POLICY BRIEF: EMERGING ISSUES

The Sustainable Agriculture Transition:

How to make the most of transformative technology[1]

Sophia Murphy and Mali Eber Rose

March 2021

Three technologies could make a significant contribution to the transformation needed in agriculture and food systems: off-grid renewable energy systems, batteries, and information and communications technology (ICT). The main focus of this policy brief is the application of these technologies for solar-powered irrigation.

Recommendations for governments, technology firms, producers' organizations, and financial institutions to support transformative change in agriculture:

1. Talk to farmers and their enterprises about the technologies and their potential, and understand what technologies are already in use, potential improvements, and how to enhance accessibility through better costs and design.
2. Provide education, training, and extension services for these technologies to farmers in collaboration with public and private stakeholders.
3. Monitor how new technologies are contributing to environmental, social, and economic sustainability goals, as well as related risks.
4. Measure and monitor changes in employment patterns and ensure adequate social safety nets are provided where mechanization and automation reduce or redistribute labour.
5. Increase investment in research and development and target consumer subsidies for worthwhile products with high start-up costs.
6. Introduce regulations on financial institutions for responsible lending to protect small-scale borrowers and establish financial literacy programs to reduce the risk of them becoming over-indebted.
7. Support ICT development and adoption through improved telecommunications and Internet infrastructure.
8. Strengthen institutions that test and license products.

[1] This paper is part of the *Food & Agriculture: Emerging Issues* series, which explores emerging policy trends in agriculture, trade and investment.

Introduction[2]

Photo: Paul Kagame (CC BY-NC-ND 2.0)

Worldwide, food and agriculture systems face three complex challenges. First, demand for nutritious food continues to rise globally. More than 3 billion people lack affordable healthy diets (Food and Agriculture Organization of the United Nations et al., 2020). Second, food and agricultural systems are stressing or exceeding the planet's tolerance for freshwater use, soil depletion, chemical inputs, and greenhouse gas emissions. At the same time, food and agriculture are among the sectors most affected by the changing weather patterns and growing conditions that result from climate change. Third, farmers and farm workers around the world face economic precarity and vulnerability, especially in low- and middle-income countries. Hundreds of millions of the people who grow the world's food live in poverty and chronic hunger (Cheong et al., 2013).

The scale of these challenges is daunting. It calls for transformative change. This policy brief provides a concise overview of the key findings from a recent IISD report (Bizikova et al., 2020), which studied three technologies that could make a significant contribution to the transformation needed. The three technological innovations are: i) off-grid renewable energy systems, made affordable with a significant drop in the cost of solar photovoltaics (PV); ii) the rapid and dramatic improvements in battery technology that have exponentially increased batteries' usefulness as an energy source; and, iii) the evolution of information and communications technology (ICT) resulting from the expansion of "big data." The full report highlights three agricultural applications of these technologies to illustrate their potential: solar-powered irrigation, precision agriculture, and indoor agriculture (soil-free and vertical farming).

The main focus in this policy brief is solar-powered irrigation, which utilizes two of the transformative technologies (solar PV and batteries), to highlight the risks and opportunities associated with these technologies. It concludes with broad policy recommendations regarding the implementation and possible consequences of transformative technologies.

2 This brief is based on a report published by the International Institute for Sustainable Development (IISD): Bizikova, L., Brewin, S., Bridle, R., Laan, T., Murphy, S., Sanchez, L., & Smaller, C. (2020). *The sustainable agriculture transition: Technology options for low- and middle-income countries.* IISD. https://www.iisd.org/sites/default/files/2020-08/sustainable-agriculture-transition-technology.pdf

What Makes Technology "Transformative"?

Before exploring the potentially transformative nature of solar PV and batteries when applied as solar-powered irrigation, it is essential to first unpack the term "transformative" as we use it in this brief.

> It is not just that the technologies are new and effective; they also address structural challenges that have defied rural development efforts since industrialization began.

Technologies are transformative for agriculture when they either displace an established technology and can effect change throughout the whole sector or when they create a new industry altogether. It is not just that the technologies are new and effective; they also address structural challenges that have defied rural development efforts since industrialization began. Each has the potential to significantly strengthen the resilience and sustainability of food systems and agriculture.

