POWERING AGRICULTURE:

AN ENERGY GRAND CHALLENGE FOR DEVELOPMENT

TECHNOLOGY CASE STUDY:

Clean Energy Agro-Processing

CONTENTS

INTRODUCTION

The Clean Energy-Agriculture Nexus

Agriculture is the main means of livelihood for 2.5 billion people worldwide,[1] primarily in developing countries, where approximately 45 percent of the population relies on agriculture as a chief source of income.[1] A strong agriculture sector is crucial for economic development, accounting for as much as 30 percent of developing countries' gross domestic product.[2,3] For these countries, increased agricultural productivity is a key driver of food security, income generation, and improved quality of life in rural areas.[1]

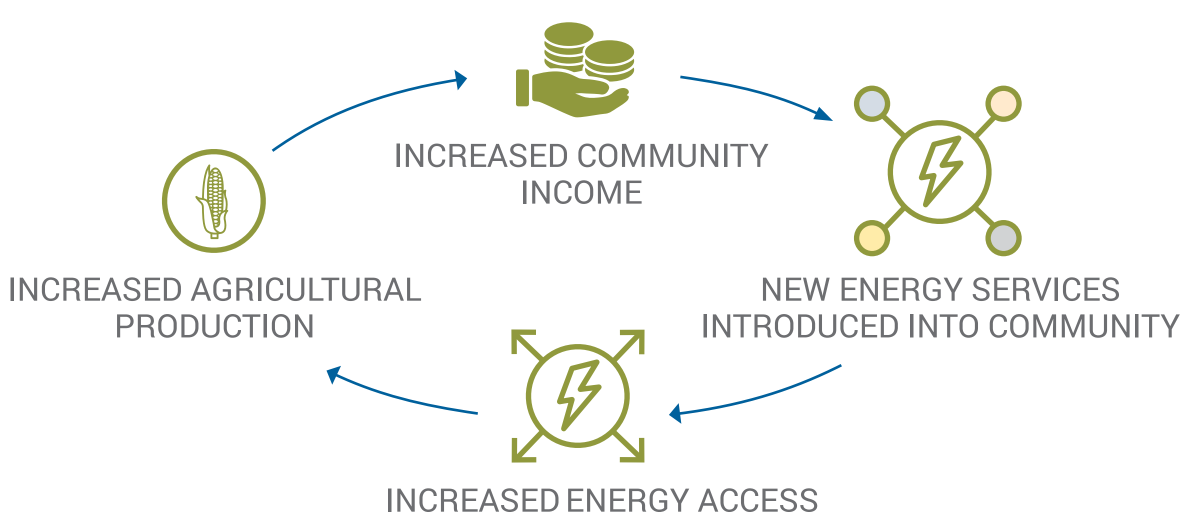
Increasing agricultural productivity will require access to increasing amounts of energy. Today, food production accounts for 30 percent of global energy consumption,[4] and energy use will continue to grow as the world's population rises. The Food and Agriculture Organization of the United Nations predicts that between 2006 and 2050, food production will need to increase by 170 percent to accommodate a 130 percent rise in global population.[5]

Clean energy services offer a sustainable alternative to meeting agricultural demand. By deploying clean energy technologies, farmers can mechanize operations, process raw products to add value to commodities, and extend the shelf life of produce through refrigerated storage.[5]

The relationship between clean energy and agriculture is a virtuous cycle that can be harnessed to maximize developmental impacts in rural areas. The cycle begins by providing poor, rural families access to cleaner, more affordable energy, which can improve community health and provide more opportunities to earn income.[4] Farmers can both diversify and increase agricultural production using affordable energy.[4] With increased income, households and communities can purchase more energy.[1]

This increase in energy demand can enable new or improved energy products and services,[1] which can create more opportunities to enhance livelihoods and strengthen the energy-agriculture cycle, as illustrated in Figure 1.

Figure 1 THE ENERGY AND AGRICULTURE VIRTUOUS CIRCLE[6]



Recognizing the interconnectedness of clean energy and agriculture, the U.S. Agency for International Development (USAID), the German Federal Ministry for Economic Cooperation and Development (BMZ), and the Swedish International Development Cooperation Agency (Sida), along with the Overseas Private Investment Corporation (OPIC) and Duke Energy, founded Powering Agriculture: An Energy Grand Challenge for Development. This partnership supported the piloting of new and more sustainable approaches to accelerate the deployment of clean energy solutions to increase agricultural production and value in developing countries. Powering Agriculture selected 24 innovators through a competitive process to receive funding for clean energy pilot projects, such as solar pumps, cold storage, and micro-grids. Their experiences informed the development of this case study.

