The Opportunity for Productive Agriculture Activities to Strengthen the Commercial Performance of Community Minigrids

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FACTOR[e] VENTURES

With the support of the Shell Foundation and the UK's Department for International Development through their **CASEE program**, Factor[e] Ventures has been building a world leading portfolio of impact ventures at the ag-energy nexus while simultaneously developing key insights to move innovation at this intersection forward. In 2019-20, Factor[e] developed a program of demonstration projects with the Rockefeller Foundation to examine how to accelerate rural development through better access to energy in agriculture. The report from that program can be found **here**.

A concept that we tried to assemble in our portfolio of scalable demonstration projects was to match a cooling-as-a-service business with a minigrid. This would show how post-harvest loss and rural electrification can be tackled in concert. The challenge was to match the technology provider, energy service and off-taker together.

We hoped that:

- InspiraFarms (a Factor[e] investee) would provide the cold storage solution and sector expertise. The capital cost would be less because no standalone solar system would be required.
- A minigrid operator (such as PowerGen) would manage the energy infrastructure, provide reliable and affordable power, and share performance data.
- The "off-taker" (likely a horticultural exporter) would purchase produce from local farmers and trade that produce out of the cold storage and agri-processing facility.

We found it challenging to pull these project components together during our program, but the reasons for this are instructive. Cold storage technology and the minigrid sector are still young in Africa – commercial refrigerated capacity is 1% of Europe's capacity,[1] and there are fewer than 2,000 active minigrids in operation.[2] Agribusinesses need to be persuaded to operate 'off-grid' where trading has been unfeasible and logistics expensive and difficult. They must also put their faith in the nascent minigrid sector to deliver off-grid projects on schedule. As a result, there are not a plethora of matchmaking opportunities; cultivating them requires long term planning.

To gauge the value of this opportunity in theory and increase the likelihood that others will succeed in future, we carried out a modeling exercise to quantify the benefit of cold storage for minigrid operators based on how a cooling business actually operates. A lack of real-life data in the productive use and minigrid sectors makes it hard to evaluate demand stimulation opportunities in practice. In our experience operators are often optimistic on the demand they can capture, and underestimate the costs and expertise needed to do so. We also modeled the horticultural drying opportunity and the potential for biogas to displace diesel to power the minigrid's back-up generator.

Our analysis shows that the cold storage opportunity should be pursued as part of a broad program that incentivizes partners to work together over a longer time horizon. We are less convinced that distributed drying and biogas production offer a similar strategic opportunity to boost the remote community minigrid business model. For both there are important trade-offs to consider, but these should not put off operators from pursuing them opportunistically.

Case Study 1:

Co-locating Cold-Storage with a Community Minigrid

Figure 1: *An off-grid cold-storage system designed by InspiraFarms, installed in Rwanda*

Post-harvest loss is one of the biggest obstacles to rural development and distributed cooling technology is one of the most obvious solutions. At the same time, a recent benchmarking study of African minigrids reported that the median household consumed only 3.5 kWh per month, which translates to only a few dollars of revenue for the rural utility.[3] If the need for cooling can be matched to existing or planned community minigrids that need to boost demand, there could be a mutually reinforcing commercial opportunity with broader benefits for rural development.

Minigrid designers try to minimize capital expenditure and balance the role that a diesel generator must play to provide readily dispatchable power to customers when demand is high. This trade-off means that minigrids still have excess production in times of low demand, resulting in solar energy curtailment (see right).

Solar curtailment implies reducing production of a renewable energy source because the power system cannot absorb more electricity at that time. For solar minigrids, more than 20% of power generation capacity can be wasted when battery banks are full, demand is already being met, and the sun is still shining.

Thermal storage describes a system for storing cooling potential (e.g., in the form of ice), so that the availability of energy can be de-coupled from the provision of temperature control to the unit. This operates similarly to how chemical energy storage (i.e., batteries) allow a system to power energy demands even if electricity is not being generated in that instant.

Solar power can be used to store cooling capacity if it is used to build ice (charge the thermal storage system) when the sun is shining. The system can mobilize temperature control when required, such as to remove field heat from a large volume of produce introduced into a cold storage unit after harvest.

