term Investment and Capacity Building: Delivery of long-term equity and credit to agribusiness through AgDevCo, a not-for-project investment vehicle ($24m)
USAID	$2.5m (grant)	Scaling Off-Grid Energy Enterprise Awards	• Not specific to PULSE products
AFD	EUR 120m	Sustainable Use of Natural Resources and Energy Finance East Africa (SUNREF)	• Aimed to finance green investments in East Africa (Uganda, Kenya, and Tanzania) • Not specific to PULSE products
UNCDF	Grants of $100,000–500,000 on cost-sharing basis (40–60 percent of investment) and working capital in local currency coupled with guarantees (~$1.5m in total)	CleanStart challenge fund for solar PV and clean cooking	• Recipients of grants include M-Kopa, GRS Commodities, Power Trust, Aptech Africa, Azuri, and Village Energy. • Recipients of loans include All in Trade, Aptech Africa, SolarToday and BM Energy.
FCDO	$1 million (grant)	Efficiency for Access Coalition	• Supports and accelerates innovation in off-grid appliances technologies and markets • Focuses on productive use • Not specific to Uganda • Focuses on SSA

Development partner	Amount	Initiative / facility	Comments
AlphaMundi Foundation (USAID, SIDA, BMZ)	Grant, debt, equity, or mezzanine financing $100,000–$2m per company	Powering Agriculture Investment Alliance (Powering Agriculture: An Energy Grand Challenge for Development (PAEGC)	• Catalyzes finance for businesses providing clean energy solutions including agricultural productivity • Focuses on SSA, not specific to Uganda
Austrian Development Agency and Nordic Development Fund	Grant of EUR 200,000–500,000 per company	EEP Africa	• Aimed to provide early stage and catalytic financing to innovative clean energy projects and technologies with a focus on solar PV • Not specific to Uganda or PULSE products • Focus on eastern and southern Africa

Source: World Bank, UOMA analysis, websites of institutions.

4.6 Civil society

There are over 30 civil-society organizations active in the field of renewable energy in Uganda[127], including international NGOs, national NGOs, CBOs, and membership-based networks. Their activities include advocacy, implementation of projects that promote renewables, awareness-raising campaigns, and capacity-building projects. Examples of organizations invested in the PULSE space in Uganda include:

- Energy4Impact. This non-profit organization works with businesses in off-grid communities on solar irrigation, agro-processing, and refrigeration, supporting the implementation of various initiatives including the Global LEAP Awards for best-in-class PULSE products.
- The Centre for Research in Energy and Energy Conservation (CREEC) is a research, training, consultancy, and testing center located at Makerere University. It has conducted research for CLASP on PULSE available in the Ugandan market.

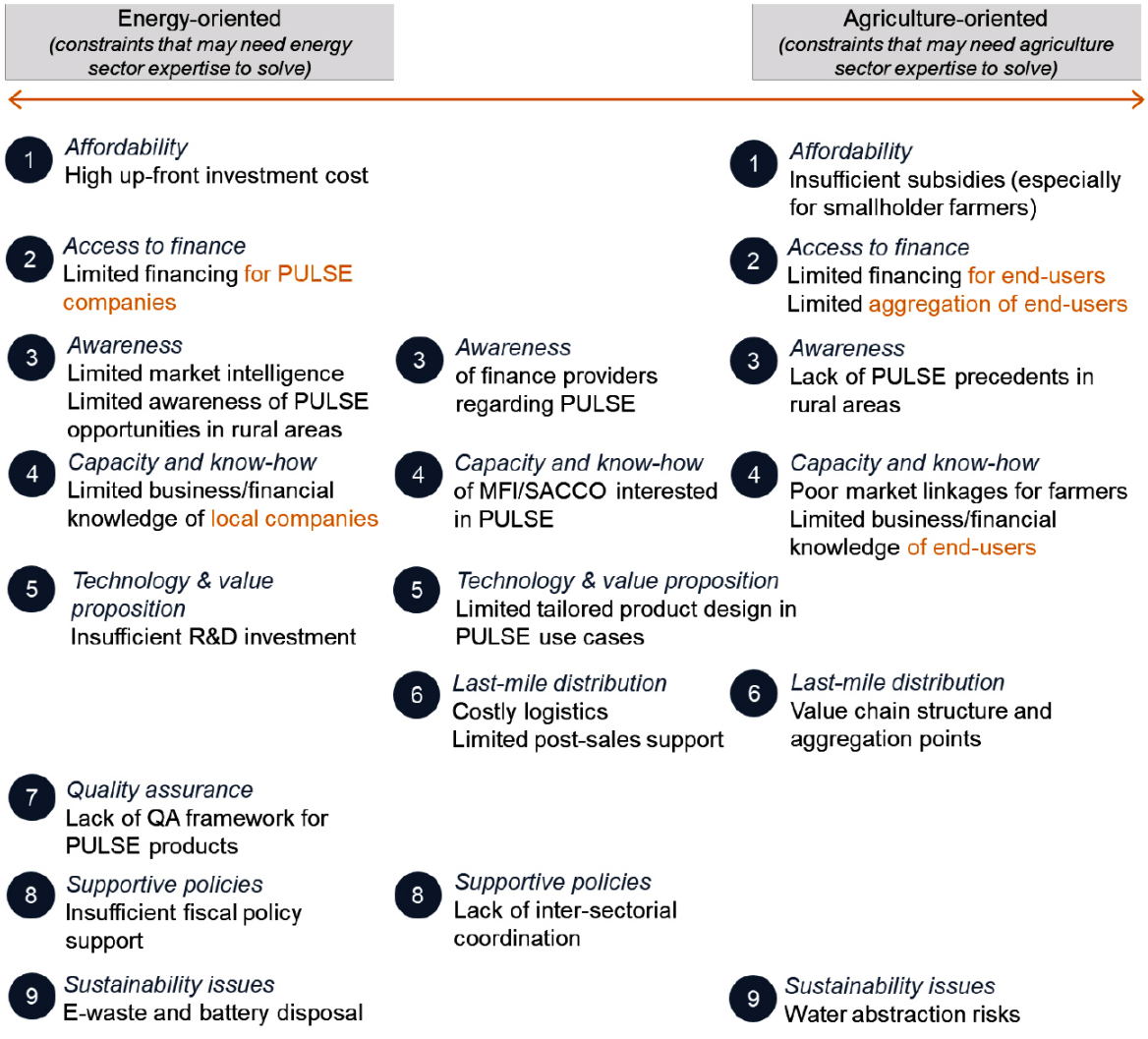
127 From the Renewable Energy Civil Society Organizations (RECSOs) Sector Performance Report for FY 2017/2018. Based on Joint Sector Review, 2017/2018. November 2018.

05

MARKET BARRIERS AND RECOMMENDATIONS

We have identified nine main market barriers in this PULSE assessment. These are summarized in Figure 33, which classifies them according to whether they relate to the energy sector, the agricultural (or water) sector, or both. For example, energy-sector stakeholders may be best placed to address the issues (access to finance, capacity-building, etc.) relating to PULSE companies, while agricultural- and water-sector stakeholders may best placed to address the issues faced by end-users – farmers, agribusinesses, and aggregators. Collaboration among stakeholders of all these sectors will also be needed to unlock constraints to scaling PULSE.

Figure 33 Market barriers to scaling PULSE and type of expertise needed to solve them



Source: Adapted from Lighting Global's "Market Opportunity for PULSE in Sub-Saharan Africa" assessment.

The identification of barriers was based on an extensive literature review and interviews with about 50 Ugandan stakeholders including PULSE suppliers, aggregators, financiers, and donors.

The following sections present each of the main market barriers, together with possible solutions to overcome them.

5.1 Affordability

The price of the most affordable PULSE appliance ($700–800) is equivalent to eight or nine times the average monthly income of rural households.[128] The affordability of PULSE products for smallholder farmers is therefore a concern and is explored in detail in subsection 5.1.1.

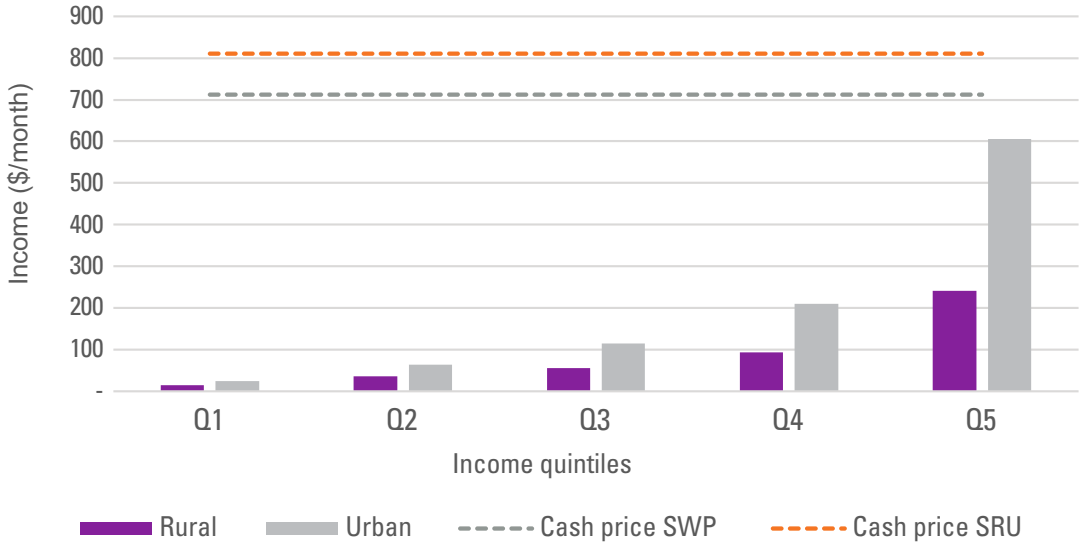
For medium-sized PULSE products, suitable for commercial farmers, cooperatives, or SMEs, household income is a less relevant metric of affordability. For this segment, economic feasibility coupled with access to finance is considered more. This is presented in subsection 5.2.3.

5.1.1 Small PULSE appliances and smallholder farmers

Affordability based on income

As pointed out in section 3.2, SWPs and SRUs can be very lucrative investments for smallholder farmers, with PBP of under one year in certain conditions. With adequate financing, the cost of these products could be met by increased yields and productivity, or reduced losses. However, affordability of the initial cost of the technology, before such increased yields materialize, may be problematic. Figure 34 shows the estimated monthly household income distribution for rural and urban consumers in Uganda compared to the cash purchase price for the most affordable high-quality small SWPs and SRUs on the market. The cash price of these products is significantly higher than the monthly income of the wealthiest quintile of the population. These products can, however, be accessed with credit.

Figure 34: Distribution of household income (2018–19, est.) vs PULSE prices



References: UNHS 2016–17 (UBOS, 2018), UNHS 2012–13, (UBOS, 2014), Futurepump, M-Kopa. To estimate 2018–19 values, income distribution was extrapolated from data in UNHS 2012–13, considering average incomes in UNHS 2016–17 and inflation and exchange rates.

128 Small SWPs (e.g. Futurepump) retail for $710 and small SRUs (e.g. M-Kopa solar fridge) for $810 (both cash prices). The average monthly income of rural households was 303,000 UGX, according to the Uganda National Household Survey (UNHS) of 2016–17 (UBOS, 2018). This monthly income is estimated at $88 today, considering exchange rates and inflation.

Solar energy companies offering PULSE products on credit or a PAYG basis typically require an up-front deposit of 10–20 percent of the retail price. These companies consider this cash deposit as the best metric of affordability and the creditworthiness of rural farmers without credit history. In order to estimate the affordability for smallholder farmers of this up-front deposit, it has been assumed that 10 percent of a household's income over six months[129] is available to pay it. The result of this analysis is shown in Figure 35.

This size of cash deposit is close to the average affordability of income quintile Q5 (rural), which means PULSE equipment would only be affordable to around 10 percent of the rural population (around 580,000 households). If only 5 percent of income is considered available for investment in PULSE appliances, the number of farmers who could afford these products is significantly smaller (less than 5 percent). This sensitivity analysis is shown in Figure 36.

Figure 35: Affordability for smallholder farmers of cash deposit for small PULSE product

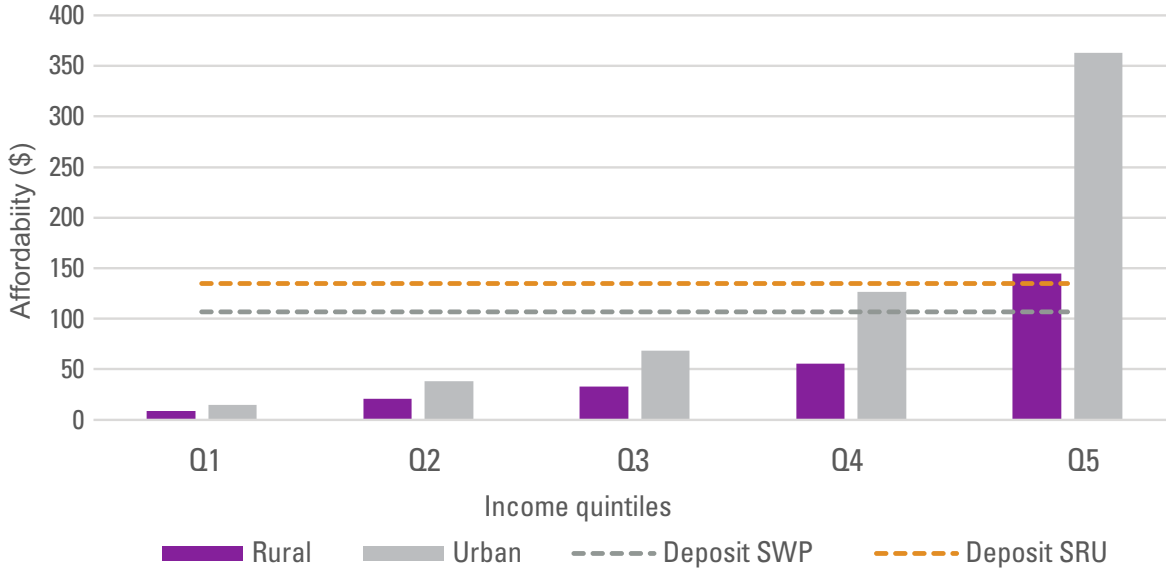
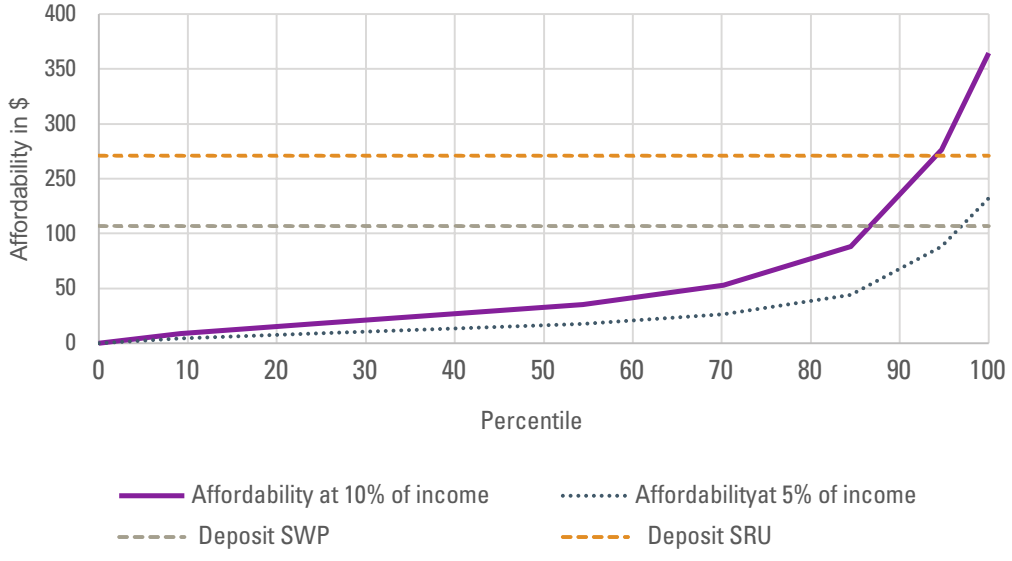


Figure 36: Affordability of cash deposit for small PULSE (sensitivity)



129 According to UNHS 2016–17, expenditure in relevant item categories amounts to 10.5 percent of total expenditure (furnishings and household equipment 3.7 percent, miscellaneous goods and services 3.6 percent, non-consumption expenditure 3.2 percent). It is also assumed that most farmers will have disposable income on a seasonal basis, hence the six months' income assumption.

