GET.INVEST MARKET INSIGHTS

DEVELOPER GUIDE / MODEL BUSINESS CASE

GET.invest
Mobilising Renewable Energy Investments

Uganda: Renewable Energy Cooling and Processing for the Food Industry

Developer Guide

In collaboration with

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A NOTE TO THE READER

This Developer Guide is meant to be a 'reference document' to inform early market exploration. The Guide is supplemented with Model Business Cases accessible at www.get-invest.eu.

ABOUT GET.INVEST MARKET INSIGHTS

The first series of GET.invest Market Insights were published in early 2019 covering four renewable energy market segments in three countries, namely: renewable energy applications in the agricultural value-chain (Senegal), captive power (behind the meter) generation (Uganda), mini-grids (Zambia) and stand-alone solar systems (Zambia).

Each Market Insight package includes **a)** a 'how to' Developer Guide and **b)** Model Business Cases. The Developer Guide enables the reader to navigate the market and its actors, to understand the current regulatory framework and lays down the step-by-step process of starting a new project/business. The Model Business Case analyses project economics and presents hypothetical, yet realistic, investment scenarios. It hence indicates the criteria for a viable project/business to enable the reader to identify the most cost-effective project/business opportunities.

GET.invest Market Insights therefore summarise a considerable amount of data that may inform early market exploration and pre-feasibility studies. It is recommended to cross-read all three products to gain a comprehensive overview. The products are accessible at www.get-invest.eu.

ABOUT GET.INVEST

GET.invest is a European programme which supports investments in renewable energy. The programme targets private sector business and project developers, financiers and regulators to build sustainable energy markets in partner countries.

Services include market information, a funding database, matchmaking events and access-to-finance advisory. Since 2022, GET.invest powers the Team Europe One Stop Shop for Green Energy Investments, an access point for information about and facilitated access to European support and financing instruments for energy projects and companies in Africa.

The programme is supported by the European Union, Germany, Sweden, the Netherlands, and Austria, and works closely with initiatives and business associations in the energy sector.

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ABBREVIATIONS

ACE–TAF	Africa Clean Energy Technical Assistance Facility
AECF	African Enterprise Challenge Fund
AFALU	Association of Fishers and Lake Users of Uganda
BoP	Bottom-of-the-pyramid
C&I	Commercial and Industrial
CaaS	Cooling-as-a-Service
CAPEX	Capital expenditure
CEI Africa	Clean Energy and Energy Inclusion for Africa Foundation
CFA	Communauté Financière Africaine (African Financial Community)
COMESA	Common Market for Eastern and Southern Africa
DDA	Dairy Development Authority
DFIs	Development finance institution
DFR	Directorate of Fisheries Resources
ESIA	Environmental and Social Impact Assessment
FAO	Food and Agriculture Organisation of the United Nations
FI	Financial institution
FRS	Financial Readiness Support
G4A	Green for Access First Loss Facility
GMG	Green mini-grid
GWP	Global Warming Potential
Ha	Hectare
HCFC	Hydrochlorofluorocarbon
Hp	Horsepower
IoT	Internet of Things
Kg	Kilogram
KMM	KeyMaker Model
kWp	Kilowatt peak
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MCC	Milk Collection Centre
MT	Metric tonnes
MTPA	Metric tonnes per annum
NAADS	National Agricultural Advisory Services
NAFIRRI	National Fisheries Resources Research Institute
NEMA	National Environment Management Authority
O&M	Operations and Maintenance
ODS	Ozone-depleting substances
OGS	Off-grid solar
OPEX	Operating expenditure
PAYGO	Pay-As-You-Go
PAYS	Pay-As-You-Store
PFAN	Private Financing Advisory Network
PUE	Productive use of energy
RBF	Results-based financing
SACCO	Savings and Credit Cooperative
SHS	Solar Home System
SIINC	Social Impact Incentives
SME	Small and Medium-Sized Enterprise
UBOS	Uganda Bureau of Statistics
UECCC	Uganda Energy Credit Capitalization Company
UFPEA	Uganda Fish Processors and Exporters Association
UFVEPA	Uganda Fruits and Vegetables Exporters and Producers Association
UGEFA	Uganda Green Enterprise Finance Accelerator
UGX	Ugandan Shilling
UHEPA	Uganda Horticulture Exporters and Processors Association

UIA	Uganda Investment Authority
UNBS	Uganda National Bureau of Standards
UNCDF	United Nations Capital Development Fund
UNCTAD	United Nations Conference on Trade and Development
UOMA	Uganda Off-Grid Energy Market Accelerator
URA	Uganda Revenue Authority
URSB	Uganda Registration Services Bureau
USD	United States Dollar

EXECUTIVE SUMMARY

Access to electricity remains an ongoing development challenge for Uganda. In 2020, the national electrification rate was approximately 42%, with the urban electrification rate (70%) nearly double the rate of access in rural areas (33%).[1] The Ugandan government has made significant progress in expanding electricity access in recent years, aided by rapid growth in the country's off-grid sector, which is expected to account for more than half of new household connections in Uganda through 2030.[2]

Across sub-Saharan Africa, off-grid solar solutions are employed to power a wide range of productive use of energy (PUE) applications more economically than conventional alternatives (i.e., diesel, petrol or kerosene). Productive use technologies enable businesses to add value to products or services and to build new income streams, while PUE customers such as SMEs or industrial users support the commercial viability of energy access providers/operators with predictable demand and stable revenues. Hence, new and innovative PUE business models – such as Pay-As-You-Go (PAYGO), Pay-As-You-Store (PAYS), Cooling-as-a-Service (CaaS) and the KeyMaker Model (KMM) – have been developed in the recent years, enhancing the socio-economic impact of electrification and making PUE part of a larger integrated approach to rural economic development.[3]

The majority of the Ugandan population resides in rural areas and depends on farming for their livelihood, with the agricultural sector contributing to 25% of GDP and employing about 70% of the population.[4] Several of Uganda's food industry production and distribution value chains face constraints during the post-harvest stage, especially due to limited access to cold chain infrastructure. The milk industry, which was Uganda's second highest earning sector in export revenue in 2020, experiences post-production losses of about 20%. With an estimated 500,000 smallholder farmers, Uganda is the second largest producer of fresh fruits and vegetables in sub-Saharan Africa; however, this sector also experiences significant losses before produce reaches a point of sale. Uganda's fisheries sector, which employs about 1.5 million people, faces similar challenges around spoilage and losses due to a lack of refrigeration and cold storage across its value chain.

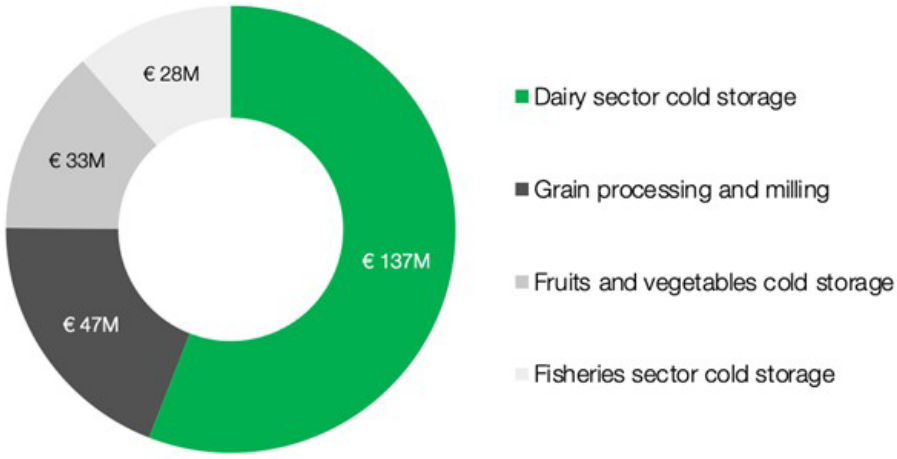
This Developer Guide explores the opportunity for solar powered cooling and processing PUE applications in the food industry in Uganda, focusing on four market segments – dairy, grain processing, fisheries and fruits and vegetables – including how each value chain is organised, key market actors and business models, PUE solutions for businesses in each sector, applicable laws and regulations, and market barriers and opportunities.

The estimated market opportunity for PUE applications to support cooling and processing across each of the four analysed food industry value chains at the smallholder level is presented in **Figure ES-1**.[5] Cold storage for the dairy sector represents the largest market opportunity (€137M), followed by grain processing and milling (€47M), cold storage for fruits and vegetables (€33M) and cold storage for the fisheries sector (€28M).

1) "Tracking SDG7: The Energy Progress Report 2022," IEA, IRENA, UN, World Bank, and WHO, (2022): https://trackingsdg7.esmap.org/data/files/download-documents/sdg7-report2022-full_report.pdf
2) "Energizing Finance: Taking the Pulse 2019: Taking the Pulse of Energy Access in Uganda" Sustainable Energy for All (SEforALL), (2019): https://www.seforall.org/system/files/2019-12/Taking-Pulse-Uganda_0.pdf
3) Wearne, A., van der Linden, J., and Bloomfield, Z., "Energy for Rural Industrialisation – Productive Use of Energy 2.0: New Scaling Opportunities and Innovations in the Sector," GET.transform, (August 2022): https://www.get-transform.eu/wp-content/uploads/2022/08/Productive-Use-of-Energy-2-0_GET.transform2022.pdf
4) "Uganda Country Commercial Guide: Agricultural Sector," International Trade Administration, U.S. Department of Commerce, (August 15, 2022): https://www.trade.gov/country-commercial-guides/uganda-agricultural-sector#:~:text=Eighty%20percent%20of%20Uganda's%20land,and%2033%25%20of%20export%20earnings

5) The market sizing activity estimated the total investment needed to capture the existing market opportunity as well as the future potential of the market of up to 10 years. See **Section 4.1** and **Annex 1** for more details.

FIGURE ES-1. Estimated market size of food industry market segments in Uganda



Overall, the market for solar powered cooling and processing technologies in Uganda's food industry remains relatively nascent. Currently, solar applications for agricultural cooling represent a potentially profitable business opportunity, especially when applying the Pay-As-You-Store business model.[6] The same is not true for solar milling, or micro milling, which despite recent improvements in the technology, likely needs more time for costs to reduce and throughput to increase.

In order to capture this market opportunity, companies must navigate the capital-intensive nature of solar-powered PUE systems, requiring large sums to be tied up in receivables or equipment, with direct implications on the affordability of these products, especially for smallholder farmers. Market interventions to expand access to financing should include both public and private capital sources and strategies, with the aim of leveraging in private local capital. Key areas of support for the sector's development include:

— Increased availability of concessional debt, equity and grant funding as well as local sources of capital.

— Participation of rural cooperatives, especially Savings and Credit Cooperatives (SACCOs), who can help reduce affordability gaps by enabling smallholder farmers to aggregate funds and resources to purchase products and services they would not be able to afford individually.

— Improved internal financial management capacity of local off-grid and PUE companies to meet investor and lender requirements and access and manage funding. Local commercial banks can also benefit from a better understanding of off-grid solar businesses and financial models, with capacity building to design loan products specific to the sector.[7]

Increasing the uptake of PUE technologies in Uganda will require the government, development partners, financiers and the private sector to collaborate in order to enhance the enabling environment for the sector. Off-grid solar operators and suppliers

6) Please refer to the Cold Storage Model Business Case that was published together with this Developer Guide.

7) Several donor-funded programs are providing technical assistance to off-grid companies for this purpose, including the African Enterprise Challenge Fund (AECF), the Private Financing Advisory Network (PFAN), and several GET.invest services, including Finance Catalyst (https://www.get-invest.eu/finance-catalyst/), Finance Readiness Support (https://www.get-invest.eu/about/who-we-are/get-invest-finance-readiness-support/), and Capacity Development for Domestic Financiers (https://www.get-invest.eu/get-invest-expands-capacity-development-for-domestic-financiers/).

of productive use products and systems require considerable financial and technical assistance to support their expansion and address affordability gaps. Notwithstanding these challenges, the market for solar powered cooling and processing technologies remains extremely dynamic. Innovative business models that are replicable and scalable hold great promise to boost growth across Uganda's food industry value chains and are inviting to the Ugandan private sector. This Developer Guide has captured input from a wide range of market actors, partners and stakeholders, and therefore serves as a manual for the private sector. It also serves as a conversation starter to support collaborative work across Uganda's burgeoning productive use sector.

SECTION 1

Introduction

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This Developer Guide is a reference document intended to inform project developers, private sector technology suppliers, innovators and entrepreneurs about opportunities for renewable energy applications in Uganda's food industry. The Guide specifically examines how four key sectors of Uganda's food industry – grains, dairy, fisheries and fruits and vegetables – can benefit from solar powered cold storage technologies and processing equipment. The Guide explains how these sectors are organised, who the key market actors are, what business models are being deployed, who are the potential financiers, what returns on investment might be expected, and other opportunities and challenges that exist for the development of the food industry using renewable energy technologies in the country.

This Guide is organised into three main sections (following this introduction):

1) **Principles of agricultural cooling and processing in sub-Saharan Africa:** This section provides context for renewable energy solutions in the food industry in sub-Saharan Africa, including a snapshot of the latest technologies, as well as the innovators in the sector and different business models that are being applied.

2) **Renewable energy for cooling and processing in Uganda:** This section looks specifically at the food industries in Uganda and renewable energy for cold storage and processing in the country, including a deeper dive into four key sectors of Uganda's food industry – grain processing (milling), dairy, fisheries and fruits and vegetables.

3) **Route-to-Market:** This section explores how to leverage the market research presented in this Guide to start up a renewable energy business in Uganda that targets the food industry.

This Guide is part of a package of products under the GET.invest Market Insights. Each package is country specific and covers a certain renewable energy market segment. In addition to this Developer Guide, the Market Insights package also includes corresponding Model Business Cases.

There are two Model Business Case documents that accompany this Guide:

1) **Containerised solar-powered cold storage:** The first Model Business Case examines a business that sells and rents space in containerised solar-powered cold storage units (also known as 'walk-in cold room') to cooperatives of dairy and fruit/vegetable farmers under two different scenarios: (i) outright cash purchase/direct ownership of the technology; and (ii) under a Pay-As-You-Store (PAYS) model.[8]

2) **Green mini-grid KeyMaker Model:** The second Model Business Case analyses a mini-grid developer that multiplies its revenue streams by producing and selling ice to fisherfolk and also buys and commercialises fish from those same fisherfolk (referred to as the KeyMaker Model, initially developed by INENSUS GmbH).[9]

8) The PAYS model is described in further detail in **Section 2.3** and in a Model Business Case published together with this Developer Guide.
9) The KeyMaker Model is described in further detail in **Section 2.3** and in a Model Business Case published together with this Developer Guide.

SECTION 2

Principles of Agricultural Cooling and Processing in Sub-Saharan Africa

This section provides context for renewable energy solutions in the food industry in sub-Saharan Africa, including a snapshot of the latest technologies, as well as innovators in the sector and different business models and financing mechanisms that are being applied.

2.1 TRANSITION FROM FOSSIL FUELS TO SOLAR ENERGY FOR COLLING AND PROCESSING

Off-grid solar (OGS) solutions can power a wide range of productive use of energy (PUE) applications and businesses across the food industry value chain, often more economically than conventional alternatives powered by diesel, petrol or kerosene fuels. Productive use applications enable businesses to add value to products or services and to build new income streams, typically by creating a new product or service (e.g., ice) or by enhancing the value of an existing product or service (e.g., milling maize). In sub-Saharan Africa, solar-powered water pumping and irrigation, milling and processing, and cold storage and refrigeration are common PUE applications that add value to food industry production and distribution value chains.

Productive use applications such as milling and refrigeration can transition from fossil fuels to renewable energy sources, benefitting local business owners and their communities.

Milling

In order to process staple crops such as cereal grains and tuber vegetables (rice, maize, millet, sorghum, cassava etc.), rural communities throughout Africa use milling equipment that is typically powered by diesel motors. Diesel mills are relatively cheap to purchase but have high operating expenses and cause pollution. Grain milling businesses in Africa are predominantly run by women or women's cooperative groups. Historically, these businesses are unprofitable, as the price that customers pay for milling services often does not cover the cost of delivering the service. The main cost associated with milling, however, is the diesel fuel, which can be eliminated by using an electric motor powered by a solar mini-grid or standalone system (standalone solar micro mills are a newly-emerging technology).

Village mills, which are ubiquitous in rural areas across Africa, are important for freeing women and girls from the more traditional and arduous pounding and cleaning of grains, providing them with time for other productive activities or school. It is estimated that rural women in Africa spend approximately 40 billion hours of unpaid time on processing agricultural produce each year.[10]

While electric motor mills are not new (and are common in grid-connected areas), there are economic, logistical and supply chain constraints associated with solar milling in newly-electrified rural areas that hinder the growth of this technology. An electric mill is about double the price of a diesel-powered mill – approximately EUR 2,000 compared to EUR 1,000, respectively. However, fuel consumption for a diesel-powered mill can cost EUR 5 per day, and diesel motors have on-going maintenance issues. If a 7 kWp solar system powered an electric grain mill in a rural setting, the approximate EUR 20,000 system cost is equal to 4,000 days of fuel consumption by the diesel-powered mill.[11] An existing diesel mill can be retrofitted to be powered by electricity simply by changing the motor and transmission mechanics. New solar-powered electric micro mills are an emerging technology; however, these mills currently have far reduced energy requirements and correspondingly lower throughput capacity (serving fewer customers in a given period of time).

Refrigeration[12]

Cold storage and refrigeration is another critical productive use application in rural parts of Africa. Cooling technologies, such as refrigerators, freezers and cold storage facilities, allow producers

10) "Solar Milling: Exploring the Market Requirements to Close the Commercial Viability Gap," Energy4Impact and Efficiency for Access Coalition, (January 2020): https://energy4impact.org/file/2169/download?token=yCMroy-3
11) Current electric grain mills on the market are more appropriate when powered by a solar mini-grid - and are often critical to the feasibility of the mini-grid project.
12) Although the focus of this report is on the food sector, off-grid refrigeration is also critical for the rural health sector, providing cold storage for vaccines and other medicines.

to avoid spoilage and reduce losses, supporting agriculture, dairy and fishing value chains at the smallholder level. Refrigeration allows small retail and service businesses to sell cold beverages and ice for a wide variety of needs in rural community markets. Like milling solutions, refrigeration is particularly beneficial to rural African women, who often spend hours each day walking to food markets. Solar refrigeration, cooling and processing equipment enables traders and livestock farmers to sell dairy products, while cold storage of agricultural produce can reduce losses and increase output (**Box 1**).