These technologies have already established their potential to increase productivity at a reduced environmental cost in richer countries. Applications include providing reliable power for high-efficiency irrigation systems, dramatic reductions in fertilizer runoff through the use of precision tools, and the introduction of mechanized equipment that does not require oil or gas. All of these applications bring significant productivity gains for agriculture: they support higher yields, reduced inputs, and lower costs. For example, ICT can be used in precision agriculture to monitor and anticipate climate-related and environmental changes, as well as to better track water and nutrient input needs for crops. By using data-driven assessments, ICT can precisely control the targeted application of water, fertilizers and pesticides, reducing costs and improving the sustainability of the food system.

Ensuring Transformative Technology Is Accessible

None of the technologies that were reviewed is new, but the sharp decline in what it costs to use them is opening new markets and applications. The technologies are already widely diffused in high-income countries; slowly, they are being introduced in developing countries as well.

> Solar-powered irrigation is already improving small-scale producer productivity and incomes.

Solar PV and batteries are also delivering power for mechanization, transportation, and storage. Small-scale producers are using apps, text messages, and radios to access information and advice on a range of subjects, including weather conditions, production practices, and input and sale prices. Innovative new uses of the technologies are emerging all the time, including apps that manage the

shared use of farm machinery and transport and provide access to virtual marketplaces and financial services. The challenge now is to make these technologies accessible and useful to more farmers, especially in low- and middle-income countries.

The flow of information is two-way. Governments, companies, and development organizations all have better information than ever before about the communities and clients they serve. There is a huge opportunity for them to develop better policies, products, and interventions for a wider range of rural actors. If the deployment of renewable energy and ICT in low- and middle-income countries is accompanied by sustainable improvements in small-scale producer and worker productivity and income, then the technologies will contribute to the achievement of a range of development goals, including many of the United Nations' (UN) Sustainable Development Goals for 2030. The opportunity is too important to let it pass.

Risks and Opportunities of Transformative Technology: The example of solar-powered irrigation

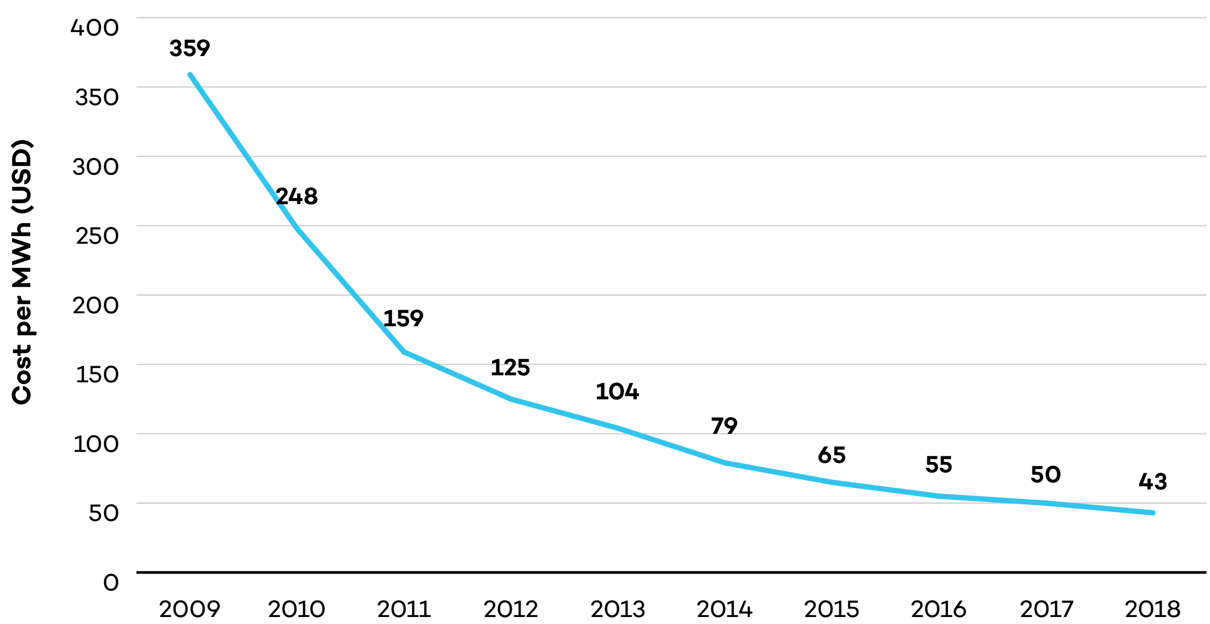
Solar-powered irrigation is becoming increasingly cost-effective in low- and middle-income countries thanks to the rapid cost reduction and performance improvement in two transformative technologies: solar PV technology, which generates the power, and better batteries, which provide a way to store the power. Solar PV technology enables electricity to be produced directly from sunlight on a very small scale, allowing for decentralized, off-grid electrification. The panels require almost no maintenance (other than cleaning) and can last more than 30 years. Solar PV has been used for several decades in low- and middle-income countries to power irrigation systems, pump drinking water for animals, electrify fencing, and control pests, as well as for drying units, cold storage, egg incubation, and aeration for aquaculture.

