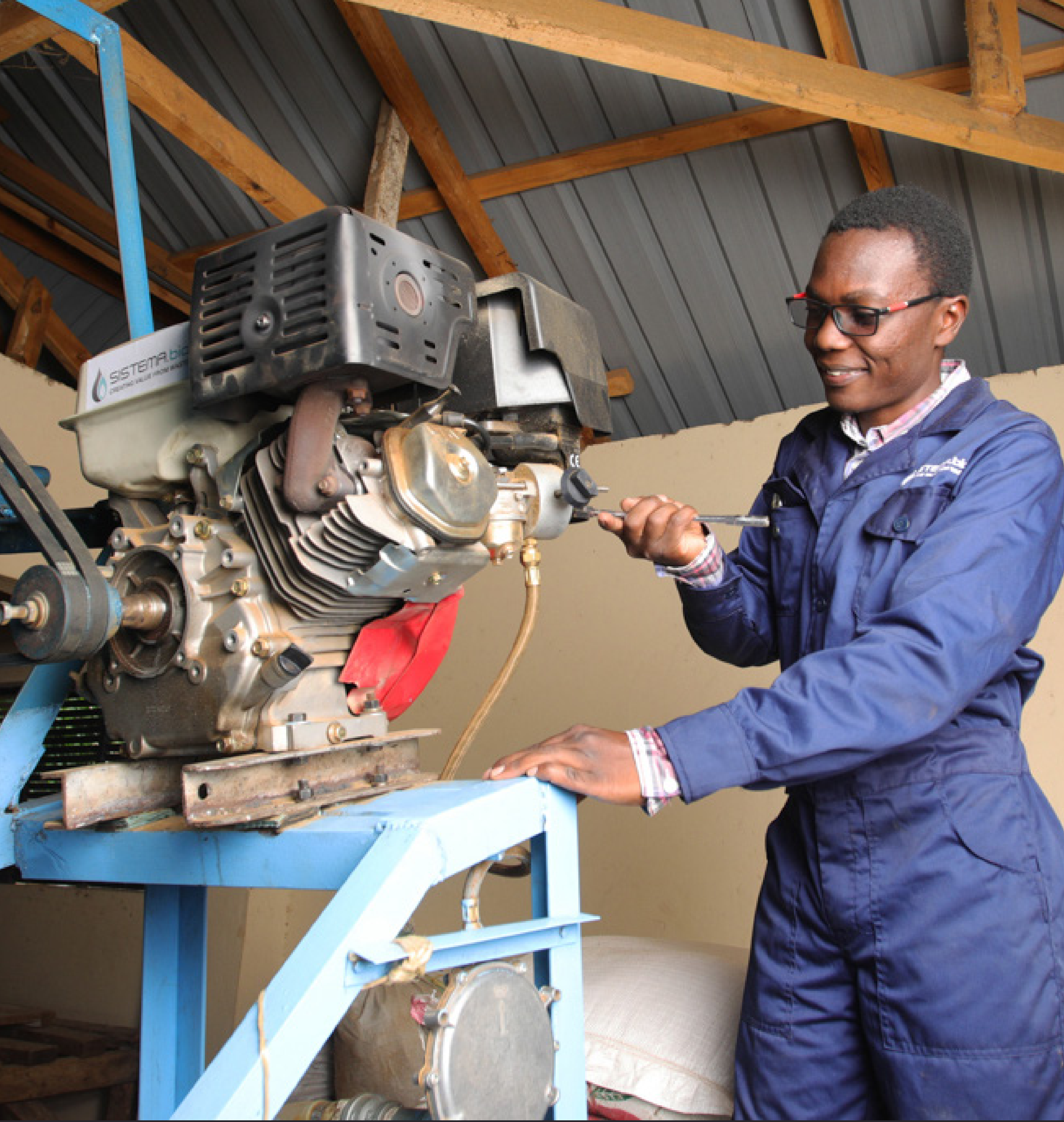

The Opportunity at the Nexus of Energy and Agriculture

December, 2020

FACTOR[e] VENTURES

Acknowledgments

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Of course, we also thank our implementation partners without whom we would not have been able to put risk-tolerant philanthropic capital to work to learn more about the potential at the ag-energy nexus.

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Project Partners

About Factor[e] Ventures

Factor[e] Ventures is a team of impact venture builders dedicated to supporting the people and ideas that turn challenges in energy, agriculture, mobility, and waste into de-carbonized solutions for emerging and frontier markets. Working across the globe, we bring disruptive innovation to the world's fastest-growing markets. We serve as a conduit between philanthropic and commercial investors who are like-minded in their pursuit of sustainable development.

We use a thesis-driven investment strategy to identify critical market needs in the energy, agriculture, mobility, and waste sectors. Then we use a technology-forward analysis coupled with our deep understanding of the economic and social contexts in which we work to identify investment opportunities. Where we don't find solutions to the identified problems, we pull together world-class talent with technologies to incubate and then scale internal concepts.

With decades of combined experience supporting ventures in emerging markets, we're obsessively focused on providing companies with the tools and resources they need to scale their businesses and impact globally.

Our work in these areas, particularly at the ag-energy nexus, would not be possible without the invaluable ongoing support from The Shell Foundation and The UK Department for International Development, which fuel our core investment activities, alongside the research and learning that power our investment theses.

About Rockefeller Foundation

The Rockefeller Foundation's mission is to promote the well-being of humanity throughout the world. Today the Foundation advances new frontiers of science, data, policy, and innovation to solve global challenges related to health, food, power, and economic mobility.

About Windward Fund

The Windward Fund seeks to build a more impactful environmental movement by connecting people across diverse geographies, sectors, and communities, enabling them to share expertise and resources, and providing a vehicle for effective, community-based, grassroots grant making that elevates the voices of those most impacted by environmental degradation. As a 501(c)(3) public charity, Windward incubates and hosts initiatives which pursue bold solutions to environmental challenges from a range of angles. Windward's platform allows donors to convene and collaborate on these issues, leveraging the work of other interrelated projects housed at the fund to strengthen their efforts and advance the field. Windward provides strategic support, guidance on best practices, expertise on operational efficiencies, and specialized compliance knowledge to hosted projects.

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Executive Summary

Even as the continent urbanizes rapidly, Africa's economies are still agrarian. Agriculture plays an important role in driving the sustainable development goals (SDGs) by achieving food security, reducing poverty, and improving nutrition. By 2030 the African agribusiness sector is projected to be worth $1 trillion.[1] But expanding threefold from its recent valuation is far from guaranteed.

Agricultural systems in Sub-Saharan Africa are underpowered. Energy is an essential service for modern agricultural economies enabling farmers to irrigate, work the land, refrigerate, dry, heat, process, and transport crops. However, the lack of robust energy services in rural areas is a fundamental obstacle to development. With limited energy and technology to grow, harvest, and process crops, profits are lower, restricting the potential income for farmers and frustrating the growth of rural communities and the agricultural sector.

Growing agribusinesses and smallholder farmers need modern energy to thrive, but generally lack the technical knowledge, financing, and project development and management capacity to access energy services. Rural energy enterprises, in turn, need reliable energy consumers anchoring demand for their services. Agriculture should be a key market for rural energy providers. However, these energy providers generally don't have the customer and market understanding or the capacity and interest to develop and serve opportunities in agriculture. With few examples of successful projects at scale and many barriers to entry, investors understandably view the opportunity as high risk with questionable returns. There is a clear gap in designing and demonstrating ag-energy projects that can be attractive candidates for commercial investment.[2]

To explore the most promising ways to fill that gap, Factor[e] Ventures, with the support of the Rockefeller Foundation and the Windward Fund, building on the backing of the Shell Foundation and the UK Department for International Development, launched a program to develop projects at the intersection of agriculture and energy in off-grid contexts. Factor[e] is an impact venture builder that provides capital and hands-on support to early-stage, technology-enabled companies solving challenges in energy, agriculture, mobility, and waste in emerging and frontier markets. Factor[e] approached this opportunity with technical and sectoral expertise and the perspective of an investor seeking returns and impact. Through this lens, we were able to evaluate potential opportunities for progress from a combined commercial and developmental view.

In this program, we developed four off-grid ag-energy opportunities including (1) scaling solar irrigation in Kenya, (2) electrifying common agricultural loads at a minigrid site in Nigeria, (3) introducing advanced distributed technology to transform community drying centers in Uganda, and (4) unlocking productivity for dairy farmers in Kenya with biogas powered appliances. A fifth project linking commercial cold storage with a minigrid to serve agricultural trading, which we explored across multiple countries, was frustrated by the challenge of finding a competitive agricultural trader active in the same place as an existing or planned remote minigrid.

Key Lessons

This portfolio was built around selection criteria that focused on innovation, which necessarily drove us towards projects with a higher risk profile. By design, therefore, the early results are a decidedly mixed bag; some opportunities clearly come up short while others show meaningful promise. In this report, we outline the key lessons that emerged.

1. Ag-energy opportunities are real and compelling, but difficult to realize and access.

We need to focus first on how energy meets agricultural needs, not the other way around. Agriculture cannot neatly "solve" the rural electrification business model. The development community must focus on what it takes to create impact for the smallholder farmer.

Agricultural systems are profoundly complex, effected by markets, weather, climate, farmer and customer behavior, political context and more. Something as fundamental as seasonality in agriculture can frustrate an attractive ag-energy opportunity and flummox energy service providers. This complexity underscores why ag-energy opportunities need to be carefully planned, with the agricultural demand at the center. Fundamentally, energy is a service, and agricultural actors are the potential customers. When thinking about the role agricultural customers can play in embellishing the business case for rural energy services, it is important to recognize that agricultural processors and traders will be naturally drawn to better infrastructure and lower costs on-grid or at the "grid edge" rather than to complex off grid operating environments.

In this program, we looked for an agri-trading company willing to operate from a cold storage unit on a remote minigrid. Through our search, we learned that the inconvenience and logistical complexity of remoteness and the uncertainty associated with minigrid project development are significant deterrents. Likewise, grain milling is ubiquitous in rural areas and often thought to be a prime opportunity to improve the financial performance of remote minigrids. However, in Nigeria, we saw that, on closer inspection, milling activity at one minigrid site was not sustained or substantial enough to justify that project.

Recommendation:
Ag-energy opportunities need to be driven by the agricultural imperative; energy is a service, after all. This requires an understanding of the unmet needs – only some of which are related to energy – of smallholder farmers and of the agribusinesses growing up around them. Those needs must drive project design and development.

2. For agriculture to lead, a stronger foundation across the agricultural sector is required.

Most agribusinesses in the region today lack the resources, expertise and management capacity for complex projects, yet quality execution is the key to a successful ag-energy project. In our project design and selection, we filtered thousands of ventures and prospective partners, but this large pool quickly winnowed to only a few serious candidates.

We worked eagerly to develop an opportunity with a hatchery in Ethiopia, but over time it became clear that management capacity and financing were at least as important to the company's success as energy access.

Across this program's portfolio, the projects that came up short of their potential were the ones where the lead implementor strained under the challenge of executing the plan while staying faithful to the original concept. Under pressure, projects reverted to higher-touch approaches like individual farmer sales and demonstration plots in each community that are well-trod, but that are unlikely to replicate and scale rapidly.

Recommendation:
Growing agribusinesses and smallholder farmers need support to develop technical and management capacity as well as access to working capital and asset finance. Foundations and governments should recognize the critical role they play as engines of rural growth and establish combined finance and capacity facilities to support them in each country or regional market context.

3. Even with strong agricultural partners in the lead, a deeper pool of quality innovative enterprises is needed to seize ag-energy opportunities.

