Improving Rural Livelihoods, Energy Access, and Resilience Where It's Needed Most:
The Case for Solar Mini-Grid Irrigation in Ethiopia

Matthew Ingram, Jonathan Phillips, Hizkyas Dufera, Liuel Hizikias, Marc Jeuland, and James Lovedale

Nicholas Institute for Environmental Policy Solutions
James E. Rogers Energy Access Project

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Matthew Ingram[1], Jonathan Phillips[2], Hizkyas Dufera, Liuel Hizikias[1], Marc Jeuland[3], and James Lovedale[1]

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Author Affiliations

1. Ethiopian Agricultural Transformation Institute, 2. James E. Rogers Energy Access Project, Duke University, 3. Sanford School of Public Policy, Duke University.

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EXECUTIVE SUMMARY

Ethiopia has one of the highest energy deficits in the world, with 56 million people lacking any access to electricity, including 61% of the rural population. Lack of access to energy is a major constraint on Ethiopian agriculture, a sector that is both central to rural livelihoods and increasingly vulnerable to climate change impacts. Agriculture accounts for 78% of the country's employment, 40% of GDP, and the majority of export revenues. Chronic food insecurity already affects 10% of the population, and high reliance on wheat imports from Ukraine and Russia are certain to further undermine food security and affordability at a time when inflation is already very high. Over the coming decade, climate-induced harms to agricultural productivity are expected to worsen.

The Ethiopian government is approaching these twin challenges of agricultural productivity and energy access with an integrated approach, of which the new Distributed Renewable Energy-Agriculture Modalities (DREAM) project is an example. The project aims to demonstrate the viability of distributed solar mini-grids as a solution for delivering improved irrigation services, greater agricultural productivity, expanded rural electricity access, and enhanced gender and social inclusion. As the largest mini-grid irrigation project in the world, it will be a source of valuable learning—both for Ethiopia as it aims to scale the approach across the country, as well as for other African countries facing similar challenges.

The DREAM project will begin with nine pilot projects scheduled to break ground later in 2022. To understand the likely impact of solar mini-grid-powered irrigation on farmers, the Ethiopian Agriculture Transformation Institute and Duke University developed an economic viability model that uses site-specific data to calculate likely impacts on farmer incomes. The model accounts for average planting, cultivation, harvesting, and marketing and distribution costs, as well as irrigation costs for both diesel-powered irrigation (the current technology in use at the sites) and a new electric irrigation alternative. This brief summarizes the findings of this analysis, which include:

- Transitioning from diesel-powered irrigation systems to solar mini-grids would increase production and farmer incomes significantly across all nine of the pilot sites analysed.
- Profitability for farmers at the pilot sites increases between 23% and 237%, consistent with findings from earlier studies.[1]
- Mini-grid irrigation tends to deliver the greatest productivity and income gains at sites with ample water availability and horticultural crops that have high year-round water requirements—such as multiple dry season plantings of onion and tomato, or fruit trees such as banana—and where the level of current irrigation is low due to diesel-related pumping constraints.

With greater confidence in adequate water supplies for their crops, farmers will be better positioned to raise yields, produce higher-value and higher-nutrient crops, and expand production. Scaled nationally, electric irrigation could potentially unlock $1.2 billion in additional revenues for farmers by 2025.

Identifying, demonstrating, and scaling new low-carbon development strategies that bolster pillars of human and economic well-being—like food and energy systems—must be an urgent global priority. Climate investors—both public and private—have thus far found few entry points into these types of projects in low- and middle-income countries, with just 1.7% of the roughly $600 billion in annual climate finance flowing to small-scale agriculture. The success of country-driven approaches like DREAM will be determined by whether pilots deliver on their expected promise and if investment models can be sufficiently de-risked to mobilize the capital needed for scale.

[1] Site profitability increases due to a combination of yield increases driven by increased productivity through increased irrigation and decreased irrigation costs, due to high and rapidly rising diesel costs associated with diesel-powered irrigation, compared to more cost-efficient electrified irrigation.

AN INTEGRATED SOLUTION FOR MEETING ETHIOPIA'S ELECTRIFICATION AND FOOD SECURITY GOALS

Ethiopia has the third highest energy deficit in sub-Saharan Africa, measured by the number of people lacking energy access.[2] In 2020, 49% of Ethiopians (56 million people) lacked access to electricity, including 61% of the rural population (55 million).[3] Those rural households that do have access rely primarily on small solar lights or highly intermittent grid service, sources ill-suited for powering commercial loads and driving productivity gains.

At the same time, Ethiopia is a drought-prone country with an agrarian-focused economy—a combination that leaves it among the most climate-vulnerable countries in the world. Agriculture accounts for roughly 40% of Ethiopia's GDP, nearly eight of every 10 jobs, and three quarters of export earnings.[4] Chronic food insecurity already affects 10 percent of the population, and between the current drought and the conflict in Northern Ethiopia, UNDP projects that domestic agriculture production could decline in 2022.[5] The war in Ukraine is likely to further stress Ethiopian food security, as the country imports 25% of its wheat, nearly a third of which comes from Ukraine and Russia. In addition to the 42% year-over-year food inflation recorded in February 2022 (prior to the Russian invasion), a tighter supply of imported wheat resulting from the conflict places additional upward pressure on domestic wheat prices and food affordability.[6]

Longer-term, estimates suggest worsening climate change may reduce Ethiopia's GDP by up to 10% by 2045, primarily from agricultural productivity losses.[7] The country is expected to face 1–2°C of warming by 2050, increasingly erratic and unpredictable rainfall, and increased incidence of drought and other extreme weather and pest events.[8]

