POWER FOR ALL

#PoweringAgriculture

Powering Agriculture eBooklet

A Knowledge Resource for the Productive Use of Renewable Energy in Food Systems

About this Booklet

The ways in which decentralized energy access can boost productive agriculture

According to the World Bank, agriculture contributed to one-fourth of global gross domestic product (GDP) in 2018 and it is not only essential towards boosting food security for an estimated 8.9 percent of the world's population who go hungry, but also plays a critical role in improving livelihoods through increased incomes. These benefits from agricultural activities can also be attained when current agriculture practices include decentralised renewable energy (DRE) powered technologies, such as solar water pumps, solar powered mills, and solar powered refrigerators which help boost agribusiness value chains, reduce food waste, and reduce pollution especially for smallholder farmers.

DRE powered agriculture technology is in the early stages of innovation and there is still room to develop appliances that have better technical and commercial viability. To this end, Power for All has recognised the need to generate broader awareness of DRE in powering agro-appliances for agro-productivity and agro-processing activities thus unlocking the benefits of a productive and sustainable agricultural sector. Through our Powering Agriculture campaign, we aim to make decentralised renewables a key part in scaling agriculture and food productivity in emerging African and Asian markets.

A thorough understanding of the facts and key trends in DRE powered agro-productivity, agro-appliances and agro-processing is necessary for shaping the evolution sector and seeing tangible benefits in smallholder farming communities. Power for All's Platform for Energy Access Knowledge (PEAK) is a tool for easily exploring these facts and trends. Through exploring the best available literature, PEAK's researchers have prepared a series of short, sharp, synthesized content. These include (a) fact sheets, that highlight key agriculture and energy insights from several recently published reports; (b) research summaries, that highlight key agriculture and energy insights by deep-diving into a single recently published report or article; and (c) technology spotlights, that highlight the latest technology innovations in the agriculture energy nexus.

Our Powering Agriculture eBooklet compiles this ready-to-share content powered by PEAK for use and dissemination by broad audiences. These syntheses are designed to help readers draw out the clearest data points articulating the direct relationship between decentralized energy access and agriculture productivity. This is a living compendium -- as new data becomes available, we will update the resources accordingly.

Platform for Energy Access Knowledge (PEAK) platform

Contents

POWER FOR ALL FACT SHEET

Mini-grids productive use of energy (PUE) in agriculture

This fact sheet provides a view on the latest trends in mini-grid productive uses of energy (PUE)[1] in agriculture. It provides highlights on the opportunities, tested and proven business models, and challenges of PUE in the agriculture value chain. These insights are based on recent studies by the National Renewable Energy Laboratory (NREL),[2] the International Institute for Environment and Development (IIED),[3] the Energy and Environment Partnership (EEP),[4] and Energy 4 Impact (E4I).

$0.32/kWh

TARIFF AT WHICH ELECTRIC MILLS BREAK EVEN WITH DIESEL MILLS

10–20%

FISH CATCH LOSSES CAN BE PREVENTED BY PROVIDING FISHERMEN WITH ENOUGH ICE.

34%

PROFIT MARGIN OF EGG INCUBATION WITH MINI-GRIDS AT A TARIFF OF US$0.9/KWH

Using mini-grids in agricultural values chains provides an opportunity for rural communities to boost local economies. Some agricultural activities that have effectively benefitted from mini-grids include milling, oil pressing, egg incubation and ice making for fish.

» Electric, motor-driven mills are a prefered to diesel-driven mills because they are easier to operate, require less maintenance, and reduce labour by removing time and cost required to travel for fuel purchases. Moreover, if electricity costs are less than $0.32/kWh, electric motor-driven mills are less expensive to operate. (M1, p.28)
» A 250 kW hydro mini-grid in Sierra Leone powers a palm oil pressing plant along with a community of 300 households. The palm oil pressing plant improved the financial case for the power plant as an anchor client, buying one-third of the electricity generated. The power plant created 7 permanent jobs locally and supplied affordable power with an uptime of 85%.[5]
» For rural communities, egg incubation offers an attractive business opportunity due to the low upfront cost and potential high returns. A pilot in Tanzania shows that for an initial investment of US$122 investment in a 100W incubator, entrepreneurs can expect 34% profit margins if the mini-grid tariffs are set at $0.90 per kWh. (M1, p.31)
» In Ukara island, Tanzania, mini-grid systems have been used to make ice and reduce inefficiencies in the fishery value chain, resulting in less fish catch losses that could be as high as 20% in the area, and lower fuel costs for ice boats. (M2, p.28)

More research is needed to quantify the social impacts in the adoption of mini-grid systems for agricultural activities. However, based on past evidence of rural electrification, there are expected impacts in gender equality, job creation, and environmental impact.

» A study in India found that around 90% of the women who gained access to mini-grid electricity highly appreciated the increased ease of daily chores. Women's involvement in personal development activities also increased by 0.5 hours per day from benchmark.[6]
» Automating the milling process would free up a significant amount of time for women and girls, which could be put towards other productive or educational activities.[7]
» Access to electricity can create jobs by helping new businesses form and existing businesses expand. Also, jobs created by PUE can have a multiplier effect as workers spend part of their income on the local economy. (M1, p.41)

From its portfolio companies EEP Africa identified three key business models that are currently being used to promote mini-grid PUE in agriculture: Energy Supply Model, Business Acceleration Model and Supplier-Offtaker Model.

» EEP Africa has identified 3 business models from their portfolio that mini-grids developers integrate PUE activities with: 1) the Energy Supply Model, in which the mini-grid developer produces and supply electricity, 2) the Business Acceleration Model, in which the mini-grid developer also provide appliance and loans, and 3) the Supplier-Offtaker Model, in which mini-grid developer operates agricultural activities as the main electricity offtaker. (M3, p.13,24,31)
» An effective model is characterized by 1) a direct increase in project IRR, 2) indirect financial benefits brought to mini-grid customers, and 3) social benefits such as better health for the community at large. (M4,[8] p.129)
» A Supplier-Offtaker Model in Cape Verde failed to achieve financial viability due to the low cost of electricity, high cost of back-up diesel generation and little revenue from the agricultural applications. This case, however, excelled in technical implementation and affordable, high quality supply of electricity and PUE service. (M4, p.51,52)

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POWER FOR ALL FACT SHEET

Mini-grids productive use of energy (PUE) in agriculture

By the Numbers:

$0.32/kWh

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PROFIT MARGIN OF EGG INCUBATION WITH MINI-GRIDS AT A TARIFF OF US$0.9/KWH

Despite the promise of increased local economic activities, mini-grid system developers and communities are confronted with several barriers to replicate or scale success, including high upfront costs, lack of skills and knowledge, technical challenges and market constraints.