We have long known from our investment experience that bringing off the shelf technology and solutions to rural environments does not work without contextualization and business model innovation. Appliances and energy solutions need to be carefully matched to the rural context and nuanced demand of each customer. While there are elements of technology convergence between industrialized and energy access markets, distributed, renewable energies are not inherently well suited for agricultural applications. The biggest challenge is that agricultural energy requirements are often seasonal and require an uninterrupted supply of high power. The supply of innovative impact enterprises that can overcome these challenges is still far too limited to bridge this gap. We need a factory for building such ventures.

Fortunately, we were able to rely on several innovative enterprises in our investment portfolio like S4S Technologies, Sistema.bio, and InspiraFarms to anchor this program. These companies are category leaders that have been put through the paces and are aligned to scale innovative solutions. We need more companies like these operating in the sector.

Recommendation:
Philanthropy must recognize the need – and directly invest in – building innovative enterprises that serve agribusiness, farmers, and energy service providers across multiple markets. In exchange for its extremely risk tolerant capital, philanthropy should demand transformative potential and scale from these investments.

4. A matchmaker is needed to bring innovative enterprises and robust agribusinesses together around ag-energy opportunities at scale.

With looming SDG deadlines and big opportunities to realize at the ag-energy nexus, we need faster progress than the status quo will supply.

Most ag-energy projects combine an energy services provider, an agribusiness customer, and a technology solution. The role of matchmaking to filter for high quality partners and bring them together is an important function to accelerate development. Sometimes all these components are brought together by a single company, at other times three or more entities are needed.

In Uganda, we brought in a technology solution from India, an entirely different emerging market. It is doubtful that Enimiro, a local agribusiness joint venture, would have encountered this solution on its own and S4S were not looking to expand their footprint into East Africa. In Kenya, we matched Amiran's experimental asset finance unit, Madaraka, with Lorentz, a leading irrigation equipment company, and FarmHand, an innovative irrigation asset management upstart. Thus, grant funding and matchmaking helped to create partnerships and transfer technology that otherwise would not have happened.

Recommendation:
Funders and governments with interest in powering agricultural development should work to both establish and sustain project development facilities. To accelerate adoption of new technology by new customers and in new markets, explicit support and matchmaking is required. These facilities need to be staffed with teams that combine expertise in agronomy, energy technology, and project development and management.

5. When it comes to the ag-energy opportunity, scale matters.

Although there are higher risks, larger projects may be more likely to succeed than small demonstrations. Larger projects offer greater returns and attract the attention of high-quality developers and partners. Larger projects also allow for mid-range and integrated planning.

A project to test new approaches to scaling solar irrigation was hamstrung by the limited scale of the pilot, which struggled to sustain the focus and interest of a larger partner. Our efforts to match cold storage with rural minigrids were not fruitful within the time and resource constraints of this program. However, a larger scale effort that matches minigrid concessions with agricultural value chain development, including investments in the cold chain, would provide the kind of planning needed to pull agricultural and energy investments together in the same places at the same times.

Recommendation:
The public sector must take the lead to develop large scale opportunities. Planned, regional initiatives with clear incentives or subsidy are needed to realize the potential of cold storage and irrigation. Government must play its role in educating farmers and agribusinesses about modern practices and new technologies.

The ag-energy opportunity remains an area of chronic under-investment, but with a clear understanding of where investment is needed, a laser focus on quality execution, an appetite for impact, and the sustained and productive commitment of foundations and government partners, the prospects for accelerating development at the intersection of agriculture and energy are exciting. While many of these opportunities are not yet ready for harvest at a meaningful scale, they are surely ripening.

About the Catalytic Grant Program

In 2019, Factor[e] launched a trial program to validate the ag-energy opportunity. Grant funding for this program was made possible by the Rockefeller Foundation and was disbursed to Factor[e] Labs Fund, a fiscally sponsored project of The Windward Fund. Windward contracted with Factor[e] Ventures to execute the programmatic work affiliated with the grant. This program was specifically designed to be cross-sector and cross-discipline with a focus on farmers and agricultural systems. The purpose of the program was to identify, manage, and assess concrete ag-energy demonstration projects with promising technology innovation and a sound business model. Factor[e] leveraged its institutional knowledge of innovation in these sectors along with a network of entrepreneurs, co-investors, funders, non-profits, and related partners.

The key goals of this program were to (1) identify high potential projects that demonstrate the opportunity at the ag-energy nexus, (2) harvest broader lessons for accelerating progress at this nexus, and (3) make recommendations for how agriculture and energy leaders can deliver long term success at scale. Catalytic grant funding supported project development costs and provided the asset financing needed to reach risk saturated customers or new markets with new technology and approaches for the first time.

With this mindset, and armed with criteria for farmer impact, innovation, commercial viability and scale, Factor[e] set out to find worthy projects. This report describes the key lessons and challenges from this work. It also highlights lessons from evaluating investment opportunities in the sector and from the four selected demonstration projects that tested solutions to key industry challenges:

Demonstration Project Overview:

1. **Leveraging outgrower networks to become a key distribution channel to market technology to smallholder farmers, Kenya.** To demonstrate the use of outgrower networks as a viable distribution channel to aggregate demand for solar irrigation solutions to smallholders and to test the performance of and repayment for precision irrigation packages over time.

2. **Introducing new technology to improve production through matchmaking, Uganda.** To demonstrate the viability of a distributed community fruit drying center model where technology is a key barrier to productivity.

3. **Developing a finance model to de-risk new technology to help smallholder farmers commercialize, Kenya.** To demonstrate the capacity of biodigesters to power farm appliances to solve cost and logistical challenges for farmers, unlock productivity improvements for yield and quality, and graduate productive scale farmers to new commercial and processing activities.

4. **Establishing a repeatable approach to stimulating demand for remote minigrids through common appliance electrification, Nigeria.** To demonstrate the improved commercial profile of minigrid sites when existing common agricultural loads are electrified and to develop a methodology to capture them.

Introduction

The Importance of Africa's Agricultural Industry

Agriculture is the backbone of Sub-Saharan African economies. Despite contributing only 15% to GDP, smallholder agriculture supports the livelihoods of more than half of the total labor force, directly employing about 175 million people.[3] But productivity is severely limited. While the continent has more maize acres than the United States, they are only around 20% as productive.[4] In comparison, Thailand alone exports more in agricultural goods than all of the Sub-Saharan economies combined.[5] Mired in under-productive and disconnected farming systems, Africa's smallholders are among the most under served populations in the world.

Technologies and practices that have improved agricultural productivity elsewhere have not taken root in Africa. Fertilizer has transformed agriculture around the world, yet, Africa, as a region, makes up less than 3% of global fertilizer use.[6] Across Africa, only around 4% of cropland is irrigated compared to the global average of 18%.[7] If only existing technology were successfully adopted, crop yields could double or triple for smallholder farmers in Sub-Saharan Africa in the next 20 years, lifting 400 million people out of poverty.[8]

Energy access is one of the key challenges inhibiting growth in the agricultural sector. African agriculture is severely underpowered. Engines supply only 10% of farm power in Sub-Saharan Africa and animal traction is still widespread.[9] Smallholder farmers, located in remote areas, lack access to both capital and modern energy services. Meanwhile, studies suggest that economic growth from agriculture is four times as effective as other sectors in reducing poverty.[10] Though investing in rural agricultural markets is high risk, solving these challenges will reduce poverty, improve livelihoods and unlock the $1 trillion growth potential of agribusiness on the continent.

Understanding the Challenges with Energy Access

Smallholder farmers are the most likely population to lack access to modern energy services, which is a key input to increased productivity. Globally, one in seven people live without access to electricity, of whom 90% are in sub-Saharan Africa and South Asia.[11] An even greater share of the world's population, roughly 40%, lives in an economy that lacks the robust, high energy systems that are central to every modern economy.[12] While over 1.7 billion dollars has flowed to off-grid energy development by 2019,[13] this investment has not transformed rural economies because it has not targeted income generating activities in agricultural communities.

Developers and investors struggle to make investments in high-quality energy infrastructure without productive clients, like the agri-industry, to make the energy business commercially viable. At the same time, energy is a critical input to farming. Reliable, robust electricity is needed to power appliances like water pumps and milling machines. In addition, thermal and mechanical energy is needed for processing, storage, and the manufacturing of food products. Other forms of energy, like the energy embodied in fertilizer, which comprises 2% of global energy use, are also critical to farming.[14]

Distributed, renewable energy is increasingly the cheapest, best solution for new power generation. However, medium and high-power appliances are not naturally suited to standalone renewable or distributed energy systems. Until there is the right combination of high-quality energy with advanced, yet appropriate technology, farmers are unable to use energy productively and profitably.

Technological advances have transformed the efficiency of fundamental energy services like lighting and mobility. These advances, coupled with economies of scale in manufacturing, have the potential to be revolutionary in creating energy access. For example, the global proliferation and massive cost reduction in LED lighting and photovoltaics for solar power generation in combination with Africa's mobile money revolution, enabled the growth of the off-grid home lighting and energy service industry. However, the process of technology development, cost reduction, and diffusion to energy access markets tends to be slow and rarely occurs naturally without a catalyst.

Effective global technology diffusion often requires a bridge that will not build itself. The renewable, distributed technology to transform energy access is already available. However, the challenges lie in adapting technology for rural consumers, delivering it to remote smallholder farmers, and developing business models to bring it to scale.

The Opportunity at the Nexus of Agriculture and Energy

Energy is a fundamental building block of agricultural systems and agriculture can anchor rural energy systems. Indeed, almost a third of global energy is consumed in agriculture and food systems, which produce a fifth of global greenhouse gas emissions.[15] As a result, the ag-energy nexus has long attracted interest and study, particularly from international development funders. Most recently, a major partnership of USAID, GIZ, and SIDA, for which Factor[e] formed a part of the innovative finance facility, focused on tackling this opportunity. The efforts from this partnership highlighted how energy is needed to "power agriculture" across the value chain (Figure 1). Among these areas, consider just a few that highlight the scope of both the opportunity and the challenge associated with ag-energy nexus (Table 1).

Figure 1: Energy in the Agricultural Value Chain. Energy is needed to power agriculture across the value chain, as illustrated in this graphic from the Powering Agriculture partnership. https://www.usaid.gov/energy/powering-agriculture/opportunity

Table 1: The landscape of key ag-energy nexus opportunities in Africa

	STATE OF PLAY	PRIMARY LIMITATIONS
Irrigation	Only 4% of agricultural land in Africa is irrigated. This figure contrasts with 37% of cropland that is irrigated in Asia.[16]	Environmental and market data is limited, stymieing efforts to concentrate on the core market for irrigation services. Business model innovation is needed that includes market mapping, financing, farmer education and behavior change, as well as improving market access for high value products. Effective policy and public subsidy to enable innovative partnerships and business models.
Cold Storage	The developed world has 200m^3 per 1,000 people of refrigerated storage capacity. In the developing world it is 19m^3 and in Kenya and Nigeria it is less than 3m^3.[17]	Technology adaptation to enable the delivery of refrigeration in the absence of uninterrupted power. The cost of controlling the temperature of agricultural products must also be more closely matched with the value refrigeration creates at each point in the agricultural value chain. Business model innovation is needed to embed financing into refrigeration products and effectively transfer risk within a value chain.
Agricultural Processing	Farmers can lose up to 30% of grain due to mycotoxins and bacteria from poor storage and drying.[18] Africa imports over $400m of processed fruit and vegetables a year, but agro-processing is predicted to be the fastest growing sub-sector in the next decade - a $122bn revenue increase.[19,20]	Technology adaptation for context and business models that can deliver processing capabilities in more distributed and remote contexts. Farmer aligned[21] agribusinesses operating in remote areas that can partner with and source from smallholder farmers, add value, and link their products to markets.
Agricultural Waste-Energy Applications	Less than 0.5% of available Africa biomass waste residues are currently being used for energy.[22] At the same time, fuel for generators alone accounts for 24% of the total spent by consumers on electricity, while providing only 7% of electricity service.[23]	Technology development and adaptation is needed to deliver the benefits of waste-to-energy solutions to smaller and more remote farming operations. Mechanisms to aggregate agricultural waste and the behavior change to recognize its value will be required to harness this resource to power farming activities.
On Farm Productivity	Engines supply only 10% of farm power in Africa.[24] Cereal yields in Africa are 70% less than the rest of the developing world.[25]	Distribution systems and a lack of farmer financing are the primary barriers to boosting productivity. Public and private (and partnered) means of providing farmers with physical and financial access to inputs, mechanization, and machinery must be developed and scaled. Technology innovation is a limitation, particularly for mechanisms that deliver and scale sustainable means for boosting on farm productivity.