Linking rural electrification strategies with the agriculture sector is critical for Ethiopia's long-term development and resilience. Given the high cost of extending grid access to many rural areas—further complicated by Ethiopia's mountainous terrain—and the desire to create economic opportunities for rural communities, the government has made a commitment to power at least 35% of its unelectrified population using off-grid technologies, mostly solar mini-grids. This decentralized approach can provide potentially transformative benefits when linked with rural livelihoods activities in agriculture, unlocking a range of improvements in production (for example through irrigation and small-scale mechanization); storage and distribution (through refrigeration); marketing (through improved access to market information and cold chains); and value-addition (through milling, processing, packaging). These improvements can translate directly into a range of quantifiable adaptation gains, as illustrated in Figure 1, many of which relate directly to enhanced female empowerment. Rigorously evaluating the impact of these technologies and approaches on resilience—and making that impact data available to climate investors—can be instrumental in chanelling additional climate finance into the sector.[9]

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[2] World Bank, "New World Bank Financing Supports Ethiopia's Goal of Universal Electricity Access by 2025," March 29, 2021, https://www.worldbank.org/en/news/press-release/2021/03/29/new-world-bank-financing-supports-ethiopia-s-goal-of-universal-electricity-access-by-2025.

[3] International Energy Agency, the International Renewable Energy Agency, United Nations Statistics Division, World Bank, and World Health Organization, *Tracking SDG7: The Energy Progress Report,* 2022, https://trackingsdg7.esmap.org/country/ethiopia.

[4] Federal Democratic Republic of Ethiopia, National Electrification Program 2.0 Integrated Planning for Universal Access, 2019, https://minigrids.org/wp-content/uploads/2019/04/Ethiopia-2.0.pdf; National Bank of Ethiopia, *Annual Report 2019-20*, https://nbebank.com/wp-content/uploads/pdf/annualbulletin/Annual%20Report%202019-2020.pdf.

[5] United Nations Development Programme (UNDP), "Quarterly Economic Profile: Ethiopia," March 2022.

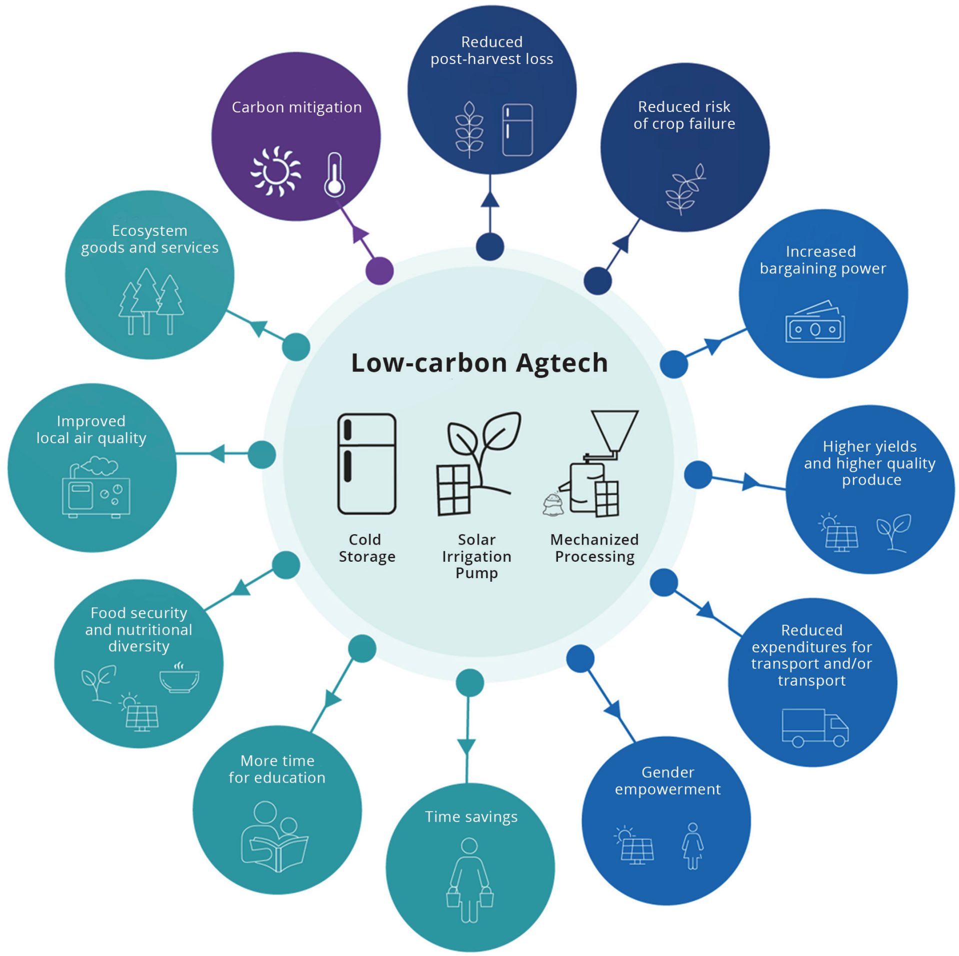
[6] UNDP, "Quarterly Economic Profile: Ethiopia."

[7] USAID, "Climate Change Risk Profile Ethiopia," 2016, https://www.climatelinks.org/sites/default/files/asset/document/2016%20CRM%20Factsheet%20-%20Ethiopia_use%20this.pdf.

[8] USAID, "Climate Change Risk Profile Ethiopia."

[9] Phillips, Jonathan, Victoria Plutshack, T. Robert Fetter, Marc Jeuland, Francis Elisha, Abigail Vanover, Elizabeth Yoder, *Catalyzing Climate Finance for Low-Carbon Agriculture Enterprises*, (Shell Foundation, 2022), https://shellfoundation.org/app/uploads/2022/02/Climate_finance_Report-1.pdf.

