Uganda Off-Grid Energy Market Accelerator

Productive use of off-grid energy

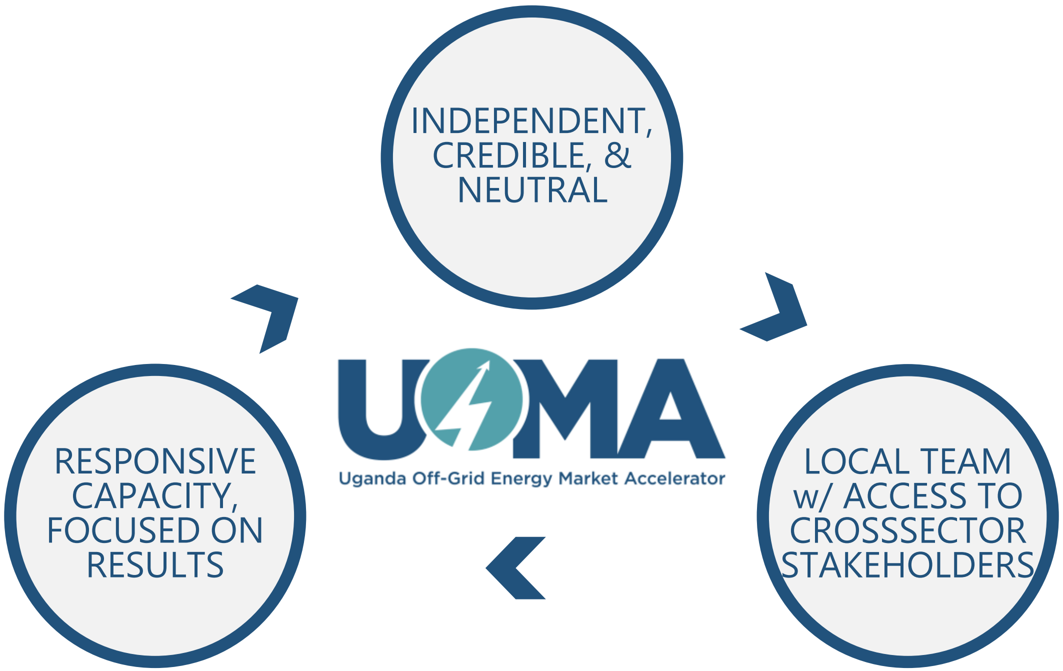
The business case in Uganda's dairy value chain

August 2019

Contents

Background & rationale

Uganda Off-Grid Energy Market Accelerator (UOMA) is a dedicated and neutral intermediary, focused on scaling off-grid energy access



We accelerate the off-grid energy market in Uganda through:

- **Research & Insights:** providing data, analysis, and insights to businesses, investors, development partners, and policy-makers
- **Coordination:** coordinating industry actors and resources to increase efficiency; and
- **Direct Interventions:** catalyzing interventions where necessary to reduce barriers to off-grid energy access.

Source: UOMA

Off-grid renewable energy presents a promising opportunity to scale productive use applications for last-mile customers

Productive use of energy (PUE) refers to use of energy for technologies in agricultural, commercial, and industrial activities that result in the production of goods or the provision of services[1]

Off-grid energy includes solar home systems (SHSs) as well as larger component based solar systems and mini-grids