> Despite its many uses, however, uptake of solar PV has been limited. The main barrier in poor rural areas has been its cost.

That barrier is now reduced. A dramatic fall in prices has made the technology cost-effective in an increasing range of applications. In the United States, the cost of solar PV fell by 88% between 2009 and 2018, from USD 359 per megawatt-hour (MWh) to USD 43 per MWh (see Figure 1)

(Lazard, 2018). One MWh is equivalent to a power of one million watts applied for a duration of one hour. These low prices are not limited to countries with established solar industries, nor are they limited to grid-connected systems—they apply to off-grid systems, too. Globally, the levelized cost of energy for new off-grid or grid-tied distributed solar, including storage, is now below USD 0.20 per kWh, compared to USD 0.60 per kWh for small diesel and petrol generators (Crown Agents, 2018). Although there is still a high upfront cost to the installation of off-grid solar pumps, in the long term, solar pumps are cost effective because they are so inexpensive to run and maintain. It is estimated that over a 10-year period, the net cost of installing and running a solar PV pump is roughly two thirds of the cost of a similar diesel pump (Beaton et al., 2019).

Figure 1. Cost per MWh of solar PV, 2009–2018



Source: Adapted from Lazard, 2018, p. 7.

The second transformative development is the quickly decreasing cost and increased storage capacity of batteries. Of particular significance are the developments regarding so-called "advanced batteries," such as those that use lithium-ion. Compared to lead-acid batteries, they are generally smaller and lighter for the amount of power they can store. They can discharge more of their stored energy without compromising the battery life, have low losses while charging and discharging (making them more efficient), and have a longer lifespan. As with solar PV, price is often seen as one of the main challenges to the use of lithium-ion batteries in low- and middle-income countries, but the costs are now decreasing rapidly. The cost of lithium-ion battery storage has decreased by 87% in 10 years, from USD 1,100 per kWh in 2010 to USD 156 per kWh in 2019, with a further predicted decrease to USD 100 per kWh by 2023 (BloombergNEF, 2019).

The combination of solar PV technology and lithium batteries at affordable prices creates an attractive alternative to fossil fuel-based generators in off-grid areas. The introduction of a low-cost decentralized energy source would bypass the prohibitive costs and infrastructure requirements of connecting remote areas to a regional electricity grid, improving rural communities' access to electricity. This could provide small-scale producers with the electricity needed for ICT equipment and mechanization, which can increase yields through improved irrigation, planting, weeding, and harvesting technologies. A low-cost energy source lowers farmers' costs, improves the possibilities for storage and processing, and improves the prices farmers receive by raising quality and reducing waste.

Opportunities for Solar-Powered Irrigation

Irrigation systems are an important application for low-cost solar energy unleashed by cheaper and better solar PV and lithium battery technology. Affordable solar pumps make irrigation accessible to more farmers and are associated with strong positive benefits for agricultural productivity and farm income. Irrigation can improve yields on existing cropped lands and can allow farmers to expand the total cropped area, letting farmers grow more and higher-value crops. In some cases, irrigation can even create the possibility of adding an extra crop cycle in the year. The potential of solar-powered irrigation systems continues to rise as technological improvements have increased the power and efficiency of the systems.