Figure 1. Contributions of low-carbon agriculture technologies to climate adaptation and mitigation



Note: Dark blue circles represent direct adaptation benefits. Light blue circles represent direct enhancement of adaptive capacity. Green circles indicate indirect enhancement of adaptive capacity, and the purple circle represents mitigation benefits.

Source: Phillips, et al., *Catalyzing Climate Finance for Low-Carbon Agriculture Enterprises*, 2022.

This integrated strategy of expanding rural electricity access alongside agriculture modernization is enshrined in Ethiopia's National Electrification Plan 2.0 (NEP), which includes an overall goal of achieving universal electrification by 2025.[10] Given the limited availability of public financing, the NEP outlines approaches to support sustainable business models and mobilize private sector investment.

ELECTRIFIED IRRIGATION REPRESENTS A TRANSFORMATIVE USE CASE FOR OFF-GRID ENERGY

Irrigation offers a particularly valuable use case for mini-grid electrification, especially given that only 10% of irrigable land in Ethiopia is actually being irrigated.[11] Horticultural crops like head cabbage, tomatoes, peppers, onions, garlic, avocados, bananas, and mangoes can be profitable but require a large and consistent supply of water. Lacking reliable water supplies, most farmers cultivate less valuable cereal crops rather than more valuable and nutrient-dense horticultural crops. In 2020, 79% of Ethiopian land

[10] Federal Democratic Republic of Ethiopia, "National Electrification Program 2.0."

[11] Haile, Gebremedhin Gebremeskel, "Irrigation in Ethiopia, a Review," *Journal of Environment and Earth Science* 5, no. 15 (2015): 141-147.

under cultivation was used for cereal crop production, with less than 3% dedicated to horticultural crops.[12] From the perspective of farmers, electrified irrigation facilitates access to greater volumes of water on demand, and assures farmers that the water supply to their crops will be reliable. Greater certainty in water supply will enable farmers to raise crop yields, produce higher-value and higher-nutrition crops, and expand production, which previous research has indicated could potentially generate $1.2 billion in additional revenues by 2025.[13]

From the perspective of the mini-grid, irrigation provides significant and predictable demand for energy. It introduces flexible loads in the form of water pumping, which can unlock other daytime loads (like agricultural processing) and allow the same system to sell more power and increase the return on assets. Irrigation schemes significantly increase the electricity demand of rural communities, as household energy requirements are typically low. Analysis of pilot sites suggests that electrifying irrigation systems would increase total power demand by a factor of 15 compared to servicing households alone, with irrigation making up 70-90% of total load. As such, irrigation serves as a valuable 'anchor load' for a mini-grid, de-risking the mini-grid investment and offering the potential to cross-subsidize tariffs that support rural households' and institutions' use of other energy services. Irrigation schemes therefore offer the potential to serve as the foundation for rural mini-grid electrification and enable commercially viable distributed renewable energy schemes. The system economics are a contrast to the more heavily subsidized mini-grid pilots without irrigation loads that are deployed via the public sector, and receive subsidies of up to 80% on capital expenditures.

However, despite the clear potential, mini-grid-powered irrigation remains a largely untested model in Ethiopia and in sub-Saharan Africa more broadly. The Government of Ethiopia is the first to conceptualize and develop the renewable energy-irrigation nexus in a manner that leverages the energy demands of large-scale clustered farming services. The DREAM pilot project is expected to validate commercial viability and bankability, and demonstrate the impact of such a model on energy delivery, irrigation service, agricultural productivity, community resilience, and gender and social inclusion.

The Agricultural Transformation Institute (ATI), a government institute aiming to catalyse the growth and commercialization of Ethiopia's agricultural sector, has been exploring the potential of electrified irrigation to support horticultural farmers in its flagship Agricultural Commercialization Cluster (ACC) program. The Institute has led this effort in conjunction with government ministries such as the Ministry of Water and Energy and the Ministry of Irrigation and Lowlands. The ACC program currently supports over 3.5 million farmers across Ethiopia with targeted interventions across the value chain that support commercialization of production and increasing rural incomes.[14] Integrating electrified irrigation into the ACC program will complement efforts by the ATI to facilitate access to other key agricultural inputs—high productivity seed varieties, fertilizers, pesticides, etc.—and to high-volume institutional buyers.

[12] Dorosh, Paul A., and Bart Minten, eds., *Ethiopia's Agrifood System: Past Trends, Present Challenges, and Future Scenarios,* (Washington, DC: International Food Policy Research Institute, 2020), https://doi.org/10.2499/9780896296916.

[13] Borgstein, Edward, Dawit Mekonnen, and Kester Wade, *Capturing the Productive Use Dividend*, (Basalt, Colorado: Rocky Mountain Institute, 2020), https://rmi.org/insight/ethiopia-productive-use.

[14] 2020-21 relates to Ethiopian calendar year 2013 (September 2020-September 2021); Ethiopian Agricultural Transformation Initiative (ATI), Agricultural Commercialization Clusters (ACC) Program Monitoring Office, 2021. This number excludes Tigray, as data could not be collected in EC 2013.

DREAM: A SOLAR MINI-GRID IRRIGATION MODEL FOR BOOSTING FARM PRODUCTION AND ENERGY ACCESS

To harness the value of rural electrification and irrigation, a diverse group of Ethiopian government and development-oriented institutions have launched the DREAM (Distributed Renewable Energy-Agriculture Modalities) project. This consortium includes the Ethiopian Ministry of Irrigation and Lowlands, Ministry of Water and Energy, and the ATI, working with the Rockefeller Foundation, the African Development Bank, Duke University, Keller-Bliesner Engineering, Veritas Consulting and SNV Netherlands Development Organisation.