Cold storage can be an important commercial customer for minigrids, particularly when the cold storage technology comes from an innovative provider like InspiraFarms. Their solution uses thermal storage to decouple the availability of electricity (when the sun is shining, or unreliable grid power is flowing) from the need for power (when produce needs to be quickly cooled).

Excess energy that is otherwise wasted by the minigrid during periods of solar curtailment can instead charge the ice battery in the Inspira cold storage unit. The cooling capacity stored in this battery can provide up to 48 hours of backup temperature control. The minigrid developer can therefore increase their overall electricity sales without increasing their costs for battery storage (CapEx) and diesel fuel (OpEx) by incentivizing the cooling business to shift demand by offering lower tariffs when solar production peaks.

The Modeling Exercise

We chose Butajira, Ethiopia to characterize the performance and cost for a standard solar battery, diesel-powered, community minigrid because we knew that an Inspira cold storage customer is already operating there. To model the cold storage demand, we would have liked to build a composite demand profile from Inspira's existing units but they do not yet collect consumption and energy storage capacity data that would allow us to do so. Instead, they provided stylized demand profiles for their 30m^2, 60m^2, 90m^2 and 120m^2 capacity units. These assume that cooling requirements are proportional by crop mass and unit size. We analyzed the financial impact of these units on the theoretical minigrid at Butajira by using multiple scenarios run in HOMER, a technical and economic modeling software to optimize minigrid design.

Time-of-use Tariffs and the Cost of Energy

Household tariffs will deter an off-taker from operating a cold storage unit at a minigrid site. Unless pricing is meaningfully cheaper they will prefer to operate standalone solar or on-grid systems since these solutions are at least perceived to be more predictable and easier to manage. A different tariff is also needed during peak electricity production to incentivize the cold storage operator to shift demand. Table 1 shows how a much lower time-of-use tariff of $0.25 was applied to deliver an overall operating cost that is attractive for the offtaker while incentivizing the offtaker to shift demand to peak production times.

Table 2 shows how demand is shifted by the cold storage operator to optimize time-of-use energy costs. French green beans have a higher cooling requirement because they have a greater mass and are stored overnight. In contrast blueberries are stored for only a few hours and then shipped. The system will be designed around the main crop, in this case green beans. Other crops, like blueberries, fill in the gaps to maximize utilization of the cold room as far as possible. As demand loads are seasonal and based on crop cycles, efficient design to match the minigrid and cooling opportunity is important to minimize the periods when either minigrid or cold storage capacity is idle and unproductive.

Table 1: *Time-of-use tariff for Tier 4 (Cold Storage) demand to align to solar curtailment*

Hour	Tier 1 Cost: *(<12 Wh/d)*	Tier 2 Cost: *(<200 Wh/d)*	Tier 3 Cost: *(<1 kWh/d)*	Tier 4 (Cold Storage) *(<3.4 kWh/d)*
0900	$0.58	$0.58	$0.58	$0.58
1000	$0.58	$0.58	$0.58	$0.25
1100	$0.58	$0.58	$0.58	$0.25
1200	$0.58	$0.58	$0.58	$0.25
1300	$0.60	$0.60	$0.60	$0.25
1400	$0.60	$0.60	$0.60	$0.25
1500	$0.60	$0.60	$0.60	$0.25
1600-0900	$0.60	$0.60	$0.60	$0.58