Photo: Jeffery M. Walcott/IWMI (CC BY-NC 2.0)

One study found that a solar-powered drip-irrigation system in Benin farmed by a women's cooperative saved each woman up to four hours per day in labour and increased production by an average of two tonnes per month (International Renewable Energy Agency, 2016). The more reliable income flows from these changes to production helped the women to independently feed, educate, and provide medical care to their families. For farmers who already use some form of conventional water pump for irrigation, a shift to solar-powered systems can also increase incomes in the medium to long term because of the low recurring costs associated with the technology. Solar–diesel hybrids to power drip-fed irrigation systems (which water plants with a small regular stream) can be operated for less than half the cost of diesel-only systems (Carroquino et al., 2015). Similarly, farmers can use solar PV systems to run pumps for longer hours than previously due to improvements in the storage capacity of batteries. Rooftop solar panels have also been used to power cold storage and solar charging facilities.

Financing Options for Solar-Powered Irrigation

Despite many benefits and falling prices, there remains a high upfront cost to the installation of off-grid solar pumps, which continues to be a barrier to their uptake in low- and middle-income countries. The average upfront cost of a solar pump is 5 to 15 times more than diesel equivalents. Importantly, this cost disadvantage diminishes over time because the solar systems are so cheap to operate and maintain (Beaton et al., 2019). One solution is financing for solar PV systems to make them more affordable for farms by spreading the capital cost over time. Digital payment systems, now widely used in many low- and middle-income countries, allow for the regular and reliable electronic transfer of funds. This reduces risks for the lender, lowers the overall cost of the financing, and also allows for pay-as-you-go payment structures that are more accessible for users.

> Targeted subsidies are another way to help small-scale producers overcome the high initial capital costs of investing in off-grid power generation.

The Risks of Solar-Powered Irrigation

No technology is risk free. At scale, decentralized irrigation could be “too” successful; if productivity in a region rises for a large population of farmers, the increase in yields could depress prices unless farmers are able to access new markets for the increased supply.

Another risk associated with the low recurring costs of solar-powered pumps is that if there is no charge for water use, there is no economic incentive to irrigate conservatively. An expansion of irrigation could stress freshwater resources by encouraging over-extraction and harm soil health by increasing the possibility to expand or intensify production.

Recommendations

Transformative technologies have considerable potential for agricultural practices. Many of the technologies are already operational in well-financed and high-input settings, and they are beginning to be deployed in resource-poor settings, too. Their transformative power rests in their ability to revolutionize food production by raising productivity while improving sustainability. They could support food production on marginal or degraded land. They could support farmers to make more efficient use of inputs while reducing environmental harm and the overuse or misapplication of potentially polluting inputs, such as synthetic fertilizers. Nonetheless, inclusive sustainable food and agriculture systems do not come about by accident; they require thoughtful public interventions, especially if small-scale producers and food workers are to benefit. Without effective regulation, environmental degradation will continue to be a feature of food and agricultural systems. Done right, however, the adoption of these technologies will support the achievement of the UN Sustainable Development Goals, notably those on combating hunger, poverty, and climate change.

Photo: Mulugeta Ayene/WLE (CC BY-NC 2.0)

Some of these transformative technologies will require specific policy interventions based on the individual risks they pose. For example, with respect to solar irrigation, governments should consider the introduction of incentives and infrastructure to encourage farmers to sell excess power or install drip irrigation. These flanking policies would prevent over-extraction and encourage the use of efficient distribution systems. Similarly, governments and financial institutions need to work with farmers to help them plan risk-management strategies to cope with the potential for financial stress as a result of price depression from rapid increases in local production.

More broadly, the successful application of transformative technologies in agriculture requires a range of public interventions to create an enabling environment for the adoption of the technologies and minimize the potential risks associated with them.

Here are eight ways for governments, technology firms, producers' organizations, and financial institutions to support transformative change:

1. Talk about the technologies and their potential to small- and medium-scale producers and the enterprises that provide inputs and sales advice, as well as processing, transportation, and marketing services. Understand what technologies they are already using, what improvements they would like to see, and how the design and cost could be managed to protect accessibility.
2. Work with government and non-government institutions to provide education, training, and extension services for farmers on the design and appropriateness of new technologies, including when and how to use the equipment and data.
3. Monitor how new technologies are contributing to environmental, social, and economic sustainability goals and indicators. Where required, introduce regulation and enforcement mechanisms to manage the risks associated with new technologies.
4. Measure and monitor changes in employment patterns and ensure adequate social safety nets are provided where mechanization and automation reduce or redistribute labour.