The project aims to: 1) demonstrate the viability of distributed solar mini-grids to boost agricultural productivity and expand electricity access at nine pilot sites; and 2) catalyse private investment to scale a model of solar mini-grid-powered irrigation in Ethiopia. The pilots will create approximately 4,300 total electricity connections, including approximately 2,500 households—impacting an estimated 12,000 people across the sites—and deliver irrigation services to approximately 1,325 hectares of farmland, making it the largest mini-grid-powered irrigation project in Africa.[15] All pilot sites are supported by the ATI's ACC program and cultivate high value horticultural crops with significant irrigation requirements.

Farmers at the nine selected pilot sites currently irrigate on a limited basis, mostly through unreliable diesel-powered pumps. Currently, obtaining diesel is expensive and time-consuming, pump maintenance services are limited, and downtime is high. Diesel pumps are also highly emissions intensive—displacing the 500 diesel pumps at the mini-grid sites will reduce emissions by 20,750 $MTCO_2e$ annually, the equivalent of more than 52 million miles driven by the average passenger vehicle.[16] Manually-dug wells currently in use are typically shallow, and therefore provide reliable access to only limited volumes of water. Providing improved, electrified irrigation systems based around deeper tubewells will enable farmers to overcome these constraints and increase the productivity of their farmland.

BENEFITS TO FARMER INCOME FROM TRANSITIONING FROM DIESEL TO MINI-GRID IRRIGATION ARE POTENTIALLY LARGE

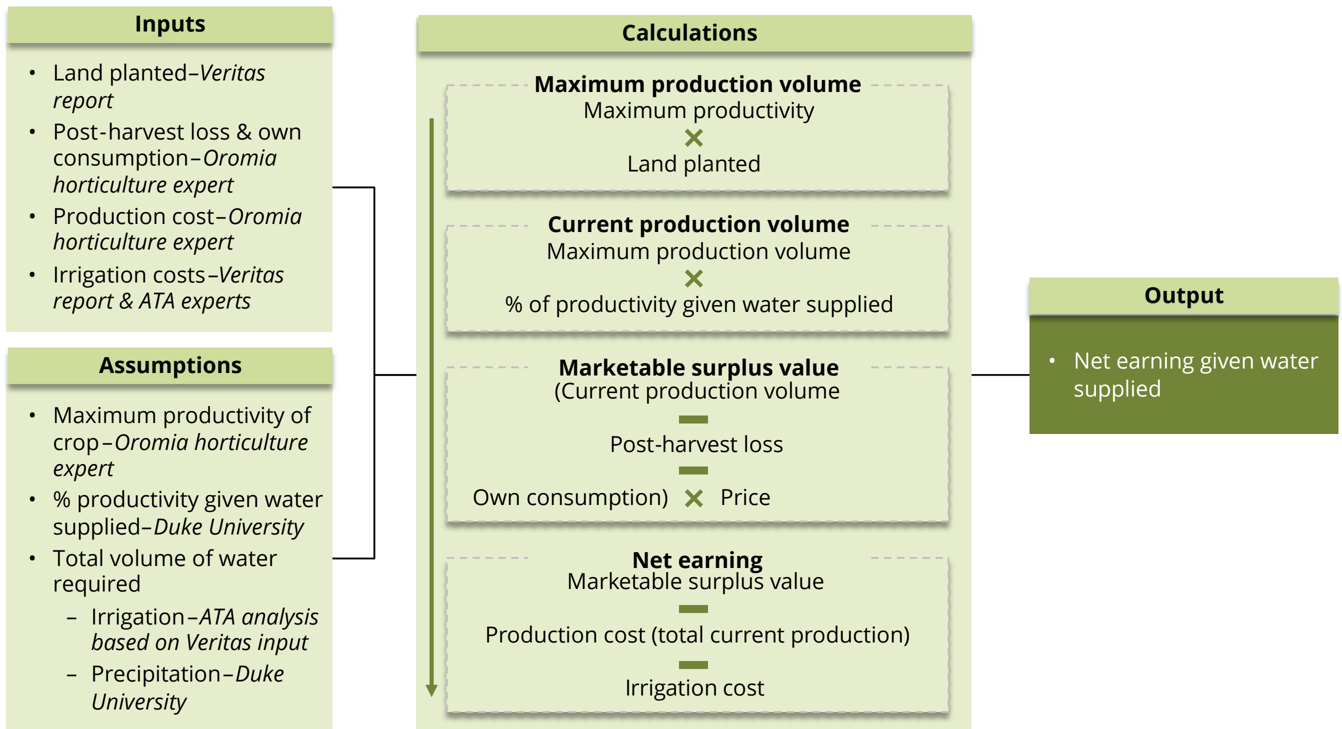
To understand the likely impact of solar mini-grid-powered irrigation on farmers, the ATI and Duke University built an economic viability model that uses site-specific data to calculate average farmer incomes at each pilot site, as outlined in Figure 2. Farmers' net incomes at current productivity levels were calculated for each pilot site based on current production volumes and average annual prices for the commodities that they cultivate. The model accounts for average planting, cultivation, harvesting, and marketing and distribution costs, as well as the irrigation costs for both diesel-powered and mini-grid-powered irrigation.[17]

[15] Ethiopian Agricultural Transformation Initiative (ATI), Agricultural Commercialization Clusters (ACC) Program Monitoring Office, 2020. Based on latest irrigation designs from Keller Bliesner.