The Need for Small Scale, Low-Power Agro-Processing

tion of agricultural products undergo some degree of transformation between harvest and ocesses such as milling, grinding, grating, and drying help preserve agricultural products and add value to them. However, many smallholder farmers who grow crops on less than two hectares perform this work by hand, which is both time-intensive and produces products of lower quality than machine-processed products.[1]

Conventional large-scale processing technologies powered by diesel, gasoline, or large alternating current (AC) motors often fail to meet the needs of smallholder farmers.[7] In general, the capacity of both fossil fuel- and AC-powered processing equipment is too large for the small quantities of crops that smallholder farmers periodically bring for processing. As a result, the incumbent technologies create a semi-centralized network of service providers that caters to communities with larger population densities.

For example, an average rural family consumes one to two kilograms (kg) of staple crops per day, but when the processing occurs is a function of the crop.[8] Rice is usually processed in larger batches after harvesting (e.g., 30 to 50 kg per day), while maize can be stored and processed throughout the year in smaller batches (e.g., five to 25 kg batches).[9] Many diesel-powered processing machines can process larger, seasonal batches of 50 kg in five minutes or less, and can process the average daily consumption of a 100-family village in less than 30 minutes.[1,10] This mismatch in production and processing rates often makes conventional processing uneconomical in small rural communities. As a result, when farmers from small villages seek access to processing equipment, they must often travel between two and 20 kilometers (km) to grind, grate, shell, husk, or polish a small quantity of product at a relatively high cost.

This inefficient system presents a market opportunity for small-scale, decentralized, low-power agro-processing equipment. When powered by solar or other renewable energy sources, processing machinery can operate in areas with poor or no access to grid power and provide cleaner, more environmentally friendly operations. This paper discusses both challenges and opportunities for small-scale, low-power agro-processing, drawing on lessons learned from Powering Agriculture innovators and providing recommendations to bring the technology to underserved markets.

The Benefits of Low-Power Agro-Processing

Co-locating small-scale, low-power agro-processing equipment with harvesting activities can reduce poverty, increase food security, and stimulate economic growth.[11] As a result, smallholder farmers can improve their income by selling products at a higher price and bene om an increased demand for more diverse products.[5,10] Clean energy can power machinery to process agro-products in a fast, local, and environmentally friendly way.[12] Its use has several benefits:

Value adding. Agro-processing usually adds ten to 30 percent to the value of staple crops, but can add up to 500 percent in examples such as making virgin coconut oil. Brown rice can also attract a premium in markets dominated by larger mills that only produce white rice.

Time savings for households. Low-power agro-processing reduces the time and physical burden for smallholder households in two ways: by mechanizing manual processing tasks, and by processing products locally instead of in distant towns.[13]

In Mali, an agro-processing project reported that women customers saved an average of two to six hours per day when using a multifunctional platform powered by diesel or biodiesel instead of processing products by hand.[18] Deployment of solar-powered agro-processing equipment in Indonesia resulted in a reduction of daily rice processing time from 50 minutes to 2.5 minutes.[8]

Reduced post-harvest losses. Agro-processing activities like drying and milling can extend the shelf life and material quality of certain agricultural products, which reduces spoilage and increases income when they are sold in the marketplace.

Reduced transportation costs. Co-locating agro-processing equipment with harvesting sites reduces transportation costs because the farmer does not need to travel for processing. Additionally, processing on the farm reduces weight and bulk prior to transport.

Better market timing. Produce markets are cyclical, and prices drop when produce is oversupplied. Instead of being forced to sell into a glutted produce market when prices are low, farmers with access to low-power agro-processing can convert their harvest into more shelf-stable products and sell them when market prices recover.

More diverse markets. Market diversification is an alternative to market timing when local product markets are glutted. Rather than waiting for prices to recover, agricultural products can be processed into different end or intermediate products (e.g., cooked food) and sold in a different market.[12]

Reduced lifetime cost. Using clean energy sources to power agro-processing equipment can result in lower lifetime costs than conventional agro-processing equipment.

Agsol, a manufacturer of solar mills for African markets, highlights the gap in available equipment for crop processing when a farmer or a community wishes to mechanize. A 7.5 kilowatt (kW) hammermill is one of the smallest diesel-powered hammermills available in Kenya. Its capital cost is $1,600,[18] but the cost to hire operators, purchase diesel, and maintain the mill over ten years increases the cost to approximately $45,000.[14,15,17] A 1.2 kW solar photovoltaic (PV)-powered hammermill can process approximately 200 kg of flour per day – enough for an off-grid agricultural village – and costs $2,000.[18] Its cost over ten years is approximately $14,500.[15,16]

Reduced domestic and sexual violence. One project deploying 12 solar-powered rice mills in Papua New Guinea noted a decrease in domestic violence because of increased food availability and reduced poverty at home.[19] Locally available milling services reduce the long distances women must travel alone to access milling services, which reduces their risk of exposure to sexual assault.