BOX 1. Cold chain solutions for Indian banana farmers

India is the global leader in banana cultivation. In 2013, Danfoss, a Danish multinational manufacturing firm that offers energy system management services, partnered with the Indian government and the Confederation of Indian Industry to form a task force that aimed to deliver cold chain solutions to banana farmers in order to reduce post-harvest losses. With support from local industry associations, the task force conducted a feasibility study of the banana sector to assess how cold chains could be utilized to reduce losses and boost export revenue. The study's findings helped educate farmers on cold chain infrastructure and technologies, leading to cold storage deployment and resulting in a 300% increase in farmer income and a 20% reduction in post-harvest losses. By 2018, India began exporting bananas to Europe. India's government is now exploring how cold chain solutions can be applied to support other agricultural crops/sectors.[13]

Refrigerators and freezers in off-grid settings, which generally rely on diesel or petrol generators, consume a large amount of energy and can pose potential environmental and health risks from particulates and end-of-life recovery of refrigerant. Solar powered refrigerators, on the other hand, consume about one-quarter of the energy of a conventional fridge and use refrigerants with lower global-warming-potential (GWP).[14]

Many African governments have ambitious initiatives that aim to increase the productivity of their rural agriculture sectors. However, these efforts are often inhibited by low rural electrification rates and limited access to information about improved agronomic practices and technologies, which limits the uptake of mechanised tools and equipment, particularly among smallholder farmers. African smallholder farmers also tend to have inadequate access to markets, mainly due to funding constraints and poor rural infrastructure, which in turn restricts their ability to scale their business.

Scaling clean energy for cooling and processing will ultimately depend on the availability of innovative technologies, access to financing for the purchase of equipment, domestic energy and trade policies, and strengthened local agricultural production and supply chains. If energy access can be secured and financed, the positive impacts include improved food security, increased farm productivity, employment opportunities, improved gender equality, resilience to climate change and fuel price shocks, and economic growth and development.

2.2 EMERGING TECHNOLOGIES AND INNOVATORS IN COOLING AND PROCESSING

This section reviews some of the emerging technologies and innovators in the cooling and processing market segment in sub-Saharan Africa Africa. Energy efficient products and appliances are slowly becoming available in off-grid markets throughout sub-Saharan Africa, brought to the region by a wide range of suppliers. Markets are often driven by early-stage firms that design and develop off-grid technologies, as well as specialised distributors that help them reach customers and provide customer financing. Given that the majority of sub-Saharan Africa's off-grid population lives in rural areas and is engaged in agricultural activities, there has been an increase in the number of companies (both start-ups and established companies)

13) "The World's Banana Giant is Awake," Danfoss, (26 February 2019): https://www.danfoss.com/en/about-danfoss/news/cf/the-world-s-banana-giant-is-awake/
14) "The State of the Off-Grid Appliance Market," Efficiency for Access Coalition, (2019): https://efficiencyforaccess.org/publications/2019-state-of-the-off-grid-appliance-market-report

engaged in developing innovative products and technologies for agricultural productive use applications.[15]

Solar cooling companies such as Cool Hubs, Ecozen, Freshbox, KoolBoks, Selfchill, Sokofresh, Solar Freeze, as well as solar processing/milling companies such as AGSOL, Nadji.Bi, and Inspirafarms, among others, are early-stage innovators in these market segments. In Uganda, SolarNow offers solar powered milk coolers.[16] These companies are mostly start-ups focused exclusively on productive use technologies (solar water pumping, cooling and processing equipment) and are developing products specifically tailored for small-scale and off-grid applications. Some PAYGO companies that have successfully developed SHS businesses are now looking at the PUE sector.

Mini-grid developers are also innovating in the field of clean cooling and processing. Devergy, an energy services company in Tanzania, scaled their offering to include products for grain milling as well as freezers for meat and fish. JUMEME Ltd., a Tanzanian mini-grid company operating in Lake Victoria, deployed the KeyMaker Model (KMM) to improve the economics of a mini-grid project by unlocking local market potential.[17]

Cold storage and ice making

Cooling technologies include refrigeration, chilling systems, freezing and ice making, walk-in cooling units and fan/cooling drying units. Solar refrigerators are gaining the most traction for lower-volume, higher-value applications, such as milk chilling and fish freezing. **Table 1** presents some of the innovators in the solar cooling space.

TABLE 1. Innovators in the solar cooling and refrigeration sector

COMPANY	COUNTRY OF OPERATION	PRODUCTS	DESCRIPTION	BUSINESS MODEL
Adili Solar Hubs	Kenya	Cold rooms, ice flake machines connected to a mini grid, + software for monitoring	Provides cooling systems and ice making for fisheries sector.	Service-based model
baridi	Kenya	Cold rooms focusing on livestock market	5kW standalone chilling service combining nano-grid and cold storage technology.	Pay-as-you-Store model; direct sales; lease-to-own; and franchise
Cold Hubs	Nigeria	Modular solar-powered-walk in cold room	The solar-powered walk-in cold room is made of 120mm insulating cold room panels to retain the cold air.	Pay-as-You-Store model

15) "The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa," Dalberg Advisors, Lighting Global and World Bank, (2019): https://www.lightingglobal.org/wp-content/uploads/2019/09/PULSE-Report.pdf

16) "Synthesis Report: Solar Appliance Technology Briefs," Efficiency for Access Coalition, (August 2021): https://storage.googleapis.com/e4a-website-assets/EforA_Solar-Appliance-Technology-Brief_SynthesisReport_August-2021.pdf

17) The KeyMaker Model is described in further detail in **Section 2.3** and in a Model Business Case published together with this Developer Guide.

ecozen	Kenya and Uganda (based in India/Partner with Smart Villages)	Solar powered cold room	Solar cooling for fruits and veggies as well as dairy products. "EcoFrost" with capacity of 5-metric tons. Adding an app "Eco connect" to monitor data.	Service-based model
ecolife FOODS	Uganda	Solar powered cold room	On-farm storage structure for fruits and vegetables in rural areas. Partnership with Smart Villages to use the solutions with mini grids.	Service-based model
FreshBox	Kenya	Solar powered walk-in cold room	For fruits and vegetables mainly. Cold room offered in different sizes ranging from 9m3 to 90m3, with pricing ranging from EUR 4,000 to EUR 12,000.	Service-based model
KOOLBOKS LIFE IS KOOL	Nigeria	Solar cold storage and freezer "KoolHome"	Also developing a mobile transit unit that can be attached to a trailer. Six different sizes from 108 litres to 1000 litres capacity.	PAYGO model (developing CaaS model for clinics)
InspiraFarms	Kenya	Solar powered walk-in cold room	Integrated standard and tailor-made cold storage units for storage targeting the horticul-ture sector. Units come in various sizes, ranging from 30 to 3,000m2.	Leasing model (3 to 5 years payment terms and 20% down payment); developing asset finance model
Phaesun	Zambia / Tanzania (based in Germany)	Solar cooling systems	Cold is generated by the solar-powered SelfChill cooling units and stored in the WaterChiller, an ice reservoir.	PAYGO model

SokoFresh	Kenya / partner with ECOZEN	Mobile solar cold storage	Small mobile cold storage solutions and a digital market linkage platform to integrate small and medium-sized farmers with professional value chains.	Service-based model/PAYGO model
SOLAR FREEZE	Kenya	Mobile solar powered cold storage units + software	Mobile solar powered cold room with cold storage as a service through mobile money transaction such as M-Pesa, as well as cold storage mobile app & IOT monitoring for cold storage management.	Service-based model
solar pipo	Uganda	Solar powered cold storage	Solar Pipo is a one-stop-shop for solar projects in the dairy sector. Provides financing, assessment, design, installation and maintenance.	Service provider (financing, and connection with solar suppliers)
STATION-ENERGY	Uganda	Solar-powered cold room for refrigeration and freezing	This solution adapted for agricultural cooperatives, fisheries associations, sanitary usages (conservation of vaccines) or for ensuring cold chain integrity in food processing and distribution.	Pay-as-You-Store model
WE WIAMALA ENERGY	Uganda	Custom made solar systems for milk cooling	We Coolers focuses on solutions for the dairy sector (at farmer level and milk collection centres).	PAYGO model

Processing

Most renewable energy powered applications for agricultural processing, such as milling, threshing and grating, are not yet mature. These activities are more energy-intensive than cooling and the business case is heavily dependent on utilisation rates (throughput). As a result, products have not been fully developed for the market in sub-Saharan Africa.

The current capacities for solar milling/processing technologies are too low and not yet competitive. Most companies active in the market are new entrants, such as AGSOL and Solar Milling in Kenya, as well as Nadji.Bi in Senegal, which are targeting farmer cooperatives and micro-processor businesses rather than individual farmers. Rural cooperatives, especially Savings and Credit Cooperatives (SACCOs), can help reduce affordability gaps by enabling smallholder farmers to aggregate funds and resources to invest in products and services they would not be able to afford individually. A milling component is currently being sold by manufacturers, while the solar PV system required to power the equipment can be purchased separately from a solar company. This type of modular kit allows for expansion and the integration of other appliances, increasing the value proposition for mill owners.[18]

Table 2 presents some of the innovators in the solar processing space.

TABLE 2. Innovators in the solar processing sector

NAME OF COMPANY	COUNTRY OF OPERATION	PRODUCT	DESCRIPTION
AGSOL	Kenya and Uganda	MicroMill	AGSOL sells an agro-processing micro mill designed to process a range of dried cereals and tubers. The micro mill can produce about 300kg/day on a sunny day.
Nadji.Bi	Senegal	Solar-powered millet flour mill	The Nadji.Bi mill is accompanied by smart software application to track customer data.
Solar Milling	Piloted in Kenya; manufactured in Spain	Solar Mill[19]	The Solar Milling Zebra Mill can run for 6 to 7 hours daily (when using solar); the output is approximately 240 kgs/day of fine flour.

Source: Stakeholder interviews, 2022; company websites

Drying

Drying is an energy-intensive and cost-effective method that is used to preserve various types of agricultural products. In sub-Saharan Africa, drying by direct exposure to the sun is common. This method of open-air drying, however, relies heavily on ambient conditions and is prone to contamination by dust, rain, wind and other elements.

18) Energy4Impact and Efficiency for Access Coalition, 2020.

19) While one product is called Micro Mill and the other is called Solar Mill, they are both solar micro mills

There is significant potential for solar drying technology to reduce post-harvest losses in sub-Saharan Africa. Solar drying of fruit (such as mango, papaya and pineapple) and of meat into biltong or jerky has been common since the 1990s. Local technology is as simple as a wooden box with a glass roof and air vents in the side panels, with the interior of the box holding screens where the produce is placed for drying in the sunlight. Active solar dryers have ventilation systems to circulate the heated air inside the drying room, using solar PV or grid-connected electricity. Active solar drying is faster than the passive raditional method and better suited for larger commercial applications.[20]

To date, very few types of dryers are actually commercialized, because the technology can be so easily built by local artisans. Makerere University recently developed a commercial hybrid solar dryer in partnership with a group of pineapple farmers in Western Uganda. The dryer has a loading capacity of 300 kg of fresh and sliced fruits (approximately 450 pineapples each weighing 1 kg on average) per drying batch, a drying rate of 20 kg per hour and is capable of 10 hours of continuous drying time.[21]

2.3 INNOVATIVE BUSINESS MODELS IN COOLING AND PROCESSING

This section describes business models for cooling and processing in sub-Saharan Africa, which include Pay-As-You-Go (PAYGO), Pay-As-You-Store (PAYS), Cooling-as-a-Service (CaaS) and the KeyMaker Model (KMM). Implementing the appropriate business model is important to ensuring the commercial viability of cooling and processing solutions and optimising returns on investment.[22]

PAYGO for cooling and processing

Under a PAYGO model, a client typically pays a deposit (a percentage of the total price) and then monthly instalments to purchase the equipment over time (usually 18-24 months). In the case of cooling and processing, clients are frequently cooperatives, women's groups or associations, rather than individuals. and the systems are larger and more costly than solar home systems.

PAYGO financing solutions can offer a possible route to the household and smallholder farmer market segments via smaller products, such as individual refrigerators. However, the PAYGO model is not ideal for the commercial market and cooperative businesses, for which leasing or PAYS (a service-based model) are better suited. The larger cooling and processing systems required by these business clients are more expensive and difficult to finance – especially component-based systems like walk-in cold rooms – and sell in much lower volume compared to plug and play systems. Most of these larger systems are sold on a cash basis because they have not achieved the economies of scale needed for the PAYGO business model, and they are too small for typical corporate financing. Commercial banks and microfinance institutions often lack the due diligence skills to conduct smaller solar PUE system transactions.[23]

20) Udomkun, P. et al., "Review of solar dryers for agricultural products in Asia and Africa: An innovation landscape approach," Journal of Environmental Management, 268, (August 2020): https://www.sciencedirect.com/science/article/pii/S0301479720306629

21) Muhumuza, A., "Makerere unveils a Hybrid Solar Dryer (HSD) for perishable agricultural produce," Makerere University College of Agricultural and Environmental Sciences, (March 11, 2021): https://caes.mak.ac.ug/news/makerere-unveils-a-hybrid-solar-dryer-hsd-for-perishable-agricultural-produce/

22) A Model Business Case published together with this Developer Guide compares the financial returns from selling cold storage units to renting space.

23) "The Market for Productive Uses of Solar Energy in Kenya Status Report 2021," EnDev/SNV, (2021): https://www.snv.org/update/new-endev-reports-launched-productive-use-energy-kenya

BOX 2. PAYGO-enabled solar refrigeration[24]

Koolboks is a tech startup with operations in Nigeria that seeks to make refrigeration affordable and accessible to all. Koolboks has partnered with PaygOps, a last mile management system company, to offer its solar powered cooling products via an integrated PAYGO system that offers more flexibility to low-income customers and enables them to acquire solar refrigerators without having to make upfront payments. In addition, distributors of Koolboks products will be able to integrate with PaygOps software to efficiently manage their last-mile operations thanks to the platform's advanced lease financing, sales, after-sales and inventory management features.

Pay-As-You-Store

The PAYS business model is being implemented by companies that operate solar powered cold storage rooms. Under the model, the customer pays a fee to store fresh produce for a certain number of days in a large walk-in cold room. By transforming a product offer into a service offer, companies can utilise this business model to mitigate default risk and retain ownership and control of their product, including its maintenance.

Several companies in sub-Saharan Africa already deploy this business model:

- **ColdHub** is a Nigerian company that offers farmers a flexible PAYS subscription model, where farmers can store their produce on a daily basis (without commitment). Farmers pay a daily flat fee for each crate of produce they store, and they can renew their payment on a daily basis. Most of the transactions to date have been on a cash basis, as ColdHubs serves mostly individual farmers and vendors (there are plans to upgrade the technology to allow for digital payments in the near future).
- **FreshBox** is a Kenyan company that provides refrigeration as a service, rather than as a product. This approach allows FreshBox to reach smallholder farmers at the bottom-of-the-pyramid (BoP), while simultaneously increasing the earning potential of their retailers. Freshbox was a finalist for the 2022 Global LEAP Awards Off-Grid Cold Chain Challenge, implemented by Efficiency for Access and CLASP with support from DOEN Foundation, IKEA Foundation, Foreign & Commonwealth Department Offices (FCDO) and Good Energies Foundation.[25]

It is worth noting that none of the companies listed above have reached commercial operations yet and remain largely dependent on donor and grant funding.

Cooling-as-a-Service

Cooling-as-a-Service (CaaS) is a pay-per-service model for solar cooling systems that eliminates the upfront cost of clean cooling equipment for customers, who instead pay per unit of the technology (i.e., they are paying for the equipment, not space). The technology provider installs, maintains and operates the cooling equipment, recovering costs through periodic payments made by the customer.[26]

24) "PaygOps and Koolboks partner to make cooling accessible to all," (September 28, 2020): https://www.paygops.com/post/paygops-and-koolboks-partner-to-make-cooling-accessible-to-all

25) 2022 Global LEAP Awards Off-Grid Cold Chain Challenge Announces Preliminary Finalists: https://www.clasp.ngo/updates/2022-global-leap-awards-off-grid-cold-chain-challenge-announces-preliminary-finalists/

26) CaaS Factsheet: https://energy-base.org/projects/cooling-as-a-service-initiative/

In Nigeria, Koolboks, one of five winners selected for the CaaS incubator programme, provides energy-efficient solar powered freezers and refrigerators to local businesses and healthcare facilities.[27] Another example is Sokofresh, which offers cold storage as a service to smallholder farmers in Kenya. Sokofresh also utilises a digital platform to integrate small- and medium-sized farmers into professional value chains, thereby reducing spoilage and increasing farmer income by 30%.[28] The CaaS model thus requires little capital and minimal technical capacity on the part of the end user and enables customers to base their investment decision on the lifecycle cost rather than on the purchase price of the equipment.[29]

The model also creates incentives that optimise efficiency and maintenance. End users are incentivised to consume energy efficiently, while technology providers are incentivised to install and maintain the most efficient equipment possible. The business model also has environmental benefits, as it reduces harmful refrigerant emissions; it is estimated that the CaaS approach can reduce global emissions from electricity use and coolant leakage by up to 49%.[30] This business model, however, is still in its relatively nascent stages in developing countries, particularly in sub-Saharan Africa.

KeyMaker Model

The KeyMaker Model (KMM) is a concept developed by INENSUS GmbH that creates an additional income stream for mini-grid developers, driving them to operate more cost-efficiently and sustainably, while simultaneously establishing an end-market for local farmers to sell their produce. Under the model, mini-grid developers typically procure raw products from the local community, process them to produce final goods using the electricity from their mini-grids, and sell them to a target market, usually in urban areas where demand is high. The virtue of the concept relies on leveraging the stable supply of electricity from a mini-grid to establish an adjacent business that consumes the electricity produced by the mini-grid and also allows the developer to enter an agricultural product's value chain, usually at the processing and trading stages.[31]

For example, a mini-grid developer can also operate a village grain mill. The grain mill purchases power from the mini-grid.

The same company owns both businesses – the mini-grid and the mill – so they can share certain overhead and management costs. The most famous KMM example are the JUMEME Ltd. mini-grids on islands in Lake Victoria, Tanzania, which have successfully created several sources of income instead of the one it would have if it was solely producing and selling electricity (**Box 3**).[32]

BOX 3. JUMEME fishing industry pilot project in Tanzania

In Tanzania, JUMEME Ltd. piloted a KeyMaker Model project in the fishing sector. The project involved building the mini-grid to offer power to local residents, but also running a business that bought fish from local fisherfolk, processing and freezing them on-site using its own electricity, and then selling the frozen fish to distributors for sale across Tanzania. Using lessons from the pilot, JUMEME has expanded and now has 23 mini-grids in operation on Lake Victoria islands and the banks of Lake Tanganyika, connecting roughly 5,000 customers and supplying an area of roughly 80,000 people with electricity.

27) https://www.climatefinancelab.org/news/base-announces-winners-of-first-caas-incubator/
28) https://www.caas-initiative.org/casestudies/caas-kenyas-off-grid-cold-storage/
29) "Cooling as a Service Initiative: Scaling up Clean and Efficient Cooling Technologies around the World," BASE, (2020): https://energy-base.org/projects/cooling-as-a-service-initiative/
30) Global Innovation Lab for Climate Finance - Cooling as a Service: https://www.climatefinancelab.org/project/cooling-service/
31) Cabanero, A., Nolting, L., and Praktiknjo, A., "Mini-Grids for the Sustainable Electrification of Rural Areas in Sub-Saharan Africa: Assessing the Potential of KeyMaker Models," Energies, 13, (2020): https://www.mdpi.com/1996-1073/13/23/6350
32) Please refer to the Model Business Case that was published together with this Developer Guide for more information on the KeyMaker Model.

