Capturing the Productive Use Dividend

Valuing the Synergies between Rural Electrification and Smallholder Agriculture in Ethiopia

insight brief

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HIGHLIGHTS

- National electrification efforts have great potential to help rural smallholders power increased agricultural productivity, unlock local processing activities, and create new businesses. This opportunity will be essential if universal electrification in Ethiopia is to generate the promised benefits especially in rural areas and support Ethiopia's local and national economic growth.

- This report examines six agricultural production and processing opportunities for rural areas: horticulture irrigation, grain milling, injera baking, milk cooling, bread baking, and coffee washing. Collectively, these areas have the potential to produce US$4 billion in annual value using electric appliances by 2025. Supplying the appliances is itself a US$380 million investment opportunity.

- These six areas can also produce an additional US$22 million annual revenue stream for the utility by 2025, as the utility can sell more units of power with the same capital investment in rural areas. This revenue would help reduce the cost of providing power from both grid extension and minigrids.

- Realizing the economic and livelihood benefits of productive uses requires concerted national efforts linking agriculture and electrification. A national productive use program should address barriers and channel funding to the highest-need areas, helping to scale uptake rapidly. Immediate next steps are to study demand more closely, pilot several projects, and convene actors from different sectors to build a national vision and strategy.

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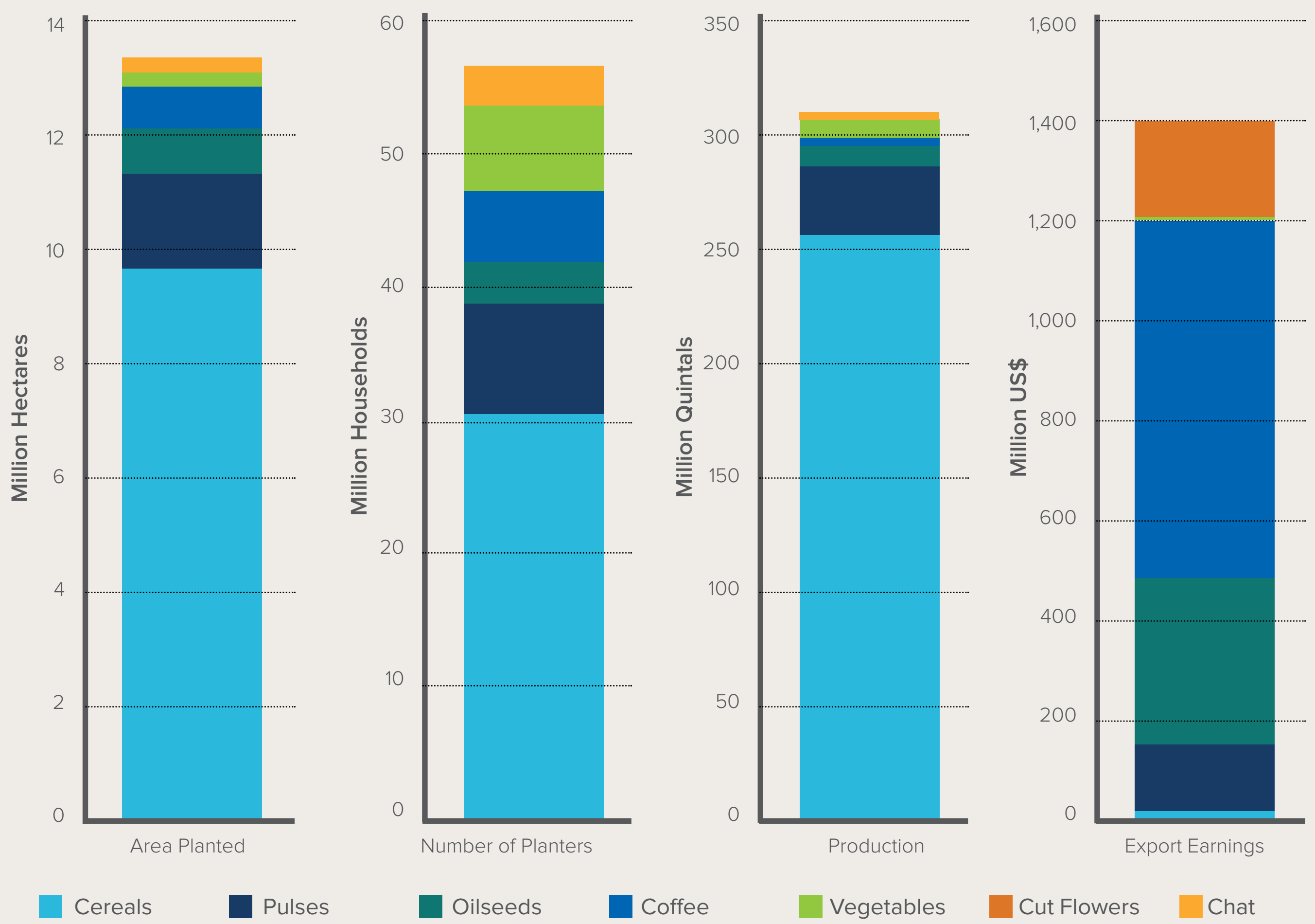
III Smallholder agriculture is the backbone of Ethiopia's economy, and rural electrification provides an opportunity to unlock value for farmers and their communities