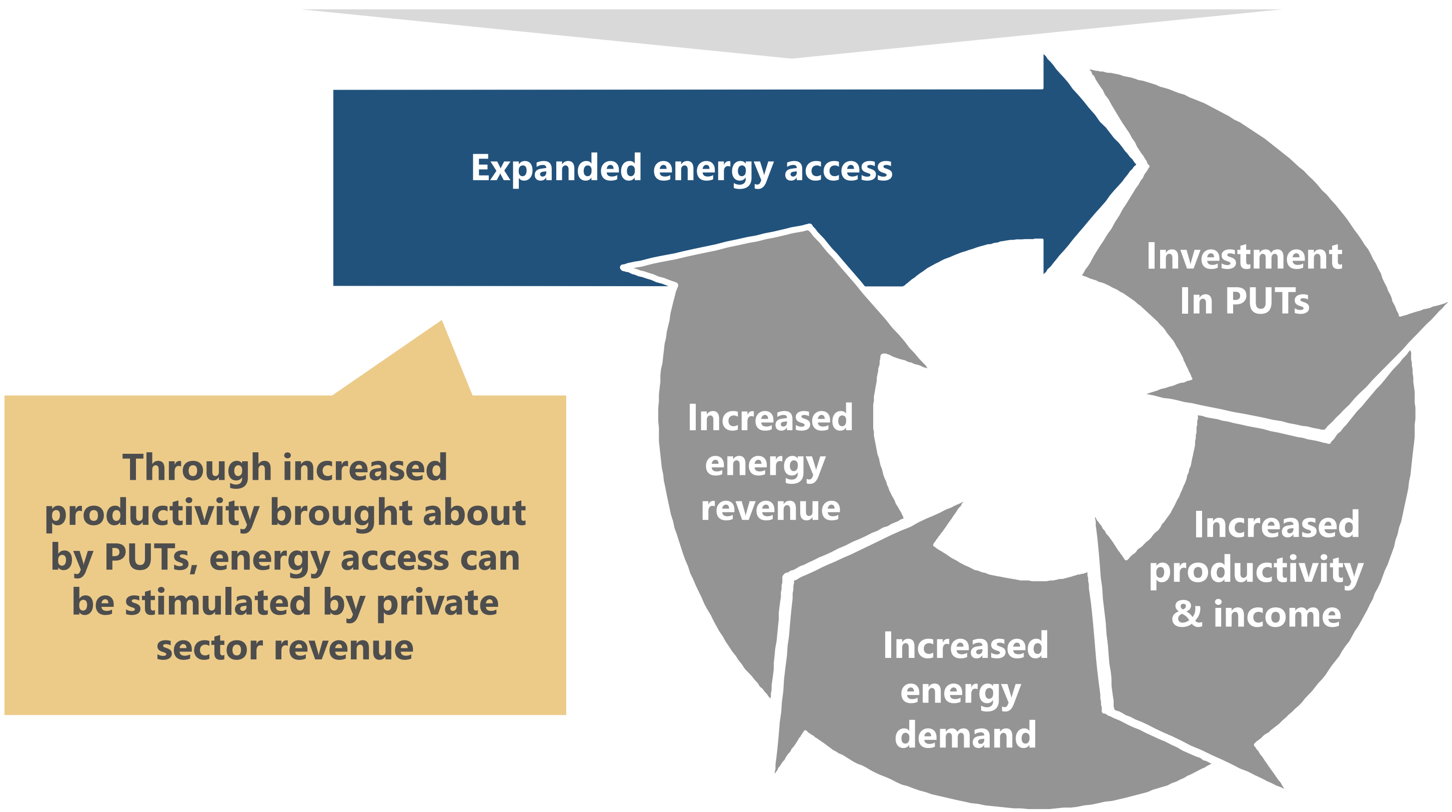
Leveraging the off-grid opportunity and extending productive use technologies to last-mile rural populations can potentially improve economic development and income generation through increased productivity

Source: [1]Power for All: What we mean by "productive use" – and why it matters; 2018. Link

Increased productive use of energy will lead to productivity gains, eventually resulting in expanded overall energy access

Productive use of energy provides a strong foundation for sustainable development

- Productive use technologies (PUTs), if properly targeted, have the potential to significantly boost productivity and drive efficiencies across numerous value chains
- Increased overall energy demand would result from increased productivity and income



Sources: OCA analysis & interviews supplemented by

1. GIZ's "Productive Use of Energy – PRODUSE A Manual for Electrifi cation Practitioners": https://www.giz.de/fachexpertise/downloads/giz-eueipdf-en-productive-use-manual.pdf
2. ESMAP "Maximizing the Productive Uses of Electricity to Increase the Impact of Rural Electrification Programs": https://www.esmap.org/node/714

Leveraging off-grid access for PUTs in agriculture has strong potential to impact millions and drive economic growth

Agriculture plays an important role in Uganda's overall economy

70%

of Uganda's population employed in agriculture – high reach and impact potential[1]

30%

potential income increase through value addition and efficiencies from productive use[2]

Several cases of off-grid PUTs for agriculture already exist

Cold chain

- Refrigeration to rural farmers can extend the life & quality of produce
- Additional applications in ice-making for fishing etc.