Key Challenges at the Intersection of Energy and Agriculture

In many ways, the ag-energy nexus presents a classic "chicken or egg" challenge. Agricultural activities need reliable energy services to commercialize and grow. Meanwhile reliable and meaningful sources of energy demand, like those from commercial agriculture, are needed to sustain rural energy delivery. At this intersection, there is a crucial role for the public sector to play in providing the incentives to stimulate demand and direct investment in the energy infrastructure itself.[26]

There are many design challenges and disincentives for technology providers when it comes to the ag-energy opportunity. Agricultural needs vary by geography and value chain, and it is difficult for technology providers to first tailor their solution and then reach enough customers to justify the investment in the product modification. Most ag-energy opportunities involve some form of asset, input, or trade finance. However, private finance providers are generally convinced (often with good reason) that the risks and transaction costs in agriculture are too high. Strong entities are needed to deliver products and services to rural farmers. The existing systems are fragmented, and in many situations the channels don't exist and are too costly to build. New technology solutions require education and training but there is rarely room in the thin margins of rural agriculture or energy businesses to cover these costs. Without established channels, appliance and processing equipment manufacturers will often only focus on customers in more profitable markets, rather than those that are poor, hard to reach, and engaged in seasonal activity. As a result, many proven technologies have not been adopted, as the cost and difficulty of design, manufacture, distribution and servicing have been too high. However, as clean technologies such as electric motors and energy storage continue to mature and scale globally, there is an opportunity to bring them into rural development settings to power growth.

Five Key Challenges

To make advances in the ag-energy nexus there are five key challenges that need to be addressed:

1. Technology

The industry needs modular technology solutions that can be adapted to fit specific energy needs.

Large-scale solutions that may work for large-scale agroindustry rarely fit the market need for smallholder farmers and the small and growing agribusinesses that serve them. Solutions are often too expensive and oversized for smaller or seasonal activities. There is a gap in energy systems that are powerful but modular with the ability to scale to fit the size and cost requirements for small, but growing operations.

2. Behavior Change

The behaviors of smallholder farmers and rural economic models are deeply rooted.

Whatever the theoretical economic argument for new solutions, risk averse consumers will approach new products cautiously. Often new technology requires smallholder farmers to seek out a solution, learn new hardware, take on debt, and adopt new practices. To succeed, enterprises need to take on the difficult tasks of marketing to risk-saturated farmers and training them to overcome barriers to adoption.

3. Business Model

Elegant technology design and pilot performance will not guarantee scale and impact.

Many technologies have been proven and yet still have not been adopted because there are few sustainable enterprises able to drive a tailored solution into the market and then scale it. Getting these solutions into the hands of farmers is difficult as customers are spread widely in hard to reach places. This function is typically delivered or subsidized by the public sector in many places but is often lacking at the last mile. Finetuning the right delivery model and enabling infrastructure are critical to the success of ag-energy solutions.

4. Access to Finance

Products and services often need to be paid for up front, but cash flows are seasonal, margins are thin, and farming is subject to seasonal and year-on-year unpredictability and climate change.

Upfront costs are difficult to justify for a return on investment far in the future. Financing enables the upfront cost to be repaid over time, aligning the cost with the payoff that it delivers. However, rural customers are generally considered unbankable. The creditworthiness of agribusinesses and the rural context in which they operate is poorly understood by traditional financing institutions. Instead, embedding financing into the technology solution has often been the answer. To be successful, providers then have to build the service, deliver it to the customer, and develop a credit function so customers can pay for it. Unsurprisingly, this can prevent new products and services from reaching the market. Creative financing models with a better understanding of these rural customers are being developed but are not yet widespread.

5. Siloed Support

Private, public, and philanthropic support typically organizes around either energy or agriculture but rarely considers both.

Each sector has its own lens, priorities, actors, experts and language. This divide can result in competition for, or jealous guarding of, resources internally and leave cross-over ag-energy opportunities under-funded. Long term, integrated policy and public-sector planning can defuse competition for limited budgets and help avoid the political challenges such competition for resources can create.

Surveying the Agriculture Energy Landscape and Selecting Opportunities

Factor[e]'s approach to identifying fundable opportunities was to find evidence of demand at the ag-energy nexus and match it with the right technology solution or energy provider. To meet our criteria, innovative projects needed to be enterprise led. Projects also needed to demonstrate a deep understanding of customer behaviors with strong operators who understand that success is most often dependent on the quality of execution. The selection criteria were established by a community of practice that included entrepreneurs, policymakers, investors, and funders that were assembled at the Rockefeller Foundation's Bellagio Center at the launch of this program in April 2019.

Factor[e] reviewed over 150 potential project ideas and partners to deliver them. Surprisingly, there were fewer that met the program's criteria for scalability, innovation and impact than were expected. There are few companies operating at the ag-energy nexus that have the technology, team, and ability to deliver projects at scale, not least because it is extremely challenging to operate successfully in these emerging markets. The difficulty in identifying a sizable cohort of fundable projects is an indication of how and why ag-energy nexus opportunities are not being seized.

Factor[e]'s role in this process was not simply evaluative, but also involved matchmaking and connecting opportunities. Each project needed a defined energy service provider, technology provider, and agricultural operator. In some cases, the same enterprise filled each of these roles, whereas others required innovative partnerships. Looking across the project concepts and our networks in energy, agriculture, and technology, we stitched together projects to trial high potential concepts with a risk profile that demanded philanthropic capital to bring them to life. The catalytic grant funding both supported the project development costs and provided the asset financing needed to reach risk saturated customers, bring new technology to new markets, or trial approaches for the first time.

This resulting portfolio is a product of where the big opportunities lie, based on the selection criteria outlined for this program and the idiosyncratic reality of where effective actors are currently operating on the continent. There were several projects that had a clear argument for scalability and impact but for whom the catalytic role of a grant through this program was less emphatic because the technology was already well-established or the enterprise was already operating effectively in-market. These ventures did not need 'de-risking' grant capital, but rather capital to scale their activities or incentives to target customers and markets that are harder to reach.

There were also exciting project concepts that we were not able to pull together within the time and resource constraints of this program. This experience was best exemplified by our efforts to fund the deployment of a small, commercial cold storage unit on a remote minigrid. The challenge was to find a community minigrid with active agricultural trading in the time frame available.†

We came closest to realizing this opportunity in a conversation with a growing avocado exporter in southwest Tanzania that has successfully onboarded 5,000 smallholders in remote rural communities over the last two years. This trading operation has increased revenue for its suppliers from $1,000 to $5,000 per acre. While their farmers are mostly off-grid, this trader preferred to locate their cold storage and pack house facilities on-grid a few hours away from their farmers, rather than entangling themselves in the cost and complexity of a community minigrid project. Even with the financial incentive that our ag-energy grant could provide, the uncertain timeline, project complexity, and undefined tariff structure meant they were not tempted to explore this opportunity further.

† *We failed to realize this project through this program, but to better understand the opportunity we carried out a detailed demand modelling analysis using example crop load profiles and running simulations on a theoretical solar minigrid in rural Ethiopia. The results of the modeling effort, which are detailed in a forthcoming companion report, show compelling benefits for the minigrid business model and for off-grid refrigeration. We hope this leads to the concept being tested in future.*

Key Gaps to Unlock the Ag-Energy Potential

Through our project selection process, we uncovered key gaps that investors need to address to unlock the potential of the ag-energy nexus. Funders, development finance institutions, and governments can help address these gaps by:

1. **Growing the number and strengthening the capacity of local agribusinesses.** The criteria were based on the premise that agricultural operators need to lead in these projects. The lack of local agribusinesses in the region limited potential projects due to the absence of a compelling lead organization. Agribusinesses need additional financial resources, management capacity, and training to grow and drive development in rural economies.

2. **Providing patient project finance and lower cost capital.** This will incentivize technology providers, energy services, and agricultural operators to enter new markets and target harder to reach customers. Capital in the market is currently limited, moves too slowly, and is over-priced, leading to the misperception that all projects are high-risk.

Table 2: Status of selected demonstration projects

PROJECT	STATUS	STARTED	PROGRESS	SCALE
Community Food Drying *Uganda*	The adoption of new technology at community drying centers has been promising and there is the potential for this model to scale if there is effective oversight, training and financing by the dried fruit offtaker.	🟢	🟢	🟢
Outgrower Irrigation *Kenya*	After a couple of false starts, the effort to increase adoption of solar water pumps through outgrower networks is now underway. With that said, we are now less convinced it will show a scalable approach to overcome the barriers to widespread adoption.	🟢	🟡	🟡
Biogas Dairy Appliances *Kenya*	There is demand for biogas powered appliances which can reduce cost and increase productivity for dairy farmers, but market specific obstacles must be overcome to reach scale.	🟢	🟢	🟡
Demand Load Saturation *Nigeria*	The sensor-led approach to demand stimulation showed that the planned project was not viable. This is partially successful as it shows how a data-driven approach saves the minigrid operator time and money when evaluating these types of opportunity.	🟡	🟡	🔴

Leveraging outgrower networks to become a key distribution channel to market technology to smallholder farmers

Project Overview

Ag-Energy Challenge:
Distribution models for improved crop irrigation technology

Location:
Kenya

Partners:
Amiran- Agribusiness Partner
Lorentz- Technology Provider
FarmHand- Technology Provider (enhancement)

Challenge:
Modern, proven, and sustainable solar pumping technology is available in the market, but generally fails to reach smallholder farmers. Instead, the challenge is one of aggregating demand to reach customers more easily at scale

Goals:
Test whether outgrower networks can aggregate demand and drive smallholder adoption of solar water pumps at a cost and rate that other approaches have failed to achieve to date.

Introduction

Smallholder farmers in Kenya still rely heavily on rain-fed agricultural production.[27] Technology is not the key challenge. Modern, proven, and sustainable solar pumping technology is available in the market, but generally fails to reach smallholder farmers. Instead, the challenge is one of aggregating demand to reach customers more easily at scale.

For a farmer, adopting solar irrigation is a high stakes decision and a high friction process. It will change their existing farming practices and directly impact their livelihoods. Often, they also must decide to switch the crops that they are growing entirely. There is little room for error. Farmers need both technical information and trusted advice about market opportunities to understand the value a new technology can bring. Installing in an irrigation system is a major upfront investment, which means they must also decide if it is better than other on- and off-farm investments they can make. Even then, farmers will also need to secure asset financing to help with the upfront costs of purchasing the pump.

Irrigation technology suppliers, meanwhile, find it hard to size the market[28] and justify the resources to serve it, even where demand exists. Irrigation needs vary widely, making standardization difficult for a smallholder cohort that are considered high risk and difficult to finance. Farmers typically lack collateral, can only afford repayments linked to seasonal cash flows, and do not have access to insurance products that help transfer the risks inherent to farming. Without a concentrated market of smallholder farmers that have access to the water resources and infrastructure to allow them to irrigate, providers will find it hard to succeed commercially. The transaction costs will continue to outweigh the margins and volumes achievable where the customer-base is hard to reach and serve.

Outgrower networks are an organized group of farmers who agree with a buyer to supply a certain volume and quality of their farm's produce at the end of a season. To help ensure these criteria will be met, the buyers often provide additional support, such as training and financing. Outgrower networks allow demand-driven buyers greater control over a crop's supply and quality. In turn, the outgrower network provides farmers access to more secure and higher value markets. Thousands of farmers can be organized in this way to serve as a distribution channel for new farming technology.