Ethiopia is growing, transforming, and industrializing, while continuing to be an economy heavily dominated by agriculture. In 2014, agriculture accounted for **44% of Ethiopia's GDP and 70% of its exports**, with eight of every ten workers in the country connected to the sector.

The landlocked nation is already an agriculture hub, as sub-Saharan Africa's largest producer of wheat and largest holder of livestock. Vital export revenues are provided by coffee, oilseeds, and cut flowers, which collectively generated US$1.3 billion in exports in 2018. Meanwhile major cereal crops (teff, wheat, barley, maize, and sorghum), which are mainly consumed domestically, dominate crop production by mass and area planted as shown in Exhibit 1.

EXHIBIT 1

Distribution of Farmers, Areas Farmed, Total Production, and Export Value across Major Crop Types (data from 2017/18)



Source data from Ethiopia Central Statistical Agency. *"Agricultural sample survey 2017/18 (2010 E.C.) Volume 1: Report area and production of major crops, and Volume II: Report on livestock and livestock characteristics (private peasant holdings),"* April 2018; and Organisation of Economic Complexity Ethiopia Database, https://oec.world/en/profile/country/eth/ (accessed November 2019).

Today, Ethiopia's population is nearly 80% rural, and 90% of farming households are smallholders (farming less than two hectares [ha]). The Government of Ethiopia has signaled its intention to transform the agriculture sector through a range of programs. National plans strongly emphasize increasing productivity on existing farmlands, expansion of extension services for rural populations, and enabling targeted crop growth—for example programs that irrigate lowlands to allow for planting and harvesting wheat. Authorities have also prioritized scaling up production of high-value crops such as fruits and vegetables, especially for export. The second national **Growth and Transformation Plan** (GTP-II) set out goals such as increasing crop production by smallholder farmers "from 270 million quintals (one quintal = 100 kilograms) in 2014/15 to 406 million quintals over the five-year target period." The first objective of the 2014 Agricultural Mechanization Strategy is to "raise the level of Ethiopian agricultural mechanization from **0.1 kW/ha to 1 kW/ha**, with at least 50% derived from mechanical/electrical power." (For comparison, India's level of mechanization was approximately 2 kW/ha in 2014, and China's was over 6 kW/ha.)