Example ColdHubs

Provides solar-powered cold rooms on a pay-as-you-store model for farmer produce

Solar irrigation

- Solar irrigation systems can offer significant time savings to farmers
- Can add additional harvest season to a year, increasing revenue

Example sunculture

Manufactures affordable and solar powered irrigation solutions for smallholders

Agro-processing

- Provide the ability to add value higher up the value chain, increasing revenue
- Eases labor burden, especially for women

Example AGSOL

Produces solar agro-processing machines, e.g. hammer mill, maize sheller, and more

Sources: UOMA analysis, supplemented by [1]CIA World Fact Book, Link; [2]National Survey and Segmentation of Smallholder Households in Uganda, Link.

Though many agricultural value chains in Uganda could benefit from PUTs, dairy presents a significant impact opportunity

Dairy[1]

- The dairy industry in UG is one of the most promising in Africa
- Increasing regional demand means strong growth potential

Maize[2]

- Maize is a major staple food in UG
- Productivity improvements can reduce hunger and increase farmer incomes

Fishing[3]

- Fishing is significant to UG's economy and food security
- PUTs for post-harvest could build a more robust value chain

Coffee[4]

- Coffee is a significant source of income for UG
- Strong global demand combined with PUTs can offer strong growth to the overall economy

With increased productivity in dairy, there is potential to satisfy increasing local and regional demand

- UG per capital milk consumption is 50 liters/year; rural consumption is 21 liters/year, yet rural consumers account for over 80% of population[5]
- Low productivity in many African countries, e.g. Nigeria, Ghana & Tanzania, has resulted in major imports from the EU[6], and therefore increased potential for Uganda to serve regional demand

With investment in dairy for higher production, we anticipate output growth of up to 7 times[7]

- Along with investment in PUTs to improve productivity, other interventions such as improved cattle management can significantly improve outcomes in the dairy value chain

Due to strong potential to increase income and boost economic activity, this report focuses on productive use for the dairy value chain

Sources: [1]Food Business Africa: Dairy industry in Uganda, Link; [2]Agona and Muyinza, An overview of maize in Uganda, Link; [3]FAO: Uganda fisheries profile, Link; [4]Fortune of Africa: Uganda coffee profile, Link; [5]Tijanni and Yetisemiyen, Dairy Cattle and Dairy Industry in Uganda: Trends and Challenges, Link; [6]The East African, April 18 2018, Link; [7]UOMA analysis

Although challenges exist across the dairy value chain, off-grid PUT solutions are particularly well situated for production and collection

	Milk production	Collection & transportation	Processing	Distribution & marketing
Description	Feeding, breeding, milking and medical treatment of cattle	Aggregation, cooling & delivery to processors/ bulk transporters	Pasteurization/ processing to make other products	Selling either through formal or informal channels
Challenges	• Low milk production • Remote farmers lack access to markets	• High transport costs • Milk spillage rates of 11%[1]	• Adulterated milk • Fluctuating milk supply from traders	• Low product shelf life • Tough competitive landscape
PUT solutions	• Small-scale cooling units • Milking machines • Water pumps • Pre-digestors	• Medium/ large-scale milk cooling unit • Pasteurizer	• Large-scale pasteurizers • Packaging machines • Yogurt / butter manufacturing line	• Glass-front refrigerators • Cold room storage • Refrigerated trucks

These PUT solutions are most suitable for off-grid applications since they support small-scale farmers operating in remote rural areas

Source: [1]FAO: A review of Uganda's Dairy Industry, Link.

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Of suitable off-grid PUT solutions, affordable cooling technologies present the most viable option for small-scale rural dairy farmers

Technology	Impact potential	Viability for rural farmers
Small cooling units	Reduced spoilage at farmer level, caused by unpredictable agents or long transportation	**High:** Viable in areas farmers experience high spoilage due to inconsistent supply chains
Medium/large cooling units	Reduced spoilage at collection centers before transportation to processors	**High:** Viable in areas of high farmer densities and for co-ops who collect from farmers
Milking machines	Increased speed in milking and reduced impurities in final product	**Low:** Viable only when farmers or farmer groups have a large herd
Water pumps	Increased availability of drinking water for cows when surface water is low	**Low:** Viable for large scale farmers or when substantial needed for other ag. activities
Pre-digester	Increased milk production and nutrient conversion for cows via faster digestion	**Low:** Viable at scale and likely high cost, most require no electricity
Pasteurizer	Increased quality of milk via elimination of the bulk of bacteria from raw milk	**Low:** Viable at scale in urban centers with on-grid connection