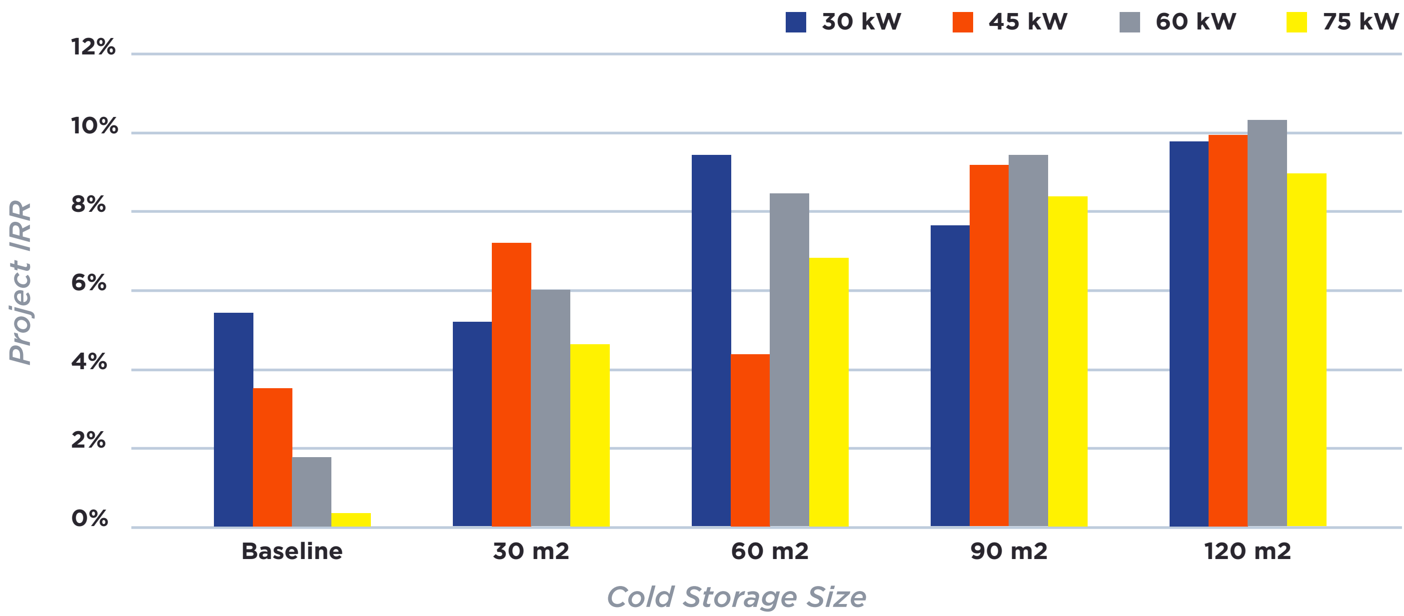
Table 2: *Demand load shifting by cold storage operator to optimize time-of-use tariff cost*

Crop	Tariff	Blueberries	Beans	Blueberries	Not Used	Beans
Hour / Load (kWh)	*Daily*	*January*	*Feb-Jun*	*July*	*August*	*Sept-Dec*
6:00 am	$0.58	0.00	2.67	0.00	0.00	2.67
7:00 am	$0.58	0.00	2.87	0.00	0.00	2.87
8:00 am	$0.58	0.00	4.10	0.00	0.00	4.10
9:00 am	$0.58	0.00	4.10	0.00	0.00	4.10
10:00 am	$0.25	1.25	4.10	1.23	0.00	4.10
11:00 am	$0.25	4.10	4.10	4.10	0.00	4.10
12:00 pm	$0.25	4.10	4.10	4.10	0.00	4.10
1:00 pm	$0.25	1.23	4.10	1.23	0.00	4.10
2:00 pm	$0.25	4.10	4.10	4.10	0.00	4.10
3:00 pm	$0.25	4.10	4.10	4.10	0.00	4.10
4:00 pm	$0.58	1.23	4.10	1.23	0.00	4.10
5:00 pm	$0.58	4.10	4.10	4.10	0.00	4.10
6:00 pm	$0.58	4.10	4.10	4.10	0.00	4.10
7:00 pm	$0.58	1.23	4.10	1.23	0.00	4.10
8:00 pm	$0.58	0.00	2.87	0.00	0.00	2.87
Total (24 Hrs)	-	**29.52**	**68.48**	**29.52**	**0.00**	**68.48**

The time-of-use tariff we applied of $0.25/kWh should deliver an IRR uplift of between 5-8% at an average cost $0.45/kWh. If the average cost drops to $0.38/kWh the IRR uplift is only 4-5% across all units and grid sizes. Still, this is not a trivial shift given that low single digit IRRs are common for minigrid projects in Africa.

The first time we ran this model without time-of-use tariffs applied, i.e. a tariff of $0.58/kWh, IRRs leapt to around 20% for the largest units, illustrating the importance of agreeing a viable tariff and pricing model that works for all parties upfront. We heard from cold storage operators that, for tariffs above $0.35, they would begin considering standalone energy systems. This is a threshold price that minigrid operators might baulk at for existing grids, but is possible if carefully planned for during design to still reliably add 3-4% to project IRRs.