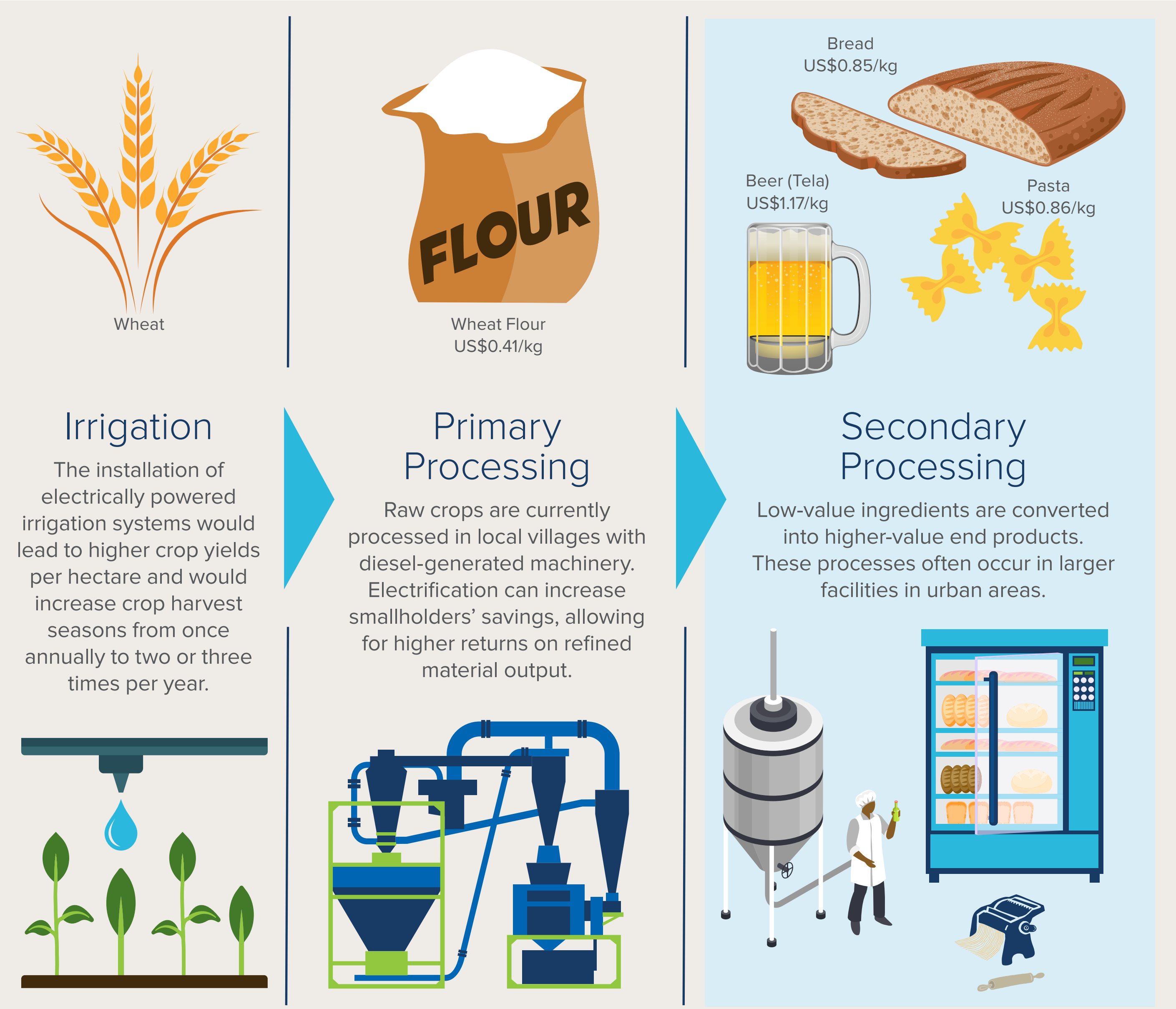
Traditionally, agriculture in Ethiopia has been "low-input, low-output," with crop production levels significantly **below regional and international levels**. In recent years, Ethiopia has dominated productivity gains in East Africa, largely by increasing fertilizer use and seed availability, to grow production at a rate surpassing that of South Asia during the Green Revolution. However, achieving further rapid growth in production of smallholder farmers requires overcoming a range of barriers. Challenges vary by crop type and region, but include insufficient transportation infrastructure and extension services, limited awareness of farming best practices, little operating capital in the hands of farmers, lack of available seeds or plant-starters for farmers, and absence of marketplace infrastructure to enable nationwide crop sales.

National equitable growth should also prioritize the creation of new value for rural households. Agricultural processing presents an opportunity for this—by enabling crop value addition, it can help drive social and economic development in rural areas. For example, in the wheat value chain, converting wheat flour to bread generates US$0.57 value addition per kilogram of flour. Exhibit 2 shows several opportunities to improve value extraction in the wheat sector by irrigating crops to boost production, and then transforming them into high-value products with post-harvest processing.

Currently, rural communities capture only a small proportion of the value from agricultural processing: in the case of wheat, factories for bread, pasta, and beer are generally largescale facilities located in or near urban areas. As such, most of the profits generated are retained by urban businesses rather than reaching these primary producers. Rural households—especially women in the household—may not have the finance, appliances, or business knowledge to produce products for local markets; they are also likely to be dependent on manual power or expensive fossil fuels to enable limited processing activities.