Seasonality of income

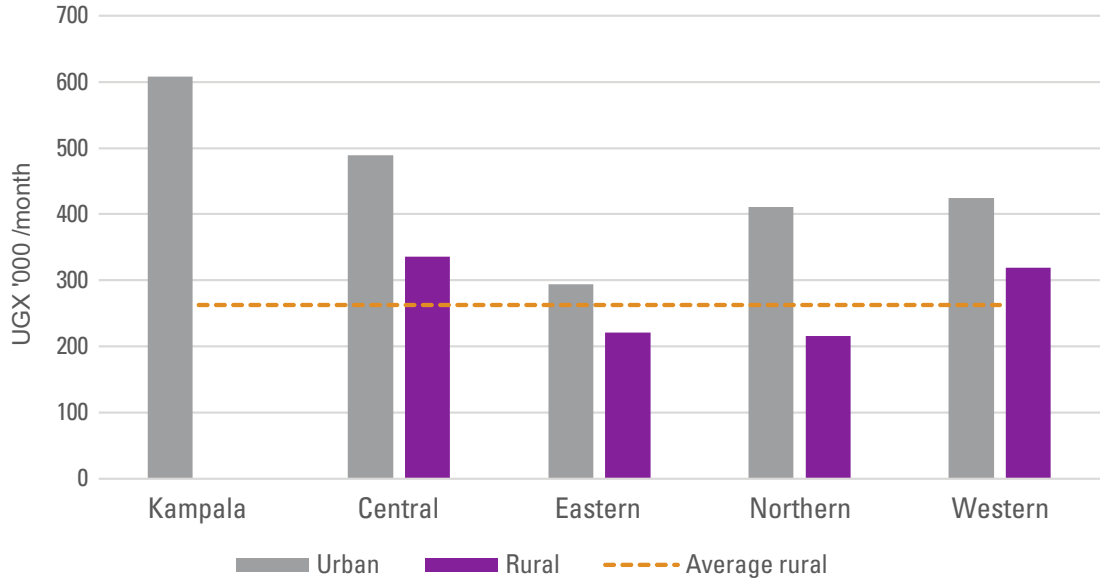
Seasonality of income may also be a concern regarding affordability if credit repayment is structured in a way that does not coincide with the frequency of income. For example, if the repayment for SWPs does not coincide with harvests, pumps could be locked during the period of cultivation. According to the UNHS 2016–17, over 80 percent of households deriving income from subsistence agriculture receive income seasonally or irregularly.

Geographic distribution

The majority of smallholders are located in western and eastern Uganda (approx. 30 percent each) followed by the northern region (23 percent) – the region with the highest poverty levels – and the central region (16 percent), which is the most economically thriving part of Uganda.[130]

In terms of income distribution, the central and western regions are best placed to afford PULSE appliances, with incomes of rural households 28 percent and 22 percent higher than the national average, respectively. The World Bank's "Assessment of Farmer-Led Irrigation Development in Uganda" (FLID) also focuses on these two regions, presumably because they are more relevant for irrigation.

Figure 37: Average household income (geographic distribution)



Distribution by type of agriculture

The financial analysis presented in section 3.2 shows that horticulture and coffee are the most attractive crops for solar irrigation. The investment in SWPs on tomato plantations could be repaid within one harvest. The performance for coffee is lower, with a PBP of about five years – it could be better depending on the type of coffee and the time of year – but is still feasible in terms of payments to PAYG companies and SACCOs. Farmers of maize, which sells for comparatively less and benefits from a smaller yield uplift with a SWP, are unlikely to be able to afford PULSE.

The analyses in Lighting Global's "Market Opportunity for PULSE in Sub-Saharan Africa" and the World Bank's "Assessment of farmer-led irrigation development in Uganda" reach similar conclusions. The assessment of farmer-led irrigation development in Uganda focuses on coffee (both Arabica and Robusta) and horticultural crops. The latter include:

- Fruit – pineapple and watermelon
- Vegetables – sweet pepper, okra, tomato, onion, cabbage, carrot, and eggplant
- Spices – ginger, chili, garlic, and hot pepper

130 World Bank/IFC, 2019, "Assessment of farmer-led irrigation development in Uganda."

Chilling of milk also shows good results in the financial analysis in section 3.2.[131] The activity is predominantly in central and western regions, accounting for over 50 percent of production in the country.

Solar energy companies offering PULSE products on credit or a PAYG basis typically require an up-front deposit of **10–20 %** of the retail price. These companies consider this cash deposit as the best metric of affordability and the creditworthiness of rural farmers without credit history.

Possible solutions to improve affordability

Table 41 provides a summary of possible solutions to improve the affordability of PULSE products for smallholder farmers. The list is not exhaustive, and the following sections also explore other barriers and potential solutions that could, indirectly, improve affordability. The overall summary of recommendations is provided in chapter 6.

Table 41: Possible solutions to improve affordability

Solution	Description	Relevant stakeholders	Intervention type type[131]
Grant financing	Grants to increase the number of farmers who could afford PULSE appliances	Government and donors (water and agricultural sectors)	Access to finance
Adequate financing	Favorable financing terms: low cost and matching PBP of PULSE and seasonality of income	PULSE companies giving credit, financial institutions (banks, MFIs, SACCOs), government, and donors	Access to finance
Reducing the cost of products with technology improvements	R&D to achieve further cost reductions or increase functionality of products. For example, products that can be shared with other farmers (mobile) or shared among different functionalities (multipurpose) will increase affordability.	Suppliers, government, and donors (providing financial incentives to develop better products)	Technology and innovation
Reducing the cost of products with fiscal incentives	Extending VAT and import duty exemptions available for solar products to PULSE products	Government (energy, water, agriculture, industry, finance)	Policy development
Reducing the cost of products by reducing distribution costs	Lowering distribution costs by aggregating demand through deals with aggregators (e.g. SACCOs, coops, off-takers) and allowing entry of larger, more streamlined suppliers Financial incentives (e.g. RBF grants) for solar companies to enter rural areas (establish distribution outlets, train their agents, etc.)	Suppliers, aggregators, government, and donors (providing financial incentives to develop distribution networks)	Demand aggregation
Encourage cooperative ownership or business-purchased solutions	In addition to aggregating demand for small consumers, larger businesses and cooperatives can purchase larger PULSE appliances (chillers, pumps, etc.) and enable use by consumers.	Suppliers, aggregators	Access to finance

131 A dairy farmer investing in a $1,000 chiller and cooling 50 liters per day will have a PBP of 1.2–2.7 years depending on assumptions about the milk price ($0.10–0.15 per liter) and avoided losses (20–30 percent). Intervention types listed in this table correspond to the classification provided in the Lighting Global PULSE market opportunity report (World Bank Group, 2019).

Aggregators have a key role in consolidating demand from remote and scattered smallholder farmers. Aggregating demand can, among other things, help reduce distribution and financing costs, which would translate into lower prices for PULSE and thus, increased affordability. Relevant aggregators include farmer groups and cooperatives, off-takers, input suppliers, extension and advisory service providers, and SACCOs. A description of these is provided in Annex A6.

5.1.2 Medium PULSE and commercial farming/SMEs

Medium PULSE projects – e.g. irrigation of farms of more than 12 acres, and milk-chillers for collection centers processing over 1,000 liters per day – require investments in the range of $10,000–100,000. At this scale, affordability is assumed to be a less relevant metric. These end-users are predominantly companies rather than households and it is financial attractiveness coupled with access to adequate financing that will motivate investment. These companies are also more likely to have assets that can be used as collateral, and, as they require larger loans, they are of more interest to banks.

The financial analysis in section 3.2 also showed that replacing diesel with solar PV in productive uses provides moderate returns (payback period of three to five years, IRR of 12–27 percent). In order to increase the financial attractiveness of these solutions, a combination of soft loans and/or fiscal incentives could be provided. For more on this, see subsection 5.2.3.

5.2 Access to finance

Agricultural lending has historically been very difficult for a variety of reasons.[132] These include the lack of usable collateral, high administrative and transaction costs due to low population density and the remote nature of clients, the small size of farms and of individual transactions, weak communications and transportation infrastructure, high covariant risks due to variable rainfall and sales prices, the absence of physical banking facilities in rural areas, and the difficulty of debt collection from smallholder farmers.

Several financing institutions are targeting farmers and the challenges noted above – notably the ACF, set up in 2009 in partnership with commercial banks and UDBL – but take-up remains slow.

Financing for PULSE will be particularly challenging as training and maintenance for the products are required, and the absence of these increases the risk of equipment malfunctioning – and thus of loan repayments not being fulfilled.

It is important to highlight that agricultural lending has a wealth of lessons learned and best practices to lean on that should be taken on board when developing solar lending for productive use.

This section covers three types of financing:

- Consumer financing
- Financing for PULSE suppliers
- Financing of medium-to-large PULSE projects.

5.2.1 Consumer financing

Financial inclusion in Uganda is low. According to a recent FinScope survey, 20.3 percent of the adult population has an account at a formal bank, 33.7 percent with a formal non-bank financial institution, 30.6 percent with an informal institution (SACCO, NGO MFI, or community group) and 15.3 percent are excluded entirely.[133]

Formal institutions are less prominent in rural areas than urban areas and only serve 14 percent of the rural population. Informal institutions play an important role in rural service provision and serve about 12 percent of the rural population.

The options for smallholder farmers to access financing for PULSE include loans from banks or MFIs/SACCOs, supplier credit, or PAYG solutions. These are presented in Table 42.

132 Key challenges listed in the Agriculture Sector Strategic Plan 2015/16–2019/20.

133 "Report of the Responsible Inclusive Finance (RIF) Working Group," AMFIU, 2016.

Table 42: Consumer financing options

Financing option	Description	Penetration figures and examples	Pros and cons (challenges highlighted)
Commercial bank loans	Formal financial institutions regulated by Uganda's central bank Maturity of 1–5 years Interest 20–30% Will require credit history, experience, business plan, and collateral	25 commercial banks. For example, Centenary, dfcu, PostBank, Stanbic, and Finance Trust Bank all have an agricultural financing window. Commercial banks only serve 14% of the rural population.	**High perceived risk** of agricultural borrowers (translates to **high collateral requirements**)[134] **Small size** of farms and of individual transactions increases cost. **Difficulties for farmers to meet requirements** (experience, business plans, etc.) **Low presence of banks in rural areas**
MFIs/SACCOs (Tier 4)	SACCOs are typically cooperative financial institutions. MFIs are externally funded. Low amounts (<$1,000–$3,000) Low tenor (<2 years) Interest 22–42% Most SACCOs do not require collateral to secure loans. Members' shares are considered collateral.	More than 2,000 MFIs in the country, including SACCOs, NGO MFIs, and community-based groups 1.4 million depositors and 553,000 borrowers (AMFIU, 2016) SACCOs are extensively used in financing SHS, but extremely limited use for PULSE. Examples: EBO SACCO (western Uganda, 46,000 members), Tujijenge MFI (eastern, 6,000 customers)	Overcoming the need for collateral and establishing closer interaction with their clients (understanding their businesses) are the key advantage of SACCOs. On the other hand, SACCOs are known to **lack managerial capacity and have poor governance.**[135] There is also **very limited experience with PULSE** or expensive productive equipment in general. The low maximum loan amount (~$3,000) limits access to PULSE but can cover small items.
PAYG/ company credit	Companies provide credit over a period of up to 2 years, after a cash up-front deposit (typically 10–20% of retail price). The deposit serves as one of the main metrics of creditworthiness. Interest rates 23–43%	SolarNow and M-Kopa are the main companies providing small PULSE on credit/PAYG. Selling 1,000–2,000 PULSE per year each. New entrants: Tulima Solar, Brightlife, Azuri, Aptech Africa.	Incentive for solar companies to provide a high level of quality and service Suppliers have an understanding of the technology and can therefore advise and train. **Collections and enforceability of customer payments** can be particularly challenging for PULSE. **Last-mile distribution is difficult and expensive** (especially since PULSE applications call for more proximity to customers to make sales and provide after-sales support).

134 High risk of crop failure and a general lack of collateral with which loans can be guaranteed. Commercial banks have traditionally limited loans to more well-secured, larger-scale agricultural enterprises, including agribusiness firms engaged in commodity processing, commodity trading, and offering a variety of financial instruments including letters of credit to import and/or export agricultural products.

135 SACCOs range from weak with poor governance to those that are well managed and capitalized and on the verge of becoming regulated financial institutions. UECCC already has a framework through which financing is availed to Tier IV financial institutions for lending-on to households and commercial enterprises acquiring solar systems. The framework recommends partnerships with financial institutions that demonstrate good governance practices and managerial capacity. For the productive use intervention, UECCC intends to work with Tier IV financial institutions that meet the framework's eligibility criteria. In its experience, working with such institutions has had very positive results, with zero defaults to date.

Financing option	Description	Penetration figures and examples	Pros and cons (challenges highlighted)
Emerging options[136]	Irrigation credit scheme model Lending to a farmer is indirect. Money is credited directly to the technology supplier's account. The supplier delivers and installs the equipment and could be required to guide and train on the proper use of equipment and/or agronomy.	This case is being applied between Balton Uganda and Centenary Bank to distribute farmer's kits of complete greenhouse farming solutions. This can be replicated in irrigation. A similar model of tri-partite (bank-supplier-farmer) was proposed for PULSE by Stanbic (based on interview)	**Very limited experience with this model,** and no experience with PULSE.
	Equipment leasing model The lessor (bank) lets the lessee (farmer) install and make use of the technology in exchange for periodic payments. This concentrates on the cash flow of the lessee to honor the rental payments rather than past credit history or collateral.	Agriworks Mobile Irrigation Systems (diesel water pumps) is using this model. dfcu Bank is also using a leasing model for general agricultural machinery and this can be scaled up to PULSE equipment.	This model helps those farmers who are unable to pay the full amount to purchase the equipment. Especially suitable for SWPs, particularly for farmers not irrigating year-round. The take-up of leasing services is still low. This could be due to **low awareness** among smallholder farmers. **Equipment needs to be movable.** **Very limited experience with this model,** and no experience with PULSE appliances.

Source: NRECA 2018; interviews with PULSE suppliers, MFIs, and SACCOs.

Possible solutions to improve access to finance for end-users

Table 43 provides a summary of possible solutions to improve access to finance for smallholder farmers.

Table 43 Possible solutions to improve access to finance for end-users

Solution	Description	Relevant stakeholders	Intervention type
Promote solutions to de-risk agricultural borrowers and overcome collateral requirements	A number of solutions are being implemented by financial institutions with dedicated products for farmers, e.g. mobile money transfers, value-chain financing, supporting SACCOs, digitizing land titles, and warehouse receipt systems (WRS), guarantees – e.g. dfcu partners with USAID and aBi Trust to offer a 50–50 risk-sharing scheme.	Financial institutions (banks, MFIs, SACCOs), government, and development partners	Access to finance
Involve institutions with experience in agricultural lending	Given the challenges of agricultural lending, it would be beneficial to involve banks and financial institutions with relevant experience (examples listed in Annex A7) in the design and implementation of a PULSE program.	Financial institutions (banks, MFIs, SACCOs), government, and donors	Access to finance
Develop emerging financing options for PULSE (irrigation credit schemes, leasing)	Drawing from and adapting existing models for larger farm equipment, banks and leasing firms could potentially scale asset loans or leasing models to lower the up-front costs of PULSE appliances.	Financial institutions (banks, MFIs, SACCOs), government, and donors	Access to finance

136 The two examples presented were sourced from literature (NRECA, 2018, Productive Uses of Electricity Program Initiative).