» Low cash flows outside of the harvest periods negatively affects the ability of users to pay for electricity and appliances. This risk can be mitigated by mini-grid operators requiring users to pre-pay for a certain service or level of consumption, and/or providing alternate finance models for appliances.[9] (M1, p.42; M3, p.44)

» Local entrepreneurs in rural areas often lack the skills to run a business,[10] while mini-grid developers lack adequate knowledge of local rural agriculture value chains. To mitigate this, accessible market information is crucial. (M1, p.43; M2, p.20,34,35)

» Mini-grid systems must be designed to serve the required loads while maintaining power quality, reliability, and availability. Inadequate assessment of the power demands leads to underuse of the mini-grid thus driving up costs. This risk can be mitigated through systems modularity and better understanding of PUE loads. (M1, p.19, 43)

Share the Message

» Mini-grids have seen successful integration of agricultural applications in various value chains, bringing various benefits for farmers while improving their financial performance. Challenges remain, however, to replicate success.

» Various business models have been tested. However, to ensure long term economic viability, mini-grid developers should build a strong understanding of agricultural practices and adapt project design to the local context.

» Rural customers are price sensitive due to variable incomes associated with seasonal harvests. Therefore, mini-grid tariffs should reflect consumers' ability to pay and financing should be provided for appliances when available.

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POWER FOR ALL FACT SHEET

Decentralized Renewables: Boosting Agriculture and Improving Nutrition

300%

INCREASE IN AGRICULTURAL YIELDS WITH SOLAR WATER PUMPS IN KENYA

75%

REDUCTION IN GRAIN PROCESSING TIME IN NEPAL WITH MICRO-HYDRO-POWERED MECHANIZATION

66,000

PEOPLE IN BENIN WITH ACCESS TO FRESH FRUITS AND VEGETABLES DUE TO SOLAR IRRIGATION

One in 9 people—795 million people—are undernourished[1], 98 percent of whom live in emerging economies.[2] UN SDG 2 targets the end of hunger and all forms of malnutrition by 2030, as well as the doubling of agricultural productivity and incomes of small-scale food producers.[3] Decentralized renewable energy (DRE) solutions can aid subsistence and low-income farmers to increase outputs, create savings, and allow for increased income for spending on more nutritious food.

DRE solutions are increasing food supplies and supporting agricultural output:

» Food is the number one good purchased by families in East Africa use savings from replacing kerosene, candles, or flashlights with solar lights.[4]

» There are 500 million subsistence farmers/smallholders providing food to support 2 billion people with the potential to increase their yields with the use of decentralized renewables.[5]

» In Kenya, solar irrigation helps smallholders grow more crops throughout the year, leading to an increase in their yields of 300 percent.[6]

» To increase farming outputs, India has announced plans to install 26 million solar water pumps[7], while Bangladesh has set a target to finance 50,000 solar water pumps.[8]

» 11 half-hectare sized market gardens powered by solar irrigation in Benin and farmed by co-operatives of 35-45 women each enable 66,000 people to access fresh fruit and vegetables.[9]

» Solar refrigeration systems can enable the storage and transport of vaccines for livestock, helping to protect farm animals from diseases like the "peste de petits ruminants" disease, which causes over $2 billion in losses each year, mainly in Africa, Asia, and the Middle East.[10]

» In Zimbabwe, solar irrigation pumps allow smallholder farmers to increase yields by 25%. Farmers were able to plant three crops per year, providing a diversity of nutritious cash crops.[11]

» DRE can increase the value of agricultural products. For instance, using solar dryers to create banana chips in Thailand can increase the price of banana chips sold by over 70%, resulting in increased income of $1.5 million per year.[12]

DRE solutions are reducing wasted food and labour through cooling and agro processing:

» The total value of food that is lost annually due to lack of refrigeration is $4 billion throughout all of Africa and $4.5 billion in India. In Sub-Saharan Africa, loss of perishable fruits and vegetables can reach up to 50% annually.[13]

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PEOPLE IN BENIN WITH ACCESS TO FRESH FRUITS AND VEGETABLES DUE TO SOLAR IRRIGATION

- Cold storage units powered by decentralized renewables save crops following harvest. In a trial in Zimbabwe, biogas powered chillers doubled the amount of milk a family is able to keep or sell.[14]
- In Uganda, where 70 percent of the population is involved in smallholder agriculture, solar powered refrigeration could cut agricultural output loss by 30–50 percent.[15]
- Currently, only 10% of global farm labor relies on machines.[16] Using decentralized renewable energy can increase productivity and speed up agricultural processing.
- In Vanuatu, it takes only a few seconds to grate and grind coconut and cassava using solar-powered machinery, opposed to 20 minutes required with manual grinders.[17]
- Micro-grid hydro plants powering grain mills in Nepal reduce the time and workload of women by over 75 percent, from at least 2 hours of grain processing by hand, to half an hour with mechanization.[18]
- After installation of solar water pumps, women in Zimbabwe who previously spent 6 hours per day walking to collect water for their gardens—containing crops like spinach, cabbage, tomatoes, beans, and others—now only spend 1-2 hours daily.[19]
- Solar refrigeration systems used to keep food fresh can also provide cryogenic energy storage, ensuring more reliable electricity supply.[20]

Share the Message

The role of decentralized renewables in improving irrigation, cold storage, and agricultural yields will be imperative to reach UN SDG 2 targets for hunger eradication, especially as climate change is projected to increase droughts and extreme weather. Join Power for All to share the following messages:

- Decentralized renewables, especially solar irrigation and water pumps, can increase agricultural outputs, as well as increase diversity of crop production.
- Decentralized renewables can power cold storage systems, drastically reducing food waste and preserving more food for people to eat.
- Mechanized agro processing powered by distributed renewables can save labor and increase the value of crops.