Outgrower networks could make it cheaper, easier, and lower risk to get new technology, like irrigation pumps, into the hands of farmers by helping to overcome some of the challenges with sizing and mapping the market for solar irrigation. These networks bring together groups of farmers who grow similar crops and should have the same irrigation needs and repayment behavior. Their contract relationship with the buyer means there is reliable market access for their crop and an existing channel for payment and information, which should lower their credit risk. Meanwhile, the buyers should have a commercial motivation to introduce new irrigation technology as farmers will then deliver more reliable and higher quality yields.

While the potential for technology dissemination through outgrower networks is great in theory, in practice, the buyers are often unwilling to take on the added work. Instilling simple best farming practice among smallholders is already a challenge and these buyers usually lack the long-term planning, larger financing vehicles, or risk appetite to extend credit for higher capital expenditures assets like solar pumps. The buyers are often over-extended themselves and struggle to manage their financial and credit relationships with farmers.

Case Study

Financing Provider: Amiran

Amiran is the operational hub of Balton CP, a leading agro-supplier active across eight countries in Africa. They offer a one-stop shop for farm solutions from productive assets to high quality climate-smart farm inputs with added training and customer support. In 2019, Amiran launched an asset financing division, Madaraka, to offer credit to smallholder farmers for purchases on terms linked to their cash flows.

Solar Irrigation Technology Provider: Lorentz

Lorentz is a leading global manufacturer and supplier of solar-powered water pumping solutions. They have an extensive distribution network of over 5,000 partners around the world. Their products and solutions serve the range of farmers from smallholders to large commercial farmers. All of their pumps are smart systems, monitoring and optimizing performance in real time and recording data for analysis. Their pump systems come with mobile applications that work in low connectivity settings and allow the pumps to be monitored via Bluetooth. For their smallholder customers, Lorentz promotes high efficiency pumps with DC brushless and sensor-less motors to deliver twice the amount of water as equivalent pumps using the same power.

Irrigation Software Technology Provider: FarmHand

FarmHand is an ag-tech start-up that provides a smart irrigation platform that uses crop data and hyper-localized weather forecasting to provide a real-time farm-specific irrigation schedule that is more precise and efficient than traditional irrigation scheduling. Field trials have shown an average 60% reduction in energy and water usage alongside a 30% increase in yields. Their Water-Hand product is IoT-enabled and cloud-based, so that it can be controlled remotely from a farmer's smartphone. Sensors on the in-field Water-Hand micro-controller collect data on humidity, temperature, and solar irradiance. These inputs allow it to deliver precision sizing and scheduling of irrigation without high-cost sensors. This "right-volume, right-time" approach improves crop yield and farm output, while saving water and energy.

Amiran has an established relationship with Frigoken, a large green bean exporter that has established an outgrower network in Kenya. For the project supported by Factor[e], Amiran designed an irrigation package that combined Lorentz' solar water pump with in-field pipes, drip lines, seeds, fertilizer, and other inputs required for each growing season. They designed their credit facility and repayment scheduling around the crop type and cash flow of farmers in Frigoken's outgrower network. Table 3 shows that this package can deliver a payback in just one year when adopting an irrigation system for the first time. Increases in yield and an extra growing season per year can double the farmer's annual income. However, the large upfront payment is a big hurdle to overcome in the first two growing seasons. Reducing this cost further and spreading repayment over several more growing seasons would lower a key barrier to adoption.

Project Objective

The purpose of this project was to test whether outgrower networks can aggregate demand and drive smallholder adoption of solar water pumps at a cost and rate that other approaches have failed to achieve to date. The benefits of solar irrigation need to be sufficient for outgrower networks, buyers, and technology providers to overcome the obstacles of delivering modern irrigation services to smallholders. To trial this model, Amiran aimed to register 12 farmers to this integrated irrigation package with a financing facility for the pilot that was sized at $50,000.

Table 3: The proposed financial payback of Amiran's irrigation package for a farmer in Frigoken's outgrower network.

Solar water pumps have high upfront costs but smallholders in Frigoken's green bean outgrower network can achieve a payback period of just over two years compared with diesel pumps and less than a year compared to no irrigation. However, a lack of financing and the upfront deposit required are substantial barriers to adoption. *(Source: Amiran)*

Price per kg = 61 KES

	Non-irrigated	Diesel Pump	Solar Water Pump
Income per year ($)	**6,264**	**12,760**	**12,760**
Income per season ($)	2,088	3,190	3,190
Seasons per year	3	4	4
Capex	-	1,800	3,100
Pump Cost		300	1,600
In-field irrigation		1,500	1,500
Opex (per season)	**1,000**	**1,163**	**1,000**
Production costs per season	1,000	1,000	1,000
Diesel cost per season	n/a	163	n/a
Financing	**Non-irrigated**	**Diesel Pump**	**Solar Water Pump**
Upfront payment		1,800	1,500
Outstanding payment (incl. interest)			1,793
Repayment per season (5 seasons)			359
Operating Income per year	**Non-irrigated**	**Diesel Pump**	**Solar Water Pump**
Year 1	**3,264**	**6,310**	**5,826**
Season 1	1,088	228	332
Season 2	1,088	2,028	1,832
Season 3	1,088	2,028	1,832
Season 4	-	2,028	1,832
Year 2	**3,264**	**8,110**	**8,402**
Season 1	1,088	2,028	1,832
Season 2	1,088	2,028	2,190
Season 3 etc....	1,088	2,028	2,190
Year 3 etc....	**3,264**	**8,110**	**8,760**
Production			
Seasons per year	3	4	4
Production (kg)	3,600	5,500	5,500

Results

Amiran's initial plan was to offer this package through direct marketing events organized by Frigoken. They designed a package for outgrowers but struggled to sell even non-irrigation packages, let alone register farmers for the pilot. This marketing approach failed to appreciate the massive scale of investment required by the farmers and needed to better address both the perceived and actual risks associated with adoption. Amiran instead reverted to a traditional demonstration-led field sales model, which was costlier and slower. This approach is undoubtedly important in the rural context and has more traction than direct-marketing efforts so far, but it is less exciting in terms of the potential for rapid scale and growth. Even then, with little previous experience of irrigation they underestimated the effort to design and install systems at these farms and faced delays and higher costs as a result.

Marketing feedback from farmers also revealed that smallholder farmers, with 4- or 5- acre plots, only use a portion of their land for the high value contract crops which they deliver to outgrower networks. The rest is used for crop rotation and to produce crops which are sold into local markets. This information fundamentally changes the financial model. Smaller plot sizes make the return on investment in an irrigation system more difficult because the "soft costs" of designing, marketing, installing, and financing an irrigation system are largely fixed, but the transaction size and farm revenues are both smaller. As a result, the actual payback period for farmers is long and the revenue opportunity for providers is less attractive.

Despite the established relationship Amiran had with Frigoken, Amiran struggled to tap into the contract farming relationship. As a result, their credit facility was not able to benefit from the established and trusted commercial relationship and payment channel.

Frigoken – and similarly situated agri-traders and export companies with outgrower networks – is probably best placed to realize this opportunity with the right support. Frigoken has the ability to facilitate the financing and repayment for new technology and should have a shared incentive to improve yields and quality. However, they do not have the capacity or risk appetite to develop and manage the pilot concept. Testing this approach at a small scale failed in capturing the attention and motivation of the key partners, especially where the larger actors like Lorentz were concerned. A larger experiment would provide greater incentive for a large buyer, like Frigoken to get involved. These aggregators need to have a long-term view of outgrower development. They often have much shorter horizons and seasonal production targets that take priority.

Ultimately, however, this project asked the question whether outgrower networks would cost-effectively scale new technology to smallholder farmers. This attempt does not suggest that, absent a public-sector led coordinated effort at a large-scale, it can transform the challenge of disseminating technology to smallholder farmers. While we do not recommend scaling or replicating this model at this stage, it is possible that adjustments to the project architecture, scale, or implementation partners would yield better results.

A solar pump is installed at a demonstration plot in Gilgil, Kenya

Lessons Learned

Costly systems are prohibitive for many smallholders, even where financing is available, as the leap is too great. Instead, investment in irrigation needs to be broken down into a series of steps to bring solar water pumps within reach. Amiran saw little traction for a single, expensive offering. A solar water pump, even with repayment over multiple growing seasons, is a big leap for a farmer who has never even purchased a basic irrigation product. An approach based on a better understanding of the outgrower farmer and how their needs evolve as they become more productive might have more success.

The cost of delivering irrigation technology to farmers is prohibitive without outgrower support. Amiran will continue working on refining their offering to outgrower networks to aggregate demand for solar water pumps. Commitment from Frigoken or a similar partner is required for success as their distribution channel offers a trusted source of information to a large network that can be delivered cost effectively. In addition, extensive education and training is needed at the farm level which is hard to sustain without outgrower support. However, Frigoken does not have the bandwidth or motivation to do so alone.

Pump solutions need to be matched to crop, topography, water and infield irrigation requirements. A demonstration-led approach may be needed to introduce technology but is not sustainable for scale. Outgrower networks can bring technologies to scale, but the cost and complexity of discovering early adopters is itself probably prohibitive. With a relatively small, disaggregated market that is still expensive to reach, it is not clear who will bear this cost and, therefore, how solar irrigation systems will spread. Each farm has their own specific irrigation needs that are difficult to aggregate. A larger scale trial of >100 pumps with greater potential for financial return could spread the soft costs of project development (market sizing and mapping, system design, marketing and demonstration, and financing) across many more customers. Partners told us this would convince them to commit more attention and resources to see these types of projects succeed.

Recommendations for Success

1. Offtakers and project partners need project management and outgrower network management support as part of a broader range of products, services and systems to meet the evolving needs of an increasingly productive smallholder farmer.

2. Irrigation programs need to be designed at large scale and underpinned by asset financing to be successful. Smallholders will always be difficult to serve individually. Some guarantee of volumes will incentivize partners to test adoption and repayment approaches over multiple growing seasons and to mitigate credit risk across several farmer cohorts or outgrower networks.

3. Joined up public sector support and resources would help to advance solar irrigation at a regional scale. Regional program initiatives would achieve economies of scale, attract technology providers, and embolden private actors to promote adoption through marketing and training. Beyond the aforementioned minimum volume guarantees, the public sector should directly subsidize market and environmental mapping costs in addition to supporting training and extension service, demonstration expenses, and incentives to early adopters to prime the local market.

4. Technical assistance and strong agricultural expertise are needed for providers who are aiming to market products and services to smallholders. Technology and energy providers need market input from agriculture-led programs.

Matchmaking new technology and community drying centers to improve production

Project Overview

Ag-Energy Challenge:
The adoption of distributed technology for drying produce

Location:
Uganda

Partners:
Enimiro- Offtaker/Agribusiness Partner
S4S- Technology Provider

Challenge:
Post-production, commercial smallholder farmers face three primary production challenges (1) high loss rates, (2) a lack of processing technology, and (3) limited access to high-value markets.