Table 3. Advantages and challenges of business models in the cooling and processing sector

BUSINESS MODEL	TECHNOLOGY	ADVANTAGES	CHALLENGES
PAYGO model	Smaller solar products such as refrigerators, micro mills	— PAYGO enables higher sales volumes and generates customer relationships. — Improves affordability for the end-user.	— PAYGO requires economies of scale to justify the interest payments and cover the default risk — The cost of higher-value PUE appliances, like walk-in cold rooms, is usually too high to be financed in-house — The cost of technology integration such as mobile money set up for PAYGO is often too high for small companies
Rental and services models (PAYS and CaaS)	Larger systems, such as walk-in cold storage rooms	— Provides services while keeping ownership of the product. — Gather data through monitoring/ IT software. — BoP potential: Financially accessible for smallholder farmers or cooperatives who can't afford to buy the technology outright. — Virtually risk-free for the end-user.	— Relatively nascent sector and business model — High amount of capital financing required of the technology supplier — Requires more R&D to be applicable to the dairy sector in order to provide a stirring mechanism
KeyMaker Model	Larger systems connected to mini grid, such as walk-in cold storage rooms	— Creative way to build value through different means. Mini grids configured to local infrastructure needs. — Supports community economic development in multiple ways.	— Requires additional capital investment on the part of the mini-grid developer — Requires additional skills — Potential competition with the status quo (i.e., commercial businesses already operating in the sector)

2.4 CHALLENGES AND OPPORTUNITIES FOR RENEWABLE ENERGY COOLING AND PROCESSING

There are a number of challenges facing the renewable energy cooling and processing industries throughout sub-Saharan Africa, but the market is extremely dynamic with constant business and project innovation. Increasing the uptake of PUE technologies will require the government, development partners, financiers and the private sector to collaborate in order to establish an enabling environment for the sector.

Challenges and market barriers

Table 4 summarizes the main challenges and market barriers facing the renewable energy cooling and processing sector, including cross-cutting issues, as well as barriers that are specific to each of the four analysed market segments (milling, dairy, fisheries and fruits and vegetables).

TABLE 4. Summary of off-grid solar PUE market barriers in sub-Saharan Africa

BARRIER	DESCRIPTION
	CROSS-CUTTING
Access to financing	— Production of cereals has been impacted by changing climatic conditions and limited farmer acreage. Growth in yields has been hindered by low input use, pests and diseases, low mechanisation and a high farmer dependency on rain. — Traditional post-harvest handling methods such as open-air drying and manual threshing affect the quality of the grains limiting profitability for farmers and millers. In addition, inappropriate post-harvest storage practices and insufficient storage capacity result in poor quality of stored grains.
Affordability	— Affordability is a constraint to the uptake of off-grid solar and PUE solutions. Solar water pumps, for example, are expensive relative to the income of smallholder farmers. Consequently, consumers tend to purchase low-cost, inefficient alternative products that are not quality verified and usually lack warranties and after-sales service.
Awareness	— A lack of awareness is a key barrier to the uptake of renewable energy and PUE technologies, as the benefits of these solutions are often not widely understood, particularly in rural areas. Awareness raising is critical to educate the public on the advantages and limitations of these technologies, how to select and purchase quality-verified products with after-sales service, and the consumer financing options available.
Competition with fossil fuels	— Fossil fuels remain the primary sources of energy in many parts of sub-Saharan Africa. The low cost of these fuels combined with their established infrastructure can make solar powered alternative technologies less attractive to investors.
Coordination	— Coordination between government agencies and among donor/development activities and programs requires strengthening to avoid the duplication of efforts, ensure efficient use of limited resources and facilitate renewable energy/PUE investment and market development. — Coordination is particularly important given the time and effort it takes to change customer behaviour and expectations, and the rapid pace of technological change.

Logistical and infrastructure	— Building a strong rural distribution and service network, especially in remote off-grid areas, is an expensive undertaking for early-stage off-grid solar/PUE companies with limited financial resources. — Poor road and transportation infrastructure in rural areas poses logistical challenges, increases costs and inhibits the delivery of services.
Market spoilage	— Low-quality products in the market have negatively affected consumer perception of PUE solutions, thus discouraging them from purchasing quality-verified systems.
Policy and regulatory framework	— The absence of effective policies and regulations is a key barrier to the development of this sector. — Uncertainty about the regulatory environment can result in investors shifting away from the market. — Fiscal and taxation policies can also be an issue, as VAT or import duties on solar products or components can have a sizeable impact on their cost/affordability.
Technical capacity	— In sub-Saharan Africa, there is generally a lack of technical capacity and specialised knowledge that renewable energy cooling and processing technologies require. — The off-grid PUE market is still in its nascent stages; thus, public and private sector stakeholders need sector-specific training and skills development. This can be in the form of capacity building for policymakers, training for financial institutions, and other technical certification programs designed to build local technical capacity, especially in the O&M of cooling and processing systems.
	GRAIN PROCESSING AND MILLING
Productivity	— Production of cereals has been impacted by changing climatic conditions and limited farmer acreage. Growth in yields has been hindered by low input use, pests and diseases, low mechanisation and a high farmer dependency on rain. — Traditional post-harvest handling methods such as open-air drying and manual threshing affect the quality of the grains limiting profitability for farmers and millers. In addition, inappropriate post-harvest storage practices and insufficient storage capacity result in poor quality of stored grains.
Economic feasibility / alternative technologies	— Solar mills have to compete with alternative technologies, including electric and diesel mills, which are often more economical to operate. with greater throughput capacity. — Solar mills currently being piloted have limited capacities (less than 1 kWp) while the upfront cost needed to acquire the technology is nearly twice the cost of a diesel-powered mill of similar capacity. — Similarly, the return on investment for a solar mill is less than the return on a diesel mill. Capital investments would only be recovered if the solar mill operated constantly at full capacity – which is unlikely due to variance in use that results from seasonality, fluctuations in demand etc. A mill powered by a solar mini-grid will compete better with a diesel mill due to lower operating expenditure. — Milling fees which are set by the market are too low, making milling as a service unattractive. As the fees rarely change, the sale of flour as another source of revenue improves the business model.[33]

33) Energy4Impact and Efficiency for Access Coalition, 2020.

	DAIRY
Short product life	— As a result of poor milking and handling practices, as well as high ambient temperatures, milk in rural areas has a very short shelf life due to the high initial bacterial load. As a result, farmers who do not have cooling equipment must sell their milk relatively quickly before it spoils. Traders and buyers therefore have greater leverage in determining prices.
Productivity	— Milk productivity is severely constrained by increased resistance to the acaricides (chemicals) that are used to kill ticks in herds of cattle. Government regulatory institutions need to improve enforcement of acaricide quality. — Farmers prefer low-grade indigenous and cross-bred cattle to the high-grade improved exotic cattle because of their high resistance to diseases and survival rates in hot and dry seasons. This leads to lower milk production. — Most dairy farmers practice rain fed agriculture; with few alternative sources of water and pasture, milk production is reduced by about 40%-60% during the dry seasons. — Many animal deaths occur during the dry seasons due to a shortage of fodder. Smallholder farmers do not have sufficient capital to invest in silage production to supplement natural pastures.
	FISHERIES
Productivity	— The absence of cooling facilities and cold chain infrastructure at landing sites/to transport fish to the market increases waste and in turn leads to overfishing. — Fisherfolk sell their fish at very low prices at the landing sites immediately as they land for fear of their fish going bad. Losses are even higher during the wet season when preservation by drying and smoking is limited.
Access to markets	— Most fishing communities are isolated and far from transportation networks. In addition, most access roads to the landing sites are in poor condition, increasing the time it takes for fish to get to the next stage of the value chain.
	FRUITS AND VEGETABLES
Productivity	— The absence of cold chain infrastructure to transport fruits and vegetables to the market increases waste. — Traditionally, a high percentage of farmers depend solely on rain to water their crops with limited or no artificial irrigation. Climate change and drought have impacted productivity during the dry seasons. — There is a high prevalence of pests/diseases which affects the productivity and quality of the produce. — A shortage of agronomists and the penetration of low quality or counterfeit agricultural inputs like seeds and fertilizers onto the market reduce the overall productivity of the agricultural sector.
Access to markets for produce	— Foreign markets demand very stringent/high-quality standards that are often challenging for local exporters to meet. — Smallholder farmers often must rely on cooperatives or associations to gain access to market for their produce; however, farmer associations throughout Africa are often under-resourced and inefficient organisations that do not have sufficient market knowledge. This leads to manipulation by the traders/middlemen who often determine the prices at which they buy the produce from the farmers.

Proposed solutions and market opportunities

A range of market interventions targeting the renewable energy cooling and processing sector can help address some of the above-mentioned barriers to the sector's development.

Above all, private operators and service providers in the off-grid solar and PUE segments need financial and technical assistance to support their expansion and address affordability gaps. Government policies and regulations should target both supply-side and demand-side market interventions with the aim of reducing costs for solar and PUE equipment. Quality assurance frameworks and standards for productive use products should also be established.

The introduction of new and innovative business models and forms of consumer financing (e.g., PAYGO) have already expanded the market for off-grid solar products and systems. Similar innovations will be necessary for PUE technologies to achieve scale (such as those described in **Section 2.3** above). Consumer awareness raising around available options to finance the upfront purchase of OGS and PUE products is also critical (financial literacy, which drives consumer decision-making and understanding of benefits and cost-savings, is typically low in rural areas).

Financing approaches should include both public and private capital sources and strategies. Currently, the most common public funding for the off-grid solar sector comes in the form of results-based financing (RBF), where financing from development partners/funders is typically a grant that is paid *ex-post*, usually based on the sale of a SHS or a mini-grid connection. In the PUE sector, RBF can be applied to the sale of a cold storage facility, or to the connection of an electric grain mill to a mini-grid.

There are also efforts to expand RBF beyond outputs to include impact – thus providing additional or different subsidies for remote, difficult-to-reach areas, for PUE, or for companies that can demonstrate gender inclusivity or other positive socio-economic impacts. As an example, the impact finance advisory firm, Roots of Impact, has developed a Social Impact Incentives (SIINC) approach as a funding instrument that rewards enterprises with payments for achieving social impact and innovation.[34] The SIINC methodology is already being deployed to finance off-grid solar initiatives managed by GIZ EnDev in Kenya and by the KfW Clean Energy and Energy Inclusion for Africa Foundation (CEI Africa).

Under CEI Africa, off-grid solar companies will propose PUE projects to the Foundation that will be evaluated using a cost-benefit approach. CEI Africa will subsidize up to 50% of a project's CAPEX in return for high socio-economic impacts in terms of income-generation, job creation and/or gender inclusion.[35]

Figure 1 illustrates the concept of capital stacking, and which resources are the first to be lost in the event of project failure.

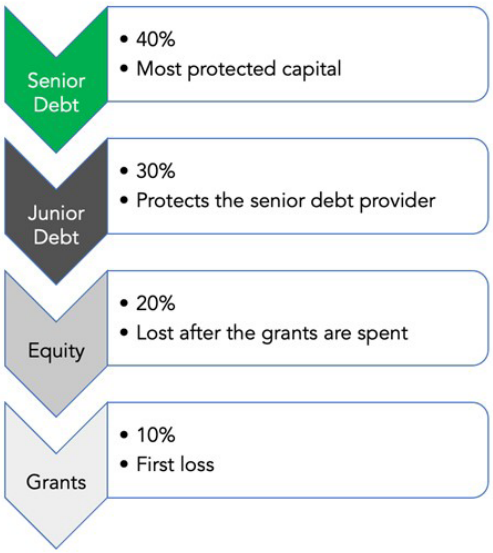
Grants and any types of subsidies provided by government or donors are the first financial resources to be lost in the case of project failure.[36] Equity provided by the project developer (or the developer's closest investors) is in the second loss position. This is in turn followed by the senior lender, who is in the most protected position, with junior debt used to recover losses before senior debt. Junior debt is oftentimes concessional financing, provided by development finance institutions (DFIs) at below market rates in order to convince more commercial and conservative lenders – like commercial banks – to invest in a project.

34) Social Impact Incentives: https://www.roots-of-impact.org/siinc/

35) CEI Africa's Impact: https://cei-africa.com/impact/

36) In **Figure 1**, grants account for 10% of the project investment, but in practice, many energy access ventures in Sub-Saharan Africa receive grants that cover a far greater share of a project's investment.

FIGURE 1. Capital stacking framework and project risk distribution



In sub-Saharan Africa, commercial banks are extremely conservative, and are only slowly beginning to invest in the renewable energy and energy access sectors. One way to expedite local currency lending from African financial institutions (FIs) to capitalise clean energy projects is to insulate them from losses by proposing a capital stack arrangement, as illustrated in **Figure 1**, where they would represent senior debt – the investor most protected from project failure.

Continued innovation in off-grid solar finance will be needed to drive market development for PUE in the agriculture and food industries. One such innovation is the Green-for-Access First Loss Facility (**Box 4**).

BOX 4. Green-for-Access First Loss Facility (G4A): Risk mitigation for local FI lending

The Green-for-Access First Loss Facility (G4A) aims to stimulate lending by the indigenous African banking sector by significantly reducing the risk of an investee not reimbursing a loan.[37] Under G4A, a local FI agrees to extend credit to a portfolio of clean energy projects in return for a cash deposit being placed in an interest-bearing account at the bank. For example, a local FI agrees to invest EUR 1M in PUE projects related to renewable energy sources and the food industry. G4A then deposits EUR 200k into an account at the institution (representing 20% of the EUR 1M loan portfolio), and those funds insure the bank against delinquent payments on the loan portfolio – i.e., covering first losses up to 20% (if the portfolio is sufficiently diversified and has been subject to proper due diligence, it is highly unlikely to incur 10% losses, let alone 20%). The G4A Facility is currently launching pilots with local FIs in Nigeria, Kenya, Uganda, Tanzania and Malawi. The Uganda pilot is with Equity Bank Uganda and protects the bank from losses in lending to farmers for the purchase of solar irrigation pumps.

37) Green for Access First Loss Facility (G4A): Risk Mitigation to Scale up Local Currency Lending for Off-Grid Energy: https://greenmaxcap.com/service/green-for-access-first-loss-facility-g4a/

Lending in local currency is important to companies in the off-grid solar sector in Africa due to the currency volatility that many countries experience. While the CAPEX for off-grid solar companies is primarily spent in hard currencies, their OPEX and revenue are primarily in local currency. Having a portion of their debt in local currency – and under terms that do not change based upon currency fluctuations – is critical for OGS companies operating in Africa (where most countries have a unique currency). In fact, currency volatility is an important consideration nearly everywhere in sub-Saharan Africa outside of countries in the African Financial Community (Communauté Financière Africaine, CFA) zones in West and Central Africa, which benefit from greater currency stability, as the CFA franc is pegged to the Euro.

Local FIs can also be encouraged to lend to the off-grid solar sector when they provide funding jointly with publicly supported credit facilities. Under such an arrangement, junior debt from ElectriFi, CEI Africa or a similar donor-supported financing mechanism is placed in front of the senior debt provided by the local FI. The local FI benefits from the project due diligence conducted by the junior lender in addition to the first-loss guarantee.[38]

The junior partner could also contribute equity to the investee. Most lenders require that an investee show a minimum level of equity on their balance sheet, which is often a disqualifying precondition for many African-owned OGS companies. In such cases, instead of being a junior lender, a DFI-sponsored investment instrument can inject equity capital into the OGS company, allowing that company to meet the minimum equity threshold required by the lender.

Other methods such as project finance, crowdfunding and catalytic financial instruments (beyond those described above) can be used alongside grant, debt, and equity financing to help attract funding to the OGS and PUE sectors. These tools offer a wide range of innovative financing solutions by providing incentives or reducing risk to investors, thereby mitigating some of the major barriers to investment.[39]

38) Interested project developers should contact one of these specialised lending facilities to see which local banks they have partnerships with.

39) "Funding the Sun: New Paradigms for Financing Off-Grid Solar Companies," World Bank Energy Sector Management Assistance Program (ESMAP), (February 2020): https://www.esmap.org/Funding_the_Sun

SECTION 3

Renewable Energy for Cooling and Processing in Uganda

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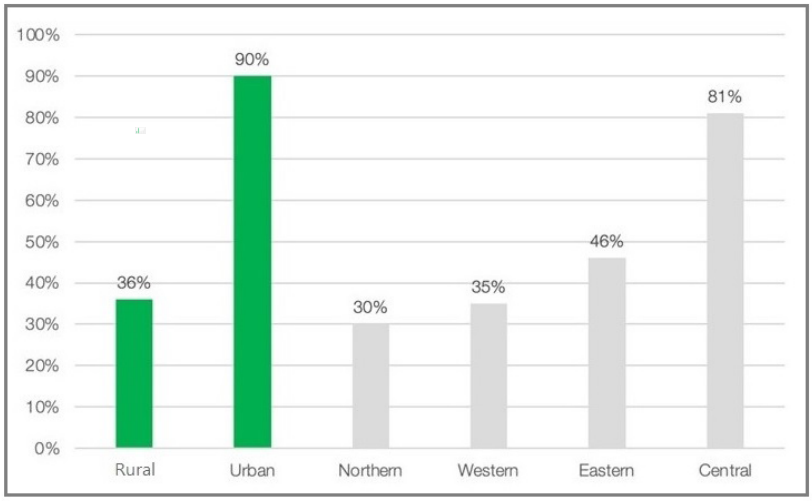
3. RENEWABLE ENERGY FOR COOLING AND PROCESSING IN UGANDA

This section describes renewable energy cooling and processing opportunities in four key sectors of Uganda's food industry – grain processing, dairy, fisheries and fruits and vegetables. Access to electricity remains an ongoing development challenge for Uganda. In 2020, the national electrification rate was approximately 42%, with a considerable difference between rates of access in urban areas (70%) and rural areas (33%).[40] Under Uganda's Vision 2040, the government set a target to increase rates of electricity access to 60% by 2027 and 80% by 2040.[41]

Uganda has made significant progress in expanding electricity access in recent years, aided by rapid growth in the country's off-grid sector, which will play a central role in achieving the country's electrification targets. An analysis conducted by SEforALL in 2019 estimated that the standalone solar sector is expected to account for more than half of new household connections in Uganda through 2030, supplying 5.3 million households with electricity at a cost of approximately USD 1.4 billion.[42] Off-grid solutions will be important for electrifying rural areas, where the national electricity grid has limited reach (**Figure 2**). A 2020 survey conducted by the Ugandan Bureau of Statistics found that OGS products and systems provide access to 29% of the population.[43] Solar energy in households is mainly used for lighting, phone charging and to power appliances such as radios, televisions and refrigerators. Pay-as-you-go solar systems sold with consumer financing business models account for most quality-verified products sold in the market today.[44]

FIGURE 2. Presence of electricity grid by region, 2019[45]



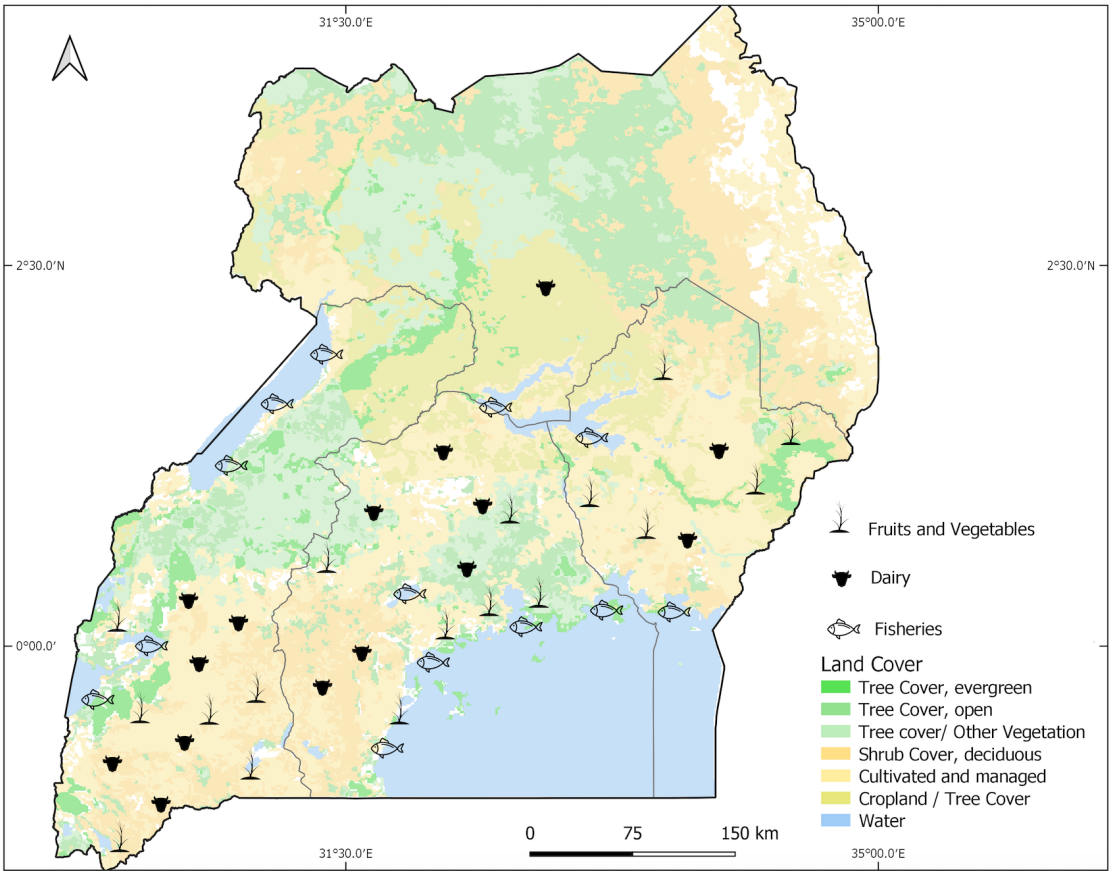
Source: Afrobarometer, 2021.