Figure 2: *The impact of cold storage unit size on minigrid IRRs*



The relationship between cold storage and minigrid size underlines this point. The IRR impact is not linear by unit size and our HOMER scenarios are not a perfect fit. The $60m^2$ unit had a smaller impact on the 45kW grid than the 30kW grid as capital investment was required to serve it. The goal in bringing a minigrid developer, cold storage technology provider and agricultural trader together is to achieve the tightest fit possible between farm production, demand for traded goods, cold storage capacity, and minigrid system capacity. This kind of analysis is somewhat complex but achievable with certain tolerances for uncertain outcomes.

Minigrids that are not designed around the cold storage opportunity are less likely to succeed, but there should be plenty of opportunities to do so. Our aim is not to declare what the opportunity is, but to illustrate how, with thoughtful analysis, this opportunity can be realized. It also explains why the chances that the commercial and physical components come together readily in a way that is attractive for all parties is slimmer than we originally thought for existing community minigrids.

But, with fewer than 2,000 minigrids active today, 4,000 being planned, and the World Bank predicting that 140,000 will eventually be needed on the continent,[4] there is a clear argument for siting and designing systems around known agricultural demand. A nascent but growing cooling sector, and agribusinesses that are not yet used to operating more remotely will become more assertive and confident, particularly once the concept has been demonstrated.

Agricultural and energy sector stakeholders should help by cheering on the pricing, planning, and logistics effort required. Minigrid developers are not best placed to assemble these multi-party opportunities themselves. For developers to whom this opportunity appears attractive, they will need to invest in understanding agricultural value chain and market dynamics, building relationships with producers in the local community, and forming partnerships with agribusinesses and traders

This is a tall order to leave on the developer's tab. The minigrid developer's role should be to develop sites where there is high potential for agricultural trading and then supply power that is cheap enough to convince the agribusiness to operate on its site rather than on grid or at a standalone site.

The matchmaking and project development role is a clear one for philanthropy, which can fund facilities to support pulling such projects together, and the public sector, which can engage in large-scale and integrated regional planning that ensures that public investments in rural electrification and agricultural value chain development are co-located and sequenced thoughtfully.

Case Study 2:

The Distributed Drying Opportunity for Minigrids

Figure 3: *A new solar conduction dryer in action near Aurangabad, Maharashtra India.*

The growing appetite for organic and healthier snacks means that the global dried fruit snack market was worth almost $7bn in 2019.[5] Countries like Uganda that are suitable for growing pineapple and banana are at a disadvantage in exporting fresh fruit because they are landlocked – the costs of export are higher. However, strong demand for dried fruit is outstripping supply because of limited processing capacity.

Through our ag-energy program, supported by the Rockefeller Foundation, we found that community drying centers in Uganda had limited capacity because they used simple solar drying technology and had operations that are sub-scale and inefficient. As a result, exporters are moving toward centralized industrial gas and electric driers to control quality and provide consistent supply. If that shift takes root, it will represent a missed opportunity to retain processing value in the community.

Our project found that fan-based dryers (FBD) and solar conduction dryers (SCD) with electric backup drying transform the viability of the community drying center model. Given that these fruit growing communities are typical of many community minigrid sites, we wanted to understand if the electricity they need to optimize the distributed drying process represents an attractive demand stimulation opportunity for minigrids.

The IRR opportunity for minigrid operators

Using the theoretical minigrid at Butajira, Ethiopia, we modeled the impact of the drying technology based on the drying approach at the community drying centers we worked with in Uganda. The superior drying system we modeled and that was used at a pilot center in Uganda has been developed by S4S Technologies out of India, a Factor[e] investee.

For modeling this opportunity, we assumed: (1) The standard tariff is $0.58, with a time-of-use tariff of $0.25 between 10am and 4pm; (2) The FBD (0.4 kW) is used for 11 hours per day overnight; and (3) The electrical back up for the SCD (3 kW) is used between 0 and 3 hours per day by season (average 1.4 hours per day) between 8am and 6pm.

Modeling Results

Based on the drying approach used in Uganda, and a time-of-use tariff during periods of solar curtailment, our modeling showed that there is a moderately positive, but meaningful impact on minigrid IRRs of around 1-3%. For larger grid sizes, a higher number of dryers can deliver a greater impact. Operating three dryers provides the capacity to process a supply of around 350kg of fresh fruit per day.