Solution	Description	Relevant stakeholders	Intervention type
Liaison with aggregators, who can provide easier access to farmers, data (land, production) and potentially guarantees	These user associations should be directly engaged to facilitate aggregation of interested investors for purposes of capacity-building, technical assistance to support the loan application process, and aggregation of loan demand towards the goal of reducing loan administrative costs tied to lower financing costs to borrowers.	Aggregators (cooperatives, off-takers, extension services), suppliers, financial institutions (banks, MFIs, SACCOs), government, and donors.	Demand aggregation
Incentivize expansion of distribution networks for PULSE suppliers providing finance	Last-mile distribution is difficult and expensive. Supporting development of distribution (and financing) networks could be encouraged with grants, such as RBF. There is considerable experience in these type of incentives for SHS.	Suppliers, government, and donors	Access to finance
Training for end-users	Training in business concepts and financial literacy for end-users, which will allow them to present better loan applications and reduce the risk for banks. Banks such as Stanbic and dfcu are already engaged in this type of activity. Training related to agronomic practices linked to PULSE.	Aggregators (cooperatives, off-takers, extension services), suppliers, financial institutions (banks, MFIs, SACCOs), government, and donors	Consumer education
Increasing awareness of PULSE among financing institutions	Banks and SACCOs are not aware of the latest developments in the PULSE industry (e.g. products, prices, target market) Awareness-creation interventions could be targeted to a wide range of PULSE stakeholders, including financing institutions.	Suppliers, financing institutions, government, and donors	Market intelligence
Training for financial institutions (especially Tier IV)	Training for MFIs and SACCOs which are interested in being involved in PULSE lending, following the precedent of UECCC's work in off-grid solar lending.	Financing institutions, government, and donors	Business development support
Develop quality standards for PULSE	Develop quality standards for PULSE to protect both end-users and financial institutions providing loans.	Suppliers, financial institutions (banks, MFIs, SACCOs), government, and donors	Quality assuarance

5.2.2 Financing for suppliers of PULSE appliances

There are a variety of financing needs of solar energy companies (importers, distributors, dealers, end-to-end integrators and, especially, companies offering consumer financing). These include:

- **Working capital,** i.e. financing stock during the period between placing an order with the manufacturer – and paying up-front – and selling the product in Uganda. This covers the import period (60–90 days for products to arrive at the supplier's warehouse from China) and in-country distribution until making a sale (another 90 days or so).
- **Receivables financing.** For companies providing customer credit (e.g. SolarNow) or PAYG (e.g. M-Kopa, Fenix International), financing is needed to cover receivables for two years or more. Local currency loans are preferable in order to match the currency of customer repayments.
- **Scale up financing,** e.g. grants and RBF. Expanding distribution networks is expensive, whether developing a self-operated physical network or establishing links with distributors, dealers, and agents. This is especially true for PULSE products, which are more complex than SHS, more expensive, and require more time and effort to make a sale. To avoid this cost translating into higher product prices, grant incentives could be provided. This type of approach has been used in SHS programs such as the Kenya Off-grid Solar Access Program (KOSAP)[137] and the Output-Based Fund (OBF) implemented by the REA of Nigeria[138]. In these cases, RBF is provided not to subsidize product prices – and thus bridge the affordability gap – but, rather, to incentivize the expansion of operations into underserved areas.
- **Resources to develop and pilot products** (patient capital or grants), grants to improve product design and value proposition for products and business models that are not yet ready to scale up (rather, piloting or demonstrating), e.g. Agsol universal mill and multipurpose platforms for farms.

Table 44 presents these types of financing, together with precedents in Uganda and the main challenges faced by suppliers and banks.

Table 44 Financing requirements for PULSE companies

Type	Description	Precedents in Uganda	Challenges
Working capital and receivables financing	Financing for stock and receivables Tenor of 2–4 years needed Local currency preferable Commercial banks in Uganda currently providing at 20–30% interest	SunFunder (syndicated loan for SolarNow), Centenary Bank (SolarNow), Stanbic (M-Kopa), FEI OGEF (SunCulture), crowdfunding loans, UNCDF	**High perceived risk** of off-grid solar businesses, which translates into **high costs, burdensome application and due diligence process, and collateral requirements** that off-grid solar companies cannot meet (they have limited access to physical collateral to which lenders would have recourse in the event of a default)[139] Limited availability and high cost of **local currency loans** (foreign exchange risk is therefore faced by supplier) **Limited market intelligence**
RBF	Grants to incentivize companies to expand their distribution networks into rural areas, disbursed on the basis of suppliers achieving milestones, e.g. selling products	LEIA is providing RBF (~20% of retail price) for best-in-class (LEAP Awards) SRUs and SWPs	**Limited grant funding** Grant funding needs to be carefully allocated to avoid market distortion. Competitive allocation of grants may favor international companies over local ones with less capacity to produce good proposals.

137 RBF incentives are tendered (reverse auction mechanism).

138 There is a prequalification process for suppliers, based on a strict technical checklist. Eligible suppliers then benefit from RBF for 20 percent of the system cost, disbursed after independent verification.

139 Banks do not yet see off-grid solar equipment as an acceptable form of collateral.

Type	Description	Precedents in Uganda	Challenges
Grants for product and business development	Grants to improve product design and value proposition for products and business models that are not yet ready to scale up (rather, piloting or demonstrating)	UNCDF CleanStart, AECF REACT, and EEP have business plan competitions to benefit from different types of soft capital.	As above **(limited funds, risk of market distortion, risk of excluding local suppliers)**

Possible solutions to improve access to finance for PULSE suppliers

Table 45 provides a summary of possible solutions to improve access to finance (different types of capital) for PULSE suppliers. The contents of this table are additional to those presented in Table 43 (relating to end-users), which are also relevant to the financing of suppliers.

Table 45: Possible solutions to improve access to finance for PULSE suppliers

Solution	Description	Relevant stakeholders	Intervention type
Promote solutions to de-risk PULSE companies and overcome collateral requirements	Credit line for PULSE suppliers (including partial risk guarantees)	Suppliers, financial institutions, government, and donors	Access to finance
	Promote and facilitate partnerships among PULSE suppliers and aggregators – e.g. solar companies with agricultural off-takers or extension services – to reduce perceived risk	Suppliers, aggregators, financial institutions, government, and donors	Demand aggregation
	Support for companies and banks in piloting alternative sources of collateral – e.g. collateralizing receivables and isolating operator risk through off-balance sheet financing structures – see Box 3 below	Suppliers, financial institutions, government, and donors	Access to finance
	Support companies in developing solutions to minimize risk of non-payment, such as companies that provide not only financing but also a broader spectrum of post-purchase support enabling farmers to grow and earn more (e.g. agronomic and agribusiness side) such as SunCulture's PAYG model – see Box 4 and Box 5 below	Suppliers, financial institutions, government, and donors	Business development support
Make grant funding available to support development of products and distribution networks	RBF and other types of grant funding to help PULSE companies improve product offering and last-mile distribution	Suppliers, government, and donors	Access to finance
Market intelligence for financing institutions	Help banks understand the market potential and specific risks of PULSE. In the nascent phase, give access to feasibility studies and de-risking mechanisms.	Suppliers, financial institutions, government, and donors	Market intelligence

Box 3: Collateralizing receivables

Off-balance-sheet financing structures

Consumer credit contracts entered into between an off-grid solar company and customers carry a high risk of default when looked at individually. However, grouped as a portfolio of hundreds or thousands of contracts, they provide off-grid solar companies with a predictable and steady stream of income that can be collateralized to leverage debt. In the event of a supplier's default, lenders can seek recourse to the continued income generated from the portfolio.

One way to address this issue is through off-balance-sheet financing structures. Companies can bifurcate their business lines into two separate legal entities: (a) an operating company (the "OpCo"), that sells, distributes, and maintains the SHS/PULSE product, and (b) a bankruptcy-remote special-purpose vehicle (the "FinCo") that exists for the sole purpose of buying the future receivables from the OpCo. In this structure, the OpCo sells SHS/PULSE products to customers – i.e. enters into contracts with them – bundles the contracts of future receivables from these sales, and then sells them to the FinCo, which buys this portfolio of contracts with a blend of debt raised from local commercial banks (collateralized by the very receivables it is purchasing) and equity from investors.

The illustration below (from SolarNow) shows the cash flows of both the OpCo and the FinCo.

AfDB–EU DESCOs Financing Program

The African Development Bank and the EU are coming together under the auspices of the DESCOs Financing Program to work with local financial institutions and DESCOs (Distributed Energy Service Companies = PULSE suppliers) to structure and execute receivables-backed, off-balance-sheet financing transactions.

In order to provide the level of de-risking necessary to better crowd in local financial institutions and improve the pricing and tenor of debt, the AfDB, supported by the EU, will provide partial credit guarantees (PCGs) on up to one-third of the debt raised by a FinCo in a transaction structured as described above. In the event of default, lenders would not start experiencing losses until the equity/retained earnings layer of the FinCo and amount covered by the PCG are exhausted.

Sources: Sun-Connect, Africa Energy Portal, AfDB, SolarNow.

Box 4: Risks of SWP financing and SunCulture's "Pay as You Grow" model

Solar water pumping is particularly unattractive for financiers because it requires both technical input for the water source and sizing of the pump, and learning to apply irrigation successfully, for the investment to translate into increased yields.

To address this issue, SunCulture has launched a "Pay as You Grow" model that not only provides financing but also recognizes the need for a broader spectrum of post-purchase support, enabling farmers to grow and earn more.

SunCulture uses a PAYG model with remote switch-off functionality and provides a broader range of customer support post-purchase. The objectives are both to reduce the cost of servicing loans and to increase borrowers' willingness to repay.

Scaling PAYG for SWPs will require both agronomic and technical understanding on the part of distributors. On the agronomic side, challenges include the unpredictability of agricultural processes including external and unforeseeable risks to harvests, such as pests and disease, that could limit a farmer's ability to repay. On the technical side, SWPs have a relatively higher value compared to most prevailing SHS and are more complex to use. They require additional time and investment from the distributor in customer education and after-sales support to ensure the correct use of the asset. Though SWPs are high in value, there is a high cost associated with recovering and reusing the equipment, and in most cases no secondary market that would enable the equipment to function as traditional collateral.

Additionally, there are questions around the effectiveness of the remote switch-off feature of the PAYG model in encouraging repayment in the long run, and of the practicality and ethics of switching off a key productive asset for a farmer's livelihood.

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

Box 5: Other mechanisms to reduce risk of non-payment for PAYG companies

Similar to SunCulture, some other companies operating in Uganda have taken steps to incentivize customer repayments and thus reduce risks of non-payment:

- Additional services and handholding: Azuri recently launched its GrowFast PAYG SWP in Uganda. This places emphasis on providing valuable support to farmers in addition to equipment, including support from an agronomist, and providing business advice (e.g. links to market). Azuri's field officers visit customers periodically to ensure the farmer's prosperity. This encourages customers to continue paying for this service.

- Due diligence: Tulima Solar conducts careful due diligence by visiting farms, assessing agronomic aspects – e.g. soil, access to water, suitable crops – assessing the farmer's experience and how quickly they pay the deposit, and so on, and maximizing the chances of the PULSE being a successful investment for the farmer.

- Payment structure (deposits): M-Kopa highlighted that deposits – 15 percent or more of the total cost of ownership – are correlated with stronger repayment and this is the main indicator of creditworthiness, given that most customers lack credit history.

- Qualification for upgrades: Similar to SHS companies, offering farmers the chance to qualify for product upgrades when they pay regularly offers an additional incentive. In the case of SunCulture, upgrades include a drip-irrigation kit to couple with their SWP.

- Clear and consistent non-payment escalation processes: In the case of Tulima Solar, systems lock after 15 days of non-payment. Clients then have up to 30 days to provide reasons for delayed payment before repossession is executed. Tulima Solar reports bad loans to be under 5 percent. It has repossessed products, but the number is negligible. SolarNow has similar procedures in place.

- Support product maintenance requests: Finally, PAYG customers will not pay if the product is not working. According to a recent survey of SWPs in East Africa by the Energy for Access Coalition, 50 percent of customers reported challenges in the functioning of equipment. Companies therefore need a clear, consistent, and timely after-sales service model.

Source: ECA interviews with companies, BFA Global post: How to design PAYGo operational models to improve repayment.

5.2.3 Financing medium-to-large PULSE projects

Loans for medium and large PULSE projects (with costs in the range of $10–100k) are granted to project owners rather than to suppliers of PULSE appliances. Project owners may include commercial farms – e.g. coffee and horticulture farms above 12 acres and dairy farms with over 50 head of cattle – cooperatives (e.g. cooperative-owned milk-collection centers), off-takers such as coffee or horticulture exporters, and SMEs (e.g. ice-making factories catering for fishers). Financing for this type of project will need to be longer term – at least four to five years – in order to adapt to the slower payback period of solar PV compared to existing diesel generators.

5.3 Awareness

Challenges and purpose of awareness raising

Ugandan consumers have a very high level of awareness of solar PV systems. Lighting Global's 2020 Off-grid Solar Market Trends Report classifies Uganda as a firmly established market. Penetration of small SHS and PAYG units is over 40 percent of the population. Moreover, a large proportion of these systems have actual income-generating benefits.[140]

Initial efforts of the World Bank's ERT program[141] focused on building markets for household solar use and did not directly focus on productive-use applications. Nevertheless, even in the absence of dedicated program support, business consumers in off-grid areas have adapted solar equipment to power applications that include refrigerators for cold drinks in shops, clippers and sound systems in barbershops, video cinemas in bars, phone-charging stations, pumps for irrigation, and IT equipment in internet cafés. These largely spontaneous developments show that PULSE markets are viable and that there is considerable demand for off-grid productive power.

Nevertheless, without directed awareness-raising efforts, a number of challenges face the development of the market for PULSE products in Uganda. First, higher-cost PULSE systems need to be proven and demonstrated before conservative rural buyers will invest in them. Second, rural farms, businesses, and SMEs must be educated about the wider potential of solar energy for income generation beyond PAYG and SHS, especially in remote areas. Third, the many negative experiences from poorly designed and assembled systems – primarily supplied by over-the-counter markets – must be overcome. Finally, financial players must be mobilized to help overcome the high up-front costs of PULSE appliances so that businesses and consumers can invest in systems.

An awareness support program for PULSE would seek to accomplish three key objectives, explained in detail in the subsections below. It would:

- Stimulate demand for most viable technologies by building on early-stage PULSE market activities and innovation
- Build awareness of PULSE potential along the entire value chain and along private-sector delivery chains
- Overcome negative views of poorly functioning larger solar power systems

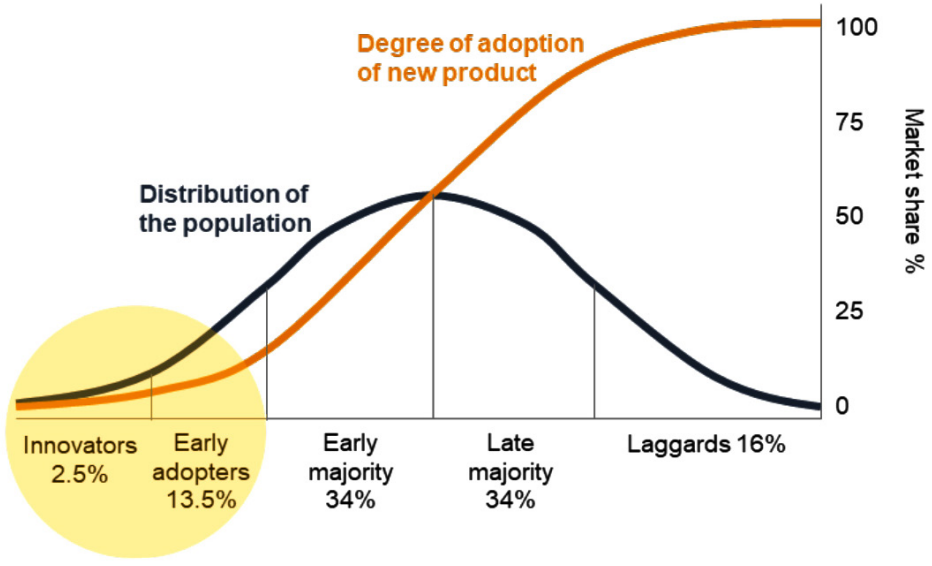
140 Actual data on penetration of solar systems is not available. The 2019 GOGLA Annual Report mentions that over 15 percent of installed systems contribute to direct income generation.

141 In particular the Second Energy for Rural Transformation (ERT II) Project, implemented between 2009 and 2016. The first component of the project was rural energy infrastructure. This component financed extension of the existing electricity distribution network, installation of independent distribution systems, small scale renewable energy generation plants, household and institutional solar PV systems, and related technical assistance and training.

Stimulating demand in early-stage markets

The Uganda PULSE market is at an early stage, emerging from a well-developed household PV market. As was the case with the early stages of the SHS market, PULSE systems will initially be most attractive to innovators and early adopters (see Figure 38). These market groups will help to increase and broaden awareness of key PULSE technology. Companies can work with early adopters to innovate, improve their products, lower prices, and widen the scale of impact.