40) "Tracking SDG7: The Energy Progress Report 2022," IEA, IRENA, UN, World Bank, and WHO, (2022): https://trackingsdg7.esmap.org/data/files/download-documents/sdg7-report2022-full_report.pdf
41) Uganda Energy Access Scale-up Project (EASP): Project Information Document (PID), World Bank, (December 2019): https://pubdocs.worldbank.org/en/822811581437816457/12136-Project-Concept-Information-CTF-DPSP-3-Uganda-WB-EASP.pdf
42) "Energizing Finance: Taking the Pulse 2019: Taking the Pulse of Energy Access in Uganda" Sustainable Energy for All (SEforALL), (2019): https://www.seforall.org/system/files/2019-12/Taking-Pulse-Uganda_0.pdf
43) Lighting Global, GOGLA and ESMAP, 2020.
44) "Global Off-Grid Solar Market Report: Semi-Annual Sales and Impact Data, January - June 2020," Global Off-Grid Lighting Association, https://www.gogla.org/reports/global-off-grid-solar-market-report/
45) Kakumba, R., "Despite hydropower surplus, most Ugandans report lack of electricity," Afrobarometer Dispatch No. 441, (14 April 2021): https://afrobarometer.org/sites/default/files/publications/Dispatches/ad441-despite_hydropower_surplus_most_ugandans_lack_electricity-afrobarometer_dispatch-14april21.pdf

The deployment of PUE technologies in off-grid areas stimulates electricity demand and creates opportunities for income generation. Productive use customers such as SMEs or industrial users support the commercial viability of energy access by providing operators with predictable demand and stable revenues. Productive use applications promote sustainable economic development across a wide range of rural sectors, thereby improving the population's ability to pay for energy products and services. New and innovative PUE business models seek to further enhance the socio-economic impact of electrification through complementary activities such as access to finance and appliances, awareness raising, training, business development and other approaches that draw on non-energy sector initiatives, viewing PUE as part of a larger integrated approach to rural economic development.[46]

This section examines the food industry in Uganda, focusing on four market segments – grain processing, dairy, fisheries and fruits and vegetables – including how each value chain is organised, key market actors and business models, and how businesses in each sector can benefit from new solar powered PUE technologies.

FIGURE 3. Geographic distribution of key market segments in the Ugandan food industry



Source: Ministry of Agriculture, Animal Industry and Fisheries, 2022

46) Wearne, A., van der Linden, J., and Bloomfield, Z., "Energy for Rural Industrialisation - Productive Use of Energy 2.0: New Scaling Opportunities and Innovations in the Sector," GET.transform, (August 2022): https://www.get-transform.eu/wp-content/uploads/2022/08/Productive-Use-of-Energy-2-0_GET.transform2022.pdf

3.1 GRAIN PROCESSING

Rural smallholder farmers in Uganda engaged in subsistence agriculture rely on several main staple food crops, including maize, cassava, millet, sorghum, bananas and sweet potatoes. Most smallholder farmers produce food on small plots of land that are typically less than two hectares (Ha).[47] Maize and cassava are the most important food crops that are produced across all four regions of the country (**Table 5**).

TABLE 5. Production of major cereal food crops in Uganda by region, 2018 (tonnes)[48]

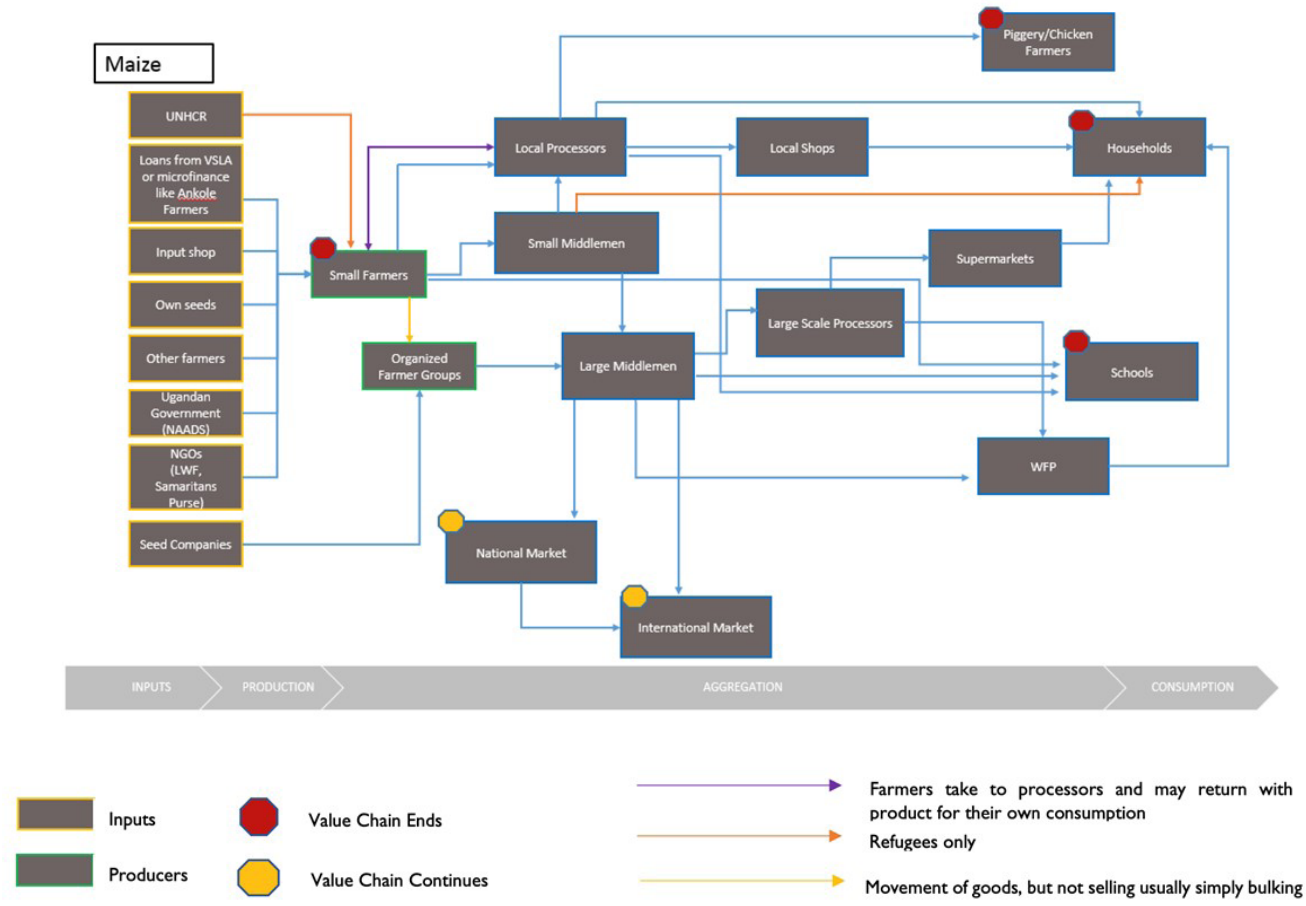
REGION	MAIZE	CASSAVA	MILLET	SORGHUM	TOTAL
Central	1,133,173	780,568	3,071	751	1,917,563
Eastern	832,954	1,087,443	50,205	184,178	2,154,780
Northern	409,182	1,677,187	44,938	49,364	2,180,671
Western	1,067,121	845,037	43,767	34,201	1,990,126
Total	3,442,430	4,390,231	141,982	268,493	8,243,140

Source: Uganda Bureau of Statistics, 2018.

Grains and cassava are consumed mostly in the form of milled products, which drive demand for milling services in both urban and rural areas. Mills are primarily used for the milling of maize, cassava and millet. Other grain and cereal processing activities include threshing, shelling, oil extraction and drying. Solar mills can be designed to mill most cereal crops; however, millet milling requires additional appliances such as threshers and hullers.[49] **Figure 4** provides an overview of the key market actors in Uganda's maize value chain.

47) Uganda Bureau Of Statistics, 2018. Annual Agricultural Survey: https://www.ubos.org/wp-content/uploads/publications/Annual%20Agricultural%20Survey%202018%20Statistical%20Release%20May%202020.pdf
48) Uganda Bureau Of Statistics, 2018.
49) Energy4Impact and Efficiency for Access Coalition, 2020.

FIGURE 4. Key market actors in the maize value chain[50]



Source: USAID, 2019.

As illustrated in the **Figure 4**, following the production stage, cereal products must be processed into flour before being incorporated into various end products. Farmers, or their groups/associations (if they do not have their own mills), transport their produce to the nearest processor that may be located a few kilometres away. More often, village agents who work closely with the farmers and small traders/middlemen aggregate the grains, which they then sell to small-scale or large processors and exporters.[51]

Formal market aggregators, who usually include processor representatives and large traders, must compete with informal small-scale traders for sourcing the raw maize. Milling is done using electrical mills in grid-connected regions and diesel-powered alternatives in off-grid areas. **Table 6** describes the key market actors in Uganda's grain processing value chain.

Figure 5 shows the percentage of maize millers by region.[52] **Figure 6** shows the production capacity of maize millers by region.

50) "Value Chain Assessment: Maize, Beans, and Groundnuts," USAID and AVSI Foundation, (December 2019): https://pdf.usaid.gov/pdf_docs/PA00WCGM.pdf

51) Daly, J., Hamrick, D., Gereffi, G., and Guinn, A., "Maize Value Chains in East Africa Technical Report," International Growth Centre, (October 2016): https://www.researchgate.net/publication/317004055

52) "Uganda: Mapping of Maize Millers: A Road Map to Scaling Up Maize Flour Fortification," USAID - Strengthening Partnerships, Results and Innovations in Nutrition Globally (SPRING), (2017): https://publications.jsi.com/JSIInternet/Inc/Common/_download_pub.cfm?id=19153&lid=3

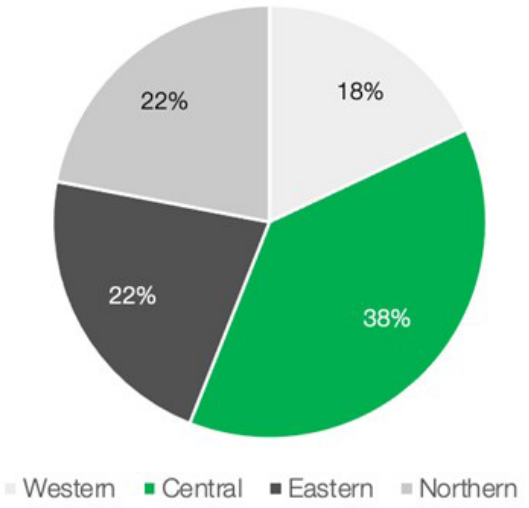
TABLE 6. Key market actors in the grain processing value chain[53]

MARKET ACTOR	DESCRIPTION	
Farmers	May be a smallholder farmer, organised group or large-scale farmer.	
Organized farm group	Any formal farming group that conducts activities together, usually including bulking, milling and selling. Examples include cooperatives, associations, rural production organisations and marketing groups.	
Middlemen	Small Middleman	Has a bicycle or motorcycle. May bulk in own store or house or may sell immediately.
	Large Middleman	Has a pick-up or tipping truck. May bulk in own store or sell immediately. Contracted Buyers are a subset of middlemen who make prior contracts with farmers about the quantity and price of purchase.
Large-scale traders/exporters	These traders usually have lorries or trailers. They buy/sell in the national market and the regional market (Kenya, Rwanda, South Sudan and Tanzania).	
Small-scale and large-scale processors	Any entity involved in threshing/cleaning/milling activities.	
Markets	Main markets are bigger in scale, while local markets (permanent or weekly) are smaller but closest to the villages.	
Local shops	Local shops where household goods are sold.	
Supermarkets	Large grocery stores, usually found in cities like Kampala, Jinja, Entebbe. Products found in their processed form or packaged.	

Source: USAID, 2019.

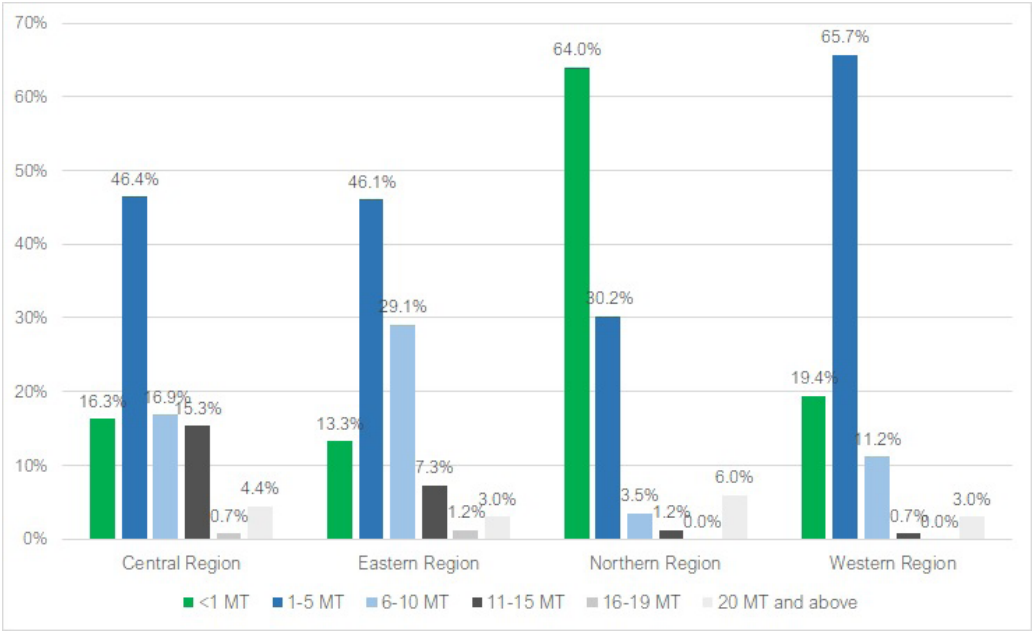
53) USAID, 2019.

FIGURE 5. Percentage of maize millers by region, 2017



Source: USAID - Strengthening Partnerships, Results and Innovations in Nutrition Globally (SPRING), 2017.

FIGURE 6. Production capacity of maize millers by region, 2017



MT = Metric tonnes
Source: USAID - Strengthening Partnerships, Results and Innovations in Nutrition Globally (SPRING), 2017.

The capacity of maize mills typically ranges from 1 to 20 metric tonnes (MT) per day and is determined by the motor's horse-power (1-100 Hp). Most mills have a production capacity of 1 to 5 MT per day. Millers in the Central and Western Regions of Uganda tend to own larger machines (75 to 100 Hp) compared to millers in the Eastern and Northern Regions, who typically operate smaller machines (40 Hp and below).[54] Due to a lack of the grid electricity, the majority of millers in the Northern Region use diesel-powered machines with outputs below 1 MT per day that are usually preferred due to their low capital costs.

Solar mills are suitable for locations with predictable sunshine hours. Because of their modularity, solar panels can be sized to meet farmers' needs.[55] In Uganda, standalone solar milling machines of 1.5 to 2.2 kWp that can process 32 kg per hour (140 kg per day, 55 MT per year) are still being piloted to test their technical and commercial viability.[56] For off-grid farmers and small-scale mill operators that produce on average 300kg of flour per day in the Eastern and Northern Regions, solar mills present a possible alternative if the technology can become competitive (greater throughput and reduced price), eliminating reliance on diesel fuel. Farmers that adopt solar mills can benefit from reduced operational costs, savings of time and money to travel to purchase fuel, reduced flour contamination from diesel spills, and improved air quality associated with fuel switching from diesel.[57]

TABLE 7. Comparison of available options for maize milling in Uganda

CATEGORY	DIESEL MILL	ELECTRIC MILL	RETROFIT MILL	SOLAR MILL
Details	Driven by a diesel-powered engine that is coupled to the mill.	Driven by an AC induction motor coupled to the mill via a belt	The existing mill's diesel engine is replaced with an electric motor	Driven by a solar PV system powered AC or DC motor
Availability	Most common in areas without electricity	Most common in electrified areas (also used on mini grids)	Not common (piloted by JUMEME on their mini grids in Tanzania)	Being developed
Power rating (kW)	7.5 – 17.5 kW	7.5 – 15 kW	7.5 – 15 kW	1.5 – 2.2 kW
Estimated cost (USD)	1,000	2,000	500	2,500
Av. throughput (kg/hour)	120 – 150	120-150	Currently not available	32

Source: Energy4Impact and Efficiency for Access Coalition, 2020.