The impact of this form of demand stimulation would differ as variables change, especially if the time-of-use pricing model were different.

In general, the complexity of pulling a project like this together would require a more compelling case to target distributed drying at scale. Where the component parts are readily available – local production, existing drying activity, and access to market – then it should be considered. Even then, if demand is limited and the impact is small, it might be cheaper and easier for operators to run dryers on standalone power systems rather than matching them to a minigrid.

It's also important to consider that drying demand is climate-driven and seasonal. The FBD is used all year round to speed up the drying process. The electrical back up for the SCD has a higher demand (3kWh) but is only needed when it is not sunny. Of course, this time of year is also when solar curtailment will be lower: there will be less sunshine available for both solar drying and electricity generation. Across a year, we estimated the SCD would be used on average for 1.4 hours per day. However, below one hour a day, the IRR impact of this produce drying system will be marginal. Given that crop cycles mean that drying centers will not operate year-round, such moderate returns suggest that this is not a universal, can't-miss opportunity for minigrids.

If pursued, the effort to set up operations and establish reliable market access should not be underestimated, even where the opportunity seems straightforward. The minigrid developer should look to partner with an existing drying center that has close ties with an exporter. In this regard, the opportunity is different (and less straightforward) than electrifying common appliances, such as electrifying grain mills, in that milling is ubiquitous, the product is consumed locally, and there is reliable demand year-round. Substituting the existing diesel or petrol mill is a simpler proposition (if the price is right) so long as reliability and quality is not compromised.

Table 3: *Impact of drying appliances on minigrid IRRs*

Solar Array	30 kW	45 kW	60 kW	75 kW
Baseline IRR	**5.29%**	**3.54%**	**1.79%**	**0.37%**
1 FBD + 1 SCD	*5.70%*	*4.32%*	*2.56%*	*1.12%*
3 FBD + 3 SCD	*5.70%*	*5.31%*	*3.65%*	*2.23%*
5 FBD + 5 SCD	*5.02%*	*5.28%*	*4.18%*	*2.95%*
10 FBD + 10 SCD	*-7.41%*	*0.56%*	*3.44%*	*-0.63%*

FBD consumption = 0.4 kWh
SCD electrical back up consumption = 3 kWh

Case Study 3:

The Biogas Opportunity for Minigrids

Figure 4: *A Sistema.bio technician carries out customer training*

There are still few successful examples of large-scale biodigesters in operation in Africa, but despite uneven progress so far, anaerobic digestion (AD) has exciting potential to solve agriculture and energy challenges for rural communities. Community-scale anaerobic digestion could result in biogas displacing diesel as an alternative, readily dispatchable energy source for community minigrids.

To quantify the benefit for minigrid operators, we took data from Sistema.bio, a leading producer and distributor of anerobic biodigestion technology and Factor[e] investee, to model the impact of expected biogas production from their systems on the operating costs for our example community minigrid at Butajira. Available biogas should directly reduce the amount of diesel required to power the back-up generator. At sufficient (and reliable) volumes, it can also reduce capital investment in battery storage.

We found the impact on the project's IRR is moderate, but meaningful between 0.8% and 2.65%. As a reference point for system size, 6-12m^3 of biogas production per day requires waste to be fed into the system that is equivalent to the waste from 10 to 20 cows or 60 to 120 pigs.

Table 4: *Impact of drying appliances on minigrid IRRs*

Change v. Diesel	30 kW Solar	45 kW Solar	60 kW Solar	75 kW Solar
Baseline IRR	***5.29%***	***3.54%***	***1.79%***	***0.37%***
6m3 per day	*+1.38%*	*+1.13%*	*+0.95%*	*+0.85%*
9m3 per day	*+2.02%*	*+1.65%*	*+1.40%*	*+1.25%*
12m3 per day	*+2.65%*	*+2.17%*	*+1.85%*	*+1.65%*

Three factors counsel some caution when approaching this opportunity.

1. Feedstock:
Commercial digesters fial due to an unreliable supply and quality of animal, horticultural, or organic feedstock that is needed to produce consistent biogas production volumes. The 10-20 cows required in this scenario produce 180 to 300 liters of waste per day that must be reliably fed into the system.