EXHIBIT 2

Potential for Electrifying Value Chain Activities for Wheat in Ethiopia

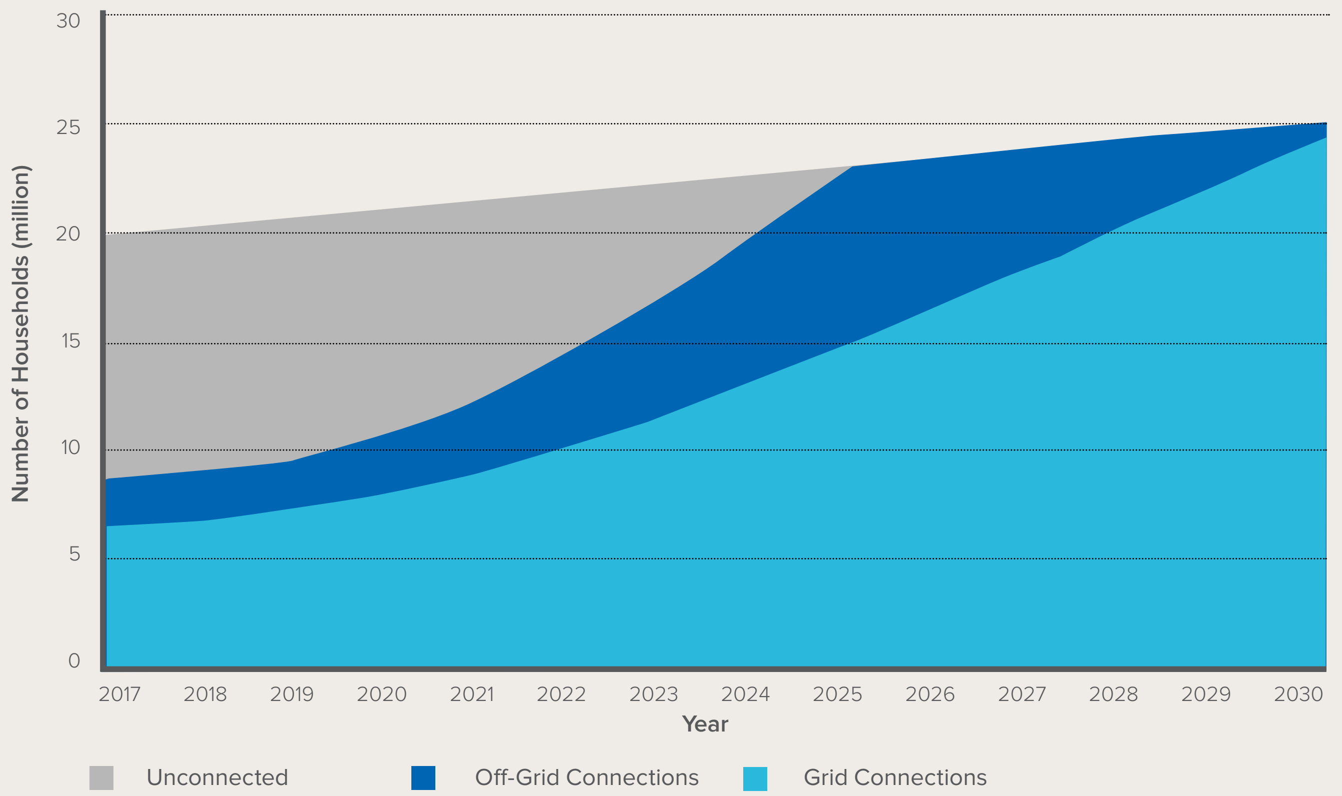


Note: Food prices quoted from numbeo.com, FAOSTAT database, and WFP Ethiopia monthly market watch.

Electrification can play a role in many activities. Agricultural processing opportunities are difficult to access without reliable, affordable electricity. Today, just **30% of the rural population** has access to electricity, often through small solar lights or intermittent grid supply. However, the Government of Ethiopia has a goal of universal electrification by 2025. **The National Electrification Program 2.0** (NEP-II) lays out plans to do this using a combination of grid extension, minigrids, and stand-alone systems, as shown in Exhibit 3. This rollout represents an enormous opportunity to increase productivity and value creation opportunities, powering economic transformation in rural areas.

EXHIBIT 3

Electrification Targets from the National Electrification Plan 2.0



Electrification of rural areas is not cheap; long distances and relatively low energy consumption mean that historically, rural electrification has been subsidized in practically every country that has high electrification rates today. In Ethiopia, the NEP-II identifies a financing need of US$5.8 billion for on- and off-grid electrification between 2018 and 2025, excluding transmission and generation investments. This is a major investment program which represents a significant subsidy, even after accounting for planned tariff increases. Investment at this scale should be expected to generate commensurate benefits, increasing incomes and driving social and economic development.

In electrification, end-use applications that help generate revenue are often described as the productive uses of energy. These activities help to make electrification successful; by creating or expanding businesses, increasing incomes, and capturing value within communities, they can unlock the promised benefits.

Importantly, these applications can increase energy consumption in rural areas. Revenue from the activities can also generate local economic development and growth that improves communities' ability to pay for energy and more appliances. In a positive feedback loop, the increased energy sales enable energy service providers to improve their returns, which could reduce subsidy needs or provide revenue for system maintenance.

The uptake of these productive uses in rural communities will not happen automatically. In fact, careful support may be required to ensure that electricity access fosters local and national **social and economic development**. Using electricity to power rural agricultural productivity, unlock processing opportunities, and create new or expand existing businesses linked to agricultural outputs will be key for reaping the benefits of rural electrification. In Ethiopia, close alignment between agricultural productivity and electrification efforts offers an enormous opportunity for both sectors.