Although solar powered mills have all the aforementioned benefits, they are still not yet commercially viable or competitive with diesel alternatives. The capital cost of acquiring the mill and its energy system remain major barriers to market entry, as is the limited throughput. There have been recent technological improvements that are promising; in 2022, AGSOL developed a solar powered maize mill that is able to achieve higher throughput at lower up-front cost.[58]

54 "Uganda: Mapping of Maize Millers: A Road Map to Scaling Up Maize Flour Fortification," USAID - Strengthening Partnerships, Results and Innovations in Nutrition Globally (SPRING), (2017): https://publications.jsi.com/JSIInternet/Inc/Common/_download_pub.cfm?id=19153&lid=3

55) "Decentralised Solutions in the Agri-Food Chain," International Renewable Energy Agency (IRENA), (2016): https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Decentralised_solutions_for_agrifood_chain_2016.pdf

56) Dalberg Advisors, Lighting Global and World Bank, 2019.

57) Energy4Impact and Efficiency for Access Coalition, 2020.

58) AGSOL Micro Mill: https://agsol.com/wp-content/uploads/2022/09/Agsol-MicroMill-Spec-Sheet.pdf

3.2 DAIRY

The dairy sector is a vital source of livelihood for about 25% of Ugandan households, mainly smallholder farmers in rural areas who own an estimated 14.2 million cattle. In 2018, cattle accounted for about three-quarters of the country's total livestock and contributed to 17.3% of agricultural GDP.[59] Most milk production takes place on smallholder farms in rural areas with a few medium and large-scale farmers that own 50 heads of cattle and above.[60] The growth of the dairy sector to its full potential is constrained by limited access to markets, mainly due to poor road infrastructure in rural areas, which inhibits collection and processing of the milk.[61]

Annual milk production increased from 0.75 billion litres in 2002 to 2.8 billion litres in 2020 – an increase of 373%. This trend can largely be attributed to an increase in the number of cattle and expansion of milk collection centres across the country, resulting in reduced waste.[62] The milk industry earned EUR 187M in exports in 2020, which was second only to revenue from Uganda's robust coffee industry in that year.[63] It is estimated that export earnings could more than double to EUR 456M if challenges facing the sector are overcome, including limited access to electricity in milk producing areas, insufficient cold chain infrastructure, the high death rates of exotic cattle attributable to tick-borne diseases (and resistance of the ticks to available acaricides), limited access to extension services and low levels of investment in feed resources, among others.[64]

An opportunity exists to stimulate electricity demand in the agricultural sector, which employs about 70% of the working population. Solar powered cold rooms, ice makers and refrigerators can support a wide range of industries, including cold storage of milk and dairy products and agricultural produce in general, which would reduce post-harvest losses and increase farmer income.

Table 8 describes the key market actors in Uganda's dairy value chain.[65]

59 Uganda Bureau of Statistics (UBOS) 2018 Statistical Abstract: https://www.ubos.org/wp-content/uploads/publications/05_2019STATISTICAL_ABSTRACT_2018.pdf

60 "Sustainable Energy for Smallholder Farmers in Ethiopia, Kenya and Uganda: Baseline Study and Market Assessment," EnDev, (2021): https://endev.info/wp-content/uploads/2022/01/SEFFA_Baseline_Study_2021.pdf

61) "Uganda's Dairy Farmers Develop Taste for New Markets," International Finance Corporation, (August 2019): https://www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+events/news/impact-stories/uganda-dairy-farmers-develop-taste-for-new-market

62) Dairy Development Authority Annual Performance Report FY 2019/20: https://dda.go.ug/assets/files/ANNUAL-PERFORMANCEREPORTFY2019-20.pdf

63) "Dairy exports jump 63 percent in three years," Ministry of Agriculture Animal Industry and Fisheries (MAAIF), (July 6, 2021): https://www.agriculture.go.ug/dairy-exports-jump-63-per-cent-in-three-years/

64) Abdallah, H., "Uganda dairy sector performing below full potential," The East African, (June 19, 2019): https://www.theeastafrican.co.ke/tea/business/uganda-dairy-sector-performing-below-full-potential-1420518#

65) Balikowa, D., "A Review of Uganda's Dairy Industry," Food and Agriculture Organization of the United Nations (FAO), (March 2011): http://www.fao.org/3/a-aq292e.pdf

TABLE 8. Key market actors in the dairy value chain

MARKET ACTOR	DESCRIPTION
Farmers	— It is estimated that 1.2 million smallholder farmers are involved in dairy farming with about 8,000 large farms. The Southern Region has 22.3% of the cattle and has the highest milk production. Farmers are organized into 367 milk producer cooperatives (98 of them operating in the Southern Region) that buy milk from the farmers and sell to processors.[66] — The Uganda Crane Creameries Cooperative Union is the country's largest cooperative union bringing together cooperatives from nine districts in the Southern Region. Other regions have primary cooperatives that operate individually. The cooperatives collect, bulk and supply milk to processors through both formal and informal channels.
Processors	— As of 2019, 135 licensed companies were operational with capacity to process 2.8 million litres per day. There are 13 large-scale and numerous small-scale cottage processors producing powdered milk, pasteurised milk, ghee, yoghurt, ice cream, fermented milk, cheese, casein/whey, among others. As of 2020, an estimated 34% of marketed milk was processed.
Traders	— These include motorcycle, bicycle traders/vendors, the middlemen "abushunda" who are very influential and control a big part of the milk market. They include collection point traders/processors agents and the insulated milk tanker wholesale buyers/operators/transporters.
Transporters	— These include motorcycle and bicycle traders/operators, the collection point traders and the insulated milk tanker operators.
Input service providers	— These include suppliers of pasture seeds, animal health products and feeds, processing equipment, packing materials, artificial insemination, veterinary, extension and business development services.
Government agencies	— The Dairy Development Authority (DDA) is the government agency under the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) that is mandated to develop, regulate and provide coordination for the implementation of policy for the industry. — The National Agricultural Advisory Services (NAADS), in conjunction with the DDA, supports the sector through the provision of milk coolers and ancillary equipment for farmers. NAADS also provides improved dairy cattle breeds, artificial insemination kits, improved seeds, agribusiness training, as well as capacity building to farmer groups and cooperatives.
Support agencies	— These include development and civil-society organizations providing financial and technical support to the dairy industry. Examples include, SNV, Heifer International, ABI Trust, Send A Cow (UK), etc.

66) EnDev, 2021

Figure 7 is a map of the six national milk sheds of Uganda.[67]

FIGURE 7. National milk sheds of Uganda

Source: Dairy Development Authority; Wozemba and Rashid, 2008.

Types of grazing in Uganda

Free range grazing involves moving cattle all over the farm without any restrictions. This is the traditional practice in grasslands common in the cattle sheds. The farmland is often not paddocked but the boundaries are fenced with a local plant. The daily routine of open grazing is morning milking, grazing, watering, evening milking and late evening grazing. This system is being phased out due to land scarcity as the population increases.

Zero grazing refers to the confinement of a few animals in a small enclosure where fodder and water are brought and fed to the animals with no outdoor grazing.

Fenced/paddock grazing is common in areas where the land holdings are fairly small. Plots of land are fenced off in paddocks and planted with improved pastures.

In **communal grazing**, pastoralists graze their cattle on communal land usually owned by the family clan. It is mainly practiced in the Northern Region.

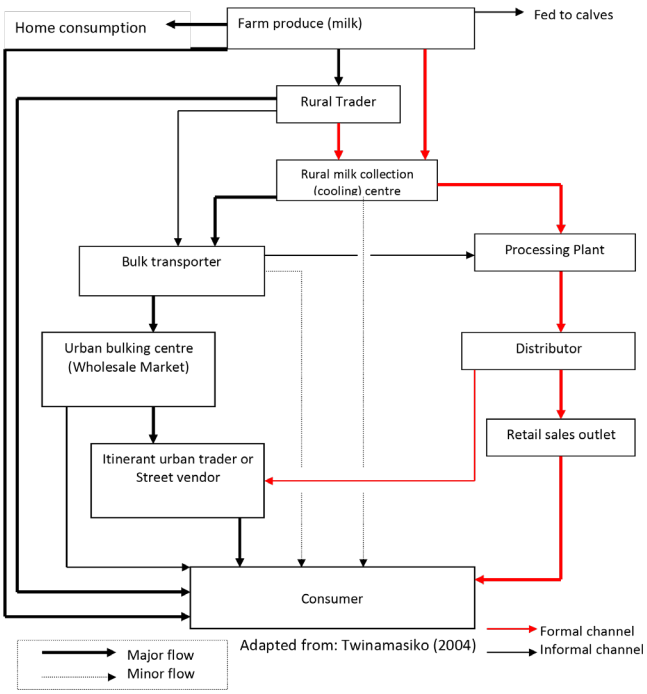
Smallholder farmers dominate the sector, owning over 90% of the cattle. Most milk production takes place in the Southern and Central Regions of Uganda, with lower rates of production in the Eastern and Northern Regions, where cattle are reared mainly for beef. **Table 9** lists some of the large-scale milk processors in Uganda and the respective regions of the country they operate in.

67) Balikowa, 2021.

TABLE 9. Large-scale milk processors in Uganda

MILK PROCESSOR	DISTRICT/REGION OF OPERATION
Amos Dairies Ltd	Kiruhura, Western Region
Brookside Ltd/Fresh Dairy	Kampala, Central Region
Jesa Farm Dairy Ltd	Kampala/Wakiso, Central Region
Lakeside Dairy Ltd	Mbarara, Western Region
Paramount Dairies	Kampala, Central Region
Pearl Dairies	Mbarara, Western Region
Premier Dairies Ltd	Kampala, Central Region
Royal Milk Enterprises Ltd	Kampala, Central Region
Vital Tomosis Dairy Ltd	Mbarara, Western Region

FIGURE 8. Marketing channels in the milk value chain[69]



Source: Dairy Development Authority; Balikowa, 2011; Wozemba and Rashid, 2008

Milk value chain in Uganda

The value of the total marketed milk, both formal and informal, is approximately EUR 775M, which accounts for about 80% of the total milk produced. Export destinations include the Common Market for Eastern and Southern Africa (COMESA) region, the Middle East, Japan, USA, Nepal and Bangladesh. The various products exported include casein, whey protein powder, ultra-high temperature (UHT) milk and milk powder, while pasteurised milk, ghee, yoghurt, cream, ice cream, fermented milk and cheese are sold to consumers on the local and regional markets. Imports include buttermilk, infant formula, milk powder, assorted ice cream and cheese. The long-term strategy of the DDA is to substitute imports with locally processed products.[68]

Milk is marketed through both formal and informal channels. The latter refers to the traditional way of marketing in which raw milk is procured from farmers and sold directly to consumers without any form of processing and/or packaging. A small fraction of milk is consumed on the farm with direct sales to consumers in the neighbourhood common.

Most of the milk is collected from farmers and stored at collection centres operated by dairy cooperatives, private individuals, companies, and processors. In 2020, there were 483 public and private collection centres with a total installed handling capacity of 1.9 million litres of milk. The DDA is in the process of rehabilitating 40 collection centres that were inherited from the privatised government Dairy Corporation.

From collection/bulking centres, milk is transported and sold through a wide range of informal operators that include middlemen, agents, small-scale rural traders, itinerant urban traders and large-scale bulk transporters/wholesalers handling less than 300 litres/day to 30,000 litres/day of chilled milk.

Transportation cooling capacity has increased in recent years from 1.6 million litres in 2015 to 2.16 million litres per day in 2019. Milk is transported through formal channels to large-scale processors located in the Southern and Central Regions, who process it for sale to the domestic, regional and international markets.

68) Dairy Development Authority Annual Performance Report FY 2019/20: https://dda.go.ug/assets/files/ANNUAL-PERFORMANCEREPORTFY2019-20.pdf
69) Balikowa, 2011.

Table 10 summarizes milk production, collection and processing capacities by region.

TABLE 10. Milk production, collection and processing capacities by region, 2019[70]

REGION	TOTAL MILK PRODUCTION	NO. OF MCCS	TOTAL MCC INSTALLED CAPACITY (LITRES)	TOTAL PROCESSING CAPACITY (LITRES)
Central	30%	86	234,330	821,970
Eastern	19%	16	35,107	1,900
Mid-Western	<10%	57	197,800	550
Northern		20	70,700	2,815
Northern		15	39,300	1,900
Southern	42%	289	1,361,285	2,054,810
Total	100%	483	1,938,522	2,892,945

MCC = Milk Collection Centre
Source: Dairy Development Authority

Apart from the Southern Region, which has a high population of dairy farmers and a high density of Milk Collection Centres (MCCs), there are relatively few collection/cooling centres in the other regions of Uganda. As a result, farmers or traders/agents must travel long distances (about 30 km) to access the nearest milk cooling centre, which increases the risk of milk going bad.

There is potential to increase the capacity of milk cooling and storage by adding MCCs in the Central and Eastern Regions and by expanding capacity in the Southern Region. A significant market opportunity exists for solar systems to provide power to new MCCs and to replace diesel generators at existing MCCs throughout the country.[70]

70) This is examined in further detail in **Section 4 (Route-to-Market)**.

3.3 FISHERIES

Uganda has an abundance of freshwater lakes and rivers with a rich diversity of fish species and is one of the world's largest producers of freshwater fish. Major fish sources include Lakes Victoria, Albert, Kyoga, Edward, George and Wamala and the Albert Nile River Basin. Lake Victoria is the world's second largest freshwater lake and the country's largest water body, contributing to about half of captured fish and 80% of the fish that is exported. Fish from Lake Victoria have the highest economic value, particularly Nile Perch and Nile Tilapia, compared to the lower economic value of Muziri and Ragoogi, the dominant fish of Lake Albert. Other fish species of commercial value include catfish, lung fish, and mukene (small silver fish).[71]

Uganda has the capacity to produce about 450,000 metric tonnes per annum (MTPA) from capture fisheries; however, this is a low estimate, as the production from many lakes is not well documented.[72] The maximum sustainable yield (i.e., the maximum sustainable catch without harmfully depleting the fish population) is estimated at 600,000 MTPA, although current over fishing practices suggest that reaching this level will be a huge challenge.[73] There is significant potential for aquaculture to lower the deficit as it currently contributes about 20% of total fish harvest. Fish and fish product imports have increased over the years, although these are not well documented.[74]

The fisheries sector employs about 1.5 million people along the production, marketing, and trading value chains. Women are mainly employed in fish trading, fish processing, and preservation activities that include sun drying, salting, frying and fish smoking in kilns.[75]

There are hundreds of off-grid islands with isolated communities in Lake Victoria, the majority of which do not have access to electricity. The lake also has hundreds of landing sites, many of which are not connected to the electricity grid and do not have any kind of cold storage facilities (**Table 11**). To provide cooling for the harvested fish, improvised wooden boxes are used with or without ice, which is usually sourced from the nearest ice-production facility or fish factory at relatively high prices.[76]

TABLE 11. Number of landing sites and storage facilities with access to electricity and cold storage on Lake Victoria, 2020

INDICATOR	TOTAL NUMBER	PERCENTAGE
No. of landing sites	455	100%
No. of sites with storage facilities	50	11%
No. of landing sites with access to electricity	87	19%
No. of sites with operational cold rooms/ice making facilities	6	1.3%

Source: Uganda Fish Processors and Exporters Associations

71) National Fisheries Resources Research Institute, 2013.
72) Ibid.
73) "Integrating Natural Capital into Sustainable Development Decision-Making in Uganda: Fisheries Resources Accounts for Uganda," National Environment Management Authority (NEMA), (March 2021): https://www.unep-wcmc.org/system/comfy/cms/files/files/000/001/895/original/Fisheries_Resource_Accounts_for_Uganda_Final_Report_June_2021.pdf
74) National Fisheries Resources Research Institute, 2013.
75) Ibid.
76) Stakeholder interviews, 2022.

TABLE 12. Supply of fish by water body in Uganda (tonnes per year)

YEAR	LAKE VICTORIA	LAKE ALBERT	LAKE KYOGA	LAKES EDWARD, GEORGE AND KAZINGA CHANNEL	LAKE WAMALA	ALBERT NILE RIVER BASIN	MINOR LAKES AND RIVERS	PONDS AND CAGES	TOTAL SUPPLIED
2010	162,930	55,810	1,700	4,500	5,600	5,200	10,300	100,000	**346,040**
2011	175,820	163,950	61,590	5,300	75,110	5,000	7,080	83,000	**576,850**
2015	238,630	149,040	41,770	6,350	4,190	5,120	9,770	117,600	**572,470**
2016	252,800	148,160	40,710	6,640	3,960	5,380	9,880	117,841	**585,371**
2018	138,040	148,640	40,130	3,070	4,300	2,790	8,820	120,000	**465,790**

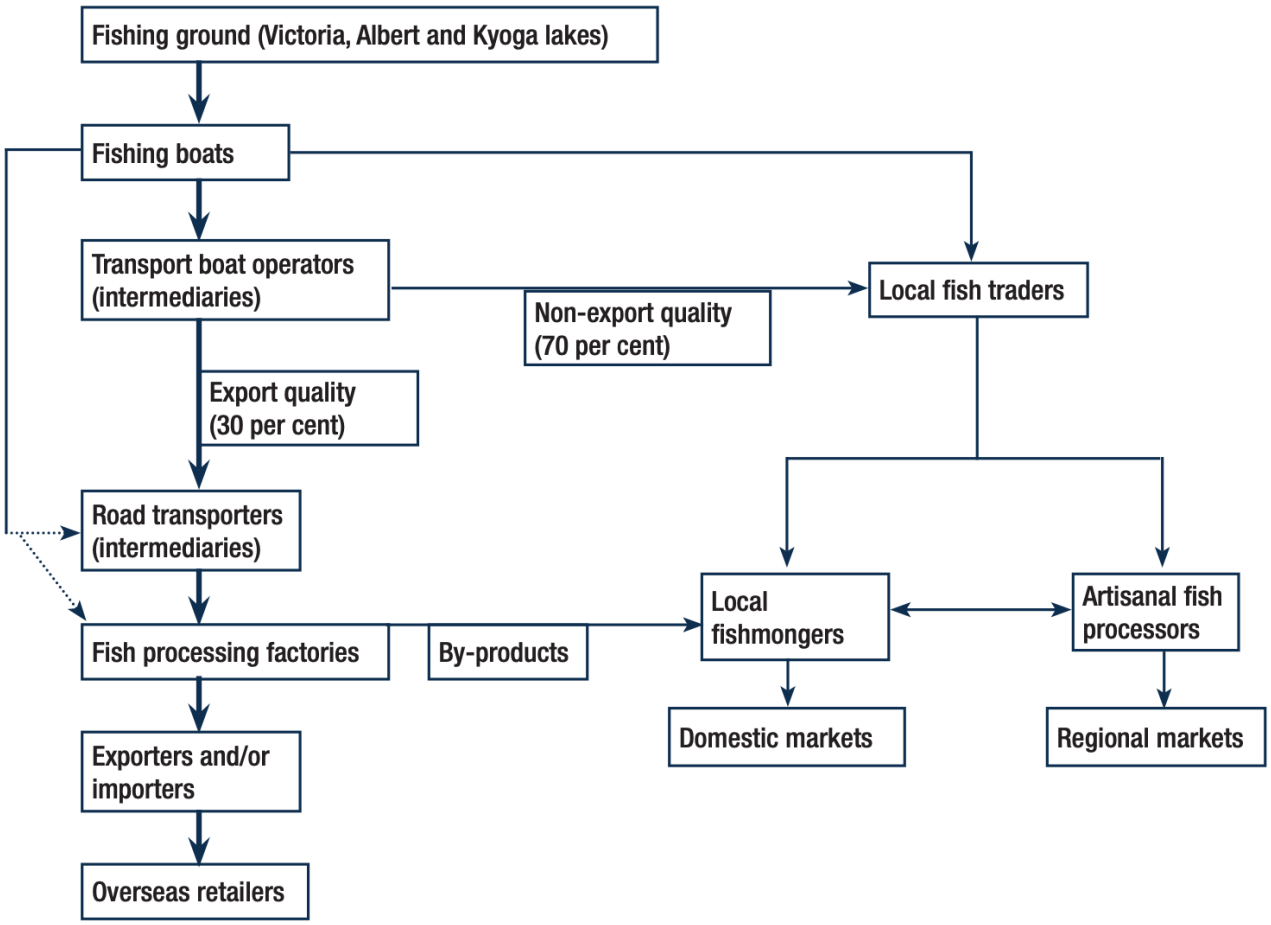
Source: National Environment Management Authority, 2021.