Food security. Milled flour and fruits can be stored for up to one year, and when processed by dryers and vacuum packers, they can be stored in the event of disasters (e.g, cyclones).

A woman processes maize on Sumba Island, Indonesia. Photo courtesy of Village Infrastructure Angels.

APPROACHES TO DEPLOYING AGRO-PROCESSING SOLUTIONS

In rural areas, smallholder farmers generally process their agricultural products using human energy. This is especially true for poor, rural households, which rely on their own farm produce for the basic staples of their diet.[1] Several hours per day may be devoted to these tasks, which are usually performed by women and children (see Box 1 on page 6). For these households, low-power agro-processing equipment is the first opportunity to mechanize their farms, thereby increasing productivity and the value of the plants they grow. Table 1 identifies the clean energy agro-processing solutions developed by Powering Agriculture's innovators that provide this opportunity.

Table 1 INNOVATORS' CLEAN ENERGY AGRO-PROCESSING SOLUTIONS

AGRICULTURAL PRODUCT	VALUE-ADDING PROCESS	BASELINE TECHNOLOGY	CLEAN ENERGY SOLUTION
FOOD PROCESSING TO ADD VALUE			
Grains or dried tubers to mak	Milling	Manual or diesel/grid-powered	Solar PV or hydropower
Cassava, taro, yam	Grating	Manual or diesel/grid-powered	Solar PV
Rice	Hulling	Manual or diesel/grid-powered	Solar PV
Rice	Polishing	Manual or diesel/grid-powered	Solar PV
Coconut	Scraping	Manual or diesel/grid-powered	Solar PV
Maize	De-kernelling	Manual or diesel/grid-powered	Solar PV
FOOD PROCESSING FOR PRESERVATION			
Fruits, vegetables, coffee, tea	Drying	Direct sunlight	Solar thermal, biomass, cogeneration

Conventional fossil fuel- or electricity-powered machinery can process agricultural products ten times faster than manual power (refer to Figure 2 on page 7). However, these machines are frequently oversized for the processing needs of off-grid and rural communities. A Kenyan agro-processing entrepreneur stated that customers typically want to mill five to ten kg of maize per visit. It takes his ten kW electric hammermill less than half a minute to mill this quantity of maize and the machine is idle for most of the day.[17] This entrepreneur purchased a much larger machine than his business requires; if a low-power hammermill had been available, it would have been more profitable to purchase it and save the difference in capital and operating costs.

BOX 1:

GENDER IMPACTS OF FOOD PROCESSING

Many cultures consider food processing to be the work of women and children. For example, a World Bank study found that women are responsible for 80 percent of Kenya's food production.[12] Women typically spend between 45 minutes to three hours every day milling, grinding, or de-husking.[8,18] Women's availability is often a key factor in determining how much time can be allocated to collecting ewood and preparing food.[12]

Maize is milled using solar-powered equipment. Photo courtesy of Village Infrastructure Angels.

Giving women the same access to productive resources as men could increase yields on their farms by 20 to 30 percent, which could in turn reduce the number of hungry people in the world by 12 to 17 percent.[20]

From a broader perspective, the productive use of clean energy encourages the empowerment of women by engaging them in small businesses. For example, Powering Agriculture innovator Village Infrastructure Angels (VIA) works with several female milling agents in Asia P

whom use solar energy to mill rice and corn for over 100 customers each. Furthermore, clean energy-powered agro-processing can give women the opportunity to earn an income and free up daytime

[12]