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TECHNOLOGY SPOTLIGHT

DECENTRALIZED COLD STORAGE FOR AGRICULTURE

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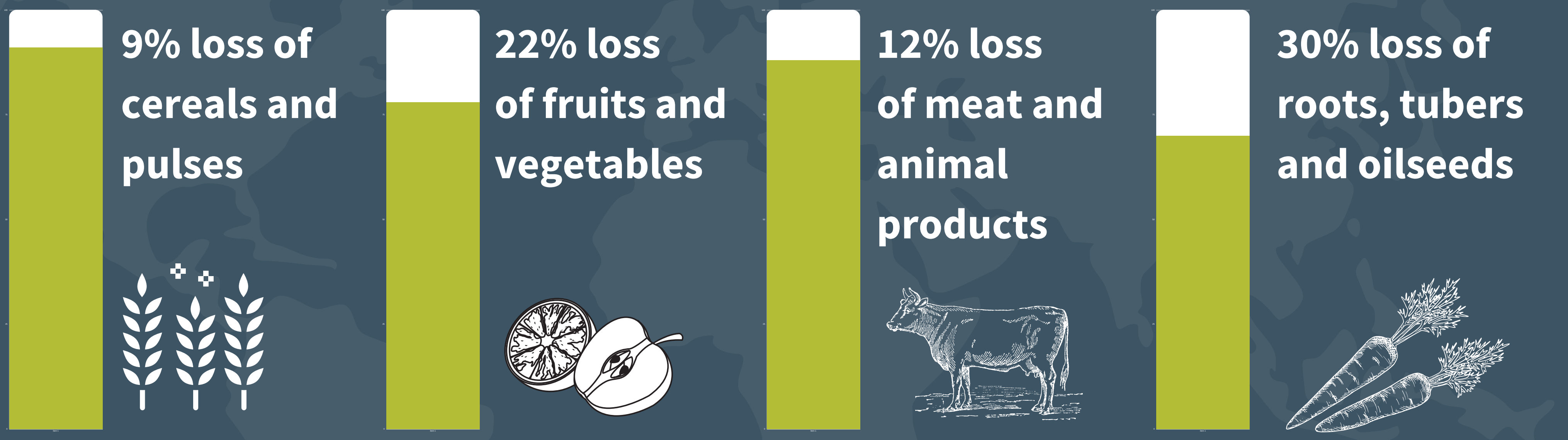
Cold storage involves the use of electric powered facilities to store fresh and/or frozen perishable fruits or vegetables, meat, seafood, or dairy products, at a desired temperature to maintain the quality of products for sale. It can have a positive impact on food security by extending the shelf-life, reducing losses, and retaining nutrients in food.

GLOBAL FOOD LOSS DUE TO INAPPROPRIATE HANDLING PROCESS [1]



REFRIGERATION SAVES 1/3 OF FOOD LOSS IN SUB-SAHARAN AFRICA (SSA)

230 million tons of food are produced in Africa each year,[1] 14% of which is lost. Refrigeration can save 30% of the post-harvest food loss.[2]

DECENTRALIZED COLD CHAIN TECHNOLOGIES

Cold chain involves a range of technologies along the agricultural value chains, including walk-in cold rooms, refrigerated trucks, and freezers. These solutions, however, favor larger, commercial farmers. Case studies show that the economic viability of solar-powered cold storage depends on the utilization rates. Business model innovations such as "cooling as a service" help improve access for smallholder farmers.

SERVICEABLE MARKET FOR SOLAR-POWERED REFRIGERATION IN SSA

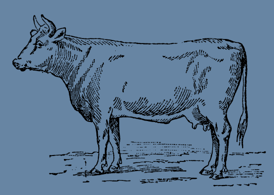
Serviceable market takes into consideration access to grid electricity and ability to pay. Of the 10 million smallholder farmers in SSA who are farming fresh produce that needs cold storage, 36% have access to grid and 62% could not afford the technology. The remaining 2% is serviceable and constituted by 225K farmers in 2018.

In 2018, 225K farmers could be serviced, representing a market opportunity of US$ 191 million.[3]

By 2030, 1.5 million farmers will be serviceable, creating a US$ 1.32 billion market opportunity.[3]

BUSINESS CASE:
Mini-grid-connected fish freezer[4]

CAPEX	US$365
Capacity	90L
Payback Period	10 months
Value add	From $2.75/kg to $3/kg



BUSINESS CASE:
Standalone milk chiller[5]

CAPEX	US$1, 700–31, 000
Capacity	50–2, 500L
Solar capacity	75W–8,500W
Payback period	2–7 years assuming 25% spoilage rate

Sources:
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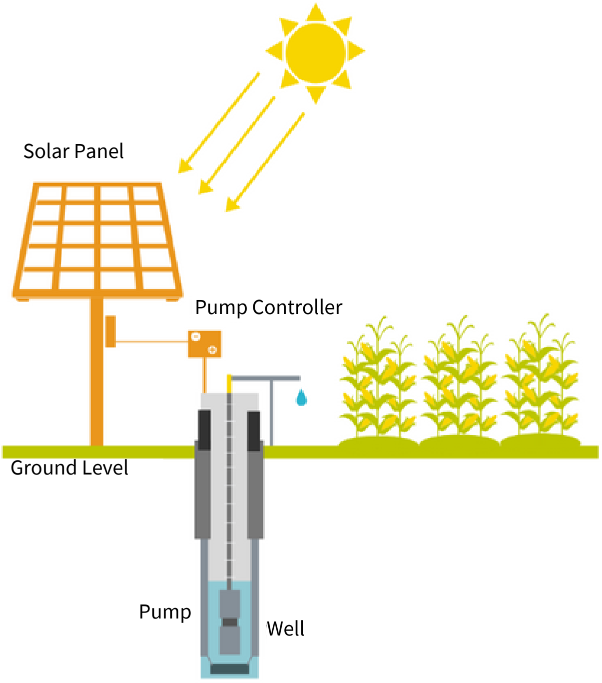
SOLAR IRRIGATION

This technology spotlight provides latest market insights for emerging applications that unlock productivity through decentralized renewable energy technology.