[16] This equates to annual CO_2 emissions savings per farmer of 8.3 metric tons. Average per capita emissions in Ethiopia are approximately 0.14 tons/year. Calculation sources: (1) El-Gafy, Inas Kamal El-Din and Walid Farouk El-Bably, "Assessing Greenhouse Gasses Emitted from On-Farm Irrigation Pumps: Case studies from Egypt," *Ain Shams Engineering Journal 7*, no. 3 (Sept. 2016): 939-951, https://doi.org/10.1016/j.asej.2015.07.001; (2) United States Environmental Protection Agency, Greenhouse Gas Equivalencies Calculator, https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

[17] Mini-grid-powered irrigation costs presented here assume an energy tariff of 20 Ethiopian Birr per kWh, equivalent to US $0.40/kWh as of March 2022 exchange rates. The final energy tariff for the project is still to be finalized, but is anticipated to be between US $0.30 and US $0.40/kWh.

Figure 2. Overview of the economic viability model approach



The model allows for comparison of the existing diesel-enabled production levels to those that could be achieved if farmers were able to irrigate at optimal levels, given the water availability at each site. To calculate the potential increase in income, existing incomes—estimated using data on existing irrigation practices—need to be compared to the incomes that could be achieved if farmers leveraged mini-grid-powered irrigation and irrigated at these optimal levels. Due to the prevalence of unreliable and shallow hand-built wells and the limitations of diesel-powered pumps, most farmers currently irrigate far below optimal levels, even though these sites have sufficient water availability to support higher levels of irrigation.

The gains in productivity delivered through increased irrigation are calculated using CROPWAT, a tool that calculates crop water requirements based on soil, climate, and crop data. An example of the CROPWAT calculation for the cultivation of onions at the Chefe Kora site during the dry season can be found in Figure 4. Farmers at Chefe Kora currently irrigate their onions with 4 million m^3 of water per year across a site that spans more than 200 hectares, which only achieves about 40% of maximum productivity.

Pilot Site Snapshot: Chefe Kora

The Chefe Kora village is in the Great Rift Valley, within the Oromia Region's Golbe Kebele. It is located on the Eastern side of Lake Ziway. There are about 100 farmers who report irrigating about 75 hectares over multiple years, with an average field size of 0.5 hectares. Another 75 hectares are farmed without irrigation, for a total of 150 hectares of farmed land. Onions and tomatoes are priority crops, with spinach, cabbage, and pepper also grown under irrigation.

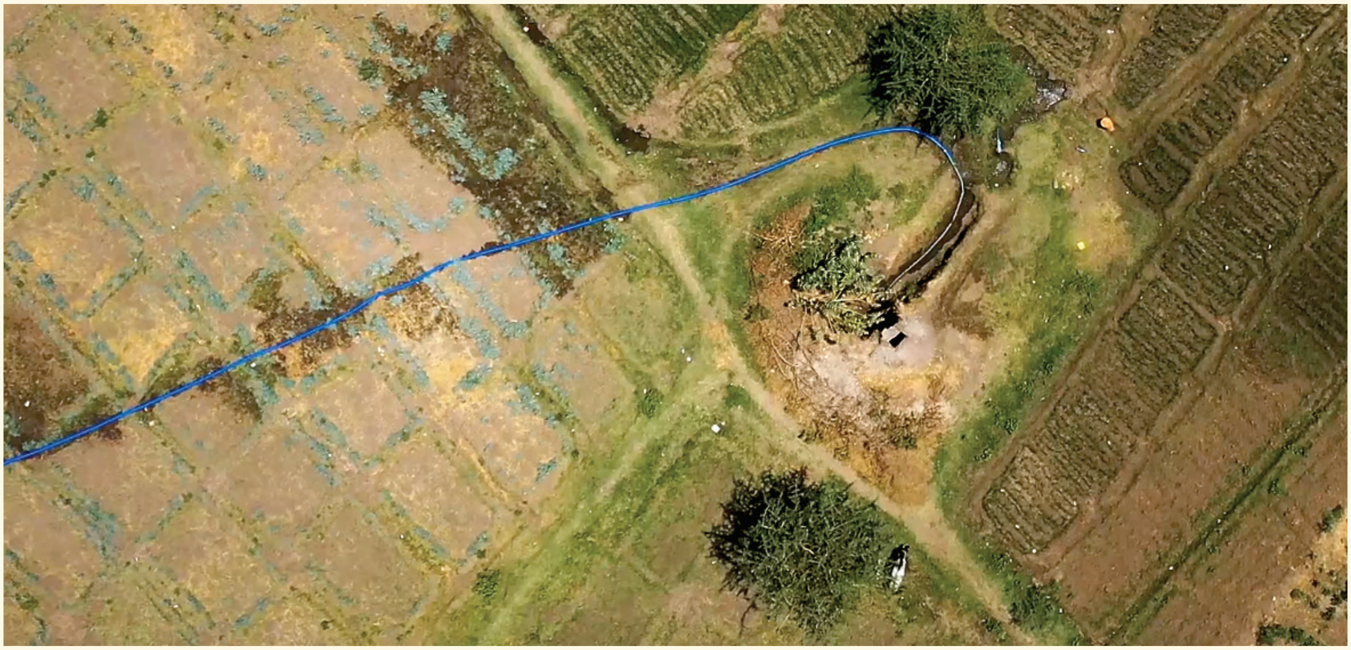
VERITAS CONSULTING

Chefe Kora exemplifies many of the challenges faced by farmers at DREAM pilot sites. Farmers currently use hand-dug wells to access shallow groundwater using diesel pumps. The wells are built with limited stabilization and collapse regularly, while diesel pumps break down frequently. Farmers also pay a high price of nearly 40ETB ($0.80 USD) per litre of diesel. The pumped groundwater is then delivered to individual farms by hoses or hand-dug ditches. Capital investments at the pilot sites will include upgrades of hoses, which are typically of poor quality and leak large amounts of water, as seen in Figure 3.