III Supporting Electrification and Agricultural Productivity Simultaneously in Rural Areas Could Have Transformative Impact

When planned strategically, the economic potential and synergies from well-planned combined electrification and agriculture programs can be transformative. Analysis by Rocky Mountain Institute (RMI) and International Food Policy Research Institute (IFPRI), with input from Ethiopia's Agricultural Transformation Agency (ATA), explored key value chains to show a snapshot of what is possible at the national level. Agricultural activities were selected that could use electricity to save fuel costs or enable new revenue generation for rural smallholders—all viable at the household level or small scale—focusing on sectors in the GTP-II and ATA priority intervention areas: grains, high value crops, and the dairy sector. These six activities have the potential to generate revenue streams worth US$4.0 billion over the next five years, as described in Exhibit 4. A detailed Appendix provides assumptions, calculations, and references used for calculating the figures below and throughout this section.

EXHIBIT 4

Six Value Chain Opportunities with High Potential for Electrification

Sector	Description	Appliance Needs	Potential Value Unlocked*
Irrigating Horticulture	Irrigate land with electric pumps for production of high value crops: head cabbage, tomatoes, red pepper, onions, garlic, avocados, bananas, mangoes	Electric pumping systems, large and small, on- and off-grid. Sprinklers, manual and automatic drip irrigation systems	US$1.2 billion
Grain Milling	Replace diesel mills with electric equivalents (this analysis focuses on maize, wheat, and teff)	Electric mills: small-scale (off-grid) and large-scale (on-grid)	US$120 million (replacing diesel-powered milling)
Injera Baking	Produce high-quality injera with electric griddles (mitads)	Efficient electric injera mitads	US$780 million**
Bread Baking	Produce bread locally in bakeries to meet growing demand in rural and peri-urban areas	Dough mixers, bread baking ovens	US$150 million
Milk Cooling	Power milk collection centers that store and cool milk from rural producers	Milk collection centers with mixers and chillers	US$1.3 billion
Coffee Washing	Pump water and run coffee-washing machines electrically, replacing diesel generators and pumps	Water pumps, coffee washing stations	US$540 million (replacing diesel-powered systems)

*Gross revenue potential from output of electric systems by 2025.

**Evolving cultural practices involving the trade of bread and injera will affect how revenue potential is realized for those sectors.

We showcase the opportunity for each of these activities to be scaled up nationally, linking with targets and projections for increased production in each area. Our analysis is limited to the potential within rural populations—specifically focused on the smallholder market share. Projections are made on a five-year basis, in line with the NEP-II target of universal energy access by 2025. Although the analysis was limited to areas that show real business potential, as shown in the example below for a small bakery, the study did not aim to demonstrate detailed business models. Instead, we focus on the appliance costs (capital costs as well as maintenance) and energy costs associated with the increased production.

EXHIBIT 5

Example of a Simplified Business Model and Revenue Streams for a Bakery

Example **Income and Outlays for a Bakery**

Breadmaking is especially viable for household businesses since it can be profitable even at the operating scale of rural smallholders. Many households already purchase flour and bake for home use; by increasing scale, bread could be produced and sold locally across the community. Furthermore, wheat and bread consumption is increasing throughout Ethiopia. A small business selling 10.8 kg of bread per day can repay the capital outlay for equipment within one year.

(Note: This does not include site-related, packaging, labor, or transportation costs)

BAKERY

Capital Outlay US$330

Tools

- Electric Dough Mixer
- Electric Toaster Oven
- Mixing Bowl
- Baking Tins
- Divider

+

Ingredients US$0.32/kg

Ingredients

- Water
- Wheat Flour
- Yeast
- Oil
- Salt
- Sugar

+

O&M Costs US$0.01/kg

Energy Costs for 2020 US$0.22/kg

=

Bread

Revenue US$0.85/kg

Profit US$0.21/kg

These values refer to the costs and revenues associated with every kilogram of bread produced assuming that a bakery produces 2.8 tons of bread annually.

Capital Outlay Investment	Annual Ingredient Cost	Annual Revenue over 5 years	Net Present Value 5 year
US$330	**US$900**	**US$2,400**	**US$3,600**

Source: Adama Science and Technology University, "Business plan on Menna Bakery."