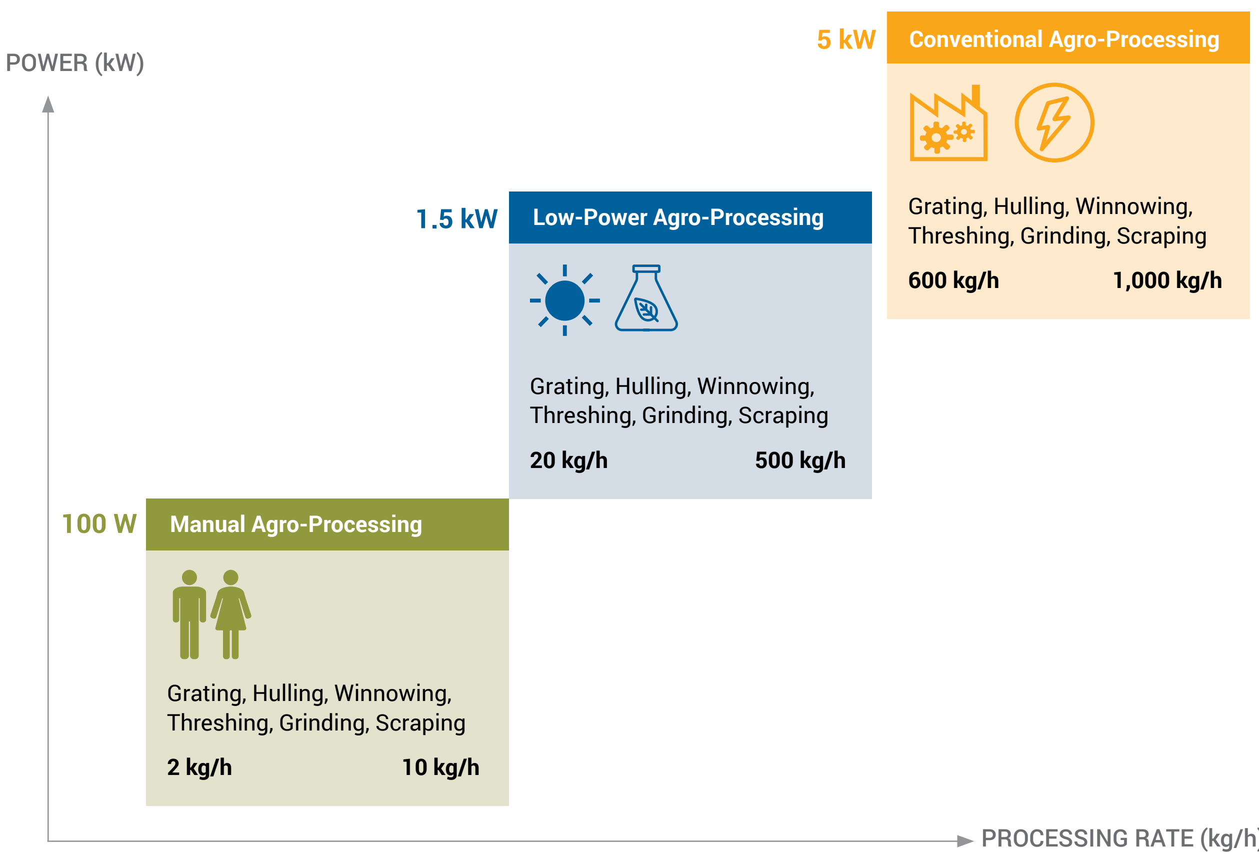
The large capacity and associated operating costs of conventional agro-processing equipment necessitates that they be located in larger population centers with enough customers to maintain a pr om smaller and more remote villages, who must travel to larger towns to process their crops. A study in Vanuatu and Papua New Guinea found that smallholder farmers often travel up to ten km to access conventional agro-processing machines.[13] Travel times of up to two hours were common, and the associated transport cost is $1 per round trip. This effectively doubled the cost of processing, even before accounting for the time lost for other economic activities.

Powering Agro-Processing

Clean energy sources like solar, biomass, and biogas are already being used in small rural communities. Many off-grid agricultural communities are located in the “Sunbelt,” the region of the world within 35 degrees of the equator that has the relatively high solar irradiation needed to power PV solutions in a cost-effective way. Agricultural communities also produce the quantities of biomass required to power biomass- and biogas-powered equipment.

Clean energy-powered processing equipment can be a better size for the processing needs of smaller communities. Figure 2 shows the power requirements for manual processing (green), low-power agro-processing (blue), and diesel-powered and conventional electric processing (orange). The e shows a gap between manual and conventional processing where the agro-processing needs of an off-grid community frequently lie. Small-scale clean energy-powered processing equipment can provide cost-effective processing solutions in this range (100 watts (W)-1.5 kW). While significantly faster than hand-processing, the capacity of these machines still allows for adequate utilization rates in smaller villages. For instance, a village of 25 households would consume roughly 63 kg per day of maize meal or flour, and a 750 W mill from Project Support Services can process 20 to 50 kg of grain per hour.[10] Milling for self-consumption in this community would require only one to three hours per day of low-power milling time, leaving three to five extra hours to dedicate to milling grain for the market.[21] A larger diesel mill, on the other hand, would be idle for much of the day.

Figure 2 DISTRIBUTED AGRO-PROCESSING SOLUTIONS POWERED BY CLEAN ENERGY (BLUE) CAN BETTER MATCH THE PROCESSING NEEDS OF SMALL COMMUNITIES[1]



APPROACHES TO SERVING THE MARKET

Technology Providers

The technology providers addressing the gap between human- and diesel-powered agro-processing predominantly focus on solar as a power source. Despite the potential market for low-cost solar-powered agro-processing machines, there are relatively few players. The German International Development Agency (GIZ) inventoried off-grid solar appliances in 2016 and identified only four technology providers in the agro-processing space:[10]

Figure 3 THE PHAESUN BOSS KIT PRO MILL[22]