Goals:
Test an innovative partnership and investigate if a modular, affordable solar conduction drying technology could transform the productivity of community drying centers in Uganda

Introduction

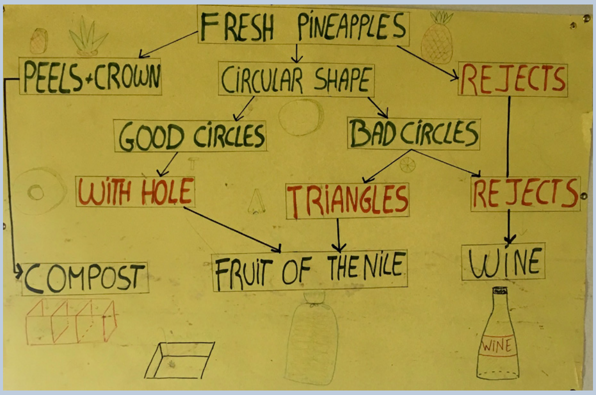
Post-production, commercial smallholder farmers face three primary production challenges (1) high loss rates, (2) a lack of processing technology, and (3) limited access to high-value markets. Pineapple farmers in Uganda, for example, have loss rates as high as 40%. This loss translates into a waste of resources, labor, and inputs and a loss of income. While commercial smallholder farmers lack the access to energy and machinery for cooling, processing, or drying, they also face a critical technology adoption challenge. Rural entrepreneurs have limited expertise to navigate the landscape of potential solutions that work in off-grid environments. Understandably there is little appetite to take a risk on technology that might not work.

Drying fruit is a straightforward way to reduce losses and add value. The market for dried produce is growing globally, driven by an appetite for healthy and organic snacks. The cost and spoilage involved in transporting fresh fruit that is twenty times the weight of the dried end product means that local, distributed drying should have an advantage. Although centralized drying allows processes and quality to be tightly controlled and operated at scale regardless of the weather, it is also energy and capital intensive.

To take advantage of the distributed drying opportunity, community drying centers were set up several years ago in Jinja by offtakers to supply the export market. They equipped a local lead-farmer or entrepreneur with a basic solar dryer to process pineapples for themselves and for other nearby pineapple farmers. With labor being the only true operating expense, the unit economics for community drying centers should be straightforward: produce and sell enough dried fruit at a price fixed by the exporter to cover the costs of buying fresh fruit. The buying price will fluctuate by season, but the center can achieve profitability if they maintain high throughput.

However, these drying centers have struggled to maintain high enough production volumes to satisfy offtakes demand. The use of basic solar drying technology has led to long drying times and, with limited capacity, centers are operationally much less efficient. These drying micro-entrepreneurs also complain that increasingly unreliable weather makes their work harder. Discouraged by poor returns, they are both failing to turn a profit and to meet the growing appetite for dried fruit for export.

As a result of poor drying ratios, community drying centers that use basic drying technology limit operating hours, batch sizes, and labor costs, which reduces their capacity and production. This means they fail to meet the demand from exporters who are more likely to revert to a centralized process they can control. Better technology, alongside standardized processes, tools and training can substantially improve the performance and drying ratios of these centers and thus their profitability, making the business model viable.



The Drying Ratio

The key indicator of profitability for a drying center is its drying ratio. This is a measure of efficiency gauging the number of kilograms of fresh fruit that are needed to produce a kilogram of sellable dried fruit. An inefficient drying process produces a higher drying ratio and profitability decreases. The target drying ratio for the community drying center in Jinja, Uganda, is 15kg of fresh fruit to 1kg of dried fruit.

There are several reasons drying micro entrepreneurs fail to reach this benchmark. If fruit is not ripe, too ripe or poorly prepared, then it is more likely that the fruit will be discolored, misshapen, and discarded. However, the inefficient technology is the biggest driver of waste. Longer drying times not only mean processing fewer batches, but also result in reduced quality and higher damages, meaning more fruit is discarded.

Case Study

Offtaker: Enimiro

Enimiro, a dried fruit exporter in Uganda, is a joint venture between Gourmet Gardens and Kasana Fruits. Gourmet Gardens specializes in organic certification and supply chain development for vanilla, cocoa and coffee. Kasana Fruits is a European dried fruit buyer that is looking to meet growing demand for high quality, organic products by building strong and equitable local supply chains. Collectively, they believe their commercial success is tied closely to the farmers and community drying centers that supply them. Unlike many agribusinesses in the region, they have the resources and motivation to find solutions to production and processing challenges in their supply chain.

Drying Technology Provider: S4S

S4S Technologies is a food preservation company based in India. They develop and use food processing technology to create a sustainable supply of processed food products. Their technology creates new valuable markets for smallholder farmers while producing ingredients, healthy snacks, and meals for the growing Indian consumer market. Smallholder farmers and rural micro-entrepreneurs are the backbone of their business. Their innovative technology not only reduces food waste, but also adds substantial value to the products of India's massive farmer population thereby increasing their incomes.

S4S's Solar Conduction Dryer (SCD)

The Solar Conduction Dryer (SCD) is a simple but robust solar drying technology designed around rural entrepreneurs and the context in which they operate. It is easy to assemble, requires little maintenance, and delivers consistent and concentrated drying within a closed system that prevents foreign objects from entering the drying space. All modes of heat transfer including radiation, convection, and conduction are used eliminating the need for a fan or other moving parts that can break.

The SCD also provides the best value. A 10-year life expectancy means that its lifetime cost is cheaper than equivalent dryers. With a higher tray loading capacity, drying throughput is improved. An electrical backup allows the dryer to operate on cloudy days or at night if needed and if electricity is available. This also means that the SCD and the fixed bed dryer that make up the drying system could function as income generating appliances to stimulate demand for rural electrification projects.

A center that processes a 200kg batch of fresh fruit incurs sourcing, transport and staffing costs. If they invest in better technology, they will also have capital costs for the assets and electricity costs to power them. Where available, electricity is used to power fixed bed dryers in sequence with solar conduction dryers to accelerate the drying process and manage variable weather.

Through this project, Factor[e] matched Enimiro with S4S. But for Factor[e]'s role in this program, these partners would not have connected. S4S does not primarily market its hardware for sale. Rather, as a young startup, it focuses on building out its vertically integrated approach in India.

Project Objective

The project provided the financing to test a partnership that wouldn't have occurred organically and aimed to investigate if a modular, affordable solar conduction drying technology could transform the productivity of community drying centers in Uganda. Factor[e] examined how different configurations of these dryers could improve drying center economics. The aim was to process a daily batch of over 300kg of fresh pineapple and consistently achieve a drying ratio of 15:1. The combination of both technologies helps centers to mitigate against poor weather so that drying can reliably be completed in a single day, maximizing capacity and limiting losses. The modular design is also an advantage as drying center owners can expand their operations gradually over time.

S4S Solar Conduction Dryers in use

Results

After six months of program implementation and 10 MT of processed fruit at the pilot community drying center, initial performance was measured. Table 4 shows a comparison of daily drying performance based on the first growing season. These results demonstrate improved drying ratios and the ability to operate at scale have an important impact on the performance and profitability of the community drying center. The drying ratio has so far improved from 22kg to 17kg of fresh fruit required to produce 1kg of dried fruit. They expect this to improve further to 15kg, which would both reduce waste and improve operating margins to above 30%. The pilot center is also able to reliably process higher volumes of up to 500kg per day.

One of the key findings is that the fan dryer is as important for drying efficiency as the solar conduction dryer, showing that established technology transfer can be just as important as new innovation. However, the improvement in performance is not just a case of implementing a simple technology upgrade. Unlocking the value that better equipment can provide requires management capacity to oversee the necessary iteration, training, and tools to improve operational efficiency and reliability.

Despite the improved margins, it is unlikely that drying centers can easily afford to purchase the equipment themselves, as well as the working capital to operate at scale. Drying centers are operated by cash poor farmers or rural entrepreneurs requiring asset finance, perpetual lease, or contract drying arrangements in which the drying machinery is supplied by the offtaker. At $1,800 per drying system, each with a capacity of 100kg of fresh fruit per drying batch, each unit delivers a profit of $4.87 per day. That is a simple payback period of 370 drying days or around two years given that the center does not operate year-round.

Results so far suggest that increased volumes will make this investment worthwhile for an asset finance partner or the offtaker. Their operating margin is already around $4 per kg and this offers greater predictability of volume and quality of saleable dried product. Alternatively, offtakers could also increase the price they pay for the dried pineapple, making the investment viable for distributed drying centers.

However, it is probably still a bit too early to report on the economics of the systems. Despite questions over equipment financing, the optimal configuration of dryers, and the approach to rolling this system out at additional centers, the exporter is enthusiastic to expand this system. They are looking to set up community drying hubs for farmers to access equipment, and where quality and training can be overseen more efficiently. This level of engagement and commitment is probably unusual, but a hands-on and vertically integrated approach will continue to be a key ingredient to the success of this model in the future.

Table 4: Drying Center Performance has improved signifigantly during the pilot.

	Historical Performance		Improved Performance (to date)		
Batch Size (kg)	100	300	100	300	500
Drying Ratio*	22	22	17	17	17
Dried Product (kg)	4.55	13.64	5.88	17.65	29.41
Price ($/kg)	4.53	4.53	4.53	4.53	4.53
Revenue ($)	**20.59**	**61.77**	**26.65**	**79.94**	**133.24**
Fresh Fruit ($)	16.00	48.00	16.00	48.00	80.00
Staff Cost ($)	2.66	3.99	2.66	3.99	6.65
Total Cost ($)	**18.66**	**51.99**	**18.66**	**51.99**	**86.65**
Operating Income ($)	1.93	2.86	7.99	27.95	46.59
Operating Margin	**9%**	**16%**	**30%**	**35%**	**35%**

Lessons Learned

Technology can be leveraged from adjacent markets to improve smallholder incomes. The technology transfer between markets was successful in making the distributed drying center model more profitable and reliable. In the hands of a competent and motivated operator like Enimiro, modular technology, carefully designed around the needs of the rural entrepreneur, improved drying rates. While it is early days in preparing for growth, the dryers are affordable if they can be financed or leased by the exporter.

Distributed rural business models can work better with the right technology, but technology alone is not enough to 'fix' them. Although outdated technology was a key reason the community drying center model was not working well, even high-performance technology does not guarantee that a rural drying center operation is successful. Procurement, training, testing, and patient ongoing operational support were all required to help Enimiro succeed. Constant iteration of the approach, drying times, tools, and configuration of the dryers was also needed to unlock the value the technology can deliver. Enimiro also had a good understanding of the smallholder farmer. They were, therefore, well placed to deploy a novel solution successfully.

Distributed drying centers can improve smallholder incomes. Enimiro is already planning to roll out S4S' systems to additional community drying centers or at community drying hubs. There is an opportunity to replicate and scale the use of robust, distributed technology beyond Enimiro's centers, especially where trading companies struggle for supply and are eager to diversify into dehydrated trade. Product diversification involves looking to other markets with nascent produce drying operations that have a need for effective, distributed technology. Based on the experience from this project, the key will be the effectiveness and motivation of the trader or exporter of dried fruit in these new geographies to install, train, and oversee these centers.

Recommendations for Success

1. Technology providers need to engage with motivated offtakers and provide technical assistance to adapt the technology to the particular value chain, local market, and trading opportunity.

2. Support is needed to first match the offtaker with technology and then to adapt the approach to new markets and products. Project management and operations support is also needed for rural entrepreneurs during deployment to install and train centers to use the technology. Factor[e] played this role in this project. Absent a philanthropically funded matchmaking function, it is not clear where these forms of support will come from down the road.

3. Financing or leasing of technology to drying centers need to include payment schedules that accommodate drying center economics. Investment is needed in agribusinesses that create value through rural processing and trade.

De-risking new technology and developing a finance model to commercialize smallholder operations

Project Overview

Ag-Energy Challenge:
Powering the dairy value chain

Location:
Kenya

Partners:
Sistema.Bio- Technology Provider

Challenge:
Smaller farmers use expensive and inefficient diesel, wood, or petrol-powered appliances for basic farm activities. Facing volatile and sometimes high energy costs, it is risky for smaller farmers to invest in appliances with large upfront payments.

Goals:
(1) examine the technology performance, adoption, and maintenance needs of the biogas digester system (2) monitor farmer repayment behavior, and (3) design a commercial package that delivers an attractive return on investment for the farmer alongside an expanded market for Sistema.bio.