Figure 38 Diffusion of innovation



Source: Diffusion of Innovation Theory, developed by E.M. Rogers.

Unlike base-of-the-pyramid energy access strategies, a PULSE program should initially channel finance, consumer education through demonstrations and outreach, and incentives toward SME and farming innovators and early adopters. These groups will validate the income-generating potential of PULSE appliances and stimulate the growth of markets along value chains.

These initial market groups are easier to reach than base-of-the-pyramid consumers because (a) they tend to be better educated and more open to new technology, (b) they are better financed and therefore able to invest, and (c) they are willing to take risks, especially with new technologies. The following groups are especially interesting for awareness-building:

- **Innovative farmers.** This group has driven the development of peri-urban and rural business in horticulture, dairy, and poultry-rearing. They recognize the value of adding new tools and processes – refrigeration, pumps, agricultural machines – that add value to their products.
- **Fishers.** Fishing economies, especially island communities on Lake Victoria, have year-round incomes and, because of the lack of nearby electricity grids, have a compelling need for solar power for refrigeration, processing, and ice-making. They already use solar electricity on a wider scale than the general population.
- **ICT enterprises** entertain and drive connectivity with rural communities. Information is an increasingly important foundation for banking, farming, small business, education, and health services.
- **Workshops and SMEs** require power for a range of uses including tailoring, woodwork, spot-welding, and electrical repair. Small solar-powered tools are increasingly well matched for this demand.

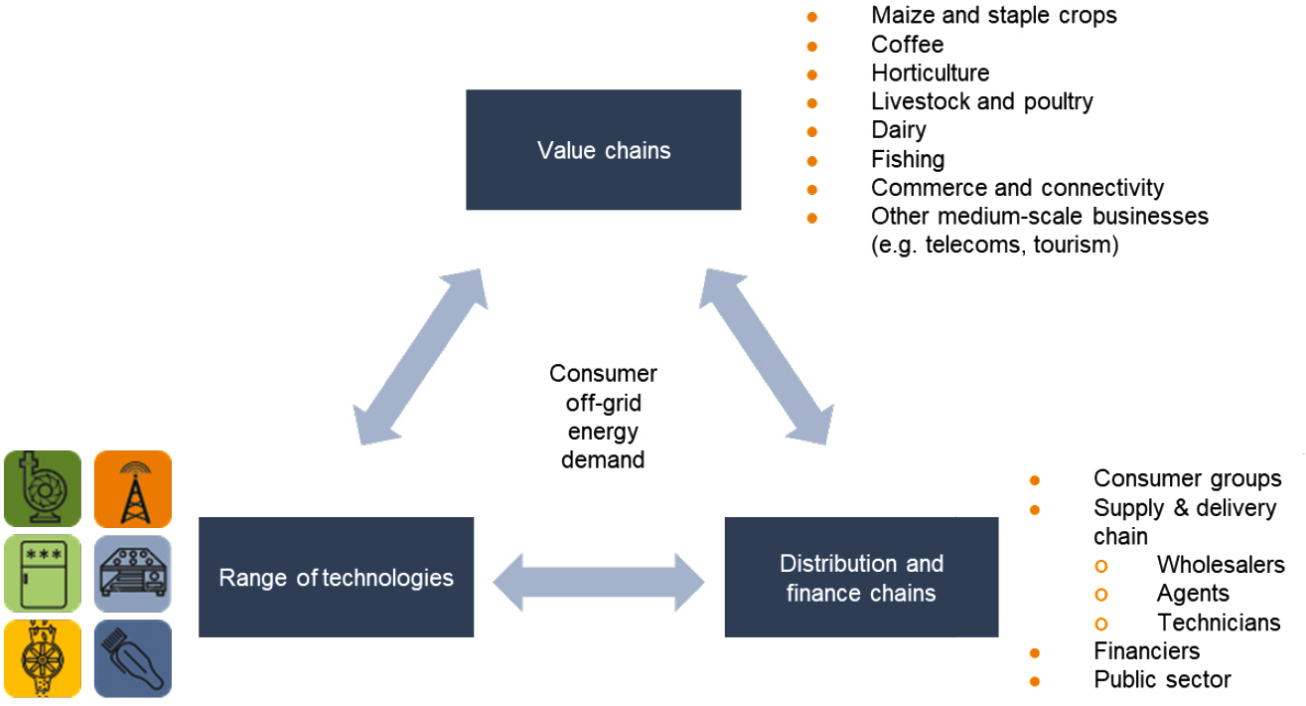
Building awareness along the entire value chain

Unlike household SHS and PAYG markets, PULSE markets are not uniform with respect to types of products and consumer demand. The geographically dispersed nature of consumers also presents a barrier to marketing and supporting larger, more expensive PULSE products and their distribution. PULSE products thus require varied approaches in building commercial demand and reaching remote areas. Products and services must be configured to match a wider range of consumer needs.

As shown in Figure 39, the diversity of appliance power demand and distribution chains make awareness-raising for PULSE challenging:

- **Appliance and productive-use technologies.** Product value chains demand a range of specialized technologies that are known by players within the value chain, and which must be absorbed by PULSE providers. For example, a dairy farm might need electricity for pumps, milk-chillers, chaff cutters, and milking machines. A fishing community might need ice-makers, processing tools, lighting, and even electric motors for boats. Small farms require irrigation pumps configured to their size and crop cycles.
- **Value chain.** As indicated above, each value chain has its own ecosystem of appliance needs. The better a supplier understands these needs, the better it can serve the value chain.
- **Distribution and finance.** Each value chain has its own aggregator groups – e.g. cooperatives and buyer organizations – sources of finance, distribution chains, and public support activities.
- **Building confidence in PULSE technology.** Awareness about off-grid solar PV is extremely high, as is demand. Nevertheless, due to the failure of larger systems, there is considerable skepticism of system performance. This is due to the limited capacity of suppliers – especially over-the-counter traders – and the lack of both large solar system standards and enforcement capability.

Figure 39: PULSE awareness-building process



Players in the PULSE awareness-building process

Ultimately, demand for appliances from early-adopter end-users will drive PULSE sales and the private sector will supply equipment. However, the nature of value chains requires that as many players in them as possible are involved in awareness campaigns. Information needs about PULSE vary by player. Businesses and consumers need to understand how products will benefit their operation. Financiers need to understand the business case for the various technologies as well as realistic expected returns (see Table 46).

Table 46: Awareness-raising efforts to target a wide variety of stakeholders

Stakeholder group	Awareness-building needs	Intervention type
End-users (farmers, SMEs) and aggregators (cooperatives, off-takers)	Information about PULSE technologies, the cost–benefit of investing in PULSE, financing solutions available, etc. This is closely linked with capacity and know-how in the next subsection. In addition to understanding solar technologies, it is important to understand the agronomy (e.g. irrigation) and the productive industry itself.	Consumer education
Suppliers (PULSE companies)	Market intelligence and knowledge on the best way to target the market (e.g. through cooperatives and aggregators) last-mile distribution strategies, financing available, and so on	Market intelligence
Financiers (banks, SACCOs)	Understanding of PULSE (e.g. products, prices, and quality standards), the business case for their adoption, and the sector's long-term growth potential. Understanding the specific risks and, in the nascent phase, giving access to feasibility studies and de-risking mechanisms.	Market intelligence
Public sector	Potential of PULSE in government programs supporting agriculture and other productive industries. For example, the role of PULSE in achieving objectives of the Agriculture Sector Strategic Plan or the National Irrigation Policy, and the specific types incentive mechanisms that governments can implement. Strategic Plan or the National Irrigation Policy, and the specific types incentive mechanisms that governments can implement.	Market intelligence

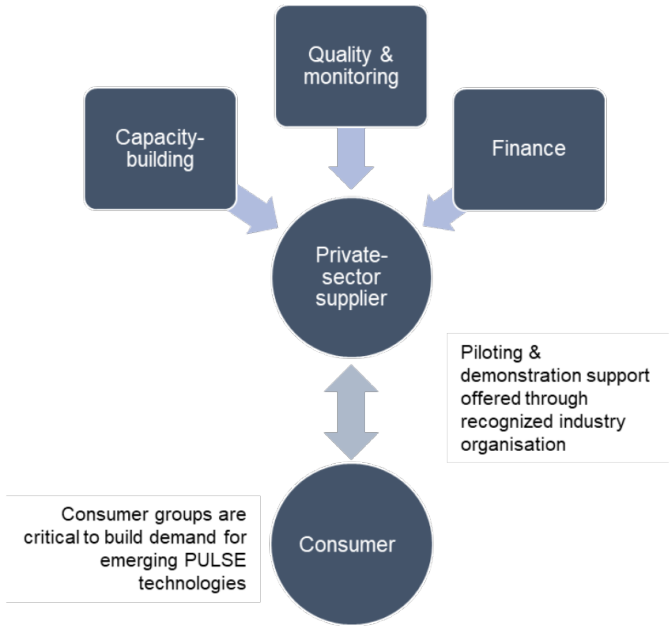
Key features of an awareness-building program

Market awareness is best driven by qualified private-sector suppliers through sales and marketing activities. Awareness work must also be coordinated with finance, quality assurance, and capacity-building providers (see Figure 40).

A successful awareness program will:

- Target early adopters and economically active off-grid populations
- Use strategic demonstrations of high-quality PULSE products to validate the viability of systems
- Make the private sector the prime mover in awareness-raising by building strong linkages to consumer groups and aggregators
- Inform about finance mechanisms available for PULSE products through suppliers and consumer groups
- Use value chains to strategically promote selected PULSE applications and raise awareness for high revenue enhancing technology in dairy, horticulture, cash-crop producers, poultry, and other sectors.
- Include small and large suppliers, and especially rural-based businesses, cooperatives, and business operations. Awareness campaigns could be designed so that consumers can better interact with and make use of the active over-the-counter informal market that is very well distributed across the country.

Figure 40 Awareness-building program



5.4 Capacity and know-how

Challenges and purpose of PULSE capacity-building work

As shown in Figure 41, there is a variety of capacity needs that must be addressed to build specific PULSE market niches. Each PULSE product (with its own efficient appliance) has specific technical, O&M, business development, sales, and finance requirements.

The increased complexity of off-grid PULSE equipment requires that stakeholders have capacity to design, finance, sell, and deliver after-sales service for durable PULSE solutions. For example, a SWP for a small 1-acre horticulture farm will have very different requirements to one for a 50-acre coffee farm. These differ not only in terms of technology and agronomy, but also in terms of financing, installation and after-sales service needs.

Some important aspects to consider when designing and implementing a capacity-building program are that:

- Programmatic interventions should ensure that all stakeholders have the necessary understanding and skills to effectively deliver PULSE products and services.
- A variety of capacity-building activities will be required along each delivery chain depending on its particular appliance needs.
- The acute needs for capacity-building in the field must be met. Consumers, local agents, and O&M providers must be able to provide operation and after-sales service in rural areas.

Players in PULSE capacity-building

Capacity-building should act at all levels of the supply chain: financier, importer, regional distributor, technician, and consumer:

- Financiers may need capacity-building relating to PULSE technologies, the agronomic component, agricultural lending, alternative types of usable collateral, and so on.
- USEA members and other solar companies require support to develop business plans, improve governance and financial management, build market strategies, train agents, and reach more remote populations that still lack access to clean energy.
- New products need to be tested and demonstrated. Many companies (and consumers) reiterated that, in the Ugandan market, "seeing is believing." Many new products must be experienced by consumers to succeed.

Figure 41: Capacity-building needs

- End-user groups – e.g. dairy coops, fisherpeople organizations, coffee apex organizations – need support to educate consumers, demonstrate and prove PULSE equipment, plan projects, and raise finance.

Figure 42 outlines some of the key capacity needs of different players in the delivery chain. Thus far, existing players in the market have had to build capacity internally. For example, to build market share SolarNow, Davis & Shirtliff, and SunCulture[142] have all invested internal resources in each stage of the PULSE delivery processes.

Figure 42 Key capacity needs of different players

Financiers	Importer, suppliers	Installers/ after-service providers	Consumers
• Due diligence on company (and consumer) • Technical aspects of PULSE and related agronomy aspects • Quality assurance • After-sales service for loan period	• Sales & marketing • Business development services • Financing • Design, installation, O&M of PV systems and appliances • Training specific to technology and value chain	• Sales and marketing • Design, installation • Financing • O&M of PV systems and appliances • Contracting • Training specific to technology and value chain	• O&M of PV systems and appliances • Consumer group/cooperative training to introduce potential innovations

142 SunCulture is mostly focused on the Kenyan market but is expanding to Uganda.

Awareness and capacity-building should involve women. Women's groups are organized and have strong potential to generate resources locally. They are often starved of start-up capital.

Programmatic resources can be made available to spread the costs of capacity-building and to address segments of the delivery chain that have not received sufficient attention. Many capacity-building services are already available from players in the market. These include programs (e.g. CLASP, Lighting Global, PAUESA, UNCDF, and Power for All), private and public vocational training institutions, government agencies, consultants, and companies.

Key features of a capacity-building program

Experience from the Lighting Global program shows that coordinated awareness-raising, capacity-building, and company/consumer finance efforts can maximize results. Capacity-building must be easily accessible and tailored to the needs of private-sector and consumer aggregators.

A capacity-building program should have the following elements, of which examples are provided in Table 47:

- **Light-handed.** The program would be flexible, easily managed, and targeted on the specific needs of PULSE in the field.
- **Focused and coordinated approach.** A low-cost capacity-building program would be coordinated with market-seeding demonstrations that stimulate demand, create jobs, and build real income. High-value chains should be especially supported with capacity-building.
- **Linked to finance disbursements.** Capacity-building should be arranged as part of finance package deals aggregated through private companies and consumer groups. Capacity-building needs should be explicit and related to the activity for which finance is provided.
- **Local service providers.** Capacity development should utilize existing accredited service providers (such as vocational training institutes, CREEC, Enlight,[143] and consultants) during training activities.

Table 47: Components of a capacity-building program

Activity	Description	Target audience	Potential responsible parties	Intervention type
Overall capacity-building administration	Coordination with industry, cooperatives, government.	n.a.	Industry association (e.g. USEA, PSFU)	n.a.
Technical needs for PULSE (solar PV, appliances)	Technical skills (sizing, installation, maintenance, etc.) needed for PULSE products integrated into vocational, secondary, and tertiary curricula.	PULSE companies (technicians), aggregators (cooperatives), SACCOs	Vocational training, CLASP, Enlight, Engineers Without Borders USA[144]	Technology and innovation
Integration of PULSE into agricultural practices	Use of PULSE in irrigation, cooling, agro-processing (technical and business-related aspects) through pilot projects and demonstrations and the development of case studies and guidelines, among others.	Consumers, aggregators, suppliers, SACCOs	Tertiary cooperatives, agricultural extension services (MAAIF, MWE, NAADS, DDA, UCDA)	Consumer education Technology and innovation
Business development services	Training for PULSE-related business operations	Suppliers, aggregators, SACCOs	UNCDF[145], consulting firms, others	Business development support

143 Enlight was launched in 2018, with support from founding partner the Signify Foundation, to work with solar companies in Uganda and across East Africa on solving their human capital challenges. For more information, visit Enlight's website.

144 EWB-USA, in collaboration with the MWE, is providing extensive capacity-building and developing best practices for SWPs in Uganda.

145 UNCDF's CleanStart program co-invests in early-stage innovations, providing hand-holding to selected companies as they develop products and business lines, and access scale-up financing.

Activity	Description	Target audience	Potential responsible parties	Intervention type
Sales and marketing	Training for PULSE sales and marketing for services and products, and for targeting consumer groups	Suppliers, aggregators, SACCOs	Consulting firms such as Business Might and Houston Consulting (precedent with USEA members)	Business development support
Equipment financing	Assistance helping companies in PULSE-related business planning, proposal development, and financial planning	PULSE suppliers, aggregators, SACCOs	Banks with dedicated capacity-building foundations, e.g. Stanbic[146], dfcu; consulting firms	Business development support
Financing of PULSE	Support to banks in testing innovative agricultural and PULSE lending practices	Financing institutions	Liaison between suppliers and banks facilitated by industry association (e.g. USEA), UNCDF, or others	Access to finance

5.5 Maturity of technology and value proposition

PULSE is a nascent technology. Suppliers are still developing their products and value propositions to better serve the productive-use market. SWPs very often present technical challenges for consumers[147], many agro-processing products are still at the R&D stage, and for existing products there can be a mismatch between their capacity and needs on the ground. Technological innovations that could be supported include:

- **Developing shareable PULSE appliances such as easily movable water pumps.** Batteries and solar panels can make equipment less mobile compared to diesel products. Often applications in agricultural value chains require a product to move to customers or market.