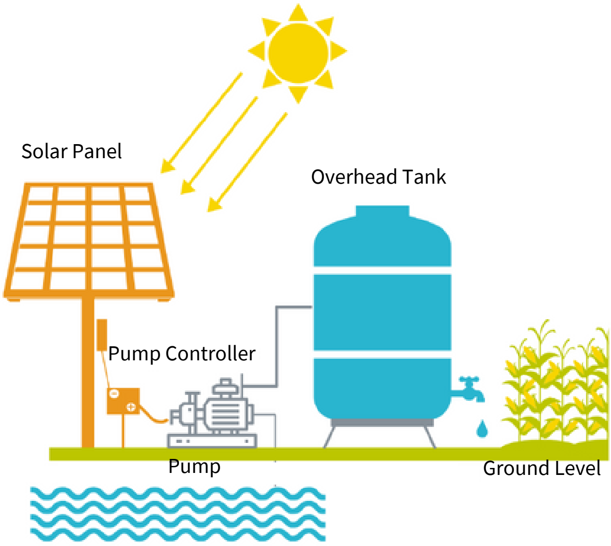
Solar irrigation converts solar power into electrical energy to power a pump that lifts and carries water. Leveraging the cost decline of solar technologies, solar irrigation pumps are increasingly adopted by smallholder farmers in emerging markets to improve yields, reduce vulnerability to rainfall variability and to enable multiple cropping cycles. Although the upfront costs are about 3-4x that of their diesel pump equivalents, the total lifetime costs of solar irrigation are already competitive.[1, 2, 3] Currently, the industry is at an inflection point, where the technology is mature enough for scale, which will continue to put downward pressure on cost.

Solar Water Pump Types

Submersible Pump



Surface Pump



"Solar Pumping Systems." Digital Image. Accessed October 25, 2018. http://galaxyenergysystems.in/solar-pumping-systems.html.

Figure 1. Illustration of a solar-powered submersible pump, which is used to pump underground water from a borehole

Figure 2. Illustration of a solar-powered surface pump, which is used when surface water is available

Market gap

- 500 million: Number of smallholder farmers around the world lacking access to modern irrigation solutions. (S1, p.9)
- 95%: Cultivated land that relies on seasonal rainfall in sub-Saharan Africa (SSA) (S1, p.9)
- 60%: Cultivated land that relies on seasonal rainfall in South Asia (S1, p.9)

Current market estimate

- 150,000: Solar water pumps that are in use today in India (S1, p.6)
- 5,000: Solar water pumps sold in SSA in second half of 2018 (S1, p.6)

Pump system capacities[4]

- 2–4kW: Solar water pump capacities in India (S1, p.9)
- <500W: Solar water pump in SSA (S1, p.9)

Average price[5]

- US$1,000–3,000: Cost range of solar water pumps India (S1, p.10)
- US$600–2,000: Cost range of solar water pumps SSA (S2, p.9)

Addressable market[6]

- India: 4.2 farming households, US$ 15.1 billion (S1, p.12)
- SSA: 700,000 smallholder farmers, US$ 456–500 million (S1, p.11, S2)

Market projection

- India: 3.7 million households, US$ 9.4 billion in spending[7] by 2030 (S1, p.6)
- SSA: 2.8 million households, US$1.6 billion in spending by 2030 (S1, p.11)

Impact potential

- 141–195%: Maize yield uplift from small-scale irrigation in SSA (S3, p.11)
- 2x–3x: Cabbage and tomato yield increase in Zimbabwe (S2, p.35)
- 50%: Profitability boost for smallholder farmers in India (S1, p.9)

Resources

1. "The Market Opportunity for Productive Use Leveraging Solar Energy (PULSE) in Sub-Saharan Africa." IFC, 2019. **(Herein S1)**
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4. Smaller pump capacities indicate smaller average plot size. India's larger pump capacities are also due to government subsidies.
5. Cheaper price range in SSA than India may be due to smaller system capacities demanded.
6. Addressable market is estimated by the cost of appliances, number of smallholder farmers and production volume, without considering grid access, affordability and other market constraints. (S1)
7. Number of households multiplied by the average cost of appliances. (S1)

POWER FOR ALL FACT SHEET

Leveraging decentralized renewables for Uganda's agricultural sectors

Decentralized renewable energy (DRE) has the potential to bridge the energy access gap in the agricultural sector in Uganda. For smallholder farmers to benefit from DRE access, however, it is vital to consider the technical and commercial viability of electrical appliances for various agricultural value chains. This summary provides an overview of successful use cases of DRE-powered productive use applications and the solutions emerging.

72%

UGANDA'S WORKFORCE IN AGRICULTURE

2 years

PAYBACK PERIOD OF SOLAR WATER PUMPS DISPLACING DIESEL PUMPS IN UGANDA

2 years

PAYBACK PERIOD OF REFRIGERATORS FOR MILK CHILLING IN UGANDA

DRE technologies are already electrifying 3% of Uganda's residential energy needs. Leveraging DRE for agriculture improves income for Uganda's smallholder farmers and creates livelihoods in the downstream stages of the agri-food system.

» Uganda is one of the countries that have the fastest electrification pace, at 4% per annum. DRE has already electrified 3% of Uganda's population and has the potential to bring clean energy to an additional 20.5 million people by 2030.[1, 2]
» Despite the rapid expansion of DRE, the mechanization of Uganda's agricultural sector is low. According to the Uganda Bureau of Standards, more than 95% of farmers rely on human power for their farming activities without mechanized support.[3]
» The agricultural sector employs over 72% of Uganda's workforce and has a significant potential for value addition across the country.
» Reports suggest productive use of energy (PUE) in agriculture could increase smallholder farmers' farm yield and farmers' income.[4, 5] For instance, the introduction of 47 maize shellers in the Busoga region of Uganda doubled local farmers' incomes in 3 years.[6]
» Key success factors included addressing the market access gap by bringing together multiple actors along the supply chain, managing partnerships through clear agreements, and developing innovative business models that bring value to each actor.[7]
» The ILO projects that agricultural productivity growth will likely see the workforce shift away from on-farm activities and will generate strong employment multiplier effects in the downstream stages of the agri-food system.[8]

DRE-powered agricultural applications already have successful use cases in various value chains in Uganda, including solar irrigation and milk chilling.