Introduction

Milk production in Kenya is still dominated by smallholder dairy farmers. Dairy production has a range of thermal, mechanical, and electric energy requirements. Larger dairy farmers in Kenya typically source energy from electricity or diesel to power a generator for their electrical needs, LPG gas for heating and cooling, and petrol to run chaff cutters. Smaller farmers will use diesel or petrol-powered appliances for basic farm activities, but also rely on more expensive and less efficient energy sources such as firewood to heat water for example. Facing volatile and sometimes high energy costs, it is risky for smaller farmers to invest in appliances with large upfront payments. Farmers rarely have access to financing to grow their small dairy farms into larger operations due to antiquated business practices. The lack of modern testing and efficient digital payment systems in the dairy value chain in Kenya make it harder and less attractive to lenders.

When there is an opportunity to invest in their dairy operation, farmers typically decide to modestly add to their herds rather than investing in equipment and appliances. As herd size increases, milking by hand becomes labor intensive and inefficient. Diesel or grid powered milking equipment is available, but farmers may not be able to afford it even when their dairy operations reach a scale where it is justified. Hot water is needed to clean milking equipment and storage containers to remove bacteria and prevent infection for cows. Farmers typically use firewood to heat water, which can be expensive and unsustainably sourced. To transport and store the milk, it is often taken first to the local market and then to collection points. The use of chillers is rare both in transit to local collection points and by distributors further downstream. Refrigeration is even more uncommon on the farm. At every stage where chilling or pasteurization is not present, bacteria proliferates, reducing quality and increasing spoilage. Investing in energy efficient appliances is rare as small-scale farmers have limited access to capital the current structure of the Kenyan dairy market does not incentivize them to do so.

Case Study

Technology Provider: Sistema.Bio

Sistema.bio is a prominent distributor of bio-digestion technology and has financed, sold, and installed over 20,000 systems for smallholder farmers from offices across Kenya, Mexico, Nicaragua, India and Columbia. In Kenya, Sistema.bio provides a modular biodigester with a servicing and financing package and trains smallholder dairy farmers to transform livestock waste into organic fertilizer and renewable biogas for various appliances. The most common appliance is a gas range for clean home cooking.

Sistema.bio’s technology captures the ‘free’ energy generated by dairy farmers through anaerobic digestion of the cow waste from their operation. A smallholder farmer with 3-6 cows can produce 2-3m3 of biogas per day, equivalent to the daily household cooking and heating needs for a family of six. As the farmer’s herd increases, this technology can power more productive appliances to support basic farm activities at a lower operating cost. If the cost can be repaid over time, biogas appliances allow the farmer to maximize the value of their dairy operation by lowering the operating cost of appliances that save time and money or that increase productivity.

The transition to biogas also improves energy security and reliability by displacing energy sources such as firewood, petrol, and diesel that leave farmers vulnerable to interruptions, price shocks and logistical challenges. Volatile inputs and energy costs are a significant barrier for dairy farmers to run efficient and productive dairy operations in Kenya. For this project, Sistema.bio, identified a customer segment in their pipeline that is a level up from their core small dairy farmer customer: larger productive scale farms. Sistema.bio can readily modify their existing offering to power thermal, mechanical, and electrical applications for these productive-scale farms and have demonstrated test cases of using their technology to power milk pasteurization, milk pumping, milk chilling, forage milling (feeds), water pumping and milk processing (cheese and butter). These farms are defined by Sistema.bio as those with over 25 cows, a segment they believe numbers over 250,000 farms, or 12% of all dairy farms in Kenya.

While Sistema.bio's current offering has achieved a tight product-market fit for smallholder dairy farmers, they needed support to expand beyond their core market and serve productive-scale farmers who can invest in larger systems. As they expand to serve larger operations, their model needs to be tested and de-risked and they need to understand which appliances should be prioritized and adapted in the Kenyan context.

Sistema.bio understands that customers require financing to access their solutions. As a result, they needed to test a larger and longer-term credit facility to match the productive-scale systems and appliances. At present, Sistema.bio's customer financing is limited to USD$2,000 per customer and single year terms.

This project focused on (1) examining technology performance, adoption, and maintenance needs (2) farmer repayment behavior, (3) designing a commercial package that delivers an attractive return on investment for the farmer alongside an expanded market for Sistema.bio. The cost of systems and appliances was subsidized to accelerate registration and in recognition of the fact that the running costs, service costs, and the payback could not be confidently predicted or explained to farmers. Without this subsidy, the payback period would have been less compelling, but the project needed to prove what cost savings, productivity improvements and wider benefits might be achieved. Additional income generation is also more difficult to estimate upfront because the appliances themselves will not generate greater volumes without further investment in production and headcount. In addition, the Kenyan dairy market only weakly incentivizes dairy quality.

Sistema.bio originally had 13 farmers in this project with a range of energy needs for whom a productive scale biodigestion system would save costs. The systems would power both existing on-farm activity and enable new activity by providing reliable, low cost energy to help them commercialize their dairy operations and enter new value-add markets for the first time. Following the advent of the global COVID-19 pandemic, several of the farmers dropped out of the pilot in order to limit their risks and avoid taking on debt during uncertain times. As a result, Sistema.bio installed six systems on productive-scale farms. These installations aim to provide meaningful annual savings and attractive (< 3 year) payback periods, including the current subsidy.

Table 5 shows what existing activities could be powered by biogas, displacing existing more costly or unreliable sources of energy. It also shows what new activity was enabled through this project, the subsidized and unsubsidized payback periods for the farmer, and their main rationale for investment. The farmers in this pilot were not motivated to improve quality as they have no price incentive to do so.

Figure 2: Sistema.bio's productive scale system design.

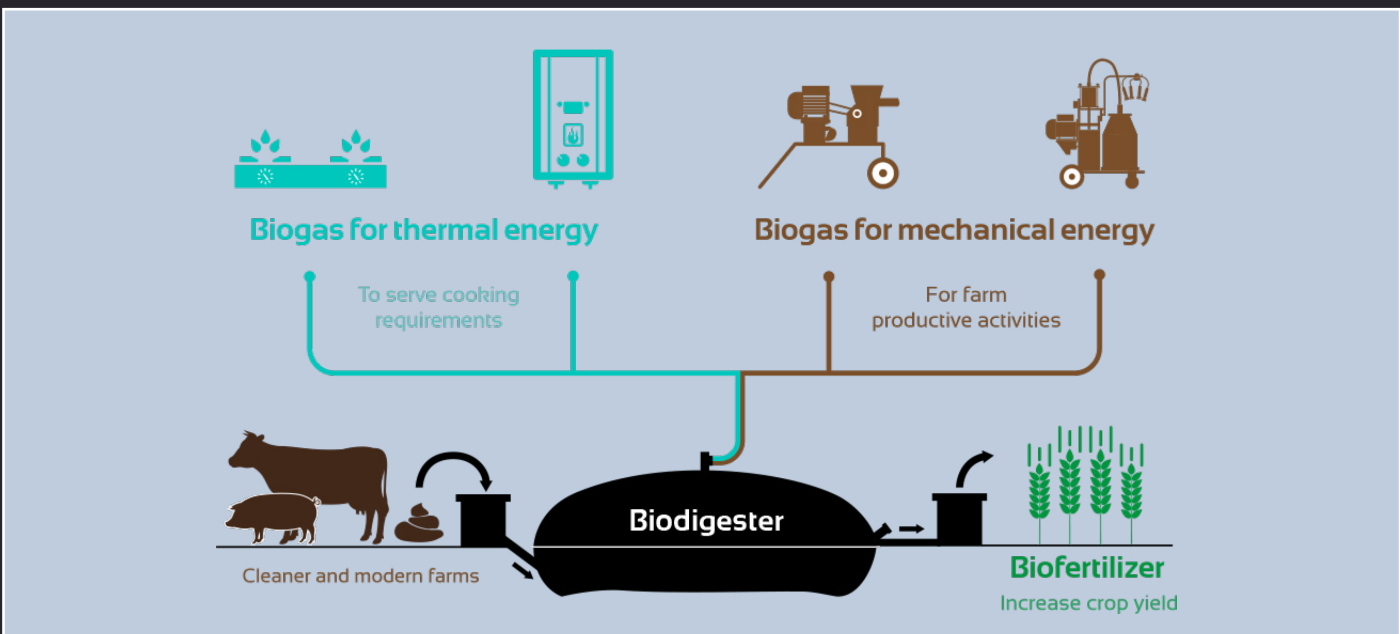


Table 5: The proposed payback is based on unlocking new farm activity and displacing energy costs.

Farm	Existing Activity	Planned Activity	Payback		Savings (Per Year)	Rationale			
			Actual	Subsidized		Cost	Security	Output	Price
1	Milking, Water Pump, Cooking	*None*	3.2	1.0	$3,330	🟢	🟢	🔴	🔴
2	Cooking, Heat Lamps	*Water Heating, Brooder*	3.0	0.9	$4,293	🟢	🟢	🟢	🔴
3	Chaff Cutter, Milking, Cooking	*Water Heating*	5.3	2.9	$1,698	🟢	🔴	🔴	🔴
4	Water pump, Chaff Cutter, Cooking, Milking	*Milking*	1.9	1.4	$3,083	🟢	🔴	🟢	🔴
5	Chaff Cutter, Milking Cooking	*Water Heating, Milking*	3.7	1.7	$2,405	🟢	🔴	🟢	🔴
6	Water pump, Cooking, Milking	*Water Heating, Milking*	4.7	1.8	$2,193	🟢	🟢	🟢	🔴

Results

The pilot was successful in deploying Sistema's larger systems and accompanying biogas appliances to a new customer market. The results show appetite for the technology and the possibility of designing affordable financing solutions for this farmer segment. The pilot also demonstrated that renewable, modularized, and distributed agricultural waste-to-energy systems can power productivity improvements and make small dairy operations more competitive.

As Table 6 shows, the installation of a Sistema 80 biodigester alongside a 5Kva generator and an improved stove for cooking with the biogas meant that Andrew, a dairy farmer who participated in the pilot, could displace 79% of his operating costs and avoid using firewood and diesel altogether. By adopting a milking machine for his 7 cows, he was able to increase the number of milking sessions per day from two to three, which in turn increased production by 13%, while also saving time.

Right sizing the system and loan size for the circumstances and particular needs of the farmer is consequential to the viability of this kind of offering in an unsubsidized context, as is the term of the loan. Based on a 24-month repayment period, Andrew's monthly operating income still only increases by 4% against baseline even after making an upfront payment of 20%. In this pilot, farmers had a 70% equipment subsidy which meant that Andrew's operating income actually increased by 23% and his payback period dropped from 31 months to 13 months.

There were delays at some farms where the biogas digesters took longer than expected to reach production capacity. Larger systems require large volumes of water and cow waste, posing a logistical and management challenge for farmers using them for the first time. This was a useful operational lesson for Sistema as they look to scale up these systems in future.

Biogas powered appliances for small scale rural dairy operations have real potential within the hierarchy of needs of the farmer. The pilot found that appliances that reduce cost, labor and the risk of animal infection such as water pumping, heating, and chaff cutting deliver a more immediate benefit than those that improve quality such as chilling and pasteurization. Only one of the customers took on chilling or pasteurizing and that customer had a direct relationship with a distributor. Although biogas systems can demonstrate a pathway for how productivity enhancing appliances can be adopted, only three of the six pilot farmers did so in this pilot.

Although the pilot showed demand among early adopters and delivered a clear benefit to their farms, this early success is not in itself a meaningful predictor for true customer demand, especially where discounts were applied to farmers. However, at the conclusion of this project, Sistema will be able to price and test demand for a product, financing and service package based on a clear understanding of costs and performance at the end of this project.

Table 6: Early results from a Sistema customer in the pilot are promising.