Fishing on all lakes and rivers is done by artisanal fisherfolk, while traders and agents of fish processors source all their fish from these small-scale fisherfolk. After fish harvests have reached the landing sites, export quality fish is sorted out and transported to processing facilities. Lower grade and undersized Nile Perch and Tilapia are then sold to a series of traders, agents and artisanal processors operating at landing sites before they reach the final consumers. The fish is transported to major domestic fish markets and through various traders to regional markets in Kenya, Rwanda, South Sudan and Tanzania using different methods of transportation, including bicycles, motorcycles, un-refrigerated and refrigerated trucks.

Figure 9 presents an overview of the fish product value chain in Uganda.[77]

77) "Fishery Exports and the Economic Development of Least Developed Countries: Case Study: Uganda," United Nations Conference on Trade and Development (UNCTAD), (August 2017): https://unctad.org/system/files/official-document/aldc2017d2_ch09_en.pdf

FIGURE 9. Fishery product value chain



Source: UNCTAD, 2017

Table 13 describes the key market actors in Uganda's fisheries value chain.

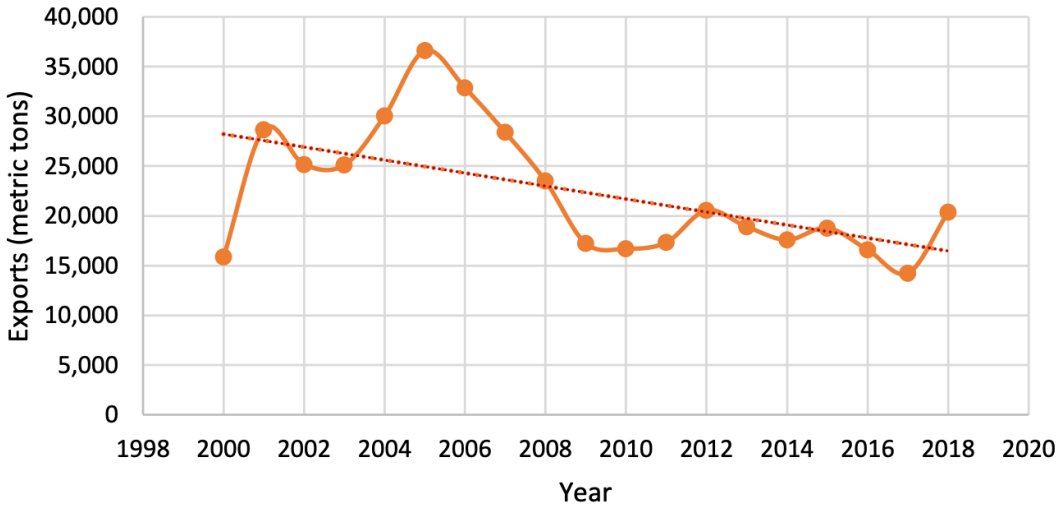
TABLE 13. Key market actors in the fisheries value chain

MARKET ACTOR	DESCRIPTION
Directorate of Fisheries Resources (DFR)	— The Directorate of Fisheries Resources (DFR) in the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) regulates activities in the fisheries sector. It is charged with formulating, promoting, developing and enforcing standards and regulations for the fish industry. — The government, with EU support, works with fish processing companies to develop legislation and standards to strengthen quality testing systems for the sector.
National Fisheries Resources Research Institute (NAFIRRI)	— NAFIRRI is a government agency with the mandate of conducting strategic research in capture fisheries, aquaculture, water environment, socio-economics and any other emerging issues in the fisheries sector.
National Environment Management Authority (NEMA)	— The National Environment Management Authority (NEMA) is a semi-autonomous institution under the Ministry of Water and the Environment with the responsibility of coordinating, monitoring, regulating and supervising environmental management in the country. It leads the development of policies, laws, regulations, standards and guidelines for the environment.
Uganda Fish Processors & Exporters Association (UFPEA)	— The UFPEA was founded in 1993. Over the years, the industry has had challenges arising from declining fish stocks as a result of overfishing and unsustainable fishing practises that have led to closure of some plants. — To date, 11 plants are operational, mainly processing Nile Perch for export. Some processors are not members of UFPEA, operating mainly in Kampala (including Icemark-Africa Ltd, Uganda Fish Packers Ltd, Ngege Ltd and Gomba Fishing Industries Ltd.); Byansi Fisheries Co. Ltd is based in Rakai District.
Association of Fishers and Lake Users of Uganda (AFALU)	— The AFALU is the umbrella organization for people employed in the fishing industry including, among others, fisherfolk, fish traders/dealers, fish input dealers, and fishing associations.
Beach management units	— In partnership with the DFR and the relevant local government agencies, Beach Management Units are responsible for the health and safety of the various stakeholders using the lakes, especially fisherfolk, as well as protection, coordination, and management of the local fisheries resources in their jurisdiction.
Small and large-scale middlemen/ traders	— Traders may bulk in their own cold store or sell immediately. Contracted agents/traders are middlemen who buy agreed quantities or make prior contracts with fisherfolk.

Fish processing and export

The liberalisation of the fishing industry in 2001 and the Amendment to the Fishing Act in 2014 advanced the sector's development in recent years. Nile Perch from Lake Victoria dominates exports; hence, the DFR bases its export records on Nile Perch. Between 2009 and 2019, fish exports increased by 35.7% (**Figure 10**), while the value of fish exports fluctuated between EUR 91M and EUR 164M per year during this period. In 2018, Uganda earned EUR 140M from the export of 20,364 tonnes of fish and fish products to regional and international markets, an increase of 33% from EUR 105M in 2016.

FIGURE 10. Trends In fish product exports In Uganda, 1998-2020



Source: NEMA, 2021

Fish products exported include fresh fish, chilled and frozen fish, dry/smoked fish, fish maws, fish meal, fish oil, fish skins and live (ornamental) fish. About 75% of exports go to the EU.[78] Other destinations include the Middle East, Singapore, China, Japan, USA and the Common Market for Eastern and Southern Africa (COMESA) region. The most common fish export is Nile Perch, while fresh tilapia, lungfish and catfish are sold in Uganda and in regional markets as cured, salted, smoked and sun-dried fish.

Although the export value has increased over the years, the volume of fish caught has declined due to over-exploitation of the lakes and illegal fishing practices. Fish farming, though not well developed, has provided additional supplies as natural stocks decline.

Table 14 lists members of Uganda's Fish Processors and Exporters Association.

78) NEMA, 2021.

TABLE 14. Members of the Uganda Fish Processors and Exporters Association

NO.	PROCESSOR	LOCATION
1	Aqua Perch Limited	Kampala
2	Fresh Perch Ltd	Entebbe
3	Port Side Fish Company Ltd	Kampala
4	Greenfields (U) Limited	Entebbe
5	Karmic Foods Limited	Entebbe
6	Lake Bounty Limited	Kampala
7	Lake Perch Limited	Entebbe
8	One to Fish Limited	Kampala
9	Lake Eco Fish Processing Ltd	Entebbe
10	Iftra (U) Limited	Kampala
11	Nyanza Perch Limited	Jinja

3.4 FRUITS AND VEGETABLES

Uganda's favourable climate and soil conditions give the country a competitive advantage for producing various agricultural products nearly year-round. According to the Food and Agriculture Organisation of the United Nations (FAO), Uganda is the second largest producer of fresh fruits and vegetables in sub-Saharan Africa (after Nigeria), with about 5.7 million tonnes of produce each year, with fruits contributing about 70% of the total production.[79] In 2019, the World Bank estimated that production from the agricultural and fisheries sectors contributed 24.2% to the country's GDP.[80] About 500,000 smallholder farmers grow several types of fruits and vegetables in different parts of the country based on local climatic conditions.

Commercial fruit production began in the late 1960s with the opening of three government processing facilities in the Eastern Region. To date, a total of 10 grid-connected juice processing factories are operational.[81] The government is working with the private sector to support the establishment of three more processing plants, one in each of the Eastern, Northern and West Nile Regions, with capacity to process approximately 500,000 tonnes of fruits per day.[82] This is intended to boost local fruit production from the local farming communities.

There are significant post-harvest losses of agricultural produce before it reaches the market. This challenge is not unique to Uganda, as the FAO estimates that post-harvest losses in sub-Saharan Africa amount to EUR 3.6B annually, with the majority of the losses occurring at the post-harvest stage before the produce reaches a point of sale. The leading causes for post-harvest losses include a lack of cold storage facilities in the value chain as well as insufficient agro-processing capacity coupled with the lack of technical skills.

As a solution to spoilage, solar PV applications powered by stand-alone systems deployed in rural off-grid areas can provide electricity for the required cold chain infrastructure. Solar technology has been utilised for irrigation to offer rural farmers a cost-effective and sustainable solution that reduces their reliance on rain-fed agriculture and diesel alternatives. This has enabled them to grow high value crops and improve their yields.[83]

Fruit and vegetable production is undertaken by a range of different farmers that include small-scale household farmers, contract farmers, large and medium-scale growers, who then sell their harvested produce to local traders/middlemen for sale in local rural and urban markets, as well as to aggregators and agents of processors and exporters. Depending on their business model, off-takers/aggregators, processors and exporters are all potential clients for commercial cold storage facilities.

Typically, before the harvested produce is transported to the markets, it is sorted to eliminate low-quality fruit and vegetables. A large percentage of the low-grade produce rots and is discarded with a small fraction processed into juices that are sold in the domestic market. High-quality fruits and vegetables are sold in large urban markets, high-end grocers and to big supermarkets.[84] Processing of vegetables, like tomatoes, is quite limited with most processed products imported.

79) EnDev, 2021.
80) World Bank Data and Uganda Bureau of Statistics, 2018.
81) Stakeholder interviews, 2022.
82) Uganda National Agricultural Advisory Services (NAADS): https://naads.or.ug
83) "Productive Use of Energy in Uganda: Learning from the Uganda Off-Grid Energy Market Accelerator (UOMA)," Uganda Off-Grid Energy Market Accelerator; USAID, (October 2020): https://uoma.ug/wp-content/uploads/2020/10/UOMA-PUE-white-paper.pdf
84) Stakeholder interviews, 2022.

With no cold chain infrastructure for direct use by farmers, traders or their agents, exporters (mainly to Europe and the Middle East) have to quickly transport the produce to their pack houses, which also lack sufficient cold storage facilities. The produce is graded and packaged according to export standards before it is transported to larger cold storage facilities at Entebbe International Airport. Multiple players in the value chain depend on the airport's cold chain facilities that are located far away from the farm gate where they are needed most.[85]

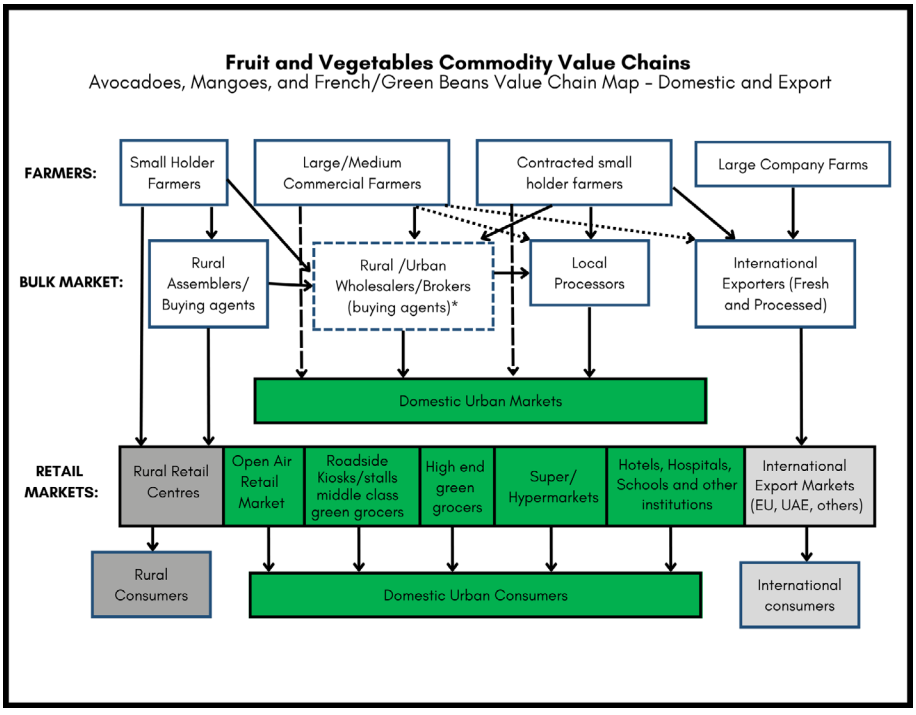
Uganda's geographic location in the Great Lakes region gives it a unique advantage of having access to a regional market of over 150 million consumers. Between 2016 and 2020, Uganda exported an average of 400,000 tonnes of fruits and vegetables valued at EUR 88M per year.[86] The main exports to the region include bananas, pumpkins, oranges and tangerines, lemons, pineapples, and watermelon, while the major exports to the EU and Asia are dried hot peppers and garden eggs.[87]

Figure 11 presents the fruit and vegetable value chain in Uganda.

Exports to the EU have recently been hampered by stringent EU market entry regulations, namely the absence of facilities for monitoring chemical use on farms, the lack of adequate packing material, a lack of traceability and certification practices. In addition, several exporters do not have sufficient packing and storage facilities and often buy their produce on the open market.[88] A small number of factories are currently engaged in juice extraction and several in fruit and vegetable drying.[89] A large fraction of processed juice has to be imported to meet the local demand.

Imported fruits include apples, mangoes, grapes, oranges, pears and strawberries, mainly from South Africa, and dates from the Middle East. Imported vegetables include carrots, turnips, potatoes, onions, cow peas, beans, green peas and garlic. Exports in the form of fresh, chilled and dried fruits and vegetables surpass the value of imports (estimated at EUR 23M).[90]

FIGURE 11. Fruits and vegetables value chain



85) Dijkxhoorn et al., 2019.
86) https://comtrade.un.org
87) EnDev, 2021
88) Dijkxhoorn et al., 2019.
89) Stakeholder interviews, 2022.
90) EnDev, 2021.

Table 15 describes the key market actors in Uganda's fruits and vegetables value chain.

TABLE 15. Key market actors in the fruits and vegetables value chain

MARKET ACTORS	DESCRIPTION
Farmers	— There are about 500,000 smallholder farmers producing fruits and vegetables, many organized into cooperatives and associations that assist farmers in aggregation and accessing markets. — The main production districts include: Luweero, Masaka, Mubende, Mukono, Mpigi and Wakiso in the Central Region; Bushenyi, Isingiro, Kabale, Kasese, Kiruhura, Mbarara, in the Western Region; Iganga, Kamuli, Mbale, Soroti in the Eastern Region; Kapchorwa in the Northern Region.[91]
Exporters and producers associations	— The horticulture sector is represented by several associations, including the Uganda Fruits and Vegetables Exporters and Producers Association (UFVEPA); the Uganda Horticulture Exporters and Processors Association (UHEPA); and Horti Fresh, formed as an apex body for the sector. — UFVEPA is the largest association, representing more than 50 stakeholders, while UHEPA has about 12 members. The more ardent exporters have their own production fields, have out-growers who they offer technical support, including inputs, and have their own packing facilities. There are 65 registered exporters of fresh and processed fruits and vegetables in the country.[92]
Small and large-scale traders and middlemen	— Traders may bulk in their own store or sell immediately. — Traders, contracted buyers or middlemen make prior contracts with farmers/farmer groups about the quantity and price of purchase
National agricultural and advisory services	— The sector is supported by NAADS, a specialised agency of the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF). It provides quality inputs and improved crop varieties to farmers and develops commodity value chains that improve food security and household income.
Uganda National Bureau of Standards	— Government agency responsible for development and enforcement of food standards

91) EnDev, 2021.
92) Dijkxhoorn et al., 2019.

SECTION 4

Route to Market

4.1 INVESTMENT OPPORTUNITIES AND MARKET SIZING

This section explores the "Route-to-Market" – i.e., how to leverage the market research presented in this Guide to start up a renewable energy business in Uganda's food industry.

4.1.1 GRAIN PROCESSING

Current solar mills of 1.5 to 2.2 kWp capacity producing an average of 300-500 kg of flour per day will be attractive to smallholder farmers and mill operators who produce less than 1 MT per day. Solar mills can be acquired by technology developers in the East Africa region by small-scale millers without electricity access/grid presence mainly in Uganda's Eastern, Western, and Northern Regions who are currently using diesel-powered mills of low capacity (10 Hp and below). Mills are primarily used for maize but are also used for cassava and mille, as well as fibre processing. A solar mill can produce 45-75 kg of maize flour per hour. It can produce about half this volume of cassava, while millet has about double the throughput of maize.[93]

Based on current technologies, solar mills can only be used for milling maize, cassava, millet and sorghum. Investment in complementary appliances, such as threshers and dehullers, are needed to prepare the feedstock for milling. Maize can be consumed as whole grain without removing the husks before milling, although flour without the husk is preferred in Uganda.

Based on the assumptions provided in the **Annex 1**, through 2030, the estimated value of the serviceable market for solar mills in Uganda is EUR 47.1M (21,168 mills sold at EUR 2,225).

4.1.2 DAIRY

The Dairy Development Authority (DDA) estimates that poor handling of milk at the farmer production stage and insufficient cold chain infrastructure in milk producing districts leads to about 20% post-production losses. Opportunities exist for the private sector to invest in milk collection/bulking and cooling facilities to reduce these losses and to develop new supply chain infrastructure, including new processing capacity to increase the quantity of milk marketed through formal channels. The milk value chain has seen little PUE market development to date, largely due to the significant investment needed to supply the sector's high power requirements.