2. Logistics:
Transporting diesel present challenges, but it is relatively straightforward to store and use on site where oversight and local management capacity is limited. The biodigester requires daily management, production, and waste storage. Alternative thermal uses of available biogas for cooking, heating, or cooling might be a better fit.

3. Cost:
Diesel is easy to access and relatively cheap and is likely to remain so for the foreseeable future. The benefit of replacing it with biomass will need to be obvious and reliable to convince operators to switch unless gas powered systems are already in use and there is a plentiful supply of waste.

If we take these complexities into account, and factor in the limited track record of large scale biodigestion on the continent, there is not a strong, immediate incentive for minigrid operators to consider biogas as a building block for their remote power systems. There is certainly the potential for biogas to be captured and used opportunistically if there is a reliable supply of waste and local management capacity, for example by a large agricultural producer or dairy farm.

Conclusion

Across these examples, we see real, meaningful, and positive impacts on minigrid project IRRs theoretically achievable through integrating productive local agricultural activities. Thermal storage powered cooling currently provides the greatest potential gains but has been elusive so far across Africa's minigrid industry. In all cases, the potential gains must be balanced against the added project development and operational complexity, which adds risk and cost. As these offerings and industries mature, however, we see real prospects for improved commercial and community impact performance.

This work shows that the cold storage opportunity is worth pursuing if the right actors have a clear commercial incentive to work together. The distributed drying and biogas opportunities are less clear cut, but this should not discourage minigrid developers where local circumstances make these options compelling.

Our 5 key lessons:

1. The opportunity is exciting, but not straightforward. Minigrids must be planned where high value agricultural production supports the cold storage model. The physical and commercial components of successful projects need to come together through design.

2. Project success means overcoming substantial operational and technical complexity. Opportunities must be convincing to justify precious time and capital.

3. Potential partners can avoid wasting time by agreeing viable tariff structures upfront. To the cold storage or drying center operator, energy is ultimately just a service. If the minigrid cannot offer it cheaply, easily or reliably enough, they will seek it elsewhere.

4. There is still a lack of data and real-world experience to show how productive agricultural activity can improve minigrid performance. We need more robust road testing of these types of opportunities.

5. Nascent technologies and sectors need cheerleaders to encourage collaboration and to enter new markets. Philanthropy should help pull projects together, and the public sector should create the commercial incentives for partners to come together at scale.

FACTOR[e] VENTURES

About Factor[e] Ventures

Factor[e] Ventures is a venture impact development firm. We specialize in seed stage equity investments in impact ventures powered by technology innovation in access to energy, agriculture, sustainable mobility, and waste and sanitation.

As a result, we encounter exciting, pathbreaking technology ventures that can help us build a more equitable, sustainable, and prosperous world. Our portfolio companies have been put through their paces to secure our investment. We believe that they are some of the world's most exciting impact ventures and category leaders in their areas.

As such, we focused on how we could deploy their offerings on minigrids as part of this analysis. Inspira Farms, S4S Technologies, Sistema.bio, and HOMER are all part of the Factor[e] Ventures portfolio. (We have exited our investment in HOMER).

S4S technologies
science for society

S4S Technologies develops and uses food processing technology to create a sustainable supply of processed food products. In doing so they create valuable markets for smallholder farmers and produce branded and white-labelled healthy snacks and meals for the growing Indian consumer market. Smallholder farmers 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.

InspiraFarms

InspiraFarms offers certification-ready, small-scale cold storage and packhouses, accompanied by asset financing and technical services, to address the challenge of post-harvest loss and market access for growing agribusinesses and their smallholder suppliers to make these businesses and smallholder value chains more competitive and sustainable. They currently have over 8,000sqm of cold storage and processing space in the field or in production with units operating in Kenya, Rwanda, Ethiopia, South Africa, Guatemala, Mexico, Colombia, Mozambique and India.

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Sistema.bio is a prominent distributor of biodigestion technology and has financed, sold, and installed over 7,000 systems for smallholder farmers across Kenya, Mexico, Nicaragua, India and Columbia. In Kenya, Sistema.bio provides a modular biodigester with a financing and training package for smallholder dairy farmers to transform organic waste into renewable biogas for various appliances and into organic fertilizer. Their solution delivers net monthly savings in costs, while increasing their customer's energy capacity.

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