	Pre-Pilot	Pilot
Milk Sales (USD/month)	**777**	**880**
Milk Sales (L/month)	2,745	3,108
Milk Price (USD/L)	0.28	0.28
Milking Sessions	2	3
Production Change	-	+ 13%
Farmer OPEX (USD/month)	**123**	**25**
Energy Expenses	104	10
Diesel	57	0
Firewood	47	0
Petrol	0	10
Pesticide & Fertilizer Expenses	19	0
Average Monthly Maintenance Fee	-	15
Total Farmer CAPEX (USD)	**0**	**6,194**
Sistema.bio quote		5,156
Biodigester		2,536
Appliances		1,761
Loan Interest (20%)		859
Milking machine purchased by the farmer		1,038
Financing		
20% Upfront Payment (USD)		1,031
Monthly Loan Payment		172
Repayment months		24
Operating Income (USD)	**654**	**683***
Payback Period		**31 months**
Payback with 70% pilot subsidy		13 months

**This includes the monthly loan repayment. After repayment, operating income increases to $855 per month*

Sistema.bio water heaters

Lessons Learned

Modular technology can help farmers reduce operating costs, save time, and increase productivity as they graduate from everyday farm activities to larger scale productive applications. Biogas appliances can deliver a cost and labor saving for basic farm activities and increase incomes through value-add activity. Sistema.bio's modular technology is well suited to the range of needs and sizes of dairy farmers, from simple to more advanced applications. Sistema.bio also has a technical team to provide the support and training required to install and commission systems. While Sistema.bio's technology has global potential, it is a single technology provider and its reach is still limited to select markets in East Africa, India and Latin America. For rural markets where Sistema.bio does not operate, another approach may be required, perhaps through partnerships.

With the right finance model in place, there is a clear immediate benefit for farmers. For farmers operating productive appliances, capturing available biogas can substantially reduce their operating cost. Sistema believe this translates into $500 million a year operational cost saving opportunity to power more sustainable productive scale dairies in Kenya. Conversely, there may not be enough farmers in this category to justify the effort required to target this market. While the farmers in this trial did decide to purchase the equipment, they were pre-selected and incentivized to do so. This project will confirm the product, service and financing package to roll out these products and create a compelling value proposition for each farmer. However, while productive-scale farms represent 60% of production, they are only 12% of farms. Sistema.bio will graduate their customers to more productive appliances, but the business model to expand the use of biogas powered appliances to the smallholder market across Kenya and beyond remains elusive.

Market incentives are needed for early adopters of appliances that improve quality. Dairy farmers also face challenges beyond energy access. In Kenya, the dairy market is mostly informal and has low quality standards. As a result, there is no price incentive for smallholders to invest in quality. Farmers need to be convinced that investment in appliances is worth the risk and effort. For cost-saving appliances, financing can be used to translate upfront costs into running costs to deliver an immediate benefit compared to the higher operating cost of diesel, petrol, or grid powered appliances. In this project, the buying price was subsidized. Without a subsidy, the payback period is substantially longer and requires Sistema.bio (or their local financing partners) to provide longer-term asset finance that is not readily available in the market. New delivery models and partnerships are needed to professionalize the dairy sector and provide a clear incentive for farmers to invest in milk quality, energy efficiency and sustainability. In other markets, large, brand buyers like Nestlé offer farmers a price incentive for their milk based on quality and when they invest in sustainable technology (like Sistema's). Sistema.bio is also working on carbon offset initiatives in Kenya to support incentives for adoption.

Recommendations for Success

1. Involvement from professional dairy distributors with the motivation to improve quality and yield across their supplier network. A more integrated and formal supply chain can provide education, access to finance, and price incentives for smallholder farmers to improve quality.

2. Financing for appliances to fit the farmer's needs with workable repayment periods in line with their cash flows and payback period. Generally, this means longer finance terms than are generally available to producers in these markets today.

3. Technical expertise for the demonstration, installation, and servicing of technology in rural areas where providers like Sistema.bio are not present.

4. Testing of shared ownership models where resources and animals are pooled to achieve economies of scale and improve market access.

Establishing a repeatable approach to stimulating demand for remote minigrids through common appliance electrification

Project Overview

Ag-Energy Challenge:
Estimating demand from and the value of electrifying grain mills for minigrids

Location:
Nigeria

Partners:
Powergen- Energy Provider

Challenge:
Grain mills represent an opportunity to provide demand for electricity that is common to many remote minigrids. However, it is difficult for minigrid developers to determine the potential value of converting them to electricity due to a lack of real data related to how grain mills are used in practice.

Goals:
Test the use of sensors to weigh up and capture demand stimulation opportunities that boost minigrid IRRs.

Introduction

In rural communities, grain mill appliances are typically powered by petrol or diesel. These grain mills represent an opportunity to provide demand for electricity that is common to many remote minigrids. However, it is difficult for minigrid developers to determine the potential value of converting them to electricity due to a lack of real data related to how grain mills are used in practice. Minigrid developers need to know when and for how long a mill runs on a daily, weekly, and seasonal basis to understand the costs and requirements an electric mill will place on the renewable power system.[29] Importantly, electric-powered mills can replace diesel mills without sacrificing performance or quality of milled product.

The minigrid business model is important for rural development. Minigrids are often the most cost-effective way to deliver electricity in remote areas. However, it takes a long time for demand to emerge after electricity is brought to a community for the first time. In addition, low usage by each customer, known as Average Revenues per User (ARPUs), threatens the viability of the community minigrid model. Without the kind of low-cost financing subsidy (and more direct subsidy) that the larger electrical grid receives, the renewable minigrid model will not be able to deliver on its promise to drive rural electrification and, in turn, economic development.

Minigrid developers recognize this challenge and seek ways to stimulate demand in the communities that they serve. While residential customers in rural areas consume little power, recruiting commercial customers can improve system utilization. These commercial customers can often act as an "anchor load" for minigrids. Stringing together multiple productive loads, such as several grain mills operating in a village, can bolster demand, resulting in increased power sales. However, even if a developer decides that a local grain milling opportunity is attractive, there is no guarantee they will succeed in capturing the market. Customers need to be convinced to switch to electrical appliances and trained to use the new equipment. Developers, however, typically lack the sales, marketing, and financing capacity to take on this additional work.

Minigrid developers need to be persuaded that there is sufficient realizable energy demand in grain mills to allocate the resources to capture it, but current methods of estimating this demand are unsatisfactory and inaccurate. Obtaining reliable data is the first step to capture the demand from agricultural and income-generating appliances at minigrid sites. The key to success for these projects is to build and iterate a repeatable methodology for measuring and capturing demand. Currently, field surveys are the dominant methodology, but these surveys consistently over-estimate the run time of the appliances and fail to capture appliance load profiles in detail.

Case Study

Energy Provider: Powergen

Powergen is an African minigrid developer that operates across several countries. In 2018, they made the decision to expand into the Nigerian market by commissioning a 60 kWp pilot site in the village of Rokota with the aim to connect 350 homes and businesses. Powergen has trialed electric mills in villages it serves in Tanzania and understood the importance of serving commercial customers to boost returns and community development.

Powergen carried out a field survey in 2018 that suggested an attractive productive load milling opportunity existed in Rokota. Their survey identified twenty-nine petrol and diesel milling and threshing machines that consumed an average of 5.4 liters of petrol or diesel per day. To capture this opportunity, Powergen proposed a market saturation approach. Through this approach, customers with existing mills would be incentivized to trade in their existing petrol or diesel mill for a subsidized, efficient electric machine through a "cash for clunkers" model. In the process, this demand would significantly improve minigrid return on investment. Based on 2018 survey data, the opportunity looked attractive. If this assessment were taken at face value and pursued, a large upfront investment to upsize the grid, and then procure, distribute and finance milling equipment would be needed. Verifying the accuracy of this demand data from this survey was key for Powergen to justify this investment.

The Sensor-led Approach to Demand Stimulation

Understanding power demand is a common challenge beyond Powergen's project in Rokota. Factor[e] has previously addressed this data and knowledge gap by studying the potential impact of a range of appliances on the minigrid business model. To improve the process of measuring the baseline for demand stimulation opportunities, Factor[e] built a demand sensor tool with Arch Systems to enable remote sensing in environments with weak communication networks.[30] The sensors are straightforward to install and calibrate. The Android mobile application operates effectively in low connectivity environments, which makes it easy for local agents to collect the sensor data. The sensor tool represents a low risk, low cost, and accurate way to evaluate the financial benefit of an electric appliance. This tool enables customers, minigrid developers, or appliance providers to understand the potential energy demand before committing time and resources to capture it.

In this project, Powergen used Factor[e]'s demand sensor tool to improve demand estimation at its site in Rokota. A throughput assessment, which gauges the milling-to-fuel ratio was used to compliment the general sensor baseline and estimate electrical loads. As a result, Powergen was able to use this remote demand sensor tool to better characterize the power demand estimation from the mills.

A petrol mill in Rokota, Nigeria

An agent monitors the app-linked demand sensor

Results

The remote sensor deployment demonstrated that customers were consuming significantly less fuel and running their mills notably less frequently than their survey responses indicated. As shown in Table 7, the 2018 survey reported four times the fuel consumption than the sensors seemingly demonstrated: as much as a 98% difference for some mills. There was also a large difference between reported mills usage in the survey and how the mills were actually being used. Milling activity was far below the levels needed for demand saturation but was also irregular. Millers would suddenly stop milling before starting again at a much higher rate. One customer only operated for two of the ten weeks when sensors were deployed. These differences and complexities highlight the perils for developers in relying on field surveys.

Table 7: Actual runtime was much lower than expected runtime

Mill	Survey (hours/day)	Sensor (hours/day)	Difference
1	3.0	0.1	-98.09%
2	3.2	0.1	-96.64%
3	1.7	1.1	-36.29%
4	2.1	0.5	-74.66%
5	0.5	0.9	82.14%
6	4.0	0.5	-88.16%
7	2.3	0.0	-98.90%
8	3.0	0.1	-95.68%
9	7.7	0.8	-98.90%
10	1.7	0.7	-58.29%

Powergen's outlook for a wholesale demand saturation approach had to change. The sensors showed the load profile of each mill and, when aggregated, showed the potential impact of electrifying milling on the minigrid's economics. Table 8 demonstrates that in reality the aggregated mills would only generate additional revenue of $159.20 each month compared to the $1,832 projected in the original survey. The project was no longer feasible, let alone attractive.

Sensor data allows tariff and electric mill packages to be designed around actual use patterns and operating costs for each miller. Still, this assumes that millers are primarily motivated by cost and not convenience or the behavior and preference of their customer. Figure 3 shows that there are peak operating hours in the evenings between 4pm and 7pm. Even if, in theory, sufficient milling were occurring in aggregate in Rokota to make Powergen's market saturation approach attractive, in practice they would also need to incentivize mill operators to shift their hours of operation to periods of solar curtailment and off-peak hours. It also assumes that Powergen could successfully convince the mill operator to exchange their existing mill in the first place.