  Today, SWPs are designed for use by a single farm, requiring technicians to support installation and servicing.[148] Since crops do not need irrigation throughout the growing cycle, it is theoretically possible for numerous farmers to share a single pump, thereby improving affordability. Solar irrigation companies can explore ways to make it easier for farmers to rent pumps or to buy them as collectives. This approach would be most relevant for surface SWPs, which are more mobile in their design.

  SWP manufacturers could also leverage the growth of the SHS market by developing products that can be powered by the same panels as solar home systems, or inversely allow for other uses of solar PV panels included in the SWP system.

- **Developing multipurpose platforms for the variety of needs on a farm,** rather than creating specific solar-powered products for each application. For example, a typical dairy farm needs energy for water pumps, milk-chillers, chaff cutters, and milking machines. A single stand-alone solar PV system can be designed to power all of these more efficiently than smaller individual systems. More information about this can be found in annex A4.

- **Support technological innovations and product development.** Products are not always tailored for a particular crop or value chain application. Recurring design issues include (a) system sizing and modularity, (b) mobility and weight, and (c) processing quality and capacity requirements. For example, Agsol's universal mill, presented in section 2.2.3, is being redesigned to better meet market

146 A recent program launched by Stanbic bank has supported many companies in the renewable energy space and other sectors to grow. Stanbic intends to scale-up this program.

147 A survey of SWPs by the Energy for Access Coalition detected that 50 percent of customers experienced technical challenges with their pumps. SWPs are a relatively new product compared to the more established SHS. Given its infancy, such a figure is not surprising. As companies iterate on solar pump development and respond to customer feedback, the number might decrease.

148 "Solar water pump outlook 2019", Energy for Access Coalition.

needs. Innovations in SWPs are moving toward IoT-enabled improvements — notably, sensors and remote monitoring—and brushless DC motors.[149] Remote monitoring of system operation, energy output, and benefits by companies, aggregators, and government demonstration projects can help build knowledge about various PULSE viability issues and after-sales service needs.

- **Improving designs for solar PV to replace diesel in specific applications,** e.g. cooling in dairy cooperatives or ice-making for fishers.

Possible solutions to support technological innovation

Table 48 Possible solutions to support technological innovation

Solution	Description	Relevant stakeholders	Intervention type
Grants to support R&D in PULSE	Given the low levels of maturity of PULSE, there is still a need for soft capital and technology transfer to address sectoral and agricultural value chain limitations, e.g. dairy spoilage at pico-scale. R&D programs such as the one implemented under LEIA could be relevant to further support the market.	Government, donors	Technology and innovation
Grant windows and competitions to address PULSE innovation requirements	Grant funding could be made available to address this challenge, similarly to UNCDF's CleanStart, AECF/ REACT, and LEIA.	Suppliers, aggregators	Technology and innovation

5.6 Last-mile distribution

In many places, logistics chains are not sufficiently developed and demand not aggregated enough to make investment in distribution viable. Several suppliers have not identified in-country and value-chain partners and business models to facilitate efficient and cost-effective last-mile distribution, including the necessary training and technical support given alongside sales.

According to the Lighting Global PULSE market opportunity assessment:

- **Distributors** are often situated in capitals or secondary cities and do not have extensive rural networks of sales agents, because of historical low demand or affordability issues. They also do not have much experience in consumer credit models, which, as discussed above, are critical to expanding the serviceable market.
- **Early-stage innovators** (e.g. Futurepump, SunCulture) are now having to build their own distribution networks, which is costly and requires operational expertise.
- **SHS/PAYG leaders** (e.g. M-Kopa, Fenix International) have existing touchpoints with rural customers and they are also becoming specialists in providing consumer financing for assets, but they do not have PULSE expertise.
- **Aggregators,** such as off-takers and cooperatives, have access to pools of smallholder farmers which often have agro-vets and hardware stores attached to them. In the case off-takers, their relationship as a buyer can de-risk farmers and make them bankable for commercial banks, MFIs, or leasing companies.

149 Ibid.

- **SACCOs** already have strong links with farmers and experience with off-grid solar financing. However, they lack knowledge of PULSE.

Possible solutions to support last-mile distribution

Partnerships between all players across the value chain (listed above) will be critical to unlocking the market for PULSE. In addition, financial incentives for PULSE suppliers to extend their distribution networks into rural areas could help remote farmers to access affordable products.

Table 49 provides a summary of possible solutions to support PULSE companies in improving last-mile distribution.

Table 49: Possible solutions to support last-mile distribution

Solution	Description	Relevant stakeholders	Intervention type
Encouraging partnerships across the value chain	Connecting value-chain actors, suppliers, and distributors, until critical mass is reached. Collaboration is increasing, but activities are mostly limited to peri-urban customers.	PULSE suppliers, value-chain aggregators, SACCOs, informal traders in smaller towns.	Demand aggregation
Incentivize expansion of distribution networks by providing finance to PULSE suppliers	Last-mile distribution is difficult and expensive. Supporting development of distribution (and financing) networks could be encouraged with grants, such as RBF. There is considerable experience in this type of incentives for SHS.	PULSE suppliers, government and donors, informal traders in smaller towns	Access to finance

5.7 Quality assurance

Challenges and purpose

Much useful work has gone into quality-assurance development for off-grid household and lighting devices, especially plug-and-play and small PAYG units. As described below, this work can be used for quality assurance in the implementation of programs that roll out PULSE equipment. However, the quality assurance needs of PULSE devices differ significantly from SHS in a number of ways that would affect how a QA framework is designed:

- First, **PULSE technology tends to be more complex than SHS technology.** PULSE systems incorporate solar PV components, sophisticated controls, batteries, super-efficient appliances and, increasingly, PAYG payment and monitoring systems.
- Second, the greater complexity necessarily means that **many PULSE products are not "plug and play."** They need to be properly designed, installed, operated, and maintained. They cannot simply be tested as self-contained plug-and-play devices.
- Third, **PULSE devices are evolving rapidly.** Many pioneer "first generation" PULSE systems have performed below expectation and created negative perceptions among consumers. Systems have failed because of poor design, inferior components, improper installation, and a lack of after-sales service and maintenance. Some providers of PULSE systems, particularly small players, "do-it-yourself" installers, and over-the-counter providers, assemble systems that are not durable, bankable, or fit for purpose. However, a new generation of PULSE products and suppliers is addressing the market more professionally, and tailoring and improving designs constantly to better serve the market's needs.
- Fourth, the **SME or farm using a PULSE product depends on the device for its livelihood and business success.** A PULSE appliance might be the single largest investment a small farm or business makes. Where off-grid electricity and working appliances are a necessary part of the business, a failed PULSE product can mean the difference between success and failure. Moreover, low-quality PULSE present risks for the entire supply chain, from end-user to distributors to financiers.

A program building sustainable PULSE markets would ensure that PULSE products overcome these challenges and perform per their specifications. However, comprehensive QA programs for PULSE appliances have not yet been developed.[150] Though QA frameworks exist for Tiers 1 to 3 SHS and for some appliances, they do not address quality for most emerging PULSE applications.

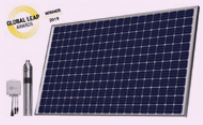
Given the multiple types of PULSE systems and the wide variety of components, individual testing of each system[151] would be expensive and difficult, and QA enforcement on such a wide variety of products would be impossible.

To help build quality assurance for PULSE products, a program would ideally incorporate four elements:

- First, financing would be made available for PULSE predicated on functionality (warranty) of the PV system and appliance over the term of finance.
- Second, participating companies would, as much as possible, be responsible for demonstrating that their equipment meets relevant component standards, has appropriate warranties (see examples in Table 50), and will work as designed and marketed. They would be required to provide substantiated evidence that their equipment performs as claimed.
- Third, a capable third party would independently verify the equipment according to the documents provided and a set of agreed standards, codes, and performance outputs.
- Fourth, over initial stages of PULSE development, the finance program would approve and accept equipment based on applications from companies that demonstrate and ensure the viability of their equipment.

Table 50 presents examples of warranty and quality standards adopted by PULSE suppliers in Uganda.

Table 50 Examples of QA warranty and standards for PULSE in Uganda

Product		Technical parameters	Warranty	Certifications/standards
	Futurepump SF2 (distributed by SolarNow and Davis & Shirtliff	Surface pump DC motor Head: 15 m Max flow: 3.6 m3/hr Supplied with 3x40 W (120 W) solar panels	5 years	Finalist in Global LEAP Awards 2019
	SunCulture Rainmaker 2 irrigation kit (with ClimateSmart Direct) (distributed by SolarNow)	Submersible pump Brushed DC motor Head: 30 m Max flow: 1.1 m3/hr Solar PV: 310 Wp	Installation and training After-sales support 3-year warranty	Winner of Global LEAP Award 2019
	Lorentz PS 150 HR-04S3 (available at David & Shirtliff)	Submersible pump Brushed DC motor Head: 60 m Max flow: 0.77 m3/hr Nominal power: 300 W Solar PV: 400 Wp	Warranty of material and workmanship for 2 years from installation or 3 years from manufacture	2006/42/EC (machinery), 2004/108/EC (electromagnetic compatibility), 2006/95/EC (electrical equipment) IEC/EN 61702:1995 (Rating of direct coupled PV pumping systems)

150 PULSE products are assembled from components that may be individually certified – i.e. PV, batteries, and appliances – but systemic standards for the assembled kit and codes of practices do not exist.

151 For example, there are now dozens of types of small pumping systems on the market, and simply testing all of these (not to mention other PULSE products) would be very expensive and time-consuming.

Product		Technical parameters	Warranty	Certifications/standards
	M-Kopa solar-powered fridge	100-l capacity 60 Wp solar PV Includes lightbulb and phone-charging ports Full warranty (2 years) Made in China	2 years on M-Kopa Solar Fridge and Home System,1 year on accessories	Winner of Global LEAP Award 2019
	SunDanzer (distributed by Aptech Africa)	Various sizes SunDanzer DC 165 has a volume of 160 liters 100 W solar PV module 2 USB ports Made in US	2-year limited warranty	Finalist in Global LEAP Awards 2019
	SolarNow refrigerators (distributed by SolarNow)	35-l (100 Wp) and 112-l (150 Wp) units	Every SolarNow product comes with a warranty and free service (up to 5 years)	Finalist in Global LEAP Awards 2019 Products are based on Dutch technology and meet international quality standards.

Source: company websites, Global LEAP.

Although individual component standards would be required, a modest PULSE program would not be able to support comprehensive testing and certification of a large variety of systems. Ultimately, PULSE product quality assurance certifications should be tied to:

- Demonstrated and proven performance of the equipment, in both laboratory and real-world settings;
- Observance and presentation of quality standards and codes by the participating company;
- Rapid verification of PULSE performance by a qualified third party; and
- Increasing ability of authorized quality assurance agencies to develop and help enforce agreed norms and work with companies and consumer groups to self-enforce them.

A program building sustainable PULSE markets would ensure that PULSE products overcome challenges and perform per their specifications.

Such a program would incorporate existing QA models and working arrangements. It would develop a portfolio of equipment which is pre-approved for finance. New equipment would be verified and added by a qualified third party based on application to the program and appraisal of its equipment. Because of the need for a rapid turnaround on their proposal (and the relatively short timescale of the project), full laboratory testing would not be possible under the program.

PULSE quality assurance players in Uganda

Table 51 presents key organizations involved in the development of standards in Uganda and those involved with QA for solar energy technology, generally. Each of these offers specific capacity for quality assurance in the market.

Table 51 Key organizations involved in development of standards

Name	Notes
Uganda National Bureau of Standards (UNBS)	National agency mandated to formulate and promote use of standards, enforce standards, ensure fairness in trade and precision in industry, and strengthen the Ugandan economy by assuring the quality of locally manufactured products.
Lighting Global	Lighting Global supports the growing global market for modern off-grid energy with a widely applicable, rigorous QA framework. The key QA activities include measuring, benchmarking, and communicating information about product quality and performance. The Lighting Global QA framework served as the foundation for — and is now based on — International Electrotechnical Commission (IEC) Technical Specification 62257-9-5. This IEC specification provides the global QA framework for off-grid lighting and SHS kits. This QA framework does not cover the appliances that are part of PULSE equipment. In February 2020, Lighting Global, CLASP, and the Schatz Energy Research Center launched VeraSol[152], an evolved QA program that responds to the market's growing needs. VeraSol builds upon the strong foundation laid by Lighting Global and expands its services to encompass appliances, productive uses, and component-based SHS. The program maintains the existing Lighting Global QA framework and merges it with comparable product data for off-grid appliances and productive uses. To better serve consumers, companies, and the market, VeraSol now encompasses technical foundations—in the form of uniform test methods—for appliances and productive uses. It will expand these services to other products in the coming years.
CLASP	Manages the Global LEAP Awards competition to identify and promote best off-grid appliances, accelerating market development and innovation. Pumps and refrigerators are currently being evaluated; TVs and fans have been assessed previously. Since February 2020, CLASP also manages VeraSol in partnership with the Schatz Energy Research Center at Humboldt State University (Schatz Center).
Energy Star rating program	A US benchmark program that enables consumers and businesses to purchase productive-use products that save money and protect the environment. Each product that earns the label is independently certified to deliver the quality, performance, and savings as assessed. Companies apply and participate voluntarily in the program.
REA	With support from ERT-III, an Off-Grid PV Solar Systems Installation Guideline was developed through the Sustainable Energy Industry Development Project (SEIDP). It focuses on local practices and capacity.
IEC, UL	Programs that independently assess and test electrical equipment (e.g. solar modules, batteries) to ensure they meet established parameters.
Uganda Solar Energy Association (USEA)	Independent non-profit association dedicated to facilitating the growth and development of solar energy business in Uganda and the East African region.
Engineers without Borders USA and Ministry of Water and Environment in Uganda	EWB-USA, in partnership with MWE, has developed guidelines for designing and choosing SWP systems, as well as referenced applicable industry standards. They have also provided extensive training for SWP companies.

152 Lighting Global News: VeraSol Launches at the Global Off-Grid Solar Forum & Expo

Recommended features of a quality assurance program

A quality assurance program should be light-handed, low-cost, easily managed and, after an exacting application and approval process, self-enforceable by companies and consumers and verified by an independent agency. The recommended features of a QA program are:

- **Company participation.** Participation by companies in the QA program would be compulsory to be eligible to receive loans and/or program incentives and support. Once a company or consumer group qualified to participate in the program, simple contracting arrangements would enable it to receive finance, incentives, or technical assistance.
- **Process.** To attract the interest of the private sector and consumers, a QA program would have to provide a quick, non-laborious route to approval for participation. Agreements for support and finance would acknowledge the needs of consumers, financiers, manufacturers, and local companies, and would incorporate after-sales service needs over the course of the loan or project support. Verification processes would be quick and simple.[153]
- **Diversity of PULSE equipment.** Any program should recognize the diversity of PULSE equipment (especially appliances) and seek to accommodate innovation. It should also seek to involve a wide range of local and international equipment providers.

Scope of PULSE quality assurance verification

Quality norms would take into account all parts of PULSE systems. Solar, inverter, battery, and other balance-of-system components would need to comply with existing IEC standards and relevant codes. Appliances would have to demonstrate some type of quality verification, i.e. approval from an existing program (CLASP, UL), some type of energy efficiency rating, or demonstrated performance. Where needed, after-sales service support would have to be demonstrated.

The following features of equipment would be covered during the quality assurance application and verification process:

- Component quality
- System sizing
- Appliance efficiency and service life
- System installation and assembly
- User information and training provision
- After-sales service and spare parts
- Warranty
- Repair/recycling/end-of-life disposal
- Product grievance redress mechanisms

Quality verification program and process

An implementable program would be developed, qualification process and rules would be established, the companies would qualify and implement activities, and the outputs of the activities would be measured (Figure 43).

Figure 43 Quality verification program and process

153 The appointed verifying agency would understand PULSE technology and be able to quickly provide a clear positive or negative response to applicants. "Experimental" or "early-stage development" equipment would not be allowed under the program due to performance risks.