» Solar irrigation has the potential to serve a large number of farmers in the north of Uganda. Due to its low operating costs, a solar water pump that displaces diesel can achieve payback in 2 years.[9, 10]
» Milk is highly perishable without appropriate cooling. In Uganda, the overall spoil rate of milk at the farm level is 22.5%, and it can be as high as 37% in informal markets. DRE-powered cooling solutions such as refrigerators and milk coolers have about 2 years of payback period and positive 5-year ROI, benefiting dairy communities particularly in the north and southwest regions.[11, 12, 13]

DRE-powered agro-processing, though just emerging, has a high potential to add value to other value chains such as coffee pulping, oil pressing, and grains milling. These activities are yet to be integrated into DRE systems' load due to various technical and commercial constraints.

» While coffee constitutes over 18% of Uganda's formal exports in 2014 at US$410 million, coffee farmers' income remained significantly lower than other farming households. Currently, solar-powered coffee pulper is already available on the Ugandan market; its high capital cost (US$2,000+), however, makes it inaccessible for smallholder farmers.[14]
» Domestic demand for milling is high. Currently, there are more than 780 milling plants. Most of them are concentrated in urban areas. Energy access is a main operational

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By the Numbers:

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PAYBACK PERIOD OF SOLAR WATER PUMPS DISPLACING DIESEL PUMPS IN UGANDA

2 years

PAYBACK PERIOD OF REFRIGERATORS FOR MILK CHILLING IN UGANDA

challenge for these mills, either due to the high electricity tariff or unreliability of diesel generators.[15]

» For solar mills to displace diesel mills, however, technical challenges persist, such as low throughput, 10x capital cost, lack of 3-phase motor. Mini-grids, on the other hand, can overcome these challenges and provide a more lucrative case at a tariff of US$0.32/kWh.[16]

» Oil pressing can add value to Uganda's top crops such as groundnuts, soya beans, simsim, and sunflower seeds, meeting its domestic vegetable oil demand while displacing imports. Oil pressing machinery, however, is expensive and not widely available locally.[17, 18]

Share the Message

» Electrifying agricultural activities can bring additional income for smallholder farmers while generating multiplier employment effects in the downstream stages of the agrifood system.

» The rapid expansion of DRE electrification in Uganda brings its agricultural sectors into the spotlight as the next frontier of energy access.

» Promising applications that can be economically viable for smallholder farmers include solar irrigation and milk chilling.

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POWER FOR ALL FACT SHEET

Rural Agribusiness Opportunities and Applications in India

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US$13 BN

POST-HARVEST LOSS DUE TO INAPPROPRIATE STORAGE AND INEFFICIENT FARMING PRACTICE

US$9.4 BN

INDIA'S SWP MARKET POTENTIAL BY 2030

2%

PUBLIC AWARENESS OF SWP SUBSIDIES

Productive use of energy (PUE) in India spans multiple applications. PUE solutions leveraging decentralized renewable energy (DRE) can provide cost-competitive alternatives to existing solutions through savings on fuel costs, efficiency and reliability. This fact sheet outlines some of the latest innovations in DRE-powered agricultural technologies and highlights their market potential in India.

As India's population gains access to electricity, its agricultural sector is challenged by grid reliability, appliance access and fuel cost barriers. DRE-based technologies might provide new opportunities.

» India remains a highly agricultural and rural country, with 65.5% of its population residing in rural areas, and 42% of the workforce and 16% of GDP value added depending on the agricultural sector.[1, 2]

» Despite its economic significance, India's agricultural sector suffers from problems of inefficiency and poor productivity, which have stagnated its growth, averaging at an annual rate of 2.88% between 2014–15 and 2018–19.[3]

» In India, about 52% of the cultivated land relies on seasonal rainfall. Post-harvest losses amount to approximately US$13 billion annually.[4, 5]

» Emerging DRE-powered agricultural technologies show promising potential for smallholder farmers to increase yield, save fuel costs, mitigate fuel cost fluctuation risks, prevent food loss and waste, prolong product shelf life, and add value through processing.[6]

Solar water pumps (SWPs) can provide new irrigation access to unirrigated lands and save costs for the 9 million pumps that run on diesel.

» Currently there are more than 180,000 SWPs in operation in India. Another 3.7 million farming households can benefit from irrigated farming, representing a market potential of US$9.4 billion by 2030.[7, 8]

» For the 30 million water pumps that are connected to either grid electricity or diesel, SWPs add more value by displacing diesel, and not as much by connecting to grid.[9] Therefore, SWP deployment strategy should target the farmlands that are further from the grid.

» The net present cost of a diesel pump – taking into account lifetime fuel costs – can be as high as US$8,000, compared to US$7,600 lifetime costs of a SWP without any subsidies. With appropriate subsidies, SWP's lifetime cost can be as low as US$4,600.[10]

» SWPs, when displacing diesel, can bring value to not only crop cultivation but also salt farming, which is often located in seasonal wetlands without grid access. Salt farmers can spend as much as 40% of their annual income on fuel for diesel pumps. Displacing these diesel pumps on salt farms brings an estimated market potential of US$150 million.[11]

Emerging technologies such as solar-powered tractors, solar drying, solar cold storage, and solar egg incubation have shown potential to displace diesel or back up unreliable grid connections.

» Farm mechanization can add up to 30% in agricultural productivity and increase farm income by an average of 39%. Solectrac, a solar-powered tractor model, has been developed jointly by the US and Indian authorities to meet the needs of smallholder farmers. It is 5 times more efficient than its diesel-powered counterpart.[12]

» Solar drying can significantly reduce post-harvest loss and prolong product shelf life. Small-scale model has emerged that costs as little as US$200, making it affordable for

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POWER FOR ALL FACT SHEET

Rural Agribusiness Opportunities and Applications in India

By the Numbers:

US$13 BN

POST-HARVEST LOSS DUE TO INAPPROPRIATE STORAGE AND INEFFICIENT FARMING PRACTICE

US$9.4 BN

INDIA'S SWP MARKET POTENTIAL BY 2030

2%

PUBLIC AWARENESS OF SWP SUBSIDIES

smallholder farmers. Demand is high from certain cash crop value chains such as tea and spices.[13, 14]

» Inappropriate cold storage due to unreliable grid power poses challenges for rapidly perishable agricultural products. Innovative cold storage technology from Ecozen Solutions runs entirely on solar power and utilizes thermal technology, removing the need for batteries and providing back-up power for up to 36 hours. This allows farmers to store and sell their products at optimal market prices, increasing their profits by more than 40%.[15, 16]

» Egg incubation requires stable sources of heat. A solar incubator can maintain incubating conditions while drastically reducing electricity costs and problems related to grid reliability. A solar incubator offered by a Kochi, Kerala-based firm costs about US$650, with an expected payback period of less than 3 years and lifetime of 10 years.[17]

DRE-based agricultural technologies are at various stages of maturity and require different deployment strategies. India's experience in deploying SWP provides valuable insights for other emerging technologies in terms of policy, financing and consumer awareness.