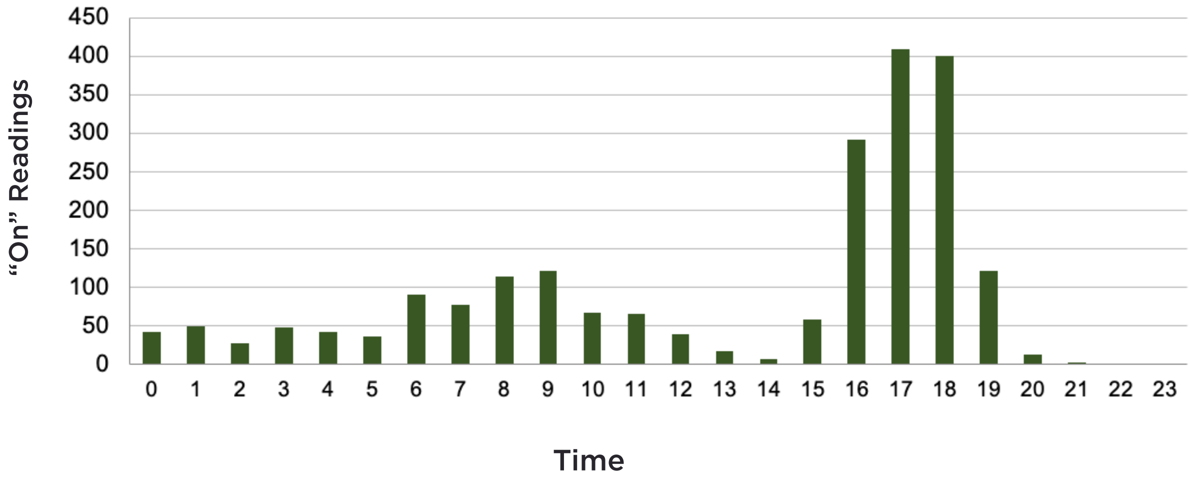
The minigrid at Rokota remains significantly underutilized. For this reason, any additional revenue streams captured by the minigrid will provide an improvement in the Internal Rate of Return (IRR) as Powergen can accommodate additional loads. Powergen will still pursue electrification of milling activities, albeit with a leaner and lower-risk strategy to provide select customers with electric motor retrofits for their existing mills. Powergen also expects to adopt demand sensors as a tool to identify and target attractive loads at other sites to improve the durability and reliability of their approach.

The Powergen project at Rokota illustrates the importance of quality demand stimulation data. This project reveals the difficulty that most developers and operators face in capturing baseline demand information. This challenge is compounded by the fact that developers and operators are organized to build and operate electricity projects. They are primarily focused on power generation, transmission, and service and rarely build teams and allocate resources to prioritize demand stimulation efforts.

Table 8: The evolving IRR opportunity to electrify available mills at the Rokota minigrid site

	Site Survey	Sensor Installation	Sensor Results
Number of Mills	20	11	10
ARPU Opportunity (USD / mill / month)	$91.64	$25.44	$15.92
Revenue Opportunity (USD / month)	$1,832.81	$279.84	$159.20
Revenue change from baseline	53.80%	8.21%	4.67%
IRR change from baseline	3.50%	0.45%	0.25%

Figure 3: The aggregated demand profile of all mills



Freshly planted electricity poles in Rokota village in Niger State, Nigeria

Lessons Learned

A productized approach to capture existing agricultural loads improves planning and the use of resources for constrained minigrid operators In the short term, the demand sensor methodology should be used more widely among minigrid developers to avoid wasted resources and effort in demand stimulation projects. These sensors need to be manufactured in bulk to reduce unit costs to be used more broadly. The installation of sensors and baselining of demand needs to be more robustly tested.

Minigrid operators are not the best placed actors to target and capture agricultural loads at scale. Despite recognizing and broadcasting the importance of demand stimulation, minigrid developers are reluctant to commit resources to that work. To be successful, demand stimulation should be a priority of the project implementer. Instead, testing demand stimulation approaches is often driven by available grant funding rather than conviction that it is central to a developers' business. Positioning developers to drive demand stimulation efforts forward would require changes to the expertise, culture, and internal incentives within rural utilities. Ideally, minigrids should be planned around commercial agricultural opportunities where rural economic growth is more likely. Minigrids can then support and benefit from these agricultural development efforts which themselves will stimulate demand for electricity.

Minigrid Developers are ill-suited to take on detailed, customer-centric appliance marketing and sales work. A partnership with a specialized customer-centric entity would be more likely to succeed in delivering demand at scale. Rather than putting all the onus on the minigrid developer-operators, we suggest that associations like the Africa Minigrid Development Association (AMDA) or more publicly driven demand stimulation efforts (as with the history of the Rural Electrification Agency in the USA, for example[31]) bear the responsibility for sourcing, marketing, and financing such appliances. Operators can then focus on providing support for installation, maintenance, and payment processing.

Recommendations for Success

1. An entity that has the responsibility and motivation to evaluate, procure, market, and finance electric versions of common appliances at minigrid sites. Developers are well placed to service appliances and process payments, but they are not built to deliver other functions needed to stimulate demand. A third party should play this role to support developers.

2. Rather than a single site, a portfolio of project sites should be addressed at the same time. Grouping project sites would justify the added complexity of managing bulk appliance orders and project implementation.

3. Long term financing using demand sensor data should be used as the basis for repayment plans and tariffs so that running costs are less than the incumbent diesel or petrol mill based on actual use.

Key Lessons and Recommendations in Supporting Programs at the Nexus of Agriculture and Energy

To professionalize and grow the agriculture sector in sub-Saharan Africa, smallholder farmers and the agribusinesses that serve them need to have access to novel, but trusted products and services. Providers have grappled with the challenge of tailoring these products and services to the local context, but financial services are also lacking to bring them within reach. As farmers are already risk-saturated and have limited disposable income, any difficulties for them as customers will slow or prevent adoption. Farmers and agribusinesses keenly understand their own challenges but lack the resources and expertise to seek out solutions. At the same time, energy providers want productive agricultural customers, but do not have the resources, expertise, or enthusiasm to understand and reach them. As a result, energy providers are unable to design, source, and finance the solutions that use the power they are selling. To address this dilemma there are key lessons and recommendations that can shift the ag-energy landscape and accelerate change.

Lessons Learned

1. Ag-energy solutions are most successful when agricultural actors lead, and energy and technology solutions follow.

Projects that solved a known challenge for an agribusiness were more successful. Projects that were designed to test a market solution (solar pumps) or solve a challenge that an energy provider had identified (electric mills to stimulate electricity demand) were less successful. Although energy companies want the agricultural demand for energy, they lack the expertise, bandwidth, or commitment that is needed to capture it. The right mix of partners are needed to bring these components together and to see projects succeed.

Recommendation:
Ag-energy opportunities need to be driven by the agricultural imperative; energy is a service, after all. This requires an understanding of the unmet needs of both smallholder farmers and of the agribusinesses growing up around them. Those needs must drive project design and development.

2. Existing local agribusinesses lack the resources and management capacity for complex projects.

Skilled implementation and quality partners who understand agriculture and have the resources to lead projects are a critical success factor. Solutions need to be molded to the needs of customers, designed for the right operational size, and priced within reach. Implementation partners that understand different market segments and offer tiered solutions are more likely to succeed. Financing and training for small- and medium-sized agribusiness will lead to more credible partners and projects. Bandwidth is also an issue. Dedicated partner resources are needed to navigate challenges and indicate the project's strategic importance to the company.

Recommendation:
Growing agribusinesses and smallholder farmers need access to working capital, asset finance, and training to develop capacity. Foundations and governments should recognize the critical role they play as engines of rural growth. By establishing facilities that combine financing with a range of support services, funders can lay the foundation for development for each country or regional market context.

3. The opportunities to create value at the ag-energy nexus are vast, but the pipeline of quality innovative enterprises is limited. Innovative enterprises are required to seize ag-energy opportunities.

Our investment experience has long highlighted that off the shelf technology or solutions without business model innovation do not work in these environments. While there is an element of technology convergence between industrialized and frontier markets, distributed, renewable energies are not inherently well suited for agricultural applications. Solutions need to be robust, modular, and financeable. Modularity can itself be a reliable way to make a technology more financeable by design. When an asset directly creates income for the customer and a financing solution converts upfront costs to running costs for the farmer or agribusiness, innovative technology can deliver an immediate positive impact, lowering the hurdle to adoption. In developing this program, we leaned on category leading technology ventures like S4S Technologies, Sistema.bio, and InspiraFarms that have been put through the paces and are aligned to scale innovative solutions to anchor this program. We need more companies like these operating in the sector.

Recommendation:
Philanthropy must recognize the need and directly invest in building innovative enterprises that specifically serve agribusiness, farmers, and energy service providers across multiple markets (countries or regions depending on size and integration). In exchange for extremely risk tolerant capital around, philanthropy should demand transformative potential to scale from these investments.

4. Most ag-energy projects combine an energy services provider, an agribusiness customer, and a technology solution. A matchmaking and filtering role creates important connections that often would not happen organically.

The landscape for energy technology solutions can be confusing and expensive to navigate, even if they are proven and established elsewhere. Even motivated partners with dedicated resources struggled to deliver projects on time. It is unlikely that Enimiro would have procured S4S technology without support. Exporting their technology to other markets is not S4S' core business and they are not actively marketing for such opportunities. Even if Enimiro had found them, the Indian climate is different from Uganda's and has different product requirements. S4S might have viewed the project as a distraction to their mission and Enimiro might have viewed technology, untested in the Ugandan market, as too big of a risk. Thus, a combination of support and matchmaking made this partnership possible. Agricultural demands need to be matched with the right solutions, and best practice must be shared liberally and deliberately to lower the cost and effort of adopting new approaches. Facilitating these connections will accelerate progress.

Recommendation:
Funders and governments with an interest in powering agricultural development should establish and sustain project development facilities. These need to be staffed with teams that combine expertise in agronomy, energy technology, project development and management. They should work alongside existing agriculture and energy development programs to facilitate connections between technology providers, agribusiness, and energy services. The facilities must also provide support in procurement, low-cost financing, and project management along with funding for project development, market testing, and pilot testing. This holistic support will lower the barriers to innovation and technology adoption.

5. Scale matters. Larger projects are more likely to succeed than small demonstrations because they keep the attention of high-quality partners and lend themselves to mid-range and integrated planning.

Larger agribusinesses and technology providers with the capacity to solve ag-energy challenges can see the potential of the smallholder market but believe the cost of capturing it is high. It is expensive to serve smallholder farmers, and even those like Frigoken. with a direct commercial incentive to see new technology adopted, do not believe it is worth the investment. Agrosuppliers who market to farmers need a clear incentive to invest in the market research and expertise required to serve large but fragmented smallholder demand. Technology providers need to see a path to scale. The bigger the project, the easier it is to draw exciting actors together. If programs are planned at sufficient scale, the commercial rationale and motivation will be clear. High-quality partners will collaborate to seize the opportunity and technology providers will enter new markets.

Recommendation:
The public sector must lead to develop ag-energy opportunities at scale. Planned, regional initiatives with clear incentives or subsidies are needed to realize the potential of cold storage and irrigation. Government must play its role in educating farmers and agribusinesses about modern practices and new technologies.

Conclusion

If agribusiness in sub-Saharan Africa is to become a one trillion-dollar industry in the next ten years, rural development efforts will need to span both energy and agriculture. Projects need to focus on big target opportunities to encourage agribusiness, energy, and technology actors to work together. At the same time, energy access and technology adoption in agriculture must accelerate through motivated agricultural, energy, and technology enterprises. This means building the capacity of those operating in agriculture and assembling the physical and financial infrastructure they need to grow.

Renewably powered technologies can seem an alluring fix to the problems that agriculture faces. However, the many established innovations that have not been widely adopted show that technology alone is not enough. Solar irrigation pumps remain substantially underutilized despite attracting lots of funding. To unlock the value that solar dryers can deliver, drying centers need strong leadership from a motivated dehydrated products trader to operate effectively. Biodigesters can deliver energy from on-farm waste, saving costs and increasing productivity, but without a market signal that values quality, the full potential of these systems to improve smallholder incomes will go unrealized. There are few partners around whom minigrid developers can build a reliable value proposition and they struggle to build the expertise and teams that are needed to stimulate demand in the villages in which they operate. Thus, it is the combination of the right technology tailored to offer value for rural customers, a rural focused business model to capture and grow that value, and an effective operator to deliver the model that are required for success.

Strong partners rooted in agriculture are critical, but agribusinesses are not natural candidates for venture impact investment. Market-specific impact investors and funders should cultivate the local agribusiness sector and support the partners who have the right combination of incentive and capacity to deliver results. With sufficient scale and a clear signal, programs can bring together the three key ingredients including agribusiness, energy services, and technology providers to unlock the ag-energy opportunity and enable Africa's rural economies to thrive.

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