To expand milk collection capacity, in its Strategic Plan 2021-2025, the DDA plans to install an additional 105 Milk Collection Centres (MCCs) throughout the country – 50 of them in the Southern Region.[94]

Based on the assumptions provided in the **Annex 1**, through 2030, the estimated value of the serviceable market for large walk-in cold storage units[95] for the dairy sector in Uganda is EUR 11.5M, while the estimated value of the serviceable market for small cooling solutions is 126M. Combined, the market for cold storage solutions is estimated at EUR 137.5M.[96]

4.1.3 FISHERIES

The majority of landing sites and remote islands on the lakes do not have access to electricity and have no ice making or cold storage facilities. Usually, fish traders at the sites near Kampala, Jinja and Entebbe procure the ice from ice making and fish processing plants in those three cities. Solar PV mini-grids and standalone solar systems can provide the quickest and most cost-effective energy services to these typically isolated fishing communities.

Solar energy can support the establishment of cold storage and ice making facilities at landing sites. To keep the fish fresh, solar powered cold boxes are needed by fisherfolk on their boats, as well as by traders at the landing sites, transporters and market vendors. This will facilitate the establishment of a fully integrated cold fish supply chain, thus improving the quality of fish supplied to the domestic markets and the capacity of processing facilities.

Based on the assumptions provided in **Annex 1** through 2030, the estimated value of the serviceable market for solar coolers, ice makers for cold chains in fish transportation, freezers and refrigerators is EUR 21M (representing 1,400 cold storage or ice making units). Additionally, there is a market for smaller fridges for traders and vendors at hundreds of landing sites and markets.

93) Energy4Impact and Efficiency for Access Coalition, 2020; based on AGSOL prices.

94) DDA Strategic Plan III, 2020/21-2024/25

95) Also known as 'walk-in cold rooms' or large milk chillers.

96) To realize this market potential, however, current R&D needs to develop stirring mechanisms for the milk placed in walk-in cold storage units.

4.1.4 FRUITS AND VEGETABLES

Most fruit growing districts are located in rural areas without access to electricity. In addition, traders, processors and exporters do not have sufficient cold storage facilities. Investment in cold storage infrastructure along the value chain is critical to reducing spoilage, especially at the farm gate level and at aggregation centres.

With a favourable climate and good soils in many parts of the country, most fruits and vegetables are available year-round, especially if crops are irrigated during the dry seasons. Pineapples, passion fruits, mangoes, bananas, and citrus fruits are the most widely developed fruit crops, and avocados, passion fruits, bananas and pineapples are grown and harvested year-round. Vegetables, including tomatoes, onions, beans, peas, peppers and hot chillies, are produced in two seasons, which can be extended with irrigation.

Based on the assumptions provided in the **Annex 1** through 2030, the estimated value of the serviceable market for walk-in cold storage facilities is about EUR 30M (representing 1,330 walk-in cold storage facilities). This figure would be significantly higher if the units were installed near the horticulturists and they were offered the opportunity to Pay-As-You-Store.[97] Smaller 100-200 litre solar cold storage equipment sold to shops, retailers and market vendors in each district could generate another EUR 3M, for a total estimated market value of about EUR 33M.

4.2 LAWS AND REGULATIONS FOR COOLING AND PROCESSING IN UGANDA

Uganda has not established a regulatory framework specific to the productive use sector; however, regulations exist that are applicable to cooling and processing applications. These laws do not indicate whether the source of energy (renewable vs. non-renewable) is a consideration. **Table 16** summarizes the laws and regulations that pertain to cooling and processing solutions in Uganda's food industry.

TABLE 16. Laws and regulations for cooling and processing in Uganda

LAW/REGULATION	DESCRIPTION
Montreal Protocol and Kigali Amendment to the Montreal Protocol, 2016	— As a signatory to the Montreal Protocol, Uganda has put in place local laws to regulate the production and consumption of man-made chemicals referred to as ozone-depleting substances (ODS). — In 2001, the Uganda National Environment Regulations on Substances Depleting Ozone Layer was passed to specifically regulate ozone-depleting substances and products.[98] The law implemented measures to phase out Hydrochlorofluorocarbons (HCFCs) in cooling appliances (namely, refrigeration and air-conditioning equipment). — In 2016, the Kigali Amendment to the Montreal Protocol was passed to phase out production and consumption of harmful refrigerant chemicals used in refrigeration equipment and to promote the use of low Global Warming Potential (GWP) refrigerants through new appliance standards, labelling and conversion of equipment manufacturing. Uganda became a signatory to the Kigali Amendment in 2018.[99]

97) Please refer to the Cold Storage Model Business Case that was published together with this Developer Guide.
98) http://nema.go.ug/sites/all/themes/nema/docs/management_of_ozone_depleting_regulations.pdf
99) Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer, Kigali, Rwanda, United Nations, (15 October 2016): https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-2-f&chapter=27&clang=_en

Finance Amendment Bill, 2010[100]	— With this bill, the Ugandan government made it illegal to import used refrigerators and freezers
National Environment Act, 2019[101]	— This act added items to the list of restricted products for use in Uganda. Products containing controlled substances include old models of refrigerators, freezers, dehumidifiers, water coolers, ice machines, heat pump units, insulation boards, panels, air conditioning and pipe covers.
Environmental and Social Impact Assessment (ESIA) Regulations	— Uganda has established regulations for food processors such as maize and dairy processors. For medium to large-sized food processing facilities, an ESIA is required. An ESIA is a process used to predict the environmental and community impacts of proposed projects, activities, or actions of development. Below are some of the sectors that this law applies to: 1) Milling facilities with a capacity of at least 1000 kilograms per day, including for grains, cereals, pulse feeds, and other agro products 2) Manufacturing and refining of vegetable and animal oils and fats 3) Processing of dairy products 4) Abattoirs/slaughterhouses and meat processing plants 5) Production of canned foods 6) Sugar factories and jaggeries 7) Support facilities to (1) to (6) — The ESIA process should incorporate public input and environmental audits on the impact the facility will have on the community and the environment. The ESIA report is typically undertaken by certified and registered environmental practitioners listed on the NEMA website.[102] — The payable fees range from UGX 250,000 (EUR 60) to UGX 2,000,000 (EUR 500). In addition, for each ESIA, NEMA charges a fixed fee equivalent to a percentage of the total project cost.

100) Finance Amendment Act 2010: https://old.ulii.org/system/files/legislation/act/2010/22/Finance%20%28Amendment%29%20Act%2C%202010.pdf
101) National Environment Act 2019: https://nema.go.ug/sites/all/themes/nema/docs/National%20Environment%20Act,%20No.%205%20of%202019.pdf
102) National Environment Management Authority: http://nema.go.ug/sites/all/themes/nema/images/List%20of%20Environmental%20Practitioners%20-2018.pdf

4.3 REGISTERING A BUSINESS IN UGANDA

There are two main steps required to register a business in Uganda:[103]

- **Step 1: Registration of a Business:** The first step in securing an investment license is to register the private or public limited company at the Uganda Registration Services Bureau (URSB), where a Certificate of Incorporation, Memorandum and Articles of Association of the company will be issued. Requirements are described in **Table 17**.

- **Step 2: Application for an Investment License:** In order to secure an investment license, foreign investors are required to have a minimum of EUR 91,000 in planned investments recognized by the Uganda Investment Authority (UIA), while local investors need to have a prospective investment of half of this figure.

While it is not mandatory for local investors to obtain an investment license, foreign investors must possess this legal instrument to be able to carry out any business investment. Traders do not require a license from the UIA but must prove that they have operating capital of EUR 91,000 before local authorities can issue trading licenses and entry permits. More details on the minimum requirements are gazetted in the Investment Code Act.[104]

TABLE 17. Business registration requirements in Uganda

REQUIREMENT	DESCRIPTION
An application for an investment license is made in writing to the Executive Director of UIA containing the following information:	— Name and address of the proposed business enterprise, its legal form, its bankers, the name and address of each director or partner as the case may be and name, address, nationality and shareholding of any shareholder who is not a citizen of Uganda
	— Nature of the proposed business activity and proposed location of the business
	— Proposed capital structure, investments and projected growth over the next five years or more
	— Estimated number of persons to be employed
	— Qualifications, experience, nationality and other relevant information about management/staff
	— Incentives for which the project could qualify and any other information relevant to the application
	— The Executive Director shall liaise with government ministries and departments, local authorities and other bodies to support the investment license holder to comply with the requirements when seeking authorisations, regulatory licenses and land for the purpose of establishing the business enterprise

103) Uganda Investment Authority, 2015. Brief Guide to Investing in Uganda: https://www.ugandainvest.go.ug/wp-content/uploads/2016/04/Guide-to-investing-in-Uganda.pdf

104) Republic of Uganda, Investment Code Act, 2019: https://www.ugandainvest.go.ug/wp-content/uploads/2019/03/Investment-Code-Act-2019.pdf

The documents required for granting of an investment license include:	— Copy of the certificate of incorporation
	— Copy of the memorandum and articles of association
	— A brief business plan
	— Proof of financial ability to implement proposed project. Bank statements or letter of project support from a bank
	— Proof of proposed physical location of the project

Source: Uganda Investment Authority

The One–Stop–Centre at the Uganda Investment Authority enables investors to obtain all the services that would otherwise be available from the different government agency offices at the UIA.[105] This initiative is intended to reduce the applicant's time and resources needed for project licensing and implementation. Representatives of the Uganda Registration Services Bureau (URSB), Uganda Revenue Authority (URA), Department of Immigration, Uganda National Bureau of Standards (UNBS), National Environment Management Authority (NEMA) and Ministry of Lands are housed at the centre.

4.4 FINANCING RENEWABLE ENERGY FOR COOLING AND PROCESSING IN UGANDA

Despite its impressive growth, the off-grid renewable energy sector in Uganda still needs significant concessional debt, equity and grant funding to further scale up rural electrification. Off-grid companies, especially PAYGO solar businesses, have been mainly financed through foreign currency loans from international agencies. Grant funding remains an important vehicle for early-stage OGS business expansion, while equity financing is needed to leverage debt.

A blend of equity and debt financing is sourced from foreign and local providers in Uganda. Seven foreign organizations that include Bamboo Capital, British International Investment, Cordiant Capital, CrossBoundary Energy, Oikocredit, Nordic Funds and Symbiotics have invested a total of EUR 751M in the country's off-grid solar sector to date.[106]

This financing, which is primarily provided in foreign currency, can be risky for local companies, as their revenues are based in local currency (UGX) that is prone to devaluation. Local sources of capital will therefore be especially important for the sector's future development (this topic is discussed further in Section 2.4 above). To date, local commercial banks have not pursued this market opportunity, as many have a limited understanding of off-grid solar businesses and financial models and require capacity building to design loan products specific to the sector.

Debt financing and TA for off-grid enterprises

Development partners such as the World Bank, the EU and the UN are providing concessional financing to support Uganda's off-grid energy sector. Blended finance is one method of supporting early-stage OGS companies to reduce their risk profiles for commercial investors. As an example, the UN Capital Development Fund (UNCDF) extended a two-year unsecured EUR 227k working capital loan to a solar SME, helping it build a credit history in a process that subsequently enabled it to access a EUR 727k loan from Stanbic Bank.[107]

The Uganda Energy Credit Capitalization Company (UECCC), a government entity that is majority funded by the World Bank, was set up to pool resources from the government and development partners to catalyse investments in the renewable energy sector. It has a concessional working capital facility of EUR 7.7M, accessible by off-grid businesses through partner FIs. The partner banks include Absa, Centenary Bank, Finance Trust Bank, Pride Microfinance, Post Bank and Stanbic Bank, among others. The banks can access the facility at a rate of 9% and then on-lend to solar SMEs, which can borrow up to a maximum of

105) https://www.ugandainvest.go.ug/resources/uia-one-stop-guide/
106) "Mapping the Ugandan Off-Grid Energy Market - 2019 Edition" Uganda Off-Grid Energy Market Accelerator, (2019): https://uoma.ug/wp-content/uploads/2020/10/UOMA-PUE-white-paper.pdf
107) "Demand-side barriers to financing for off-grid solar businesses in Uganda," Uganda Off-Grid Energy Market Accelerator (UOMA), (2021): https://uoma.ug/wp-content/uploads/2021/06/UOMA-A2F-DSB-paper-3.pdf

EUR 1.36M at a capped interest rate of 15%. In 2020, two local solar vendors received facilities worth UGX 600M (about EUR 150k) and UGX 1B (about EUR 250k) through Centenary Bank. However, since the government's adoption of a stringent Quality Assurance Framework for the solar sector, accessing the facility has proven challenging, resulting in underutilisation of UECCC debt financing.[108]

The Uganda Green Enterprise Finance Accelerator (UGEFA) is an EU-funded program that provides training and technical assistance to green enterprises in Uganda, with a focus on building their financial capacity, scaling up their businesses, and engaging with partner banks to help the companies access loans tailored to their technologies and business models. UGEFA works with three pioneer banks – Equity Bank Limited, Opportunity Bank Limited and Yako Bank Limited – that will deliver EUR 5.5M in debt financing to green SMEs by 2023.[109]

In the agricultural sector, the Bank of Uganda Agricultural Credit Facility was established in 2009 to provide medium and long-term loans to farmers and agri-businesses through participating financial institutions. Loans under the facility are disbursed at more favourable terms than is usually available from banks, with the interest rate set at a maximum of 12% per annum and maximum loan sizes of UGX 5B (EUR 1.2M). Eligible projects include acquisition of agricultural machinery, post-harvest handling equipment, storage facilities and agro-processing machines.[110]

Of the 24 licensed commercial banks in Uganda, 30% are subsidiaries of international banks. The majority of banks do not have tailored lending processes for the off-grid sector, treating renewable energy lending as standard commercial bank lending and charging high interest rates and collateral requirements. This can be attributed to the bank's failure to understand OGS business operations and technologies, as well as to the inability of OGS companies to satisfy loan application requirements. The interest charged ranges from 18-22%, as the prime rate, and from 28% per year for Tier I institutions, depending on the risk profile of the borrower, rising as high as 48% for Tier II institutions.[111] Interest charged for foreign currency loans at 9-10% is lower than for domestic currency loans due to the built-in currency risk.[112]

The typical loan sizes offered by domestic banks and demanded by OGS companies are relatively small compared to what investors would offer (financing requirements for OGS companies are in the range of about 50k).[113] Typically, banks with international roots will offer EUR 90k as the minimum ticket size, while most domestic banks will set EUR 13,600 as the maximum (depending on the risk profile of the business).[114] Off-grid solar company requirements thus fall between the local maximum and the international minimum. These small local loan sizes, combined with short tenors (usually two to three years) suggest a high perceived risk within the industry.[115]

End-user financing

Financing is also available for end-users in the off-grid solar and PUE markets. The UECCC has an end-user facility accessible through prequalified banks and microfinance institutions. A consumer must satisfy the bank's established terms to access the facility, whose interest rates are lower than conventional market rates. Companies such as Solar Now offer asset financing for PUE technologies such as water pumping and cold storage. Commercial Banks are increasingly looking at financing OGS and agricultural PUE applications, including food processing, at their standard commercial terms.

GoParity, a Portuguese fintech crowdfunding firm that finances sustainable projects has partnered with SolarPipo, a developer of solar energy projects in the dairy sector in Uganda, to raise EUR 200k to finance the installation of solar powered cooling equipment for four dairy cooperatives. As of the end of 2021, seven cooperatives had been selected as funding beneficiaries, with a total of EUR 400k invested. EnerGrow Asset Financing is another

108) "The Uganda Stand-Alone Solar Market Update," Africa Clean Energy Technical Assistance Facility (ACE-TAF), (2021): https://www.ace-taf.org/kb/stand-alone-solar-sas-market-update-uganda/
109) "UGEFA Partner Banks: Leveraging the Ugandan banking sector for green growth," Uganda Green Enterprise Finance Accelerator (UGEFA), (September 2021): https://ugefa.eu/news/ugefa-partner-bank-launches
110) Bank of Uganda Agricultural Credit Facility: https://www.bou.or.ug/bouwebsite/ACF/
111) Based on available capital, financial institutions are classified by the Ugandan Central Bank as Tier 1 to Tier IV. The minimal capital requirements are EUR 6M and EUR 240,000 for Tier I (commercial banks) and Tier II (micro-credit institutions), respectively.
112) Mugimba, C., Akello, M., Reza, F., and Paulo, L., "Off-Grid Renewable Energy Policy Framework and Availability of Local Bank Lending in Uganda," (October 2018): https://pdf.usaid.gov/pdf_docs/PA00W4WV.pdf
113) UOMA, 2021.
114) https://www.globalbrandsmagazine.com/list-of-commercial-banks-in-uganda/
115) Mugimba et al., 2018.

fintech start-up that supports sustainable, productive rural electricity demand in Africa through productive asset financing. EnerGrow provides loans that are repayable over a period of six months to three years, for assets and appliances valued at EUR 45 to EUR 4,500 to micro, small and medium businesses.

Access to financing

Access to capital remains a significant market barrier for Uganda's off-grid solar and PUE sectors. Renewable energy and PUE technologies and solutions require access to financing with attractive terms and the deployment of financial products structured and adapted to the needs of specific market segments. Banks and financiers are often reluctant to invest in nascent technologies due to their risk perceptions and because they lack the training and skills to perform the appropriate project due diligence.

With limited success mobilising financing to date, off-grid operators in Uganda face a funding shortfall that jeopardizes the country's long-term electrification plans and objectives. It is estimated that the growth in funding for the off-grid sector will require an average annual investment of EUR 86M over the next three years (increasing thereafter). The sector is expected to raise only a fraction of the capital needed to realise universal electricity access, with large companies absorbing most of this funding.[116]

Domestic banks have limited understanding of the OGS sector, which is generally perceived as high-risk for a low return. Many FIs do not include the off-grid sector as part of their broader lending strategy, as they focus on other sectors perceived to be more attractive. However, OGS companies that market PUE technology can piggy-back on lending targeting the agricultural sector. Banks apply lengthy and complex lending procedures with generic due diligence processes that are not aligned with OGS business models and cashflows. Existing bank loan products often do not meet the requirements of OGS companies; for instance, the majority of business loan products offered have very short tenors that do not allow energy service providers to recover their investment costs and meet desired returns. The minimum ticket sizes offered by banks are either too high or are not aligned with the needs of the majority of off-grid operators.

Banks charge prohibitive interest rates as high as 25% if the borrower is not backed by an external de-risking mechanism, such as a loan portfolio guarantee. Banks demand collateral in the form of hard assets (e.g., land titles and premises owned by the business). Other banks require the financed asset to remain the property of the bank until the loan is fully repaid. Banks also struggle to assess the technical quality of technology and their potential value as collateral.[117] Domestic banks have utilised the USAID Development Credit Authority guarantee mechanism, which provides partial loan guarantees to reduce the risks of commercial lending to new sectors and new borrowers.

Off-grid and PUE companies also need to improve their internal financial management capacity to meet investor and lender requirements and access and manage funding. Local companies are generally SMEs without full-time financial and operational management personnel or corresponding financial systems, which results in low-quality financial reporting as they resort to part time staff or external accountants and auditors to prepare their books so as to comply with statutory reporting requirements.[118] Several donor-funded initiatives are providing technical assistance to off-grid companies for this purpose, including the African Enterprise Challenge Fund (AECF), GET.invest Financial Readiness Support (FRS), and the Private Financing Advisory Network (PFAN).