This report builds a business case for uptake of off-grid cooling in the dairy value chain due to high viability/ impact potential

Source: UOMA analysis

Business case for cooling technologies

20-40% of all milk production in Uganda is wasted due to lack of timely cooling[1]

Solar cooling technologies can provide consistent cold storage for areas with no or unreliable energy access, offering significant impact potential

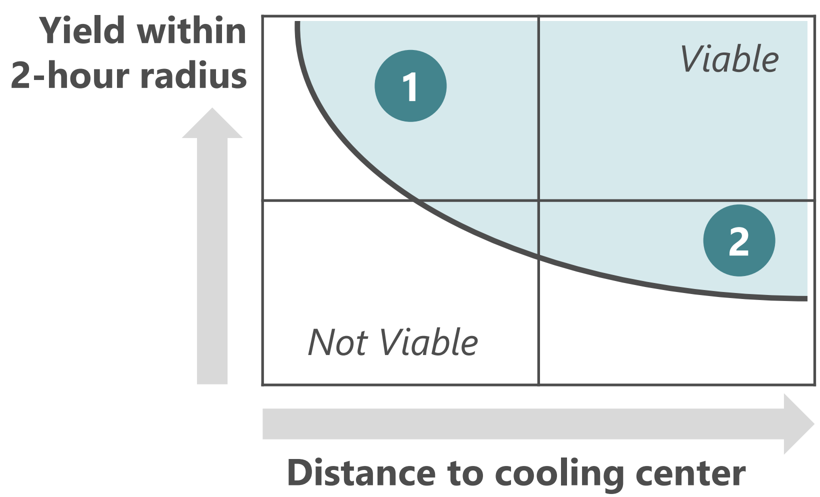
Source: [1]Tijanni and Yetisemiyen, Dairy Cattle and Dairy Industry in Uganda: Trends and Challenges, Link.

The viability of cooling systems is closely linked to farmers' distance from a bulking center and total milk yield

Long distances are a challenge to farmers who need to cool their milk at collection centers before milk spoils

- Typically, farmers milk their cows twice a day – morning and evening
- Freshness is maintained by transporting milk to collection centers with large cooling tanks that are within two hours
- Quantities of evening milk are usually lower (~40% of morning yields); these small quantities are either consumed by family, stored then sold in the morning, or wasted due to inadequate storage[1]

Large and small coolers both have viable cases depending on distance to cooling centers and yield



1 Shorter distance + high yields
Needs closer collection center using larger cooling tank, likely powered by a mini-grid (3,000L-5,000L)

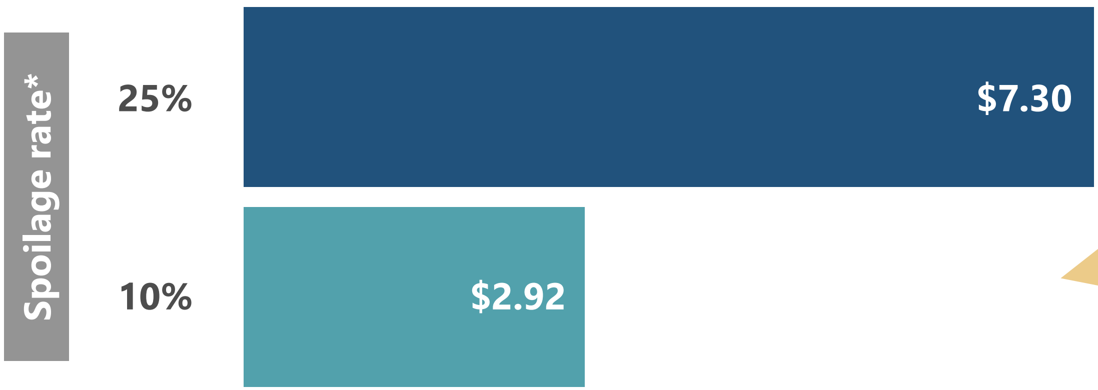
2 Longer distance + medium yield
Satellite system where milk is chilled closer to production area before transporting to larger center with smaller cooling tank (100L-500L)