1. **Phaesun**. Based in Germany, this solar manufacturer focuses on the off-grid sector in Europe, South America, Africa, and the Middle East. Its catalogue includes pre-packaged solar kits with oil expellers or mills.[22] See Figure 3 for an example of a Phaesun commercial solar PV processing kit.
2. **Seine Tech**. Based in Spain, this solar pumping and milling appliance provider focuses on the African market.[23,24]
3. **Project Support Services (PSS)**. Based in China, PSS has produced a variety of solar PV mills primarily for P ver the past 15 years.[25]
4. **Agsol**. A three-year-old spin-off of PSS, this company is designing a solar-powered mill tailored to the needs of the East African market.[26]

These four technology providers represent the spectrum of approaches companies can take in creating new solar agro-processing technology. At one end, Phaesun assembles commercially available components into agro-processing kits that include battery backup to drive AC-powered mills and oil expellers. Unlike Phaesun, Seine Tech designed its own AC-powered grain mill, removing the batteries to eliminate the signi cant associated capital and maintenance costs. PSS incorporated direct current (DC) motors into existing polishers and dehuskers, but has not attempted to design a new product from scratch. While both Phaesun's and Seine Tech's AC-powered equipment requires more than one kW of power, most of PSS's equipment (eight out of nine mills in their catalogue) require less than 750 W, which reduces capital costs — but at the expense of throughput. Agsol is the only company of the four that is designing its own DC-powered agro-processing equipment rather than assembling kits from commercially available components or converting machinery to have lower power.

IMPROVING THE VALUE PROPOSITION FOR LOW-POWER AGRO-PROCESSING TECHNOLOGIES

Most prospective customers do not realize that solar-powered machinery is an option for their agro-processing needs. Such equipment repr e for smallholder farmers in off-grid areas. Even if a farmer is convinced to undertake the risk of adopting this new technology, she or he may face barriers in securing cash to pur
a portion of the capital.

Technology providers are actively r alue propositions to smallholder farmers and small agro-processing entrepreneurs to make their products more compelling and increase sales. The following elements will be key to making a convincing business case:

Matching equipment capabilities to customer needs. The value proposition for agro-processing machinery depends heavily on maximizing utilization rates.

Affordability and financing. Technology providers must overcome the barriers associated with high capital costs in order to make their products affordable to a larger market segment.

After-sales service. Regular maintenance and prompt servicing, even in remote areas with few trained technicians, are crucial to maintaining and growing consumer confidence.

Matching Equipment Capabilities to Customer Needs

Clean energy-powered agro-processing has the potential to disrupt existing agro-processing sectors by making processing more accessible to smallholder farmers. However, the question of how to design equipment to best match the characteristics and needs of smaller, more distributed rural communities remains a business element that equipment suppliers are actively exploring. The value proposition of a given piece of equipment depends heavily on its utilization rate: the closer to operating at capacity day-in day-out, the faster the equipment can provide a return on investment. However, agro-processing is often an intermittent task; an individual farmer may only need to process crops at specific times or days of the week. The processing demand for certain crops may be characterized by seasonal peaks, leaving processing equipment idle in the off-season.

Solar customers pay the same amount for a solar-powered mill whether it is idle or active, whereas a diesel-powered mill will avoid fuel costs if it is idle. Solar customers' prepayment for energy strongly incentivizes them to maximize equipment operation throughout the year, thus understanding how to maximize the utilization rate of the system is critical in creating the value proposition. This presents both a challenge and an opportunity to equipment suppliers as they seek to differentiate themselves and identify the most viable market niche.

Equipment providers are actively exploring ways to increase utilization rates by evening out demand and promoting year-round processing. In Africa, for instance, Agsol chose to target maize because it can be dried, threshed, and stored. A farmer can then take a small amount of maize to be milled into a weekly basis. This pattern results in low seasonal variability that improves the utilization pr of the equipment.[21] The same mill can also process dried cassava, millet, sorghum, and other food crops, further improving utilization rates.

Some staple crops are not as easy to store as maize. In markets where rice mills are a popular offering (e.g., Indonesia and Papua New Guinea), mills are only utilized during the two to three months of rice harvest. In response to their customers' need to process throughout the year, PSS and VIA introduced additional solar-powered equipment such as cassava graters and coconut scrapers that take advantage of complimentary processing seasons. As rice milling tapered, cassava grating ramped up. By clustering productive use technologies, they sought to maximize the solar equipment utilization.[9]

Another key consideration for equipment providers is correctly matching machine capacity with community size. Both VIA and Agsol noted an opportunity to market equipment to communities of 50 to 200 people.[9] They see this as a market sweet spot that keeps them out of direct competition with diesel-powered machinery while providing access to a large enough customer base to help reduce variability in processing demand. Since processing is not typically a daily task for an individual smallholder farmer, a steadier demand stream can be ensured by serving the processing needs of an entire community.