Consequently, current water provision is typically less than 40% of optimal irrigation levels (*see Figure 4*), resulting from high levels of pump and well downtime, farmers not accessing full water availability, and the high cost of pumping (*see Figure 5).* Solar mini-grid irrigation systems at Chefe Kora and other DREAM pilot sites allow farmers to irrigate at more optimal levels, thus unlocking the potential for gains in productivity and income.

The DREAM project consortium has worked to create irrigation scheme designs tailored to the geography of each pilot site. These designs allow an initial assessment of the operating expenses (opex) and capital expenses (capex) that would be incurred if communities transitioned to electrified irrigation.

Figure 3. Aerial image of leaking hoses under existing irrigation scheme



VERITAS CONSULTING

Figure 4. Dry season onion crop productivity under current (diesel-powered) irrigation levels and piloted, optimal (solar-powered) levels, Chefe Kora site

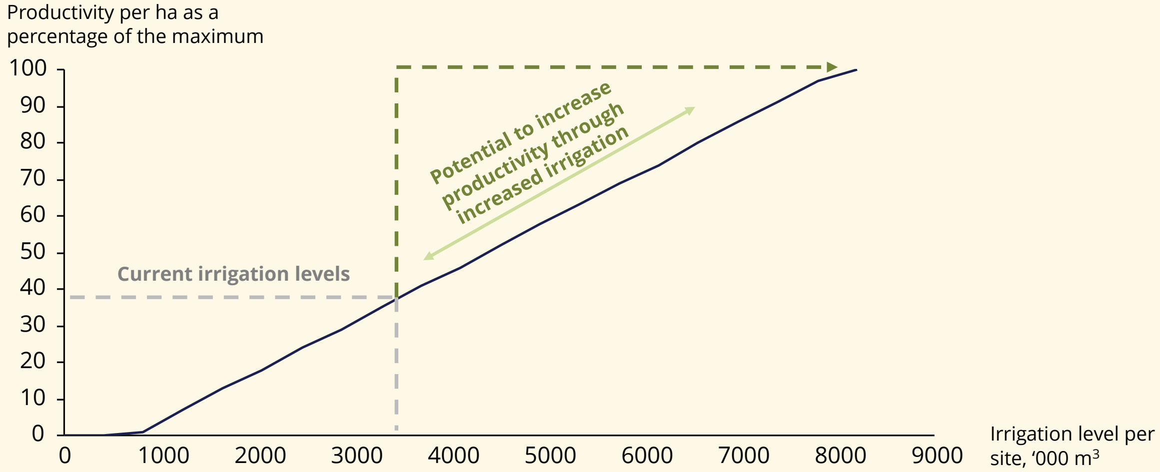
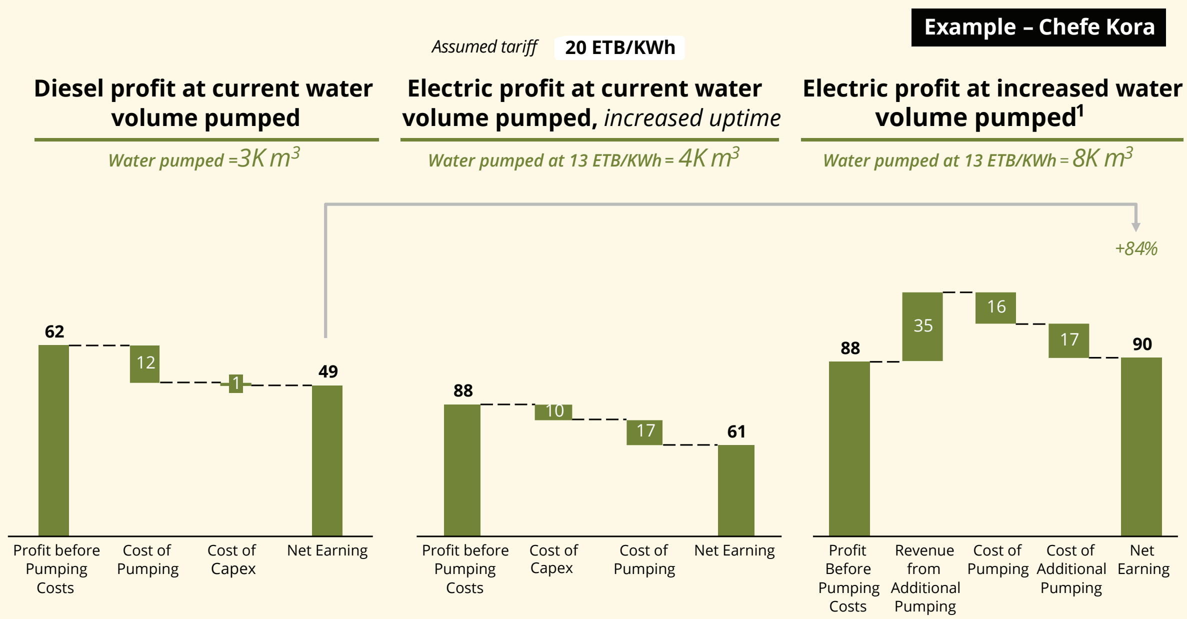


Figure 5. Profitability of different irrigation pumping scenarios, Chefe Kora site



[1] Potential water supply does not necessarily mean the optimal supply. Farmers could reach the optimal before fully using the potential.