» Since 2014, the Ministry of New and Renewable Energy (MNRE) has been promoting SWPs through a series of capital subsidy programmes. Adoption, however, has been slow and actual deployment falls under set goals of 1 million pumps by 2021–22.[18]

» Instead of a capital subsidy of 25%, spreading the subsidy across the loan term of SWP with an interest rate subsidy might be more cost effective for the government. Farmers' perception of an interest subvention scheme needs to be further investigated.[19]

» A survey in 2018 found that only 2% of the farmers are aware of the subsidy scheme for SWPs. Therefore, policy awareness is important to its success.[20]

Share the Message

» DRE-powered agricultural applications such as solar irrigation, solar salt farming, solar cold storage, solar drying and solar incubation can save costs, reduce loss, and increase yield for farmers.

» Deployment strategies of various DRE-powered agricultural technologies can learn from India's experience promoting SWPs.

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POWER FOR ALL RESEARCH SUMMARY

Productive use leveraging solar energy is the next frontier of energy market

POWER FOR ALL

IFC's Lighting Global released a market study on productive use leveraging solar energy (PULSE) in October 2019, focusing on smallholder farmers in sub-Saharan Africa (SSA) with a deeper dive in Kenya, Zimbabwe and Cote d'Ivoire[1]. The three PULSE applications included in this report are: 1) irrigation, 2) cooling and refrigeration, and 3) agro-processing. This Research Summary highlights key market trends and insights of these PULSE applications from the study.

US$ 11 BN

ADDRESSABLE PULSE MARKET IN SSA

US$ 734 MN

SERVICEABLE PULSE MARKET IN SSA

700,000

FARMERS WITH DEMAND FOR SOLAR IRRIGATION IN SSA

With a large farming population still dependent on human or animal power, market potential for PULSE appliances in SSA is high. However, most technologies are not yet mature except for solar irrigation.

» There is a demand at scale for PULSE. About 90% of land in SSA is farmed by human or animal power. Only 15% of irrigable land is irrigated in Côte d'Ivoire, 50% of milk is spoiled in Kenya's informal markets and 50% of maize is threshed manually in Zimbabwe. (14,34,39)
» As of 2018, the addressable market for PULSE appliances is estimated to be US$ 11 billion today in SSA. However, the serviceable market is only US$ 734 million, taking into consideration the affordability challenge. (20)
» Solar water pump is ready to scale. Among the US$ 734 million serviceable market in SSA in 2018, solar irrigation made up 62%, cooling and refrigeration 26% and agro-processing 12%. (20)
» In SSA, 700,000 farming households have demand for solar water pumps in 2018. It has the potential to reach 2.8 million by 2030. In the second half of 2018, only about 5,000 units were sold. (21,22)
» Solar cooling and refrigeration, although contributing to more than half of PULSE applications' addressable market of US$ 11 billion, has a serviceable market of barely US$ 191 million because of poor utilization and affordability challenge. (22)
» Solar agro-processing is least ready for scale, with the potential to serve 54,000 smallholder farmers in SSA. Milling and threshing put high pressure on solar systems and is often not competitive with diesel units. (16)

PULSE applications often favor larger, commercial farmers because smallholder farmers are limited by the ability to pay for the upfront costs, low appliance utilization and access to market to ensure product uptake.

» Although yield uplifts can be as high as 2.5- to 3.2-fold, solar water pumps' capital cost is still more than 60% higher than their diesel-powered counterparts, which makes them inaccessible for many farmers. Currently, over 65% of solar irrigation is utilized by commercial farms. (33,35)
» Solar cold chain's economic viability is dependent on its utilization. Only milk farmers who produce more than 15 liters/day in Kenya or 7.5 liters/day in Zimbabwe can benefit from solar milk chilling. (36)
» Agro-processing activities put high pressure on PV-based systems and are rarely proven as commercially viable. Solar grinders, for example, are twice as expensive as diesel ones and their costs increase every third year due to component replacements. (38,40)
» In Kenya, highly-utilized (85%+) solar mills can break even with diesel mills after 2 years. This means that solar mills need to be located where population density is high. (38) Côte d'Ivoire has high demand for rice mills. However, solar hullers have 70% less capacity than diesel ones but cost 6 times more. (39)

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POWER FOR ALL RESEARCH SUMMARY

Productive use leveraging solar energy is the next frontier of energy market

By the Numbers:

US$ 11 BN

ADDRESSABLE PULSE MARKET IN SSA

US$ 734 MN

SERVICEABLE PULSE MARKET IN SSA

700,000

FARMERS WITH DEMAND FOR SOLAR IRRIGATION IN SSA

Energy access and agricultural actors must work together to realize full PULSE market potential, leveraging appliance cost decline and growing consumer ability to pay.

» Energy access and agricultural actors working together can break down market barriers that both sectors share, such as consumer financing, last-mile distribution, access to market intelligence, etc. (43,44)
» Governments can support the synergy between energy access and agriculture by incorporating PULSE into electrification and agricultural transformation strategies. (42)
» The serviceable market for solar water pump may grow by 12.3% annually, solar cooling 17.4% and solar agro-processing 13.9%, considering product cost decline and growing consumer ability to pay. (21,22,24)
» A 40% drop in price can make solar milk chillers economically viable at year 2 for smallholder farmers in Kenya who produce 10 liters per day, and for solar grinder in Côte d'Ivoire to achieve 2-year payback at 50% utilization rate. (36,37,39)
» Entrants of large multinational companies such as Lorentz and Embraco signals high potential of PULSE and can potentially drive down cost due to their economies of scale. (29)

Share the Message

» PULSE is the next frontier of energy market, with solar irrigation already at the tipping point of scale and solar cooling and agro-processing emerging.
» Energy access and agricultural practitioners must not work in silos, as the two sectors serve similar customers and share similar challenges of finance and distribution.