Program development. A simple program with enforceable guidelines, established using best practices from previous programs.[154] In the QA program design, the following should be considered:

- PULSE financing to be contingent on meeting QA requirements.
- The project is open to as many players in the sector as possible (as long as they meet the terms of the QA program).
- The project accepts a variety of PULSE technologies.
- Guidelines and/or verification procedures would need to be developed specifically for the program. They would incorporate existing standards and codes of practice, and utilize other international best practice where useful.
- The program encourages companies to demonstrate how their equipment meets applicable codes and standards.
- The verification agent is hired by the program – ideally based locally – and able to handle applications quickly.

Qualification. The program should establish a clear process by which companies and equipment qualify. This should be based on:

- Established company capacity
- Demonstrated PV system and equipment viability (internal "testing" process)
- After-sales service and user engagement plan
- Companies able to pre-qualify based on demonstrated products and capacity
- A quick and complete verification process

Implementation. Once a company or project is approved, there is a clear and efficient procedure for releasing funds. Systems are installed according to agreed parameters, including:

- Agreed system designs and submission of specifications
- Commissioning and verification procedures
- Early coordination with pilot initiatives, capacity-building, policy development, and awareness-raising activities

Monitoring. In order to assess the benefits of PULSE, the program must ensure that guidelines are followed and that installation, performance, and associated benefits of systems are accurately monitored. A program would:

- Conduct online monitoring of initial systems and later a representative sample set of PULSE[155]
- Follow up with selected sites and value-chain representative(s)
- Measure technical, social, and economic performance outputs of PULSE systems, especially SME and farm output, and financial parameters

Lighting Global supports the growing global market for modern off-grid energy with a widely applicable, rigorous QA framework. The key QA activities include measuring, benchmarking, and communicating information about product quality and performance.

154 See, for example, "Vanuatu Rural Electrification Program (VREP) November 2014–September 2022: Subsidy Implementation Manual," Vanuatu Rural Electrification Project, January 2018.

155 Innovex Uganda has been monitoring productive-use applications in Uganda for a number of clients. For more information, visit Innovex's website.

Table 52 Possible solutions to support PULSE quality assurance

Solution	Description	Relevant stakeholders	Intervention type
Implement a QA framework for PULSE	A QA program should be light-handed, low-cost, easily managed and, after an exacting application and approval process, self-enforceable by companies and consumers and verified by an independent agency. Verification procedures would need to be developed specifically for the program and a third-party verification agent hired.	PULSE suppliers, financiers, government, and donors	Quality assuarance
Quality assurance in installer training programs	The QA program should include support to assist training institutions to build applicable QA training that assists in the rollout of PULSE.	Vocational schools, universities, NGOs, specialist consultancy	Quality assuarance
Quality assurance awareness among consumers	The QA program should work with consumers and finance agents to educate consumers about the need for quality in PULSE and about the developing standards and codes of the QA program itself.	USEA, consumer groups, value-chain agents, participating finance groups, SACCOs, and cooperatives	Quality assuarance

5.8 Tax policy and fiscal incentives

One of the policy actions taken by the Government of Uganda to support the expansion of the off-grid solar market was the removal of taxes on off-grid solar products[156]. Private companies say this was an important step in improving the products' affordability and attracting private companies in this nascent market.

USEA, in collaboration with the government, developed a handbook to guide solar companies, customs officials, revenue-collection officials, government officials, and other stakeholders on how to apply tax reductions and exemptions related to the off-grid solar sector in accordance with the current law.

While solar panels and solar charge control units are fully exempt from VAT and import duties, most PULSE products are still subject to some form of taxation. Table 53 summarizes the tax policy that is relevant for each type of PULSE appliance.

156 Section 19 of the VAT Act, Cap 349 provides that a supply of goods or services is exempt if it is specified under the Second Schedule of the Act. Some of the goods in the schedule of the VAT Act relating to the solar industry include the following: (a) the supply of photosensitive semiconductor devices, including photovoltaic devices, whether or not assembled in modules or made into panels; light emitting diodes, solar water heaters, solar refrigerators and solar cookers; (b) the supply of deep cycle batteries, composite lanterns and raw materials for the manufacture of deep cycle batteries and composite lanterns; (c) the supply of any goods and services to the contractors and subcontractors of solar power. No quality standards are referenced in the law.

In the financial year 2016/17, the Government of Uganda introduced a VAT zero rating on the importation of irrigation equipment for agricultural purposes. The challenge, however, is that there is no proper laid-out way of exempting multipurpose equipment that serves both agricultural and non-agricultural irrigation activities (e.g. pipes, pipe fittings, pumps, landscape irrigation parts, and water tanks).

Table 53 Current Ugandan tax policy for PULSE appliances

PULSE		Import duty* (%)	VAT* (%)	Withholding tax* (%)	Infrastructure levy* (%)
	SWPs (both submersible and surface pumps)	0%	18%	6%	0%
	SWP control unit	0%	18%	6%	0%
	Solar irrigation sprinklers[157]	0%	0%	6%	0%
	Solar mills	0%	18%	6%	0%
	SRUs	25%	0%	6%	1.5%
	Solar hair clippers	25%	18%	6%	1.5%

*Source: USEA 2019. *Import Duty: rates are 0%, 10% or 25% for the import of goods from outside the East Africa Community (EAC), depending on the product. VAT: In Uganda, supplies are categorized into standard-rated, exempt, or zero-rated supplies. The standard rate is 18%. Withholding tax: imports of goods into Uganda attract WHT at the rate of 6% and this is paid by the importer unless exempted from WHT. Infrastructure levy: imposed on goods imported from outside the EAC in order to collect funds for regional infrastructure projects. All imported goods (from outside EAC), except those exempted under the law, are subject to a levy of 1.5%.*

Challenges and benefits of tax exemptions

Tax exemptions are one of the policy tools for providing financing support to off-grid solar products, including for productive use. Subsidies are another possible fiscal tool. Among the benefits of tax exemption, the following are often cited:

- Evidence from other sub-Saharan African countries suggests that removing taxation on off-grid solar products can have a significant impact on accelerating their deployment.
- For companies involved in the importation of off-grid solar products, VAT and import duties have a negative impact on cash flow and, subsequently, financial viability. Tax exemptions can ease these financial difficulties.
- Although common concerns relate to loss of revenue for governments, other macroeconomic benefits could exceed the forgone tax revenues, such as increased VAT revenue from increased productivity (for taxed products) and reduced fuel imports.

On the other hand, tax exemptions may have the following downsides:

- As tax exemptions are applied across several solar products, the policy does not provide any incentive for private companies to target certain geographical areas or segments of the population.
- The risk of providing tax exemptions to poor-quality products, if the law or procedures do not specify quality standards.
- The challenges of identifying quality products at the point of importation, and therefore applying a different tax rate only to quality products.

157 In practice, when an importer declares inbound goods as irrigation equipment and they are verified as such, they are exempted from VAT and only pay withholding tax. These exemptions may not apply to locally manufactured multipurpose equipment and fittings or to importers that do not declare pumps as irrigation equipment. To resolve this, the government can use an invoice-based method of tax waiver so that the irrigation project going to the farmer is the one being exempted, rather than the stock items.

Possible solutions to promote favorable fiscal policies for PULSE

As a first step, further research is required to assess the net economic impact of tax exemptions for high-quality PULSE products in relation to other fiscal support options, such as grants and concessional financing. If tax exemptions on PULSE products are found to be a cost-effective option, these should be coupled to a quality assurance program.

In any case, it is important to take steps to facilitate the importation of PULSE products to Uganda. This would ease product introduction and allow the industry to establish a more efficient supply chain for delivering the products to consumers. Table 54 lays out possible solutions beyond tax exemptions.

Table 54: Possible actions to promote favorable fiscal policies for PULSE

Action	Description	Relevant stakeholders	Intervention type
Conduct research to determine economic benefits of providing fiscal incentives to PULSE	Evaluating whether tax exemptions should be extended to PULSE to incentivize take-up, considering benefits such as reduced fuel imports, increased VAT revenue from increased productivity, and jobs in solar energy.	PULSE suppliers, government, and donors	Policy development
Implement tax exemptions linked to a quality assurance program	If tax exemptions on PULSE products are found to be a cost-effective solution, they should be implemented to allow the industry to establish an efficient supply for delivering them affordably to end-users. Exemptions should be granted only to high-quality products, and therefore linked to a QA framework.	PULSE suppliers, government, and donors	Quality assuarance
Remove importation barriers	Reduce difficulties arising from product standards, conformity assessments and other policies in importing countries..	Government agencies, donors	Policy development

5.9 Sustainability issues

5.9.1 Water availability

Water-table depletion is often an issue that is raised in association with water pumping – however, it is not of high concern in most of the areas in Uganda where agriculture is practiced. According to a water stress assessment[158] by the World Resources Institute (WRI), water stress is low in most of the country, with the exception of the a few areas in the north (see Figure 46).

For the particular case of deploying SWPs in water-scarce regions, possible solutions that can be considered include[159]:

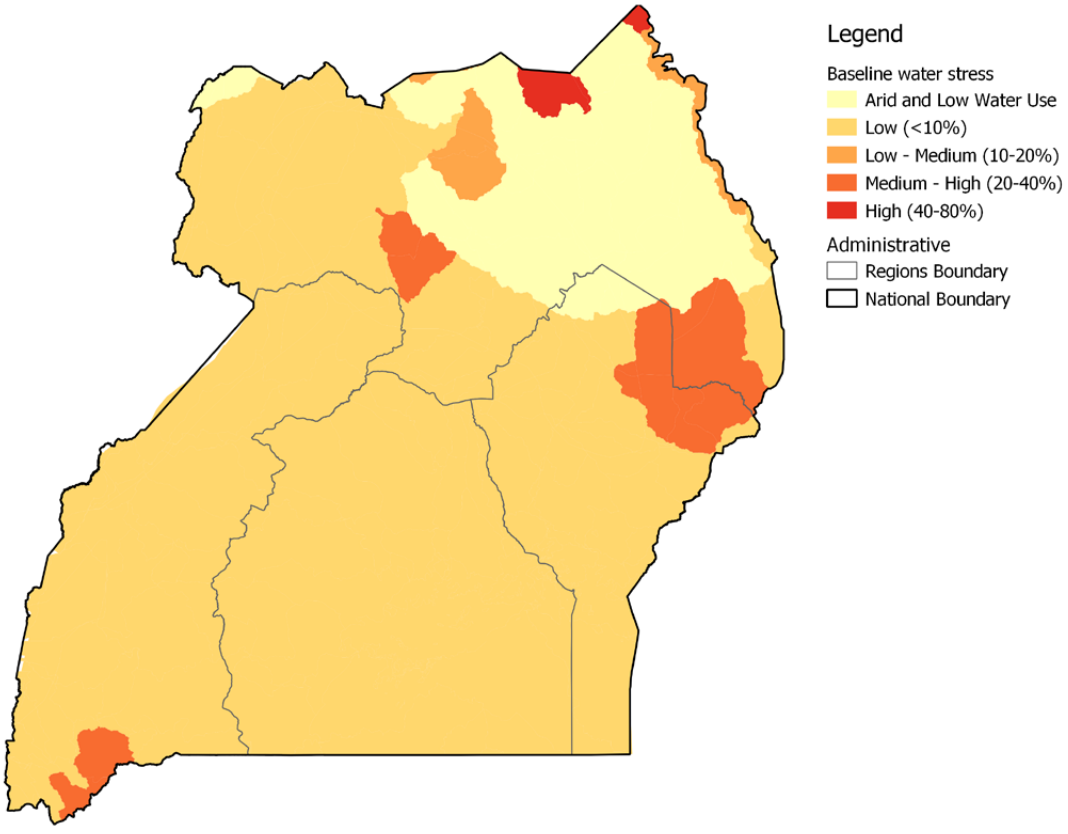
- Limiting the depth of bore-wells and size of pumps.
- Promotion of water-efficient solutions such as drip irrigation or sprinklers.
- Creating a market to sell water suggested to augment farmer income, increase solar panel utilization, and incentivize efficient use of water.
- Promotion of less water-intensive crops.

158 Baseline water stress measures the ratio of total water withdrawals to available renewable surface and groundwater supplies. A higher ratio indicates more competition among users. Water withdrawals include domestic, industrial, irrigation, and livestock consumptive and non-consumptive uses. Available renewable water supply includes surface and groundwater supplies and the impact of upstream consumptive water use and large dams on downstream water availability. Values were calculated based on data from 1960 to 2014.

159 Drawn from experience in India. Bhati, P., Singh, M., and Jhawar, P. "Silver Bullet: Redesigning Solar Pump Programme for Water and Energy Security," New Delhi: Centre for Science and Environment, August 2019: 46.

- Promoting rainwater harvesting.
- In geographic areas or situations where the risk of water depletion is deemed high or critical, consider licensing the use of SWPs – especially high-flow, high-head submersible pumps – and placing a cap on the number that can be used. It is important to highlight that this is not currently a concern in the development of irrigation schemes, which mostly rely on surface or low-depth water.

Figure 44: Baseline water stress



Source: WRI, Baseline water stress 1960-2014

5.9.2 E-waste and battery disposal

PULSE equipment represents an important part of the "green economy." Nevertheless, as noted elsewhere, solar systems contribute to rural e-waste problems. With the growth of the off-grid solar sector in sub-Saharan Africa, there is an increasing need to invest in solar e-waste management to mitigate the risks e-waste poses to human and environmental health.

Most e-waste from solar equipment cycles tends to come from "disposable" and packaged small solar systems which are housed in molded plastic containers and which tend not to be made with replaceable components. Studies of e-waste from solar products have found that solar equipment represents a small but visible part of rural waste streams, mostly from short-life over-the-counter consumer products.

Durable products, such as those meeting the Lighting Global Quality Standards, have a much longer life than comparable low-cost solar and non-solar lighting products. In addition, small off-grid solar products have certainly contributed to reduced use of kerosene and torches using disposable dry cell batteries for lighting.

In general, PULSE products are neither short-life or "disposable." They are assembled from replaceable components that have a long life – solar modules, charge regulators, inverters, batteries, and so on – and they can be made durable.

Batteries are the most noxious e-waste from PULSE equipment because they have short lives and contain dangerous chemicals. To alleviate potential issues from batteries and other components, the following, as a minimum, are necessary:

- Requirements to mandate repair, recycling, and safe disposal.
    - Companies should be required to list estimated lifetimes of components in specifications (e.g. batteries) and provide product end-of-use guidance to customers.
    - End-of-use guidance would recommend how all components should be repaired, recycled, or disposed of. If the recommendation is disposal, then safe disposal guidelines should be provided.
    - The program should provide support to (a) ensure that companies repair or replace products and components under warranty, and (b) require that companies buy back and manage disposal of components that are toxic or otherwise dangerous to the environment or farming practices.[160]
- Clear warnings about dangerous chemicals in PULSE.

CLASP has launched a Global LEAP Solar E-Waste Challenge, which identifies and funds innovative approaches to e-waste management in the off-grid solar sector in sub-Saharan Africa.

160 Note that there is already near 100 percent recycling of lead acid batteries in East Africa because of the intrinsic value of lead. Products that are of particular concern as e-waste include lithium ion batteries and lightbulbs, and components that contain dangerous metals or chemicals. Companies should be encouraged to buy back or help recycle plastic housings, packaging, and parts as well.

ANNEXES

A1 SUMMARY OF MARKET BARRIERS AND RECOMMENDATIONS

Potential interventions

Growth in rural electricity demand is a gradual process, and proactive measures to encourage it are often required to achieve commercial viability. A measured and coordinated program with long-term objectives will be needed to develop and scale up the market for PULSE products.

Table 55 provides a summary of the recommendations provided under each of the market barriers presented in sections 5.1 to 5.9. They are classified by "intervention type," corresponding with the categories used in the Lighting Global PULSE market opportunity report.