However, this model also pushes companies into a regime where they must sell predominantly to small-scale agribusinesses, targeting off-grid entrepreneurs or communal organizations that process crops instead of selling directly to smallholder farmers. This provides its own set of challenges – namely, it requires the emergence of small business owners in remote and rural communities who are accustomed to a different model of accessing these agro-processing services. Agsol sees an opportunity for women's or community agriculture groups to come together to purchase a machine and operate it as a business, but notes a high level of effort associated with bringing groups together and socializing the potential of this business model.[21]

Technology providers also need market information. To effectively design and market equipment, they cannot be experts only in engineering and manufacturing machinery, but must also have detailed information on local farming and business practices. At the same time, they may have to actively promote behavior change in order for farmers to realize the full value proposition of the solar-powered equipment.

For instance, in Kenya farmers typically process their cr the late afternoon,[21] and in northern India farmers typically process their crops in the evening when it is cooler.[9] However, for solar-powered processing equipment, the processing sweet spot is during daylight hours when sunlight can be directly converted to power. While new business models may emerge to r op-off service where farmers leave their crops in the morning and pick them up in the afternoon), there is often considerable inertia associated with changing long-standing practices. It is safe to say that market entrants are in the early stages of developing equipment offerings for this market, and a great deal of experimentation remains for the best business opportunities and clear winning strategies to fully emerge.

BOX 2:

POWERING AGRICULTURE CASE STUDY – VILLAGE INFRASTRUCTURE ANGELS

Powering Agriculture innovator Village Infrastructure Angels (VIA) provides solar-powered agro-processing solutions for small villages in Indonesia, Vanuatu, and Papua New Guinea. VIA employs a lease-purchase program over three to five years for community-based staple crop mill deployment, and works with village-based milling agents.

Baskets and mats made by women in Vanuatuan villages are traded at shops as payment for the use of solar mills available at local markets. Photo courtesy of Village Infrastructure Angels.

Dedicated milling agents accept handicrafts from villagers who wish to process their product, which are made with the time saved from not utilizing manual processing. This goes toward paying for the milling services of their solar-powered machines; VIA sells the handicrafts and credits the milling agent. The group's Port Vila, Vanuatu showroom, pictured here, was modernized to accommodate a handicraft shop. VIA is also pursuing opportunities to develop remote monitoring of its mills and exploring pay-as-you-go (PAY for customers.

Affordability and Financing

Depending on its size and inputs, the cost of a solar-powered agro-processing machine can range between $500 and $3,000.[10] This is a significant up-front cost for a smallholder farmer or small-scale agro-processor in a developing country, who earns between $2,500 and $3,000 per year.[4] Technology providers are trying to increase affordability by reducing equipment lifetime cost and coupling products with financing.

Technology providers are also working to lower the lifetime costs of agro-processing equipment. For instance, Seine Tech eliminated batteries from the design of their AC-powered solar mill to reduce both the initial capital expense and the ongoing maintenance costs associated with battery storage. PSS's and Agsol's decisions to incorporate nominal battery storage provides opportunity for other power off-take benefits. Additionally, these companies use DC motors rather than AC motors in their processing equipment to improve efficiency and robustness by removing failure-prone power conversion components.

Despite these technological changes, barriers remain. Equipment is still manufactured in small batches, and thus cannot enjoy economies of scale. Customer acquisition costs are also high, given the effort needed to educate and attract early adopters. Also, government policies may not yet favor clean-energy agro-processing technologies. While conventional fuels may enjoy some form of subsidy, clean energy equipment is often excluded from such regimes. Even when tariff and duty exemptions may theoretically apply to the equipment, it ma

Agricultural goods and solar devices are exempt from duties in Kenya, but other components like control systems and cables are not. If a container with solar-powered agro-processing equipment also contains taxable items, the entire container may be assessed an import duty.[27] Making separate shipments can also increase costs given the small numbers of systems being imported. This leaves early-stage equipment providers unable to take advantage of the tariff and duty exemptions for which they would otherwise be eligible.

Manufacturers like Agsol are utilizing brushless motors and solar motor controllers, which avoid the use of batteries (and the energy losses and replacement costs they incur) in their small-scale processing machines.[29]

Even with the previously mentioned proposed cost savings, most prospective customers will not be able to buy processing equipment with cash – financing is almost always required. However, technology providers are finding it difficult to overcome the lack of a standardized credit assessment methodology and the diversity within the market segments to which they are catering. Agsol identified three potential market segments for its solar-powered mill: individual farmers, individual millers, and cooperative-owned mills. As each market segment has different revenue flows and access to the formal banking sector, a financier would evaluate the creditworthiness of each segment very differently. For example, a cooperative-owned mill has access to a large number of potential clients (its members who provide a predictable potential revenue stream, making it less risky to extend credit. An individual farmer may not have the same predictability, making lending more difficult. To appeal to the greatest number of customers, many technology providers are experimenting with different ways to extend credit.