Some of these activities could occur without—but would still benefit from—universal electrification. In some sectors, mechanization has already started using diesel equipment. However, we identify an opportunity to replace diesel equipment with electric equivalents. Replacing diesel equipment for processing would enable significant fuel savings as electric equipment is more efficient—using less energy per unit throughput—and unit electricity costs will continue to be relatively low in Ethiopia. Additionally, it will help mitigate harmful emissions from diesel use. For grain milling, national rural uptake of electric mills through 2025 represents a cumulative discounted savings opportunity of US$119 million. National uptake of electric mills alone by 2025 has the potential to save 51.6 million liters of diesel annually. Decreasing reliance on diesel also presents an opportunity for reducing imports and improving the national balance of trade. We showcase the opportunity for smallholders by replacing just one diesel mill in Exhibit 6; more detailed calculations are shown in the Appendix.

EXHIBIT 6

Cost Comparison of Diesel and Electric Milling

Example

Savings and Outlays for Replacing a Diesel Mill with an Electric Equivalent

The vast majority of grains (including maize, wheat, and teff) are milled into flour (for further processing) before being consumed. In rural areas, the majority of Ethiopia's mills run on diesel fuel, so there is a significant opportunity for overall savings through electrified milling. Savings are generated from annual savings on electricity versus diesel fuel costs. The energy consumed per unit mass of grain milled is also lower for electric mills than for their diesel equivalents.

	Electric Kalmeks Electric Mill	Diesel Changfa 1125 Diesel Mill
Power Rating	18 kW	20 kW
Throughput	1,000 kg/hr	288 kg/hr
Assumed Lifetime	5 years	5 years
Fuel Consumption *Might vary by crop type milled	0.02 kWh/kg milled	0.02 L diesel/kg milled
Energy Cost *2019	US$1.06/ton milled	US$10.76/ton milled

Source data from RMI Ethiopia Site Visits and Surveying on Appliance Usage

Capital Outlay

US$5,020

Electric mill cost: US$5,020

Diesel mill cost: US$6,536

5-year Discounted Savings

including replacement of diesel mill

US$21,080

Annual Energy Savings

through 2025 assuming grain milling rate of 449 ton/year

US$3,374

Annual electricity cost US$476

Time to Recover Capital Outlay

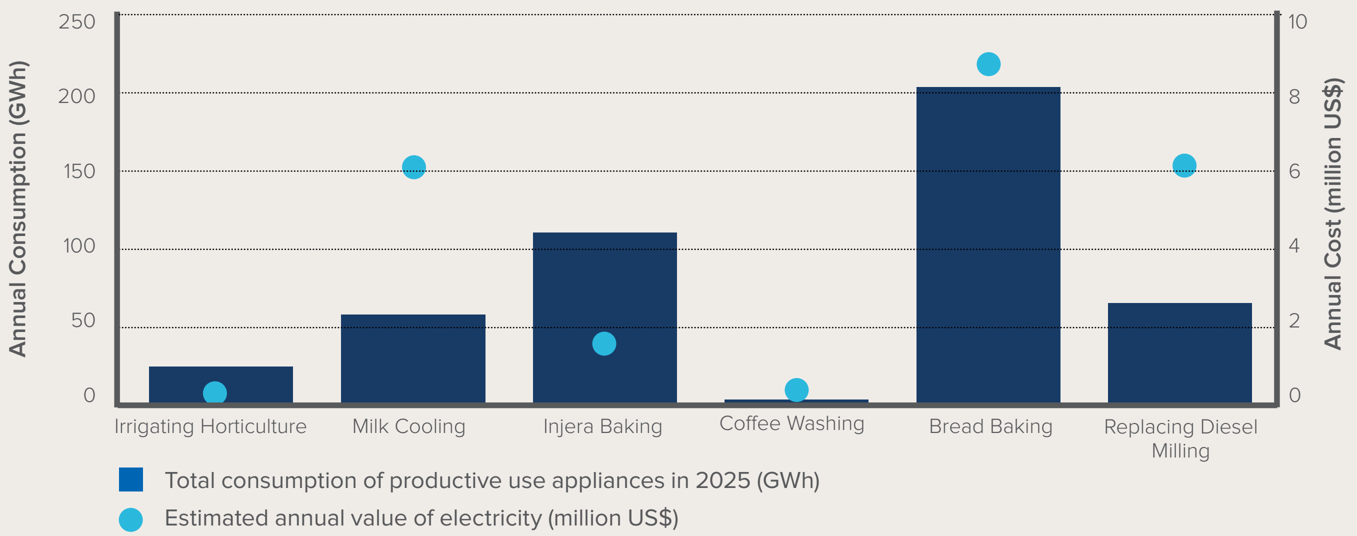
for new electric mill and replaced diesel mill

18 months

Increasing national adoption at scale of these processing opportunities also represents a potential US$22 million increase in annual revenue for the utility. Peak loads in Ethiopia are usually related to household consumption, especially in the evening. Increasing daytime loads (like agricultural processing) and introducing flexible loads (like water pumping) allow the same infrastructure to sell more power, increasing the return on assets. This is beneficial for on-grid electrification, and crucial for enabling the use of minigrids in off-grid electrification (incorporating productive uses in minigrids can reduce the cost of providing power by **over 20%**). End-use applications like those discussed above would be critical for the success of rural electrification ventures. Exhibit 8 shows a load curve for a single rural community.