Table 55: Summary of market barriers and recommendations

Intervention type	Specific recommendations	Stakeholders involved in implementation
Demand aggregation	• **Support selected value-chain aggregators** through technical and financial assistance to facilitate access to smallholders • **Encourage partnerships** between energy-sector stakeholders and agricultural aggregators	• Aggregators include extension and advisory service providers, value-chain cooperatives, SACCOs, off-takers, and input suppliers • Energy-sector industry association responsible for facilitation of partnerships, e.g. USEA
Access to finance	• Support adequate consumer financing (affordable and matching customers' frequency of income) through banks, SACCOs, and PAYG suppliers • Extend **UECCC's working-capital credit line** to PULSE companies • Involve **banks and other financial institutions with experience in agricultural lending** • Research and promote innovative mechanisms to **reduce perceived risk and to overcome need for collateral** • **Develop emerging financing options** for PULSE (irrigation credit schemes, leasing) • Provide financial incentives (e.g. **RBF grants**) for solar companies to go into rural areas (establish distribution outlets, train their agents, and so on) • **Liaison with aggregators** (who can provide easier access to farmers, data (land, production), and potentially guarantees	• UECCC • Financial institutions: commercial banks, MFI/SACCOs, financing institutions with strong links to agriculture • PULSE suppliers • Aggregators (especially off-takers and cooperatives) • Donor programs involved in technical and financial assistance relevant to PULSE
Technology and innovation	• **Technical and financial assistance to support product development** (e.g. increase functionality and/or reduce costs) and improvements	• Programs supporting R&D in PULSE, e.g. LEIA • Funds could be targeted at PULSE companies, but also other stakeholders (e.g. aggregators)
Consumer education	• **Training of end-users in technical aspects** (solar PV, agronomic practices) and **business concepts** (access to market, financial planning) • **Awareness campaigns** targeted at specific value chains, at the subnational level and through value-chain-specific aggregators (e.g. cooperatives, public authorities, off-takers, and SACCOs) • Encourage **active involvement of PULSE suppliers** in end-user training and support	• Private-sector associations (e.g. USEA, PSFU) and public authorities in the agriculture space (e.g. NAADS) are well placed to facilitate • PULSE suppliers • Aggregators (extension services, tertiary cooperatives, etc.) • Financiers, especially those with capacity-building programs (e.g. Stanbic Bank, dfcu)

Intervention type	Specific recommendations	Stakeholders involved in implementation
Market intelligence	• **Surveys, market analysis,** case studies including impact analysis, and so on for a variety of stakeholders – especially suppliers, financiers, and aggregators • Provide **information on financing options available** for PULSE	Market intelligence efforts could be led by an industry association such as PSFU or USEA. Targeted to: • Suppliers • Financial institutions (banks and SACCOs)
Business development support	• **Support to PULSE companies** with business planning, marketing strategies, financial management, and so on • **Training for MFIs and SACCOs** with an interest in being involved in PULSE lending, following the precedent of UECCC's work in off-grid solar lending	Capacity-building could be managed by an industry association such as PSFU or USEA. Capacity-building activities could be implemented by public authorities (e.g. NAADS), financial institutions with relevant foundations (e.g. Stanbic), consultants, and others. Targeted to: • PULSE suppliers • Tier IV financial institutions
Policy development	• Develop a **QA framework** for PULSE based on existing standards and players	• Involve PULSE companies and QA players in Uganda, e.g. UNBS, REA, USEA, and LEIA (CLASP)
Quality assuarance	• **Subsidies** to reduce the gap in affordability of PULSE products • Research and policy papers targeted at **improving policy and regulatory environment** • Extending **VAT and import duty exemptions** available for solar products to PULSE products • Implementation of measures (if and when relevant) to **mitigate any negative impacts of PULSE** applications (e.g. e-waste management and water abstraction)	• Government bodies linked with PULSE (energy, water, agriculture, industry, finance) • Donor-funded programs planning to provide subsidies (e.g. Micro-scale Irrigation Program) • Donor-funded programs already active in creating an enabling environment for PULSE (e.g. PAUESA, UOMA, LEIA, and ACE TAF)

Gap analysis and recommendations

This section provides a high-level overview of the different actors involved in the development of the PULSE market, in order to identify which gaps might be most relevant for further technical and financial support. Table 56 maps out the various intervention types recommended in Table 55 against the current donor programs that support PULSE.

Table 56: Current donor program interventions

Donor program	Demand aggregation	Access to finance	Technology and innovation	Consumer educationeducation	Market intelligence	Business development support	Quality assuarance	Policy development
Micro-scale Irrigation Program, World Bank (limited to SWPs)		✓		✓				✓
LEIA, UK Aid		✓	✓	✓	✓		✓	
ACE TAF, FCDO (limited to SWPs)							✓	✓
NU-TEC, FCDO (limited to northern Uganda)		✓*				✓		
Energy Africa campaign, FCDO								✓
TEA-POP (PEU challenge fund), FCDO (no Uganda-specific focus)		✓						
CleanStart, UNCDF		✓*				✓		
SUNREF, AFD		✓				✓		
PAUESA, USAID (focus on household electrification more than PULSE)	✓	✓		✓	✓	✓		✓
PAEGC, multi-donor (no Uganda-specific focus)	✓					✓		
CASEE, Shell Foundation (no Uganda-specific focus)	✓	✓	✓	✓		✓		
aBi, multi-donor		✓*				✓		
A2EI (no Uganda-specific focus)			✓					
UOMA, multi-donor		✓			✓			✓
FEI OGEF, AfDB (no Uganda-specific focus)		✓*						

Programs and their detailed scope are defined in section 4.5.

** Access to finance includes a broad spectrum of activities. Those marked with an asterisk are programs specifically providing working capital financing.*

Using the results from the gap analysis and following consultations with stakeholders in the sector, priority areas for a program supporting PULSE include:

- **Demand aggregation:** facilitating partnerships between value-chain aggregators, PULSE suppliers, and financiers through an industry association such as USEA.

- **Access to finance:** Consumer financing and working-capital financing is welcomed in the sector. There are clear benefits to scaling up access to finance through a local institution such as UECCC. However, when sizing the facility, it is important to take into consideration that other programs and financial institutions – both local and international: e.g. UNCDF, FEI OGEF, and SunFunder – are already providing this type of financing (including in local currency) to Uganda-based companies.

  In addition to the amount of financing provided, there may also be a need for a partial risk guarantee to de-risk banks lending to companies, similar to the facility that UECCC is running for SHS.

  As for grants, a PULSE support program could consider implementing RBF as a complement to loans in order to (a) accelerate demand, and (b) encourage expansion of service delivery. Grant funding in this case should be coordinated closely with other programs providing grants, e.g. LEIA and the Micro-scale Irrigation Program.

- **Consumer education:** Awareness-raising and training of end-users has been brought up extensively as one of the sector's main barriers. A PULSE support program in coordination with other programs (such as LEIA) could support these activities through local actors such as USEA, extension officers, and training institutions.

- **Market intelligence:** In coordination with LEIA, the program should support market analysis of PULSE in Uganda – surveys, sales statistics, market analysis, case studies, and so on. Market intelligence efforts could be led by an industry association such as USEA.

- **Business development support:** the program should support business development services, with a focus on PULSE companies as well as implementation partners (financial institutions and aggregators) as beneficiaries.

- **Quality assurance:** the program should implement a QA framework linked to the PULSE support program and based on existing standards and players.

The above represents a miscellaneous bundle of support requirements. The detailed scope of such interventions should be defined more closely during the program's design stage. One approach that might be considered is to establish a program to provide a flexible package of support in the areas listed above and, potentially, others yet to be identified.

Uganda has the potential to be one of the first countries in Africa to build a thriving off-grid PULSE market. In doing so it stands to benefit tremendously from job creation, economic growth, and improved resilience of rural communities in the face of climate change. If barriers are addressed through a coordinated program, a vibrant transformative PULSE market can be accomplished. We call upon all stakeholders to work together to take advantage of this exciting opportunity to advance a range of national development goals.

A2 PULSE appliances: costs and assumptions

Medium SWPs

According to interviews with suppliers, medium SWP projects cost about $2,000 per kilowatt or $600 per acre, given that irrigation power requirements typically vary between 0.2 and 0.4 kW per acre. These costs are for surface pumps and submersible pumps with a relatively low head. Drilling boreholes has not been widely used as a water source in farmer-led irrigation in Uganda, and is thus not part of the cost assumption calculation.[161]

The costs of irrigation technology (e.g. sprinklers or drip systems) can vary widely – from under $400 per acre to over $4,000 per acre – depending on the type of technology.[162] Low-cost drip systems can cost less than $200 per acre, typically used for an area under 0.25 acres. These kits use thin-walled flat plastic tubing and simple knotted-tube emitters and will last one to two years. In general, irrigation technology becomes more sophisticated and expensive for larger irrigation schemes, involving, for example, fixed sprinklers and subsurface drip.

For the scope of this assignment, based on literature and anecdotal experience, and for rough budgeting purposes, irrigation technology costs for medium-sized projects are estimated at $600 per acre. This implies that the cost of the SWP and irrigation equipment together amount to $1,200 per acre.

Small SWPs

The cost of a small SWP is estimated based on published prices and information gathered from interviews. The average cost is calculated as a weighted average considering sales estimations. The results are given in Table 57.

The products only include basic irrigation equipment, such as hose and movable sprinklers. Other equipment, e.g. drip irrigation, is not included. For example, SunCulture is now offering a drip-irrigation kit as an add-on to pumps, typically as an upgrade after a couple of years – i.e. after repayments for the pump are completed. Its low-cost drip system does not require an elevated tank and is sold for about $200.

Medium-scale solar refrigeration and ice-making

We have not found medium-scale refrigeration and ice-making equipment in use in Uganda that is powered by stand-alone solar. These, instead are powered by diesel – e.g. off-grid milk-collection centers – and mini-grids (e.g. ice-making factories for fishers on Lake Victoria islands). The cost of stand-alone solar to replace the existing source of power is estimated at $2,000 per kWp, based on a typical 10-kWp stand-alone solar PV system. The cost break down is presented in Table 58.

161 "Assessment of farmer-led irrigation development (FLID) in Uganda." Draft report. World Bank, 2019. For information, a regular borehole with a yield of about 5 cubic meters per hour costs about $6,000 to drill, and a production well with a yield of about 10 m3/hr or more costs about $14,000. As mentioned above, this has not been widely used in farmer-led irrigation in Uganda.

162 Various sources, including FLID report and a recent technology brief on low-cost drip irrigation from the Massachusetts Institute of Technology (MIT).

Table 57: Prices and projected sales for small SWP systems

SWP model (and supplier)	Cash price (USD)	Estimated annual sales (# units)	Sources and details
Futurepump SF2 (SolarNow)	712	~300	Prices: Futurepump website, SunCulture website
SunCulture Rainmaker 2 (SolarNow)	500	~300	Sales figures based on interview with SolarNow, indicating 900 units sold in 2019. This includes both Futurepump and SunCulture products, with sales assumed to be divided equally among the various products available.
SunCulture Rainmaker 2 with battery (SolarNow)	970	~300	
Sunflo S-150 (Davis & Shirtliff)	750	~900	Based on an interview with Davis & Shirtliff. Having introduced the Dayliff Sunflo line as recently as July 2019, Davis & Shirtliff estimates that annual sales will be in the thousands of units. 900 units is adopted as a conservative estimate, assuming that, as a market leader, Davis & Shirtliff may match sales of SolarNow.
Confidential supplier	1,757	~50	Estimated sales in 2019
Confidential supplier	942	~900	Projected sales for 2020
Confidential supplier	1,570	~100	Projected sales for 2020
Total/weighted average	**850**	**~2,850**	

Source: company websites and interviews.

Table 58: Cost breakdown of 10-kWp stand-alone solar PV system

Component	Cost ($)	Details
Solar PV generator	6,500	10 kWp including PV inverters and mounting structure
Power conversion	1,500	3.5 kW of battery inverter capacity (power draw assumed to be one-third of installed solar PV capacity)
Battery bank	4,000	26 kWh of battery storage, i.e. eight hours of storage at 50% DoD
Diesel generator	700	Back-up power supply
Balance of System (BOS)	1,050	8% of cost of system components above
Shipping	1,000	Assumes shared container
Installation – labor	1,000	
Other (25%)	4,000	Includes engineering and contingencies
Total cost (capex)	**19,750**	
Unit cost ($/kWp)	**1,975**	**i.e. approx. $2,000 per kWp**
Battery cost (% of capex)	*20%*	*which will need periodic replacement*

Source: ECA.

Small SRUs

The estimated cost of a small SRU is based on published prices and information gathered from interviews. The average cost is calculated as a weighted average considering sales estimations. The results are given in Table 59.

Table 59: Prices and projected sales for small SRU systems

SRU supplier and model	Cash price (USD)	Estimated annual sales (# units)	Sources and details
M-KOPA (100-liter, 60 W)	811	1,000	Price: M-KOPA website Sales: Following the introduction in Uganda of M-Kopa fridges in June 2019, 250 units were sold over the first three to four months, meaning likely sales of 1,000 units per year.
SolarNow (112-liter)	676	60	Price and sales figures of 2019 from interview with SolarNow
SolarNow (35-liter)	486	120	
Confidential supplier	(not known)	~500	Projected sales for 2020
Total/average	**771**	**~1,680**	

Source: company websites and interviews.

Compared to solar refrigerators, AC refrigerators of 100–150-liter capacity are commonly found in rural areas. These typically run on grid electricity and cost about $250 (see Annex A3). Adding an inverter-based solar PV system to these low-cost refrigerators may result in a similar price to the solar refrigerators above, but presumably with lower durability.

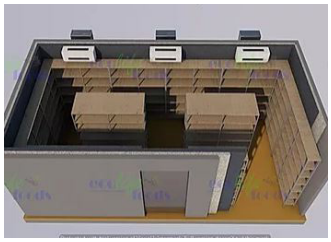
A3 Off-grid cold chain technologies

The Global LEAP Off-Grid Cold Chain Challenge (OGCCC) is an international competition to identify and promote the most energy-efficient, sustainable, and cost-effective technologies that can meet the cold storage requirements for fresh fruit, vegetables, and dairy products in Kenya, Nigeria, Rwanda, Tanzania, and Uganda.

The results of the 2018–19 competition were announced in late 2019 and the winners are shown in Table 60. More information is available on the OGCCC's website: https://globalleapawards.org/ogccc.

Table 60: Examples of other cold storage applications (OGCCC winners)

Company	Features	
Cold Hubs (Nigeria)	• Walk-in, solar-powered cold stations for 24/7 storage and preservation of fruit, vegetables, and other perishable food • Installed in major food production and consumption centers (markets and farms) • Extends the shelf life of perishable food from 2 days to 21, reducing post-harvest loss by 80% • Flexible pay-as-you-store subscription model. Farmers pay a daily flat fee for each crate of food they store. • *http://www.coldhubs.com/*	
ecozen (India)	• Technology supplier for containerized cold storage • Standalone solar capability of 5 kWp • Does not require battery storage • 4–10˚ C temperature range • Over 150 units in operation • Different ownership options offered: upfront purchase, lease and rental, and community model • OGCCC judges' observations: EcoZen's unit was identified as having high technical performance and a short repayment period, and incorporated sophisticated Internet of Things that was greatly appreciated by the farm user. • *https://www.ecozensolutions.com/ecofrost*	
FreshBox (Kenya)	• Commercial cooling unit of 9m3 that can hold over 2 tons of fruit and vegetables • Pay-as-you-go model for refrigeration services: 30–40 kg crate of fruit and vegetables for only $0.50/crate/day • Increases the longevity of a fruit or vegetable's selling period by up to 950% (depending on the produce), thus providing more consistent revenues to the retailers in produce markets • Pilot unit manufactured and assembled in Kenya • OGCCC judges' observations: FreshBox persevered through technical challenges and eventually was able to provide valuable cooling services for milk, a particularly sensitive product. • *https://www.freshbox.co.ke/*	

Company	Features	
ecolife foods (Uganda)	• Off-grid cold storage that can keep fruit and vegetables fresh for over a week • Pilot project in Luwero (Central Region of Uganda), specifically constructed for mango preservation • 22 m3 space. Brick walls and corrugated metal roof, but walls are insulated • Running on solar PV or a small diesel generator • Estimated construction cost: $8,000 • OGCCC judges' observations: Ecolife's cooling unit experienced technical challenges throughout the program. The enclosure of the cold room was insulated with recycled plastic bottles and was intended to store mangoes. • *https://ecolifefoodsuganda.wixsite.com/ecolife-foods*	

Source: Global LEAP and company websites.

A4 Survey on refrigeration for productive use

Energy 4 Impact carried out a study of grid-powered refrigeration for productive use,[163] involving 172 micro-entrepreneurs, to understand the value and decision-making around the acquisition and use of refrigerators. The survey was also carried out to investigate the case for off-grid appliances and make predictions about the market for solar refrigerators in Uganda.

According to the study, refrigerators have enabled the majority of businesses interviewed to diversify their operations and start new product lines around additional types of cold drinks and the production and sale of ice. For a number of enterprises, the product represents an add-on revenue stream to a different business line such as salons, electrical workshops, or clinics.