Providers are exploring three models to extend customer credit: lease-to-own, PAYGO, and barter-resale. VIA is especially active in testing new customer finance mechanisms. VIA primarily employs a PAYGO model in which the company purchases equipment from PSS with a blend of public and private money, and resells the equipment to end users with financing. VIA, rather than the manufacturer, takes on the lending risk and mobilizes field partners with direct customer relationships to retrieve the payments.

In communities where cash is not widely available, VIA is experimenting with accepting processed crops as payment. The agro-processing entrepreneur (VIA's customer) either immediately resells their processing payment (typically a ten percent share of the harvest), or stores and sells it after commodity prices increase. The agro-processing entrepreneur then uses the sales proceeds to repay VIA. VIA's role as a financier and distributor of PSS equipment is common in other off-grid sectors like solar irrigation or solar home systems, but has yet to catch on in the low-power agro-processing industry. VIA's asset financing experimentation is critical to PSS' success because the market needs to identify innovative ways to make agro-processing equipment affordable, but most manufacturers do not have the expertise to develop, raise funds for, and package new financing products for customers.

After-Sales Service

The downtime associated with servicing and repairing agro-processing equipment can erode the value proposition for farmers, particularly if it occurs during critical harvest and processing periods. When breakdowns occur, too much time between product breakdown and repair can contribute to negative customer perceptions. In particular, if the equipment was acquired on credit or through a PAYGO scheme, having the machine offline during critical times such as harvest may mean that the farmers or entrepreneurs won't receive the earnings they need to cover their payments. Alternatively, the equipment breakdown may provide customers a reason to feel justified in defaulting on payments.

It can be challenging to provide prompt and high-quality after-sales support in remote rural communities. Both spare parts (e.g., pulleys, screens, and belts) and trained personnel may be hard to come by.[28] Even when technology suppliers have access to spare parts and high-quality personnel, poor road infrastructure is a barrier to prompt after-sales support.

VIA currently contracts with field agents who are based in or near remote villages and operate mills. Additionally, its operator training sessions include modules on the delivery of after-sales support.[13]

New technologies also play a role in mitigating maintenance and repair issues. Some technology providers are exploring how remote monitoring can track system performance and provide alerts for preemptive maintenance and just-in-time emergency repairs. Remote monitoring can also collect data on utilization patterns, accounting, and revenue sharing to contribute to more effective revenue collection.

Capturing power for subsequent milling in the Pacific. Photo courtesy of Village Infrastructure Angels.

CHALLENGES TO SCALING UP LOW-POWER AGRO-PROCESSING

The following realities pose challenges to the growth of this market:

Lack of formal market intelligence. There are only a handful of equipment providers in this space, which has resulted in a lack of formal data on use behavior, current and expected demand, customer demographics, and willingness to pay. This lack of information can discourage new entities from entering the market.

Limited awareness of low-power agro-processing. Rural communities often have little awareness of low-power agro-processing equipment and its benefits. This can limit demand, resulting in poor economies of scale.

Low availability of spare parts and trained technicians. It is challenging to consistently provide high-quality after-sales support in rural communities where the availability of both spare parts and trained technicians is low. However, a company that does not address this gap is likely to suffer from poor reputation and reduced willingness to pay.

High capital costs can deter product uptake. The cost of low-power processing equipment can be prohibitive for smallholder farmers,[10] who often have limited access to financing options.[28] Despite micro-finance and leasing efforts, financing remains difficult to obtain for smallholder farmers.[30] There also seems to be a considerable gender bias regarding access to credit, which can limit the productive uses led by women.[12]

Market distortions. Government policies may distort fuel and/or equipment costs, making low-power agro-processing equipment less cost competitive. For example, subsidies might artificially maintain low petrol, diesel, or electricity prices, international aid programs may donate free large-scale processing equipment, or duties and tariffs may increase the costs of imported milling technologies.

Technology gap. The lack of products that address the gap between manual processing and conventionally-sized processing equipment means that most technology providers have to develop new products from scratch. Providers then have to market the product they developed as a viable solution for the existing technology gap. It is difficult for small technology providers to support research and development (R&D) and marketing expenses needed to quickly scale sales.

Large working capital requirements. Manufacturing products requires working capital to pay for component purchasing, manufacturing costs, and shipping. Additional working capital is required to pay for distribution costs like warehouse operation and maintenance, delivery costs like truck fleet costs, and customer acquisition costs like demonstrations and sales staff salaries. Normally working capital can be borrowed from local banks, but in many emerging markets local banks are hesitant to lend to technology- or energy-based start-up companies.