EXHIBIT 7

Potential Electricity Consumption and Value from Six Value Chain Opportunities in 2025



Note that the cost of electricity varies in accordance with national tariff structures: small domestic consumers are likely to pay lower rates than larger processing activities. The actual consumption and revenue realized will vary depending on the availability of appliances and technology uptake. See Appendix for further details.

Finally, capital expenditure of $380 million would be required to acquire the electrical appliances needed to unlock this value over the coming five years. This investment need represents a significant business opportunity for local manufacturers and suppliers who can scale to meet the demand. See Appendix for further details on capital expenditure for each technology.

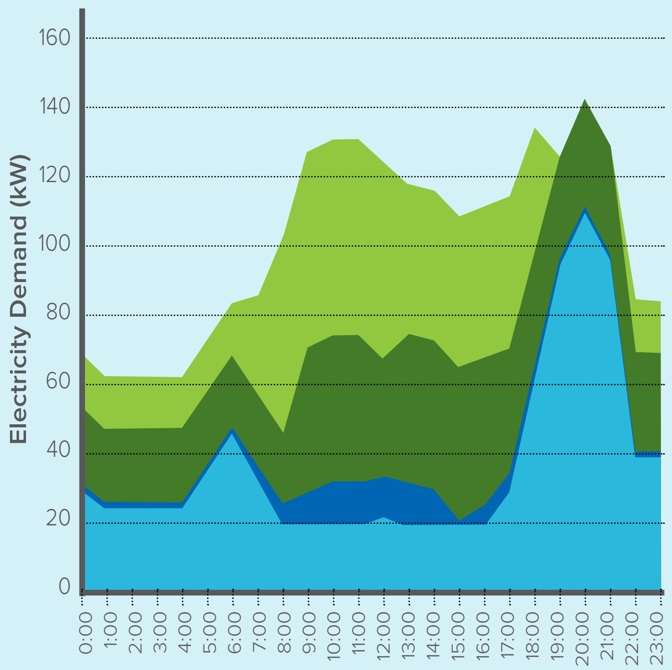
This analysis shows a snapshot of the productive use opportunity in Ethiopia across high-priority value chains. However, there are dozens of other opportunity areas across different value chains, with further economic benefit to be unlocked. RMI analysis explored the landscape of available appliances for such uses, including poultry and meat processing and welding. The synergies from electrification and agricultural productivity can play a vital role in improving livelihoods and achieving national development goals.

Example
Community Load-Curve Impacts of Productive Uses

Expected consumption of a recently electrified rural community is likely to peak in the evening, dominated by new household connections. Exhibit 8 shows the load curve of a sample community, with estimated energy consumption of electrified households, small businesses, and institutional loads. Adding irrigation pumps, grain mills, injera mitads, and bread ovens to the expected consumption (representing four of the value chains analyzed in this study) can increase the daytime consumption significantly, flattening the load profile and increasing electricity sales with little additional connection infrastructure.

EXHIBIT 8

Load Curve of a Medium-Sized Community with the Electrification of Potential Productive Uses



Modeled Energy Consumption Profiles	
Households	500 grid-connected households, of which 350 are small, 100 medium, and 50 large
Small Businesses	50 shops, 5 restaurants, 2 hotels, 1 telecom tower, 2 sawmills, 2 welders, 6 hair salons
Institutional Loads	1 health center, 4 schools, 15 domestic water pumps
Additional Productive Uses	50 irrigation pumps, 12 grain mills, 15 injera mitads, 10 bread ovens

In this case, the additional productive use load represents a 40% increase in energy units (kWh) sold for the same connection infrastructure. This energy unit sale increase would correspond to a 68% increase in income for the utility (from $48,000 to $80,000 per year, at estimated 2025 tariffs), especially as households now with greater energy usage would cumulatively pay more per unit of energy used.

Source: Aggregated site survey data collected by RMI from 2018–2020 in unelectrified sites throughout Ethiopia, complemented with regional consumption benchmarks and typical appliance specifications.

If this energy were to be provided by a minigrid, the cost of providing power would also be reduced significantly, as the daytime loads make better use of solar availability and reduce the capital expenditure required on batteries. Nighttime pumping loads could be moved to the daytime to strengthen this effect further. Previous analysis by RMI has shown the crucial role of productive uses in reducing the cost of power from minigrids.

