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Solar is cheaper than ever. Why hasn't it powered an agricultural revolution?

Lessons from cooperative energy clusters in Senegal

In the last decade, a combination of innovation, incentives, and policies has completely transformed the solar photovoltaic (PV) market – making the technology dramatically cheaper and driving expansive deployment around the world. So why hasn't the remarkable evolution in solar PV revolutionized agriculture and agri-business in low-income economies, many of which have some of the best solar resources in the world? Why do most farmers in low-income countries continue to use manual mechanization or fuel-based power to run their operations? Why is it that flour mills are more likely to be diesel operated? And why is it that even when countries subsidize solar systems for individual farms, uptake and utilization rates have been limited? The answer may be all about scale.

It's rarely economical to provide solar power to smallholder farms one-by-one

In many emerging economies, smallholder farmers work in remote, rural areas where extending the national electricity grid is not cost-efficient. But they need power for activities like irrigation, and the broader community needs power for flour milling and for cold storage. Solar home systems – the laptop-sized solar panels that provide lighting and power consumer electronics – have taken off in these markets, and power many rural households. But most farmers face a problem of scale: their energy needs are typically too large for a solar home system, but too small (and/or irregular) to fully utilize a larger solar solution. Solar is rarely an efficient (or affordable) way to power an individual smallholder farm. There are three main reasons for this:

- **Solar is capital intensive.** Solar PV requires significant upfront investment, especially at the larger scales necessary to power agricultural activity.
- **Much of the power goes unused.** Because a farmer's energy needs are often seasonal or occasional, much of the power from a larger-sized solar system goes unused – making the system even less affordable.
- **Batteries are too expensive.** Ensuring continuous power from solar systems requires the use of batteries. But battery storage remains prohibitively expensive for smallholder farmers or for agro-processing loads such as rural flour mills – especially when compared to the cost of diesel.

As a result, price points that work for solar home systems are simply unaffordable at the scales farmers would need to power larger, income-generating activities.

Cooperative farmer clusters make solar more affordable

To get around these financial and scale barriers, a group of farmers can collectively finance and share the power from a common installation. In Senegal, our team worked with a group of smallholder millet and maize farmers interested in partly switching to onion farming. Replacing millet with two higher-value onion harvests a year could increase their incomes by 10x, but would require reliable power for irrigation. If each farmer attempted to secure energy on their own, options would be limited. An individual diesel- or petrol-powered pump costs $0.60/kWh and would expose farmers to ongoing maintenance issues and imperfect fuel supply chains. Manual power (i.e., lifting and dispersal with buckets) seems free, but actually turns out to be even more expensive than fuel once you account for the implicit and explicit labor costs. Using individually owned solar systems would be financially prohibitive, requiring a much higher upfront investment than a small petrol-powered pump.

We worked with a small farmer group to develop a scheme to collectively finance and then share the electricity produced by a single solar asset. By aggregating the energy loads of multiple farmers, this model ensured a high utilization rate – and then allocated costs to each farmer based on their individual electricity use. It avoided the need for batteries by using a variable frequency drive (VFD) that allows a pump's motor to operate partially even as the solar resource declines – ultimately reducing the costs to $0.20/kWh. The systems achieved near full utilization of the solar power produced within 6 months of commissioning.

What we learned:

This approach could help farmers in other regions secure reliable, affordable electricity at scales capable of powering commercial agriculture. But several factors are key:

- **Identify load clusters.** This model depends on aggregating energy demand from multiple users, which requires a better understanding of where they are located and what their energy needs are. With interest from the Ethiopian government, we helped identify smallholder farmer clusters in need of energy for irrigation. Making this type of data available on an open-access portal could help governments and/or the private sector quickly and cost-effectively identify potentially viable load clusters.
- **Provide supporting grants and loans.** Local financial institutions and concessional lending were key to this project's success. Initial pilots received significant subsidies. But today, the Senegalese farmer groups borrow from rural banks at concessional rates facilitated by the government.
- **Start small.** The modular nature of solar technology makes it easy (and more cost-effective) to start small and expand the system as demand grows – rather than trying to model latent demand that may never materialize. As more farmer groups expressed interest, we deployed more systems, which reduced both the need for costly pre-assessments and the risk of oversizing the systems.
- **Lower distribution wiring cost.** We lowered distribution costs by using devices that ensured locally installed three-phase AC power lines could reach as far as 300 meters from where the solar system was installed, and by using insulated waterproof buried

cables installed with local labor (which can cost a fraction of pole-mounted utility-grade distribution wire).

- **Direct use of solar for daytime loads.** Battery lifetimes and storage costs remain a significant challenge for off-grid energy systems. While battery storage is essential for off-grid residential systems, agricultural loads offer the possibility of avoiding batteries by shifting energy usage to times when the solar resource is best and cheapest.
- **Build on existing social networks.** We worked with farmer groups who were already cooperating on marketing, transporting products, and sourcing seeds and other agricultural inputs – and could confirm their energy needs and challenges. Tapping into existing networks ensures higher creditworthiness and improves collaboration.
- **Upgrade regulations.** To enable the long-term success and sustainability of this approach, governments should update codes and regulations to enable interconnection with the main grid, addressing a common disincentive for investment in distributed solar.