Source: [1]UOMA consultations and analysis

Cost-savings per capacity of cooling units are directly corelated to the spoilage rate of any given area

Further research is required to assess viability of specific locations

Estimated annual savings per liter of tank capacity[1]
USD



As cost-savings are directly proportional to size of tank, larger tanks can be leveraged for areas with high farmer density for greater impact and revenue potential e.g. cooling units for a 1,000 L tank with a 10% spoilage rate could yield $2,920 in annual savings

While general statistics help us estimate cost-savings, more research on the following topics is needed to optimize site selection:

- Spoilage rates specific to an area, and the points of the value chain where the spoilage occurs
- Available and affordable modes of transportation
- Local milk prices and seasonality
- Current and future price of delivering full PUE solution, including off-grid energy

Note: * Spoilage rate refers to the portion of milk spoiled as a result of a lack of cooling; sensitivities of 10% and 25% are used here to demonstrate effects on cost-savings

Source: [1]UOMA analysis: refer to appendix 1 for detailed calculations

A number of solar refrigerators exist in the market covering, with varying configurations and economic benefit

Estimated ROIs and payback periods vary significantly across tank sizes and spoilage rates

		Refrigerator		Refrigerator		Cool container		Milk Cooler	
Specs	Retail Price	$ 2,000		$ 1,700		$ 25,000		$ 31,500	
	Cooling Volume	50 L		165 L		1,000 L		2,500 L	
	Capacity of PV module	180 W		75 W		3,400 W		~8,500 W[1]	
Financials	Spoilage rate	10%	25%	10%	25%	10%	25%	10%	25%
	Estimated annual income saved*	$135	$338	$480	$1,205	$2,920	$7,300	$7,300	$18,250
	Annual earnings (before depreciation)**	($165)	$38	$377	$1,135	($830)	$3,550	$2,575	$13,525
	Payback period (years)	-	52	8.9	2	-	7.1	12.2	2.3
	Estimated 5-year ROI	(41%)	9%	56%	253%	(17%)	71%	41%	215%
	Example units	SOLARCHILL		SunDanzer DC-Powered Refrigeration		ILK Dresden		MUELLER	

Notes: *Annual income saved based on annual production capacity of asset, assumed utilization of 80% and assumed 10%-25% of range of spoilage; **Annual Earnings before depreciation is annual income saved less maintenance cost (10% cost of asset) and financing cost (assuming 15% annual interest rate)

Source: UOMA analysis

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Both public and private players can leverage a variety of models to introduce off-grid milk cooling technologies to rural dairy farmers

Model	Description
Farmer collectives	• A group (e.g. 15-20 neighboring farmers) combine resources and purchase a milk cooling asset of a capacity equivalent to their production • This asset serves the farmers' need to preserve their milk and lowers spoilage
Dairy cooperatives	• Large cooperatives purchase a cooling technology and deploy it as a collection point • The cooperative purchases and bulks milk and later distributes profits to its members
Local government	• Government invests in assets and deploys them at community levels in high milk production areas • The asset would be administered by government extension officers to support farmers
Entrepreneurs	• Entrepreneurs invest in the asset, which would serve the farmers that are far from collection points but are in areas with potential for high milk production • The entrepreneur charges a fee for chilling or purchases farmers' milk directly
Milk processors	• Milk processors operate additional collection as an extension service closer to distant farmers in high-production/ high-potential areas • This could enable farmers to preserve their milk and sell it faster to processors

Capital source: Farmers | Government | Private business

Source: UOMA analysis

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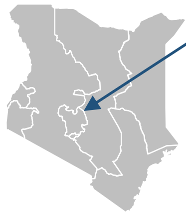
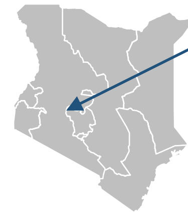
Case studies: **Large and small capacity initiatives have been piloted in Kenya with positive impact on dairy farmers to date**