5. Increase investment in targeted interventions to kickstart the diffusion of new technologies. Specifically, investments in research and development and targeted consumer subsidies for worthwhile products are warranted, given high start-up costs coupled with small recurring costs, creating an attractive investment that demands a longer time horizon than many small-scale producers can afford.
6. Introduce regulations on financial institutions for responsible lending to protect small-scale borrowers and establish financial literacy programs to reduce the risk of them becoming over-indebted.
7. Support ICT development and adoption through broadly based investments in the sector, such as improving telecommunications and internet infrastructure and either extending the electricity grid or putting in place off-grid renewable energy in rural areas.
8. Strengthen institutions that test and license products and ensure adequate aftersales service standards and warranties.

If the deployment of transformative technologies in low- and middle-income countries is accompanied by the types of policies above, the technologies will support the achievement of a range of development goals, including many of the UN Sustainable Development Goals for 2030 relating to combating hunger, poverty, and climate change. The opportunity is too important to let pass.

References

Beaton, C., Jain, P., Govindan, M., Garg, V., Murali, R., Roy, D., Bassi, A. & Pallaske, G. (2019). *Mapping policy for solar irrigation across the water–energy–food (WEF) nexus in India.* International Institute for Sustainable Development. https://www.iisd.org/sites/default/files/publications/solar-irrigation-across-wef-nexus-india.pdf

Bizikova, L., Brewin, S., Bridle, R., Laan, T., Murphy, S., Sanchez, L., & Smaller, C. (2020). *The sustainable agriculture transition: Technology options for low- and middle-income countries.* International Institute for Sustainable Development. https://www.iisd.org/sites/default/files/2020-08/sustainable-agriculture-transition-technology.pdf

BloombergNEF. (2019). *Battery pack prices fall as market ramps up with market average at $156/kWh in 2019.* https://about.bnef.com/blog/battery-pack-prices-fall-as-market-ramps-up-with-market-average-at-156-kwh-in-2019/

Carroquino, J., Dufo-Lopez, R., & Bernal-Agustín, J. L. (2015). Sizing of off-grid renewable energy systems for drip irrigation in Mediterranean crops. *Renewable Energy, 76,* 566–574. http://doi.org/10.1016/j.renene.2014.11.069

Cheong, D., Jansen, M., & Peters, R. (Eds.). (2013). *Shared harvests: Agriculture, trade and employment.* International Labour Organization and United Nations Conference on Trade Development. https://unctad.org/en/PublicationsLibrary/ditctncd2013d2_en.pdf

Crown Agents. (2018). *The solar revolution.* https://www.crownagents.com/wp-content/uploads/2018/07/Solar-Report.pdf

Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, United Nations Children's Fund, World Food Programme, & World Health Organization. (2020). *The state of food security and nutrition in the world 2020: Transforming food systems for affordable healthy diets.* https://doi.org/10.4060/ca9692en

International Renewable Energy Agency. (2016). *Solar pumping for irrigation: Improving livelihoods and sustainability.* https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Solar_Pumping_for_Irrigation_2016.pdf

Lazard. (2018). *Lazard's levelized cost of energy analysis – Version 12.0.* https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf

INTERNATIONAL INSTITUTE FOR SUSTAINABLE DEVELOPMENT

The International Institute for Sustainable Development (IISD) is an award-winning independent think tank working to accelerate solutions for a stable climate, sustainable resource management, and fair economies. Our work inspires better decisions and sparks meaningful action to help people and the planet thrive. We shine a light on what can be achieved when governments, businesses, non-profits, and communities come together. IISD's staff of more than 120 people, plus over 150 associates and consultants, come from across the globe and from many disciplines. Our work affects lives in nearly 100 countries.

IISD is a registered charitable organization in Canada and has 501(c)(3) status in the United States. IISD receives core operating support from the Province of Manitoba and project funding from governments inside and outside Canada, United Nations agencies, foundations, the private sector, and individuals.

Head Office

111 Lombard Avenue, Suite 325
Winnipeg, Manitoba
Canada R3B 0T4

Tel: +1 (204) 958-7700
Website: www.iisd.org
Twitter: @IISD_news

IISD

iisd.org