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POWER FOR ALL FACT SHEET

Harnessing the Power of Solar for Agro-processing

In rural communities, agro-processing activities[1] often rely on diesel or grid-powered machinery. A shift towards using solar-powered machinery in off-grid and weak-grid areas could improve food security, create new employment opportunities, and enhance resilience to shocks. This fact sheet provides an overview of the current state of solar-powered agro-processing machinery from studies by the International Finance Corporation (IFC)[2], the Efficiency for Access Coalition[3], and the International Renewable Energy Agency (IRENA)[4].

US$417 MN

SERVICEABLE MARKET FOR SOLAR AGRO-PROCESSING BY 2030

US$2500

COST OF A SOLAR MILL

3.2 T/year

CO2 REDUCTION BY REPLACING A DIESEL MILL WITH SOLAR IN ETHIOPIA.

32.7kg/hr

THROUGHPUT OF SOLAR POWERED MILLS

Solar-powered agro-processing machinery has the potential to improve rural livelihoods, by improving food security, creating employment opportunities, enhancing resilience to shocks, and reducing environmental pollution.

» The 26% gap in food insecurity faced by Africa's population can be minimized by reduction of post-harvest losses and increased productivity using solar-powered machinery. (AP1, p.14)
» For the smallholder farmers who do not have access to large processors and/or grid electricity, solar-powered machinery offers an opportunity to diversify value adding employment due to greater agricultural productivity and output. (AP1, p.15)
» Consumers in East Africa reported an absence of smoke discharge and lower noise levels (77dB) by displacing diesel mills with solar. Furthermore, in Ethiopia, displacing a diesel mill with solar can reduce CO2 emissions by 3.2 tonnes per year. (AP2, p.25;p.16; AP3, p.63)
» Farmers are vulnerable to fuel prices variation and fluctuation. This can be mitigated with the use of solar-powered machinery. (AP1, p.15)

The total serviceable market in sub-Saharan Africa (SSA) for solar-powered agro-processing machinery is large and growing with an expected market value of US$ 417 million by 2030. However, challenges towards capturing this market potential include: identifying appropriate crop value chains, competition from incumbents technologies, and local area logistics.

» In 2018, about 937,000 smallholder farmers can be served by agro-processing machinery; however, if grid access and ability to pay is considered, the total serviceable market is only about 54,000. (AP1, p.23,24)
» Total serviceable market is expected to grow by an estimated 14% year-on-year, from 54,000 to 257,000 units between 2018–30. This corresponds with a market value of US$ 417 million by 2030. (AP1, p.23,24)
» The market for solar agro-processing machinery is greatly determined by the composition of crops in the local agricultural sector; for example, in Kenya, smallholder agro-processing is highest for maize milling while in Côte d'Ivoire cassava grating and rice hulling is common. (AP1, p.18, 34)
» The commercial viability of solar machinery varies depending on the competition from incumbent (diesel and grid-powered) products; in Côte D'Ivoire, solar mills have 70% lower capacity and cost 6x more than diesel ones, which presents a challenge for higher uptake of solar mills. (AP1, p.27)
» Local area logistics such as proximity of agro-processing services to customers is a vital consideration towards setting up of solar-powered machines. This is because 96% of milling customers in off-grid communities are women and children, who wish to avoid carrying heavy loads (up to 10kg) of grain and flour over long distances. (AP2, p.25)

For mill operators and communities to experience the full benefits of solar milling, further research is needed to develop more technically viable solar-powered machinery that can compete with diesel-powered ones.

» A one-phase motor 1.5–2.2 kW solar mill has throughput approximately 32.7kg/hr compared with 120–150kg/hr for a 7.5–17.5 kW diesel mill. For solar mills, this throughput is too low to meet customer peak demands and customers must then wait double the time for grains to be milled. (AP2, p.7,13,17)

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Harnessing the Power of Solar for Agro-processing

By the Numbers:

US$417 MN

SERVICEABLE MARKET FOR SOLAR AGRO-PROCESSING BY 2030

US$2500

COST OF A SOLAR MILL

3.2 T/year

CO_2 REDUCTION BY REPLACING A DIESEL MILL WITH SOLAR IN ETHIOPIA.

32.7kg/hr

THROUGHPUT OF SOLAR POWERED MILLS

» As maintenance and repair infrastructure remains inadequate in off-grid communities, solar mill designs must be robust to allow for easy repair, troubleshooting, and interoperability of replacement spare parts. (AP2, p.8)
» Most available standalone solar systems can only provide power for AC one-phase motor mills; more energy efficient AC three-phase motor mills would require the addition of high cost controllers and inverters for compatibility to the energy systems. (AP2, p.16)
» Solar mill developers have the option of designing battery coupled or direct-drive solar mills. Battery coupled mills retail for US$2500 and due to energy stored in the battery bank, users can mill at any time of the day; direct-drive mills, on the other hand, are the half the cost of battery coupled mills, but milling can only be done during peak sunshine hours (AP2, p.7)

Solar mills have high capital costs and are difficult to maintain. Greater deployment of financing to appliance developers and potential mill operators can aid towards an increased use of solar mills in off-grid communities.

» Prohibitively high capital expenditure associated with solar mill ownership contributes to the low uptake among potential off-grid mill operators, who have limited access to consumer financing; battery-coupled solar mills have a lower throughput than diesel mills and cost approximately US$2,500 with a nine-year payback period, compared with US$1,000 for diesel mills and US$2,000 for electric mills. (AP2, p.21; AP1, p.23)
» Building a strong distribution and service network, especially in remote off-grid regions, is an expensive undertaking for early-stage solar machine developers. (AP1, p.42)
Potential mill operators are, however, willing to purchase solar machinery through various consumer financing options such as: pay-as-you-go (PAYGO) financing, microfinance institutions (MFIs), and mobile lending/digital loans. (AP1, p.24; AP2, p.22)
» Governments, investors and donors can make financing available to solar machine manufacturers and suppliers to support aspects of the value chain such as product research and development, and last-mile distribution and servicing. (AP1, p.43; AP2, p.27)
» Solar agro-processing machinery providers expressed a need for clear guidelines on value-added tax (VAT) and import duties associated with importation of high cost solar components such as motors and controllers. (AP1, p.42; AP2, p.21)

Share the Message

» Despite solar-powered agro-processing machinery offering a potential viable alternative to diesel-powered machinery, its technical and commercial maturity remains hindered due to high capital costs, low processing capacity, and limited time of use.
» Greater deployment capital financing by governments and investors is needed to subsidize research and development and capital expenditure associated with owning a solar agro-processing machinery.