Kenya





	Local government **Kiambu milk cooling plant[1]**	**Farmer cooperative** **Ngorika dairy farmer association[2]**
Problem	• Farmers struggled to sell up to **50%** of milk in a timely manner, resulting in spoilages	• Milk is collected in the morning, however by then majority of evening milk is spoiled
Solution	• Government purchased a cooling facility and collects **5000L/ day** from local community • **10%** of farmer earnings from milk are deducted towards maintenance	• Cooperative purchased solar farm-milk cooler to provide on-farm milk cooling of **25 L/day** • Famer cooperative uses revenue to operate the equipment
Impact	• **USD 1,000** worth of milk saved every month • **2L** extra milk for individual family consumption	• **USD 75** incremental income gains per farmer per month • **1-3-year** payback period on investment

Sources: [1]Reuters: Milking it: solar coolers heat-up earnings for Kenya's dairy farmers, 2018, Link;; [2]ISES: Solar Milk Cooling: Smallholder Dairy Farmer Experience in Kenya, 2015, Link.

Key considerations & next steps

Affordability & financing, population density, and after-sales support are paramount to achieving sustainability

Affordability & financing	Population density	After-sales support
Consumer affordability is a major barrier to sales and uptake of off-grid products. Companies should introduce innovative means to reduce costs and increase available financing to consumers	Population density is a key determinant of viable energy sources. Areas with higher population can operate mini-grids effectively, while sparsely populated areas may best be served by standalone systems	Establishing long-term relationships with customers beyond the initial sale is key to sustainability. Customers will require various after-sales services and this can also increase revenue streams

The following slides provide detailed considerations across each of these areas that market players should consider in implementation

Source: UOMA analysis

Affordability & financing: **Affordability is a key barrier to adoption, but innovative models can be leveraged to increase access**

	Challenges	Opportunities
Affordability	**Dairy farmers have limited disposable income available for the purchase of assets** • Annual income for dairy subsistence farmers ranges $890-$1,000[1] • Additionally, income fluctuates across seasons, and drops significantly in times of oversupply • Farmers typically need to supplement income through other farming activities (e.g. crop growing)	**There is potential to reduce costs at individual farmer level** 1. **Promote shared investment:** Large assets can be shared amongst farmer groups 2. **Increase R&D expenditure:** Could reduce product costs in the long-term
Financing	**Only 10% of agricultural households in Uganda have access to credit facilities[2]** • Sources of credit were mainly from self help groups (31%), MFIs (29%), & commercial banks (10%) • High interest rates and lack of collateral were cited as main reasons of not accessing credit	**Alternative financing mechanisms can be leveraged to expand access** 1. **Pay-as-you-go (PAYG):** Supports affordability by reducing up-front cost 2. **Alternative credit scoring:** Alternative credit rating methods could open access to financing

Sources: [1]African Association of Agricultural Economists: Dairy farmers access to market in Uganda, Link; [2]Uganda Bureau of Statistics: Agricultural Household and Holding Characteristic Report, Link.

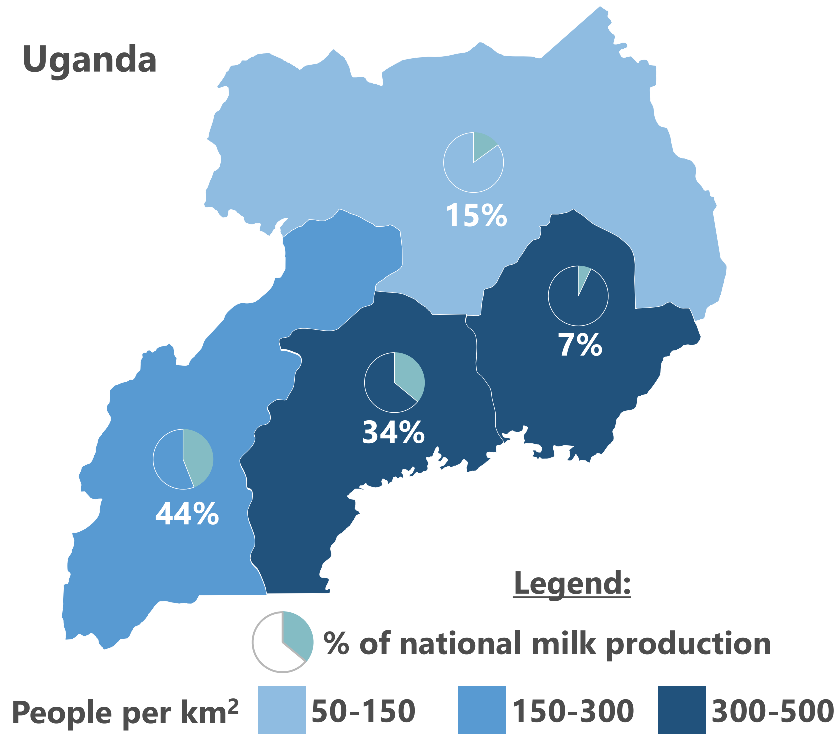
Population density: Standalone systems are well suited for dispersed populations, and mini-grids for densely populated areas