With this information, we developed three, directly comparable farmer profit and loss scenarios, comparing net incomes of farmers at each site for the following scenarios:

(1) Current levels of irrigation using diesel pumps[18]

(2) Maintaining existing irrigation practices while transitioning to mini-grid-powered irrigation, assuming that pump uptime would be increased to improve reliability[19]

(3) Increasing to optimal levels of irrigation using mini-grid-powered irrigation

As illustrated in Figure 5, farmers at the Chefe Kora site would increase their incomes by 84% on average by transitioning from current diesel to optimal mini-grid irrigation levels, resulting in major dividends for local farmers and the broader local economy.

[18] This includes consideration of diesel pump reliability. 75% pump uptime is assumed.
[19] Assuming an increase in pump uptime from 75% (diesel) to 95% (electric).

TRANSITIONING TO MINI-GRID POWERED-IRRIGATION COULD BE TRANSFORMATIVE, INCREASING FARMER INCOMES BY UP TO 240%

Transitioning pilot site farmers from existing unreliable, diesel-powered pumps to solar mini-grid-powered pumps will significantly increase access to water, allowing farmers to irrigate at optimal levels. As illustrated in Table 1, the model finds that transition increases production and incomes across all nine pilot sites, with profitability increasing between 23% and 237%. The model's conclusions are consistent with other analyses. For example, recent studies by the Food and Agriculture Organization of the United Nations (FAO) in Kenya and Ethiopia found that transitioning from diesel to electrified irrigation could increase incomes by up to 250%.[20]

Table 1. Current farmer income with diesel pumping compared to potential future income with optimal electric irrigation, across pilot sites[21]

Impact of switching energy source on farmer annual net earnings

Assumed Energy Tariff of 20 ETB/Kwh

	Current volume of Water Pumped with Current Practices using ***Diesel Pumps***				Optimal Volume of Water Pumped with Improved Practices using ***Electric Pumps***					Difference in Profit from Current Diesel Pumping to Improved Electric Pumping	
	Water Pumped *(K m)*	**Revenue before pumping cost** *(K ETB)*	**Pumping Cost** *(K ETB)*	**Net Profit** *(K ETB)*	**Water Pumped** *(K m^3)*	**Revenue before pumping cost** *(K ETB)*	**Pumping Cost** *(K ETB)*	**Capex cost** *(K ETB)*	**Net Profit** *(K ETB)*	*(increase in K ETB)*	*(% increase)*
Lelicho	3	262	59	**204**	5	313	40	21	**251**	**+47**	**+23%**
Murche	6	120	52	**68**	18	310	63	18	**229**	**+161**	**+237%**
Huluku	13	119	64	**55**	*17*	152	24	12	**116**	**+61**	**+111%**
Telifa	8	175	48	**138**	*19*	314	31	14	**268**	**+130**	**+94%**
Aregawi	3	87	21	**66**	*20*	261	*38*	11	**212**	**+146**	**+212%**
Chefe Kora	4	62	13	**49**	*8*	123	16	17	**90**	**+41**	**+84%**
Andega	4	46	11	**35**	*6*	62	5	11	**45**	**+10**	**+29%**
Telbo	6	95	37	**59**	*14*	166	27	23	**116**	**+58**	**+98%**

Irrigation capex included

The calculations presented here are based on diesel prices as of October 2021, which were significantly lower than at the time of publication due to local and global conditions. Historically in Ethiopia, diesel has been subsidized by the government. However, in January 2022, the Government of Ethiopia announced initial plans to progressively remove this subsidy. It is anticipated that this reform will increase the price of diesel by roughly 25% per quarter over the year, which would lead to diesel prices increasing from an average of 23 ETB per litre in October 2021 to approximately 60 ETB per litre by the end of 2022, which will further increase the profitability of transitioning to electrified irrigation.[22] However, the reduction in diesel subsidies and subsequent increase in tariffs is targeting non-agricuture sectors and it is not certain how these tariff changes will be implemented and pass through to farmers in in rural areas. Further, the run-up in global oil prices in the first half of 2022 resulting from Russia's war in Ukraine is also not

[20] Hartung, Hans and Lucie Pluschke. *The Benefits and Risks of Solar Powered Irrigation—A Global Overview*, (Rome, Italy: Food and Agriculture Organization of the United Nations, 2018), https://www.fao.org/documents/card/en/c/I9047EN/.
[21] Data are still being collected at the Moko pilot site in Oromia.
[22] Dadhi, Hawi, "Fuel Subsidies to Go Goose Egg Next Year," *Addis Fortune*, January 22, 2022, https://addisfortune.news/fuel-subsidies-to-go-goose-egg-next-year/.

included in these calculations but would have a similar effect on the relative profitability of electrified irrigation. Eliminating this type of extreme volatility for a key input and replacing it with highly predictable electricity tariffs will reduce the financial uncertainty of agriculture operations and help farmers and communities plan for the future.

The significant variation in impacts on farmer incomes across the different sites is due to differences in existing levels of irrigation, water availability, crop choices, and topographical and other geographic features that influence capital and operating costs. High-impact sites, where mini-grid-powered irrigation tends to deliver the greatest productivity and income gains, are those with ample water availability and a perennial crop that has high water requirements (such as vegetables and fruits) and where the current level of irrigation is low due to diesel-related pumping constraints. Improved irrigation capabilities could also lead to additional income and nutritional gains through shifting cropping strategies—for example planting higher value horticulture crops—but these are not assumed in the analysis.