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POWER FOR ALL FACT SHEET

Decentralized renewables can enhance agro-productivity in Tanzania

POWER FOR ALL

3.75kW

OIL EXTRACTOR PROFITS FOR RURAL AGRO-PROCESSORS

USD 30

DAILY PROFIT POTENTIAL FROM SOLAR-POWERED OIL EXTRACTOR

USD1000

IDEAL PRICE POINT FOR SOLAR-POWERED MILLS TO COMPETE WITH DIESEL MILLS IN TZ

Tanzania makes for a strong case in expanding the integration of decentralized renewable energy technologies (DRE) within agro-processing activities.[1] This Fact Sheet highlights the current state of DRE powered agro-processing activities in Tanzania, drawing on analysis by: Access to Energy Institute (A2EI),[2] The National Renewable Energy Laboratory and Energy for Impact (NREL & E4I),[3] the Energy Change Lab (the Lab),[4] and African Development Bank Group (AfDB).[5]

Recent studies identify agricultural value-chains in Tanzania where solar-powered agro-processing appliances are commercially viable.[6]

» A2EI assessed ten agricultural processes. For each, a business model was developed and unit economics and other financial metrics were evaluated to identify opportunities where solar energy can be used profitably in agriculture-related businesses.[7] (TZ1, p.12,14,15)
» A USD 2000, 3.75kW solar-powered oil extractor on a USD 0.60/kWh retail tariff that presses 80kg of seeds per hour and operates 7 hours a day for 50% of the year, generates daily profits of USD 30.19. (TZ1, p.6,27)
» A USD 600, 3.75kW solar-powered peanut sheller on a USD 0.60/kWhretail tariff that can produce 110kg of shelled peanuts per hour, generates daily gross profits of USD 49.86. (TZ1, p.10,70)
» A USD 1000, 4.4kW system that runs a 2.2kW solar-powered flour mill and 2.2kW solar-powered hulling machine on a USD 0.60/kWh retail tariff and processes 90kg per hour of flour, generates a daily gross profit of USD 3.74. (TZ1, p.9,65)

However, limitations have been observed in effectively integrating DRE systems for solar-powered agro-processing.

» Single-phase solar-powered mini-grids are not compatible with power-intensive agro-processing activities such as milling and grinding. These mini-grids can run motors of up to 3.7kW (5hp), whereas solar-powered mills run on 10kW motors, making them more compatible with three-phase mini-grids.[8] (TZ2, p.23,30; TZ3 p.30)
» High retail tariff structures associated with solar-powered mini-grids in Tanzania can limit an agro-processing entrepreneurs' ability to invest in their businesses and adhere to appliance payments. (TZ3, p.16,28)
» Solar mills, driven by rooftop solar PV systems, have prohibitively high capital costs (USD 2500) compared with diesel mills (USD 1000) and many rural entrepreneurs lack collateral for loans and credit histories to access financing.[9] (TZ3, p.18)

To promote DRE powered agro-processing in rural communities, productive use of energy (PUE) stakeholders can coordinate to improve local community skills gaps, after-sales servicing, and appliance distribution supply chains.

» Developing locally appropriate training materials - videos tutorials in Kiswahili and hands-on appliance demonstrations - has provided much needed technical training in how to properly operate agro-processing appliances. (TZ3, p.8,15)
» User-friendly business development training manuals have been created for rural entrepreneurs to train in: business management, financial planning, and health and safety standards. (TZ3, p.14)
» Identifying a local technical vocational training partner and local skilled technicians, especially in remote rural communities, has been essential in having local personnel who are trained in repairing solar-powered appliances. (TZ3, p.22)

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POWER FOR ALL FACT SHEET

Decentralized renewables can enhance agro-productivity in Tanzania

By the Numbers:

3.75kW

OIL EXTRACTOR PROFITS FOR RURAL AGRO-PROCESSORS

USD 30

DAILY PROFIT POTENTIAL FROM SOLAR-POWERED OIL EXTRACTOR

USD1000

IDEAL PRICE POINT FOR SOLAR-POWERED MILLS TO COMPETE WITH DIESEL MILLS IN TZ

- » Brokering partnerships and agreements between key players in the local distribution networks has ensured extension of appliance distribution to rural communities. In Tanzania, the Lab was able to broker a supply chain agreement with a local distributor to distribute appliances from Dar es Salaam to Chang'ombe and Dongo, over 365km away, (TZ, p.24)
- » Providing trial periods and warranty coverage for agro-processing appliances would allow rural entrepreneurs to test out appliances and provide assurance on their investment. (TZ3, p.22)

With support from government and partners, DRE is well-positioned to provide an enabling environment to advance agro-processing.

- » Appliance developers and financial institutions can work together to provide rural entrepreneurs access to SME guarantee schemes that would bridge the appliance financing gap; these schemes can ensure payments that align with seasonal rural incomes in case of defaults. (TZ1, p.29)
- » Increasing entrepreneurs' ability to pay for electricity can be achieved through grants that can be used to buy down a portion of the capital cost of mini-grid services and offering credit, or pay-as-you-go solutions that mirror current retail spending on energy services. (TZ4, p.66)
- » DRE projects have a high capital cost and financing conditions available domestically are not well suited to the development of DRE projects. Therefore, long-term financing through commercial banks can be offered, as well as transaction advisory services to assist developers in finding equity investment partners. (TZ4, p.66)
- » To minimize grid encroachment that can reduce the expansion of DRE projects in rural communities, the Tanzanian government has developed The Rural Electrification Investment Prospectus to identify rural areas best suited for mini-grid and off-grid electricity supply. (TZ4, p.64)

Share the Message

- » DRE agro-processing offers a strong commercial opportunity for rural entrepreneurs, however, appliance financing, business and technical skills gap and high retail tariffs remain a barrier in maximizing the opportunity.
- » Key productive use of energy (PUE) stakeholders can position themselves in engaging with local communities to offer training and financing assistance thus bridging the barriers to solar- powered agro-processing.
- » Government and partners can play a role in encouraging DRE projects by offering a conducive investment environment; they can provide long-term financing and transaction advisory services to DRE developers.

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