Desired refrigerator characteristics according to the survey are given in Table 61.

Table 61: Typical refrigerator/freezer characteristics

Characteristics	Value
Capacity*	Fridge (100–150 liters), freezer (80–140 liters)
Power rating*	200 W
Cost of appliance*	UGX 800,000 to 1 million ($ 230–270)
Cost of power**	UGX 35,000–52,000 ($10–14) per month

** Average values*

*** Although not all power consumption is attributed to the refrigerator, in most shops there were no other high-consumption appliances*

Source: Energy 4 Impact (2017).

As shown above, a typical cooling product for a micro-enterprise is between 100 and 150 liters, with an average cost of $250. This is a much lower cost than the typical price of a solar refrigerator, which ranges from $600 to $1,800, in addition to the cost of the solar PV system to power it.

The study also evaluates the business case for solar-powered refrigerators, based on two scenarios:

- Typical DC refrigerator (139 liters). Assuming a wholesale cost of $ 500, a power rating of 100 W, and energy consumption of 1.2 kWh per day, a power system of at least 300 Wp would be required for a total cost of around $1,500. This would imply a repayment period of more than 10 years for the solar panel system alone.
- Energy-efficient DC refrigerator (170 liters) designed specifically for use with a SHS. Assuming a wholesale cost of $546, a power rating of 40 W, and energy consumption of 0.2 kWh per day, a 50 Wp system at a cost of $400 would be, with a repayment period of almost 3 years.

Based on the refrigerator characteristics identified in this study, solar-powered refrigerators at their current costs continue to be too expensive to make a positive economic case for most retail businesses. However, the study concludes that energy efficiency design improvements are expected to make refrigerators designed specifically for use with a SHS more affordable, and that there will be a business case for off-grid solar refrigerators. The technology development is expected to take a promising trajectory, resulting in a 3-year payback period for the supply of a 170-liter solar-powered refrigerator, costing $546. In addition, the survey findings suggest that there is significant interest in the potential of solar refrigerators.

163 Energy 4 Impact (2017). "Grid powered refrigeration for productive use – Study of 172 micro-enterprises in Uganda to understand the case for off-grid appliances."

A5 Product development: Multipurpose platforms for farms

Since 2008, product development in the off-grid household sector has been significant. Solar modules, inverters, charge controls, batteries, product housing, appliances, and control software have developed extremely rapidly. PULSE applications are at a much earlier stage of development. Given the wide variety of appliance needs for off-grid SME uses, a wider range of products will be required and many more product niches will appear.

Refrigeration and pumping are currently a major focus of product development. However, a number of products occupy specialized niches and offer opportunities for local and international product developers and marketing partnerships. These off-grid energy supply opportunities can be arranged along value chains where the product is needed and offered. Specially designed and financed off-grid power platforms, which are essentially very small micro-grids with pre-selected efficient appliances, could be offered to various segments. For example:

- A power unit for a dairy farm might offer a water supply pump for cattle watering, a chaff-cutter, a milk chiller and, possibly, an electric milking machine.
- A power unit for a fishing value chain might offer ice-makers, processing tools, battery chargers for fishing boat lights, and so on.
- Alongside its power supply, a village power unit might offer workshop appliances, phone chargers, barbershop tools, audio-visual equipment and Wi-Fi.

A6 Relative attractiveness of PULSE technologies

The following table ranks the product categories by potential impact based on a variety of criteria.

Table 62: Relative attractiveness of PULSE technologies

Category	Current market status	Market potential (short term)	Social impact of product ownership	Alignment with stated government priorities	Estimated sector financing needs	Score
Solar pumping	High Over 25 suppliers in Uganda, including leading companies Davis & Shirtliff, SolarNow, Azuri, Tulima and Solar	High ~$7m/y on average, without considering government/NGO procurement. Leading companies are introducing new affordable products. High	New products tailored for smallholders. Two- or threefold increase in yields vs rain-fed irrigation, payback period of 3 years for SWPs replacing diesel pumps.	High SWPs align with priorities in energy, water, agriculture, and climate-change policies.	High ~$20m in working capital and consumer financing (2021–24)	High
Solar refrigeration	Medium Small units introduced by leading companies M-Kopa and SolarNow. Fenix considering introducing. Market for medium-scale SRUs not proven.	Medium–high ~$3m/y on average 2021–24 (both small and medium SRUs). Business case for medium SRUs not yet proven (pilots required).	High Allows for significant reductions in wasted agricultural products (horticulture, dairy) and fish. Currently 20–50% of production is wasted.	Medium–high Not explicitly mentioned in policies, but technology allows for increased productivity of agriculture.	Medium–high ~$7m in working capital and consumer financing (2021–24)	Medium–high
Solar milling	Low No commercial operations in Uganda yet (only a small Agsol pilot program)	Low–medium Commercial sales unlikely to be substantial in the short term (only extended pilots)	Low–medium Solar mills are not yet competitive with diesel machines (9 years PBP, according to most recent research)	Medium–high In line with Agriculture Sector Strategic Plan (improving agricultural markets and value addition)	Low–medium Funding needed to support pilots and product development. Commercial sales unlikely to be substantial in short term	Low–medium
Medium-sized systems	Medium Several companies with capacity to design and install (e.g. UltraTec)	Medium Few projects, but of significant amounts (>$10k each). Sector likely to grow given falling PV prices.	Low–medium Mostly linked to reduction in diesel consumption as opposed to increased productivity	Medium In line with renewable energy promotion targets. Specific uses may not be aligned with government priorities.	[Medium] Not assessed in detail, but estimated at ~$1m on the basis of 50 10 kWp projects over 4 years.	Medium

Category	Current market status	Market potential (short term)	Social impact of product ownership	Alignment with stated government priorities	Estimated sector financing needs	Score
Other (niche) use, for example egg incubators and milking machines	Low–medium Only informal traders, no established operations	Low–medium Only informal traders; no established operations or companies with a clear strategy to enter this market	Medium Revenue-generating opportunities in agriculture, e.g. eggs and chick incubation, milking machines	Medium–high Aligns with priorities of the agriculture sector	Low–medium Funding needed to support pilots and product development. Commercial sales unlikely to be substantial in short term	Low–medium
Commerce, connectivity	High Appliances coupled to SHS (phone-charging stations, hair clippers, TVs) sold by leading companies such as SolarNow, Fenix and M-Kopa For example, sales of PAYG TVs for SHS amounted to 14,000 in H1 2019 (GOGLA).	High Already integrated in SHS offering by leading companies It is, however, not clear to what extent these appliances are used as productive activities.	Medium–high Some of these appliances are used in businesses in rural villages (e.g. hairdressers, phone chargers, village cinemas)	Medium–high In line with renewable energy promotion targets. Aligned with rural electrification targets	[High] It is not clear to what extent these appliances are used as productive activities. Much of this market may not be relevant to PULSE.	Medium–high

A7 Mapping aggregators

Table 63: Mapping aggregators

Aggregator type	Description/relevance	Examples
Farmers' groups and cooperatives	An estimated 900,000 agricultural HH were members of farmers' groups (UBOS, 2011), i.e. less than 20% given that 63% of HH (i.e. 5 million) have agricultural land (UBOS, 2017). There are ~10,000 registered cooperatives (including SACCOs, which constitute 23% of all cooperatives). In principle, cooperatives have an important role to play, but their actual development has been limited. The Government of Uganda suggests cooperatives are the appropriate delivery mechanism to address productivity challenges and resuscitate the economy.[164] Apex cooperatives at secondary and tertiary level[165] have significant influence and provide specialized services, and could therefore be a suitable channel.	Dairy: Uganda Crane Creameries Cooperative Union (UCCCU) (tertiary cooperative, about 20,000 members) Coffee: NUCAFE (secondary, 213 farmer cooperatives/associations with 215,120 farming families) Horticulture: Horticultural Exporters Association of Uganda (Hortexa) (primary, covers over 2,000 growers, linking them to exporters) Apex body: The Uganda Cooperative Alliance (UCA) is the overall apex body for cooperatives.
Off-takers	Companies buying from smallholders to further process and/or export products. They are value-chain specific. Horticulture: four exporting companies operate out-grower schemes and many others solicit produce from contract growers. Coffee: about 10 large coffee companies control over 80% of the export market.	Horticulture: e.g. Biofresh Ltd and Unity Exporters Ltd (each operating about 300 acres of nucleus farms out-grower schemes) Coffee: Kyagalanyi Coffee Ltd, currently working with 15,000 coffee-farming households
Input suppliers	There are around 30 to 40 large companies involved in importing and wholesaling agricultural inputs, and hundreds of small traders who re-sell to individual farmers.	The Uganda National Agro-Input Dealers' Association (UNADA) has 1,300 members, including 48 large ones. Seed traders constitute another important stakeholder, organized in the Uganda Seed Trade Association (USTA).
Extension and advisory service providers	Public extension services providing technical assistance. Some of these are value-chain specific.	National Agriculture Advisory Services (NAADS), Dairy Development Authority (DDA), Uganda Coffee Development Authority (UCDA)
Savings and Credit Cooperative Organizations (SACCOs)	SACCOs are typically co-operative financial institutions, formed by a group of people who have a common factor, in order to provide a worthy return for their savings as well as empowering their members by providing lower-interest loans.	UECCC is currently working with Tujijenge Uganda Limited, Hofokam Limited, EBO SACCO Limited and Buyanja SACCO Limited to extend solar loans to households and commercial enterprises at the grassroots level.

164 National Planning Authority policy paper, "Strengthening of Cooperatives for Social Economic Transformation in Uganda," 2018.

165 A minimum of two primary societies form a secondary while two or more secondary societies form a tertiary, which provides specialized services.

A8 Financial institutions involved in agricultural lending

Table 64, based on the study "Productive Uses of Electricity Program Initiative" (NRECA, 2018), presents a number of financial institutions that are involved in agricultural lending that may have an interest in, and the capacity to, participate in a future productive-use credit program.

Table 64: Financial institutions involved in agricultural lending

Institution	Description
Agricultural Credit Facility (ACF)	Set up by the government in 2009, in partnership with commercial banks and Uganda Development Bank Ltd (UDBL), to promote access to finance among farmers. Take-up is still low, partly due to (a) limited communication and awareness about the availability of the funds to the sector and (b) bureaucracy.
Uganda Development Bank (UDB)	UDB supports both smallholder and large-scale farmers by providing loan products to cooperatives that have a minimum of 55 members. The minimum loan value is UGX 100 million. UDB offers both direct and indirect lending through cooperative societies. It also lends money through PostBank, Finance Trust Bank, and Wazalendo SACCO, which thereafter extend credit to smallholder farmers.
Centenary Bank	Centenary Bank has a widespread branch network that would allow relative ease of access to rural entrepreneurs. As with many financial institutions, a lack of collateral has presented significant challenges for potential borrowers. For borrowers who propose to secure funds for equipment and buildings, loans can be extended by requiring a lien on these new assets.
dfcu Bank	dfcu Bank serves both commercial and smallholder farmers. Due to the perceived risk in smallholders and their lack of collateral, innovative products such as "save for loan" have been developed to increase access to credit. dfcu Bank also partners with USAID and aBi Trust to offer a 50–50 risk-sharing scheme. It also supports investment clubs and financial literacy training. An investment club is a group that pools resources to invest towards a common goal.
PostBank	PostBank has developed agriculture-specific loan products that could be employed by rural entrepreneurs, including for marketing, equipment, input and seasonal production.

Source: Productive Uses of Electricity Program Initiative (NRECA, 2018).

A9 Product mix and direct beneficiaries

Table 65: Product mix and direct beneficiaries

PULSE category	PULSE sub-category	Customer type	Cost per unit ($)*	No. of beneficiaries (HH) per unit	Source and notes	Estimated demand (2021–24) (units)**	Estimated demand (2021–24) ($ '000)**	Product mix	Financing requirement (2021–24) ($ '000)****	No. of direct beneficiaries (HH)
SWPs and irrigation	Small SWPs	Individual	850	1	Price reference: weighted average price of small SWPs from SunCulture, Futurepump, and others in the market. Estimated demand includes Micro-scale Irrigation Program targets.	61,621	52,378	54%	16,023	61,621
	Medium SWPs and irrigation for individual farms	Individual	11,027	1	Cost per unit is an average of all projects, including those with investment in irrigation equipment.	1,310	14,450	15%	14,269	1,310
	Medium SWPs and irrigation for farmers' group	Group (farmers' group)	11,027	10	Total investment in medium SWPs assumed to be divided as 90% for individual farms and 10% for group farmers due to complexity of forming groups of farmers to invest in common equipment. MWE pilots (see Table 11) serve 10 to 15 farmers each.	146	1,606	2%	1,585	1,456
SRUs and ice-making	Small SRUs	Individual	750	1	Price reference: weighted average of small SRUs from SolarNow and M-Kopa	22,702	17,027	17%	8,939	22,702
	Medium SRUs (milk chillers)	Group (milk-collection center/coop)	24,250	20	Price reference: 2,500-l chiller serving 20 farmers. Weighted average price of greenfield and brownfield units. Sources: NAADS, OCA (Table 28)	54	1,310	1%	2,050	1,080
	Medium SRUs (ice-making for fishers)	Group (entrepreneur at landing site/ coop)	68,529	50	Project reference: factory producing 5 tons/day of ice (GRS Commodities), serving up to 50 fishers per day. Weighted average price of mini-grid-connected and stand-alone units	26	1,748	2%	968	1,275
	Medium SRUs (horticulture storage)	Group (off-taker/coop)			Not assessed. No examples in Uganda to date			0%		
Solar milling	Small commercial units	Group (entrepreneur / coop)	2,500	50	Price reference: Agsol pilot (50–100 kg/hr machine), assumed to serve 50–100 small-holders. 100 units reflects the possible size of a larger second pilot.	100***	250	0%	250	5,000
	Medium-sized processing facility	Group (coop)			Not assessed			0%		

Medium-sized systems	Commercial projects	Individual	20,000	1	10 kWp off-grid solar PV project for a variety of off-grid purposes (e.g. hotel, bank branch)	50***	1,000	1%	988	50
Other (niche) productive use	Small or medium commercial solutions for farms/ fishers	Individual			Not assessed at this stage			0%		
Commerce and connectivity	Small or medium commercial solutions for rural SMEs	Individual	800	1	Data on appliances' sales is being collected by GOGLA (e.g. hair clippers, irons, milling machines), but volumes are currently scattered and too small, and thus not being reported. For this rough estimation, price and sales data of SHS coupled with TVs are used, assuming 10% of sales are destined for business use (e.g. village cinema, bar) Price reference: M-Kopa Sales data: GOGLA. 14,000 units sold in Uganda in H1 2019.	10,000***	8,000	8%	2,877	10,000
Totals							**97,767**	**100%**	**47,950**	**104,495**

** In line with cost of products available in the market*
*** Per market potential calculations in chapter 3 (high scenario)*
**** Very rough estimates*
***** Calculated in the same way as in section 3.3 (Table 36)*

Stakeholders interviewed

PULSE companies and industry associations

Private Sector Foundation Uganda (PSFU), Uganda Solar Energy Association (USEA), AgSol, Aptech Africa Uganda, Azuri, BrightLife (formerly FINCA Plus), Davis & Shirtliff International, Energy Systems, Fenix International, GRS Commodities, Innovex Uganda, M-Kopa, Power Trust (U) Ltd, SolarNow, SoloGrid, Sundanzer, Tulima Solar (Simusolar), UltraTec (U) Ltd, W.Water Works.

Note: a focus group discussion was organized with support from USEA and attended by over a dozen solar PV companies active in Uganda.

PULSE end-users and aggregators

American Tower Corporation (ATC) in Uganda, Dairy Farmers Network (DAFAN), National Union of Coffee Agribusiness and Farm Enterprises (NUCAFE), Uganda Coffee Development Authority (UCDA), Uganda Hotel Owners Association (UHOA).

Financing institutions

Diamond Trust Bank (DTB), EBO SACCO, Stanbic Bank, SunFunder, Tujijenge Uganda Limited, Uganda Energy Credit Capitalisation Company (UECCC).

Public sector

Engineers Without Borders USA (EWB-USA) (working under the Ministry of Water and Environment), Ministry of Energy and Mineral Development (MEMD), National Agriculture Advisory Services (NAADS), Rural Electrification Agency (REA).

Donors and donor-funded programs

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