Stand-alone systems are likely to be more cost-effective for sparsely populated areas

- Transmission requirements, energy losses and costs are likely to be greater in sparsely populated areas to reach farmers, making mini-grids expensive[1]

Mini-grids are viable in densely populated areas*

- In densely populated areas, it is approximately half the cost to connect households to a mini-grid[2]
- Such areas are likely to provide economies of scale required for mini-grids to be viable
- Power for mini-grids can be supplied from a variety of sources, e.g. solar, biomass or diesel hybrids



Mini-grids are most viable in UG's Central and Western regions due to both high milk production and population density. Stand-alone systems could be leveraged for other areas

Note: * Refer to appendix 2 for a list of operational mini-grids in Uganda

Sources: [1]Husk Power: Electrifying Rural India with Rice Power (Husk Power), Link; [2]CrossBoundary analysis, Link.

After-sales support: Businesses must work to establish long-term relationships to achieve sustainability

Targeted support to farmers is essential to support growth and maximize ROI

Three key areas of customer support need to be considered to inform overall strategy and business model design

Installation

- Target market may not have the know-how to install products on their own and will likely be reluctant to purchase products without installation included
- Installation helps ensure proper usage and long life of the equipment and can be Integrated with LDM for cost-savings

Availability of spares

- Availability of spare parts will be essential to ensure products are sustainable for long-term use
- PUE distributors should partner with rural retail networks to ensure availability of spares; credit or consignment could help affordability barriers

Qualified technicians

- Technicians will need to be trained and organized in a distributed network to reduce costs; ensuring concentration of customers is key to efficiency
- Specialized players are beginning to emerge along the value chain focusing specifically on maintenance; partnership opportunities can be explored

Source: UOMA analysis

Next steps: UOMA is pursuing partnerships with PUT providers & ag. players through piloting of innovative business models

In parallel to continued research, UOMA is working to identify stakeholders with interest and capacity to partner, design, and test necessary proof-points of emerging business models

Pilot support activities

1 Pilot design and planning

- Articulating plans and timelines for scalable solutions with identified partners including designing of innovative pilots and identifying required incentives

2 Implementation support

- Providing targeted support for data collection and analysis and hypothesis testing for pilot redesign

3 Investment readiness support

- Developing investor materials, building requisite internal processes, and facilitating introductions to investors

UOMA's recent work in PUE

- Researched customer segments and modelled unit economics for introduction of a new solar powered milling machine in Eastern Uganda
- Assessed market for solar pumps and commercial viability for solar irrigation
- Supported pilot business model for solar refrigeration products
- Tested mini-grid business model with ice-maker serving as anchor client on Bukasa Island

Source: UOMA analysis.

Appendix

Appendix (1/2): Calculation breakdown for cost-savings for dairy cooling tanks (estimates)

Examples of 100- and 3,000-liter cooling tanks are used here to demonstrate potential returns as well as calculation methodology