4.5 CONSUMER AWARENESS OF RENEWABLES FOR COOLING AND PROCESSING

Awareness about solar technology is relatively high in Uganda, particularly for widely sold solar home systems and household appliances.[119] However, the level of awareness about PUE solutions remains low, especially in rural areas where PUE can support a wide range of applications, such as water pumping, cooling and food processing. Interest in renewable energy technology is relatively high among cooperatives and processors that tend to have better access to information, as well as a greater ability/willingness to pay.

For smallholder farmers and businesses in rural off-grid areas, awareness about the economic and environmental benefits of using solar-based solutions as opposed to diesel alternatives,

116) UOMA, 2021.

117) Mugimba et al., 2018.
118) UOMA, 2021.
119) Africa Clean Energy Technical Assistance Facility, 2021.

including increased productivity per acre and reduction in post-harvest losses, are not well understood. This is a challenge that marketing, distribution and sales networks of solar PUE businesses are working to overcome. Solar products dealers who are typically agents and representatives of importers and suppliers in Kampala have sales outlets only in major town centres. Rural farmer households are often unaware of the location of solar business outlets or their sales agents and technical staff in remote areas, making after-sales support and maintenance of solar systems difficult.

Interest in renewable energy technology is relatively high among cooperatives and processors that tend to have better access to information, as well as a greater ability and willingness to pay. There is still a need to sensitise and train farmers through pilot projects and demonstrations on the use of PUE technologies, including solar irrigation, cooling and drying applications.

4.6 PROFILES OF ENERGY SUPPLIERS IN UGANDA

Businesses offering solar powered cooling and processing technologies are still nascent in Uganda, with the number of suppliers quite limited. Most companies are still at the early growth stages, distributing household, small business and institutional systems.

Several initiatives have been implemented by private solar businesses with support from the donor community. Following testing and piloting, with support from the Efficiency for Access Coalition and Power Trust,[120] AGSOL has partnered with local retailers to distribute its solar mill as one of its product offerings in Uganda.[121] Ecozen, an innovator in the solar cooling sector, will install its first batch of mobile cooling units for a World Bank-funded project in 2023.[122] Other innovators, such as ColdHubs, InspiraFarms and Phaesun are making headway in East Africa but have not yet ventured into Uganda. **Table 18** describes the Ugandan businesses and initiatives active in distributing, supplying and implementing productive use technologies in the food industry.

TABLE 18. Productive use of energy innovators in Uganda's food industry

COMPANY	DESCRIPTION
Ecolife Foods	Ecolife Foods works directly with communities to create solutions for farmers to address the lack of affordable cold storage facilities. With support from the Efficiency for Access Coalition and in partnership with the UK-based Sustainable Villages Research Group, Ecolife Foods piloted a community walk-in cold storage solution to provide cooling for fruits and vegetables using local materials for construction and insulation.[123]
One Lamp[124]	OneLamp is a distributor of solar lamps, solar-powered milk chillers and storage solutions for dairy farmers in the Western Region. One Lamp's product offering consists of a SHS, a lithium-ion battery, LED lights and a milk cooler. Dairy farmers acquire the systems through a mobile-enabled lease-to-own business model.
WeCoolers (Wamala Energy)	With operations in the Southern Region, WeCoolers has designed a solar system with an ice-maker that can be used by dairy farmers for cooling and storing milk, hence reducing spoilage.[125] Affordability of the systems remains a challenge. Planned fabrication of part of the system locally will reduce its cost.[126]

120) Energy4Impact and Efficiency for Access Coalition, 2020.
121) Magala J., Sembatya E., Bitete L., Bhamidipati P. L., and Pedersen, M. B., "Unlocking support for local clean energy companies: Insights from the solar PV industry in Uganda." UNEP DTU Partnership (2022): https://unepdtu.org/wp-content/uploads/2022/03/unlocking-support-for-local-clean-energy-companies-insights-from-the-solar-pv-industry-in-uganda.pdf
122) Stakeholder Interviews, 2022.
123) Ecolife Foods: http://www.postharvest.org/EcoLife_Cold_Room_Innovation.pdf
124) One Lamp: https://eepafrica.org/wp-content/uploads/2021/04/UGA16434_OneLamp.pdf
125) Wamala Energy: https://wamalaenergy.com/
126) Stakeholder interviews, 2022.

The majority of clean energy technology suppliers in Uganda are solar companies expanding their offering from basic household solar PV products to standalone systems for institutional, commercial and industrial (C&I) and agricultural productive use applications such as water pumping, irrigation and refrigeration. Business models for these services have gradually shifted from cash-based to lease/rent-to-own and fee-for-service models. **Table 19** describes a selection of off-grid solar SMEs operating in Uganda.

TABLE 19. Off-grid solar SMEs in Uganda

COMPANY	DESCRIPTION
All-in-Trade	All-in-Trade is a distributor and installer of SHS, power back-up systems, large solar PV systems for C&I and institutional facilities. They also provide maintenance services for completed projects. All-in-Trade has implemented a number of projects to date, including electrification of 46 health centres, several C&I projects, as well as two dairy projects that were sponsored by Solar Pipo.[127]
Aptech Energy	Aptech Energy distributes, installs and offers after-sales services for solar PV systems for residential and commercial facilities as well as solar powered irrigation systems.
Davis & Shirtliff	Davis & Shirtliff offers products that include solar PV systems, generators, batteries and refrigerators. They are also distributors, installers and providers of after-sales services for water pumping (irrigation) solutions, power equipment and solar products.
Energy Systems Limited	Energy Systems Limited is a distributor, installer and after-sales service provider of solar products for households, social institutions, commercial enterprises and communities located in off-grid areas. Their offering includes PUE products such as refrigerators, water pumps, SHS and hybrid power systems.
Power Trust	Power Trust supplies, installs and provides after-sales services for solar PV systems, solar milling, solar refrigerators, power backup systems, generators, water pumping systems and wind power solutions.
Solar Now	Solar Now previously provided solar solutions for rural households and small businesses, but over the last decade the firm has evolved into a PUE solution provider supporting farmer households with high quality solar products. In partnership with The Inclusive Dairy Enterprise Project, Solar Now has disseminated over 10,000 household solar-powered systems including for cooling and irrigation purposes.[128]
Solar Pipo	Solar Pipo offers system design, installation and financing services for solar power systems to provide power for cooling and water pumping services focusing mainly on the dairy sector. Their major customers include dairy cooperatives, farmers groups and Milk Collection Centres, with their operations concentrated in the Southern Region. They have completed the installation of six projects and have a pipeline of over 30 projects.[129]
Solar Today	Solar Today designs, supplies, and distributes modular solar products for households, businesses and institutions operating in the Western Region. Their major productive use focus is solar water pumping and irrigation. Solar Today also supplies and installs power back-up systems.
Village Energy	Village Energy is a distributor, installer and after-sales service provider for SHS and PUE solar products for agricultural use such as water pumps. Village Energy partnered with Astonfield for the installation of the 172 kWp C&I plant for the National Union of Coffee Agribusiness and Farm Enterprises.

127) http://allintradelimited.com/
128) Africa Clean Energy Technical Assistance Facility, 2021.
129) Stakeholder Interviews, 2022.

The Ugandan mini-grid sector is also developing rapidly, with donor-backed initiatives supporting hundreds of new green mini-grids. **Table 20** describes a selection of mini-grid developers that are active in the country.

TABLE 20. Mini-grid developers in Uganda

COMPANY	DESCRIPTION
Absolute Energy	Absolute Energy owns and operates the 100 kWp Solar PV mini-grid at Bukasa Island, and the 230kWp solar mini-grid project on Kitobo Island on Lake Victoria which they developed together with GRS Commodities.
Equatorial Power	In partnership with ENGIE, Equatorial Power has completed the installation of a 600kWp mini-grid on Lolwe Island on Lake Victoria that will have 3,800 household and business connections and an agricultural business hub for milling, drying and ice making. Other innovations will include electric mobility integration. They are also piloting productive use innovation for milling on another 65kWp solar PV mini-grid that is integrated with the main grid in Mukono District.[130]
GRS Commodities	GRS Commodities is a mini-grid developer that has recently diversified into the C&I sector. GRS focuses on developing cold storage components of mini-grid projects that support local fishing economies. To-date, they operate two ice-making plants running alongside their Kitobo and Bukasa mini-grid projects. GRS participated as the EPC partner working with Absolute Energy to develop and implement the 230kWp solar mini-grid project on Kitobo Island on Lake Victoria that provides power to an ice-making plant in addition to 2,000 households and 150 businesses.[131] GRS further collaborated with Absolute Energy with support of the US African Development Foundation to provide project preparation and development support for the 100kWp solar PV mini-grid project on Bukasa Island on Lake Victoria that has an ice making facility as the anchor customer.[132] In partnership with a USA start-up, GRS set up another 10kWp solar mini-grid that provides electricity to 35 businesses on Kitobo Island.[133]
Mandulis Energy	Mandulis Energy is developing a mini-grid with a total installed capacity of 44 kW consisting of a 32 kW biomass gasification plant, 12 kw solar PV system and 64 kWh battery bank storage.
Winch Energy	Winch Energy is implementing 25 solar mini-grids (nearly 1MW of solar capacity in total) in Lamwo, Northern Uganda. The mini-grids will supply new electricity connections for at least 2,300 households, mitigating over 550 tons of CO2e per year from reduced kerosene and diesel emissions. They will also implement another set of solar mini-grids in 14 villages in Isingiro and Rakia in Southern Uganda of 30-80 kW per site with a combined installed capacity of 516KW.

130) Equatorial Power: http://equatorial-power.com/uganda-2/
131) http://ae-capital.com/kitobo-island/
132) Magala et al., 2022; and "Exploring off-grid productive use in Uganda," Power Africa, (March 8, 2021): https://powerafrica.medium.com/exploring-off-grid-productive-use-of-energy-in-uganda-91d5c4aa3bf4
133) GRS Commodities: https://www.grscommodities.com/projects.html

4.7 MARKET OUTLOOK

Despite its impressive growth, the off-grid renewable energy sector in Uganda still needs significant concessional debt, equity and grant funding to further scale up rural electrification. Local sources of capital will be especially important for the sector's development. To date, local commercial banks have not pursued this market opportunity, as many have a limited understanding of off-grid solar businesses and financial models and require capacity building to design loan products specific to the sector. Off-grid and PUE companies also need to improve their internal financial management capacity to meet investor and lender requirements and access and manage funding.

Businesses offering solar powered cooling and processing technologies are still nascent in Uganda, with the number of suppliers quite limited. Most are still in early growth stages, distributing household, small business and institutional systems. From the perspective of developers, investors or companies interested in the Ugandan market, solar applications for agricultural cooling represent a potentially profitable business opportunity, especially when applying the Pay-As-You-Store business model.[134] This contrasts with the opportunity for solar milling, or micro milling, which is still a nascent market. Despite recent improvements in the technology, solar milling likely needs about another two years of development for costs to reduce and throughput to increase.

There are a number of challenges facing the renewable energy cooling and processing segments in Uganda's food industry, but the market is extremely dynamic with constant business and project innovation. Increasing the uptake of PUE technologies in Uganda will require the government, development partners, financiers and the private sector to collaborate in order to establish an enabling environment for the sector. Off-grid solar operators and suppliers of productive use products and systems require wide-ranging assistance to support their expansion and address affordability gaps, including (but not limited to):[135]

- Access to concessional funding and local currency loans
- Consumer awareness raising (benefits of PUE technologies, consumer financing options etc.)
- Capacity building of all market actors (policymakers, FIs, service providers, technicians etc.)
- Market intelligence and R&D[136]
- Quality assurance frameworks and standards for PUE appliances and equipment
- Additional policy and regulatory interventions to reduce costs (tax incentives for solar systems and components etc.)

There is also a need for coordination among key market actors (policymakers, operators and financiers) to address barriers that cut across agri-food value chains, beginning with pumping and irrigation through milling and cold storage. Mismatches often exist between product designs and features and market requirements, such as the throughput of current solar mills relative to the needs of a typical village, or the stirring mechanisms needed to apply containerised cold storage to the dairy sector. Cold storage possibilities in Uganda are diverse in multiple sectors. A fee-for-service business model requires developing after-sales services (O&M) and deploying software and tools to track and monitor data and performance of PUE applications and products.

Given the relatively high cost of technologies, especially considering the ability to pay of farmers, fisherfolk and small traders in Uganda, rental business models (PAYGO, Pay-As-You-Store, fee-for-service) hold the most promise for renewable energy cooling and processing solutions. Indeed, the PAYGO model, which has been transformative for the off-grid solar market, is now slowly emerging for the PUE sector as well.

134) Please refer to the Cold Storage Model Business Case that was published together with this Developer Guide.

135) "Productive Use of Energy in Uganda: Learning from the Uganda Off-Grid Energy Market Accelerator (UOMA)," Uganda Off-Grid Energy Market Accelerator; USAID, (October 2020): https://uoma.ug/wp-content/uploads/2020/10/UOMA-PUE-white-paper.pdf

136) As an example, the Global LEAP Awards provide grant funding to companies that develop innovative, energy efficient off-grid technology solutions for smallholder farmers (e.g., solar water pumps) (see: https://globalleapawards.org/results-based-financing)

ANNEX 1

Assumptions and Methodology for Market Sizing

The following describes how the calculations were made in order to estimate market sizes for the different market segments studied under this Market Insights Package. The market sizing represents the total investment needed to capture the existing market as well as the future potential of the market of up to 10 years.

Grain processing and milling

The estimated market potential for solar PV mills under a group ownership and/or shared-use model is based upon the following assumptions:

- Total number of households in the four regions cultivating maize is 1,800,000[137]
- Number of households (growing maize) per farmers' group/association is 100[138]
- Number of maize farmer groups is 18,000
- Production per farmer: 2.5 MT per year; total production per group/association of 100 farmers: 250 MT per year
- Output/production of one solar mill is 55 MT per year[139]
- Number of solar mills per group/association is five

The total Ugandan market for solar mills is 90,000 mills (18,000 groups X 5 per group = 90,000). Assuming that 70% of these farmer groups lack access to electricity or do not already own and operate a diesel mill, the total addressable market becomes 63,000 solar mills (70% of 90,000). Assuming again that only 30% of these farmer groups can afford the solar mills, the market reduces further to 18,900 mills (30% of 63,000).

From the data presented in **Table 5**, millet and sorghum are about 12% of the maize tonnage. Using the same fraction (12%), about 2,268 solar mills will be needed for milling millet and sorghum.

The cost of a 1.5-2.2 kWp solar mill is EUR 2,225;[140] therefore, the value of the serviceable market for solar mills in Uganda is approximately EUR 47,098,800 (18,900 + 2,268 = 21,168; 21,168 X EUR 2,225).

Dairy

The estimated market potential for solar coolers/freezers/refrigerators for the dairy value chain is based on the following assumptions:

- Farmers are organized into 367 milk producer cooperatives. Assuming each cooperative has two 3,000 litres MCCs,[141] the total market for MCCs is 734[142]
- There is an opportunity to replace 300 diesel generators currently powering MCCs with solar systems
- Although cold storage facilities range widely in size and price, the estimated average price of a 5 MT walk-in cold storage facility is EUR 22,500[143]

137) Kilimo Trust. The Maize Value chain in Uganda. https://kilimotrust.org/the-maize-value-chain-in-uganda/
138) Daly et al., 2016.
139) Dalberg Advisors, Lighting Global and World Bank, 2019.
140) Energy4Impact and Efficiency for Access Coalition, 2020; based on AGSOL prices for mill driven by a solar PV system powered by 1.5 - 2.2 kW, AC or DC motor.
141) Stake holder interviews, Combination of two 3,000L coolers is common with MCCs: A few cooperatives have capacities of 10,000L and above.
142) Assuming successful research and development into stirring mechanisms.
143) This average is based on data collected during stakeholder interviews.

— Affordability is quite high (70%) among dairy cooperatives and traders/bulking agents

Based on these assumptions, the estimated value of the serviceable market for large walk-in cold storage units for the dairy sector is EUR 11.5M (70% of 734 = 514; 514 X EUR 22,500 = EUR 11.5M).

In addition to the large walk-in style cold storage solutions for the dairy sector, there is also a market for smaller systems. The estimated number of smallholder dairy farmers is 1.2 million,[144] which presents a huge market for smaller solar cooling technologies. The estimated market potential for these technologies is based on the following assumptions:

Based on these assumptions, the estimated value of the serviceable market for small cooling solutions for the dairy sector in Uganda is EUR 126M (70% of 600,000 = 420,000; 30% of 420,000 = 126,000; 126,000 * EUR 1,000 = EUR 126 million). The market sizing grows considerably if PAYGO options are available to the consumers.

Combined, the market for large and small cold storage solutions for the dairy sector in Uganda is estimated at **EUR 137.5M**.

Fisheries

The estimated market potential for solar coolers, freezers and refrigerators for private investors, fisherfolk associations and traders is based upon the following assumptions:

— Number of landing sites on the major fishing water resources is 1,000[145]

— Each site could potentially acquire both a cold storage unit and an ice-making facility

— Cold storage systems (5 kWp for 5 MT capacity)[146] cost an estimated EUR 22,250,[147] so 1,000 of them sold would generate EUR 22.25M

— Ice making facilities (10 kWp for 2 MT capacity) cost an estimated EUR 47,000,[148] so 1,000 of them sold would generate EUR 47.94M

— No sites currently have access to electricity

— Ability to pay is 30%

30% of EUR 70.19 million gives a total serviceable market value of EUR 21.057 million.[149]

Additionally, there exists the non-negligible market for smaller cold boxes and fridges for boats and traders. If 10 such products were sold at each of the 1,000 landing sites at an average price of EUR 750, OGS technology providers could earn another EUR 7.5M.

Fruits and vegetables

The estimated market potential for solar coolers and refrigerators for the horticulture sector is based upon the following assumptions:

— 500,000 farmers[150] are organised into approximately 200 cooperatives and associations (with each including between 2,000 and 3,000 members)[151]

— Each such association could deploy eight 5 MT walk-in cold storage facilities, or 1,600 for all the associations combined

— For about 120 fruit growing districts, 20 WICR units will be deployed at the major markets in each district making a total of 2,400 units.

— At the same time, 100 traders/aggregators could each deploy three such facilities, or 300 in total

— The 65 registered fruit and vegetable exporters could also deploy two such facilities each, making about 133 in total.

— The 5 MT unit costs EUR 22,500

— Affordability across the sector is approximately 30%[152]

144) Stakeholder interviews, 2022.
145) NEMA, 2021.
146) "The Power of the Productive Use of Energy: An impact investor frontier," Powering renewable Energy Opportunities (PREO), (October 2021): https://www.preo.org/preo-pue-opportunity-report/
147) Stakeholder consultations, 2021.
148) Stakeholder consultations, 2022.
149) CAPEX with a financing (PAYGO) model.
150) EnDev, 2021.
151) Author estimates and stakeholder interviews.
152) CAPEX with a financing (PAYGO) model.

Based on these assumptions, 1,330 (30% of 4,433) walk-in cold storage facilities at EUR 22,500 would generate nearly EUR 30M (EUR 29,925,000). If 25 smaller 100-200 litres cold storage products were also sold to shops and retailers in 120 districts – at an average price of EUR 1,000, another EUR 3 million could be generated, for a total estimated market value of **EUR 33M**.

Pay-As-You-Store business models serving smallholder fruits and vegetable farmers would generate revenue of a much greater magnitude.

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