MINI-GRID ENERGY MAY ALSO UNLOCK A RANGE OF USE CASES IN OTHER AGRICULTURE-SECTOR VALUE CHAINS

While we have mostly focused on the benefits of mini-grid-powered irrigation, this is only one agricultural use case for rural electrification. Across sub-Saharan Africa, off-grid electricity has been used to power a range of technologies that enhance rural productivity. Horticultural farmers can benefit from accessing basic agro-processing technologies such as pasting, juicing, and oil extraction to increase the per kilogram value of their products, as described in Figure 6. Off-grid electricity can also be used for basic product cleaning and packaging, or to establish cold storage facilities that reduce post-harvest loss, a major problem facing horticultural production in the Horn of Africa. These various productive uses of power can further increase smallholder farmer incomes and serve as anchor power loads. As such, these applications could also bolster the economic viability of mini-grids and balance the seasonality of power demand for irrigation. Additional productive use applications such as these may be considered in future scaling-up of the DREAM project.

Figure 6. Additional productive use cases for electrification in horticulture cultivation

	Description	Benefits
Avocado oil processing	• Avocado oil can be extracted using a simple mechanized de-seeding and pulping process • Oil can be sold as a cooking oil or in cosmetics, primarily in export markets	• More than **double net income** per unit sold vs farmgate prices for raw avocado • **Reduced wastage**, due to longer shelf life and no need for cold storage
Tomato paste processing	• Tomato paste can be extracted through a simple mechanized crushing, heating and concentrating process • Paste can then be sold into local markets, currently dominated by imports	• **Increase net income by over 150**% vs farmgate prices for raw tomatoes
Crop cleaning and packaging	• Electricity and irrigation can be used for small-scale washing and packaging facilities	• Crop cleaning and packaging can **increase incomes by up to 40%** vs farmgate prices
Cold storage	• Reliable electricity can be used to power cold storage for horticulture and dairy	• **Increase income by up to 30%** by reducing horticulture post harvest loss • Additional income streams through **dairy sales**

THE ROAD AHEAD: DEMONSTRATING THE MODEL, UNDERSTANDING IMPACTS, AND MOBILIZING PRIVATE INVESTMENT FOR SCALE

Mini-grid developers participating in DREAM have been selected through a competitive process and the pilots are expected to break ground later in 2022. Over the coming three years, as the project becomes fully operational and impacts can be measured, data and evidence will be gathered on the transformative potential of the technology.[23] The project will clarify the extent to which rural electrification and electrified irrigation advance the livelihoods of smallholder farmers, improve community resilience, contribute to gender and social inclusion, and mobilize private investment. Moreover, the pilot will elucidate whether model-based economic viability calculations such as those carried out in this planning phase, with their many behavioural assumptions, capture essential real world conditions. The evaluation results may also facilitate identification of opportunities for similar mini-grid-based irrigation in the country.

If successful, the DREAM pilots will demonstrate a scalable business model for private sector-led investment in mini-grid power and large-scale cluster irrigation schemes that can be replicated—depending on location-specific constraints and opportunities—across the 600 horticulture sites within the ACC program. Installing mini-grid irrigation at all of these sites would potentially benefit an estimated 165,000 farmers and reduce annual emissions by 1,383,000 $MTCO_2e$.[24]

Project results will also have global implications and importance, given the opportunity for scaling smallholder irrigation across much of the African continent. Models such as DREAM, which demonstrate new, low-carbon approaches to development—while also delivering financial returns—are ideal investment destinations for public and private investors seeking climate change mitigation and adaptation outcomes.

Figure 7. Roadmap to private sector investment

Increasing private sector leadership →

	1 Initial proof of commercial viability *Pilot*	2 De-risked private sector investment *Scale-Up*	3 Full private sector investment
Stage Description	• Mini-grids will be installed at nine ACC pilot sites • Farmers will pay a fee to cover electricity use, irrigation system operations, and service provider margins • Capex covered by grant funding	• Private investors will provide funding to construct mini-grid-powered irrigation systems • Funding will be supported by development capital, blended finance, or government subsidy • Farmer fees will cover cost of irrigation system capex	• Private investors will provide full funding to construct mini-grid-powered irrigation systems • Potential for use of concessionary financing • Farmer fees will cover cost of irrigation system capex
Outcome	• Initial proof of concept that – Farmers will reliably pay for electrified irrigation services – Farmers can cover the costs associated with electrified irrigation while still increasing net income	• Proof of concept that – The private sector can profitably install and operate mini-grid-powered irrigation systems – Farmers can cover the cost of irrigation system capex while increasing net income	• Sustainable business models established for private sector investment in mini-grid-powered irrigation systems

[23] Updates and resources from the 2022-2025 research study led by Duke University and Haramaya University will be available at https://energyaccess.duke.edu/distributed-renewable-energy-agriculture-modalities-dream/.
[24] There are 165,495 farmers across the 600 ACC horticulture sites today.

Today, with a lack of purely commercial projects and few blended capital facilities focused on the sector, climate investment in agriculture in low- and middle-income countries represents a major gap. In fact, small-scale agriculture accounts for a tiny amount—just 1.7%—of the roughly $600 billion in annual climate-related financing globally.[25]

As outlined in Figure 7, the DREAM pilots are a critical first step towards understanding the viability of a commercial model, as well as understanding how solar mini-grid-powered irrigation contributes to the resilience and economic development of beneficiaries. A scale-up phase will then clarify if the model has been adequately demonstrated and de-risked, and what combination of public and private capital is needed to support it. As such, the project represents a significant opportunity to address Ethiopia's dual rural energy and agricultural productivity deficits, and transform mini-grid and irrigation investment across the African continent and beyond.

[25] Chiarac, Daniela, Baysa Naran, and Angela Falconer, *Examining the Climate Finance Gap for Small-Scale Agriculture*, (Climate Policy Initiative, November 2020), https://www.climatepolicyinitiative.org/publication/climate-finance-small-scale-agriculture/.