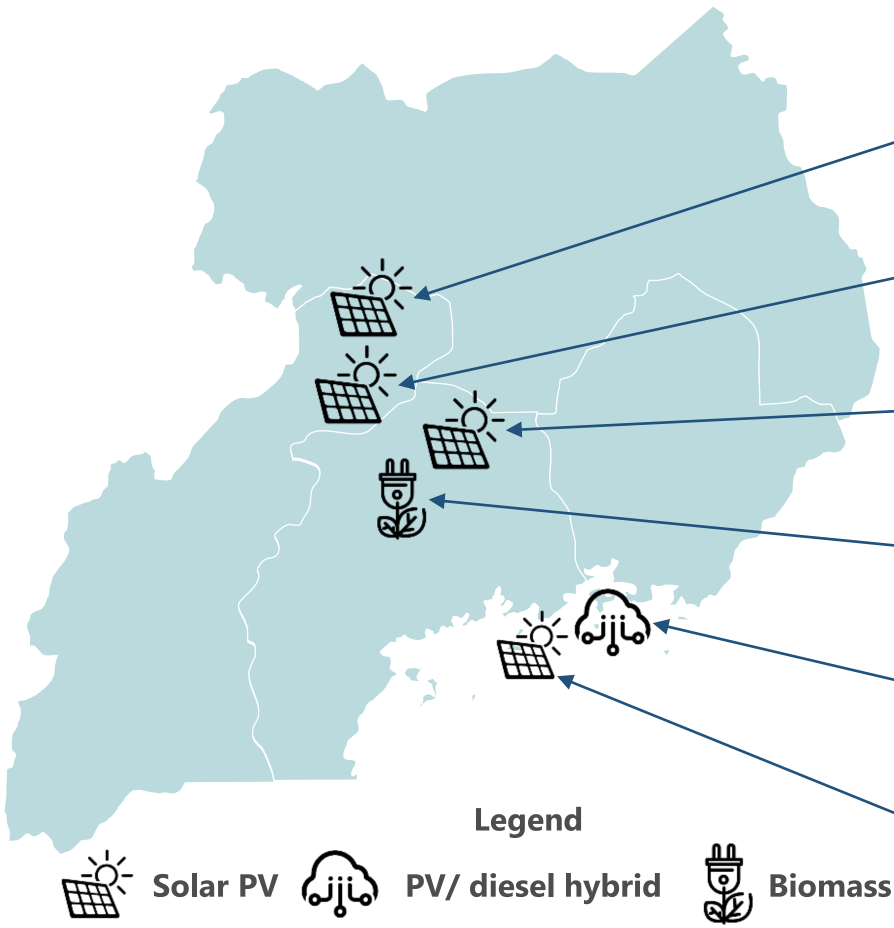
Cooling tank capacity (Liters)	(A)	100		3,000	
Average yield per cow (Liters/day)[1]	(B)	2.5		2.5	
Average # of cows lactating per day**	(C)	60%		60%	
Total cows needed to fill tank	(D=A/B/C)	66		1,991	
Annual capacity in area (Liters)	(E=A*365)	36,500		1,095,000	
Cooler utilization	(F)	80%		80%	
Annual Liters chilled (Liters)	(G=E*F)	29,200		876,000	
Spoilage rate in the area*	H	**10%**	**25%**	**10%**	**25%**
Milk saved from spoilage (Liters)	(I=G*H)	2,920	7,300	87,600	219,000
Sales price (USD/Liter)	(J)	$0.10	$0.10	$0.10	$0.10
Annual income saved from spoilage	**(K=I*J)**	**$292**	**$730**	**$8,760**	**$21,900**
Income saved per liter of tank capacity	(L=K/A)	*$2.92*	*$7.30*	*$2.92*	*$7.30*

Notes: *Assumes a range for spoilage rate; **Assumed that lactation days of indigenous breeds is 220 days – calculation was 220 days/365 days of year

Source: [1]World Bank: Uganda Dairy Supply Chain Risk Assessment, 2011, Link.

Appendix (2/2): Private mini-grid solutions of varying sizes and types exist in some regions, but are still relatively few

Presence of mini-grids in Uganda



#	Organization	No. of grids	Overall capacity (kW)
1	REMERGY ENERGY SOLUTIONS	1	5
2	Energy for Development	2	27
3	Kirchner Solar Uganda	1	23
4	Pamoja CLEANTECH AB	2	64
5	KIS KALANGALA INFRASTRUCTURE SERVICES LTD.	1	1,600
6	absolute energy	1	230

There are still many areas that are have no access; Standalone systems can be leveraged to provide access to these areas

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Source: UOMA: Market Map of off-grid energy in Uganda, 2019, Link.

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Contact us if you have any feedback or interest in partnering

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