RECOMMENDATIONS

The following key areas present opportunities for the promotion of low-power agriculture machines as a means to increase agricultural productivity and improve livelihoods in developing countries:

Recommendations for International Donors

Allocate funding for R&D. Compared to other clean energy appliance markets, including solar home lighting systems and water pumping, there are a limited number of small-scale clean energy-powered agro-processing technology manufacturers and products that fit off-grid communities' needs. At the same time, their customer base – off-grid smallholder farmers – has low creditworthiness and cannot tolerate high prices, making the technology unappealing to commercial investors. There is a need for donors and public sector entities to support technology providers in expanding and refining their product offerings. In particular, donors should help ensure products are developed to best match local contexts, including target crops, machinery sizing, and technology for PAYGO financing and remote monitoring. The U.K. Government is supporting the development of a second generation of VIA and PSS solar mills that will reduce purchasing prices by 30 to 50 percent.[9]

Support market intelligence generation. Donors can support discovery studies that quantify customer product needs, technology and financing preferences, and creditworthiness. These studies would help drive awareness in the financial sector and may even encourage entities operating in similar markets, like solar home systems, to enter the agro-processing market.

> **In 2017, the Papua New Guinea-Australia Fund led a pilot of 70 rice mills in Morobe Province. The project supported the distribution of PSS-manufactured mills, targeting female farmers in terms of use and awareness-building, and collected robust data to understand the mills' impact on household incomes.[31]**

Provide patient capital and spread the word. Today's low-power agro-processing technology providers are "first movers" who are generating consumer awareness and trust in agro-processing products. This can be a costly and time-consuming endeavor, especially in remote communities where farmers are conservative about adopting new technologies and agricultural practices. Patient capital can be deployed on multiple timeframes—including long-term equity and medium-term debt at concessionary rates. Credit guarantees can be also used to incentivize local banks to provide short-term debt to technology providers who need working capital. Donors can support solution providers by promoting low-power technologies in off-grid communities. This can be done through farmer training sessions, funding, promoting third-party product evaluations like CLASP's Global LEAP Awards, and awareness campaigns that target potential customer bases.[32]

Support policies that reduce market distortions and support innovation. Donors can support efforts to eliminate policies that distort the cost of fossil fuels and electricity and help level the playing field for agro-processing technologies. This includes policies that govern tariffs, subsidies, sales tax, and/or rebate programs. Additionally, donors should provide technical support to host governments that want to enact policies to facilitate agro-processing technology development, field testing, and commercialization.

Recommendations for Implementers

Determine distribution and after-sales channels early. Technology providers must make important decisions on the mechanics of both sales and after-sales support for deployed machinery. They should also consider the delivery of after-sales support early on during business model development, which can affect how other elements of the business strategy (such as distribution agent versus direct sales models) are implemented. To that end, entrepreneurs should consider business and management training on customer service and comprehensive after-sales support.[12]

Explore technology options to maximize utilization rates. Maximizing utilization rates is a critical factor in the business case for low-power agro-processing. One way manufacturers can accomplish this is to tailor their equipment to access multiple feedstocks or offering several devices to serve varying feedstocks. Remote monitoring can help capture data to ensure increased machinery use and speedy repayment. This data can also enable a more accurate quantification of user charges, after-sales support, and addressing of customer needs in a timely manner.

Prioritize customer discovery. Technology providers should understand how customers want to use a technology and how they actually use it. Interviews with prospective customers and small tests or pilots of "least-viable products" can help avoid the development of products that are not well-suited to the target market or are poorly optimized for local crops and growing seasons.

Agsol is partnering with CLASP, a leading international resource for energy efficient appliance policy and market acceleration, to field test ten solar PV-powered maize mills equipped with remote monitoring in Kenya, Tanzania, Uganda, and Zambia. This will allow Agsol to gather market intelligence, including defining a variety of uses for typical off-grid milling customers. Modifications to the product design are being made in response to the data gathered there. Tests such as these can effectively inform a company's chosen product offering and customer financing mechanisms before formally entering a market.

CONCLUSION

The low-power agro-processing market is young, especially when compared to other off-grid appliance markets. There are a handful of manufacturers and project developers in this space and limited customer and market insights from established business models. However, when compared to manual- or fossil fuel-powered processing, the technology has the potential to lower the barriers to farm mechanization in off-grid areas.

For this industry to grow, there is a need for governments and international donors to subsidize the costs associated with R&D and field testing to help proliferate and refine technologies and business models. There is also a need for better market information to support the development of equipment specifically fit to the communities they serve with respect to feedstock inputs, machinery size and capacity, and customer financing options. Taking these solutions to scale will require that market participants identify business models that optimize equipment utilization rates, address high capital costs, and incorporate robust after-sales support and services.

Although there are challenges to scaling up these technologies, the recommendations offered by Powering Agriculture innovators and other stakeholders will help ensure that more communities have opportunities to benefit from low-power agro-processing.

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A smallholder farmer using agro-processing equipment to quickly process crops. Photo courtesy of Village Infrastructure Angels.

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