Note that a comprehensive productive use program should address the needs of institutional loads and small businesses, as well as the agricultural applications described in the study above.

III Capturing electrification benefits will require intentional programmatic support for the productive uses of energy

In order to realize the full benefits available, provision of electricity will need to be accompanied by targeted productive use programs.

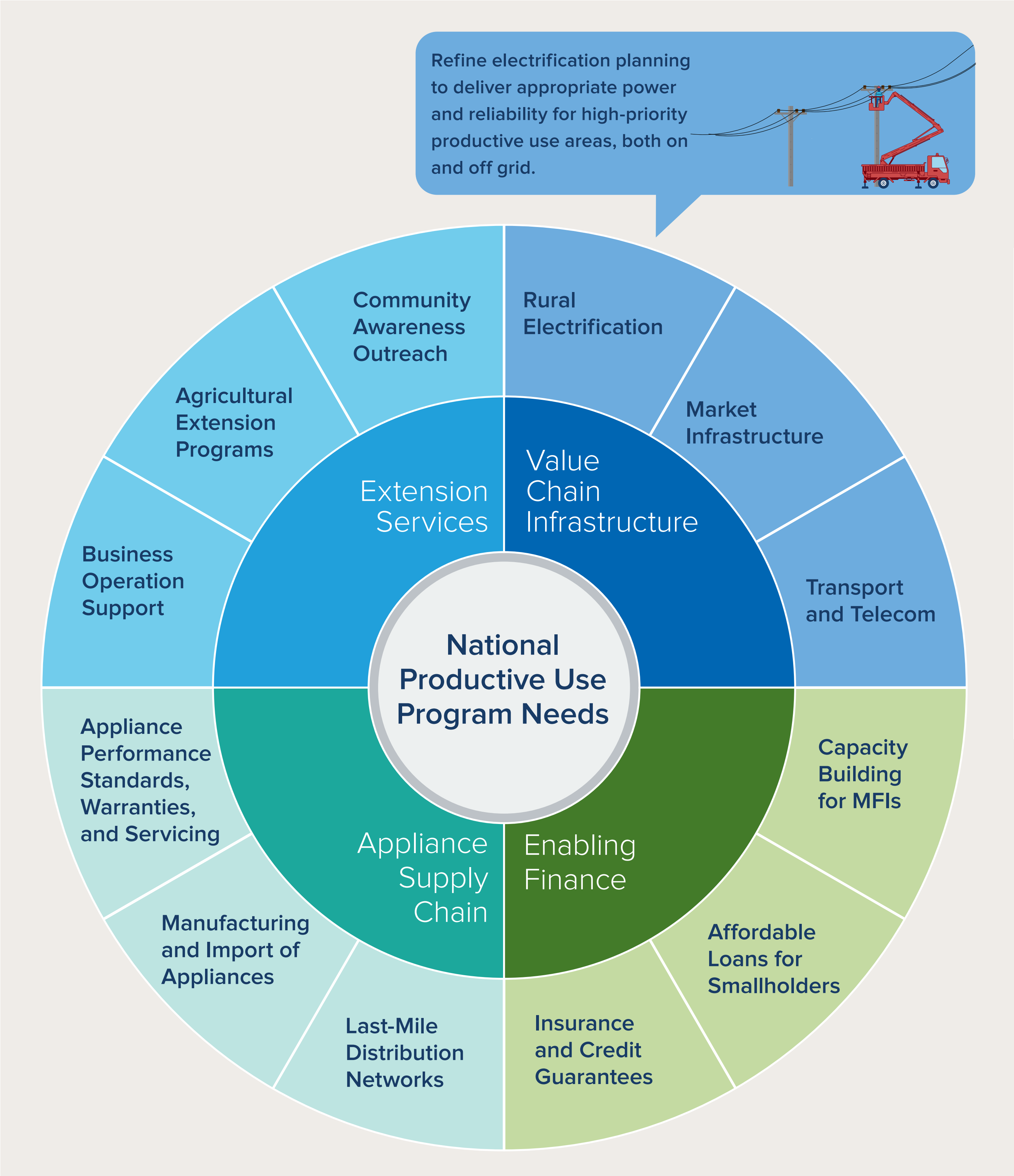
Electrification does not automatically lead to growth in the productive uses of energy. Recently electrified communities in Ethiopia often show slow load growth and limited uptake of productive use opportunities. Minigrids across Africa have overestimated the loads that will materialize after connecting new customers—often by a factor of five or more—leading to financial losses on the installed systems. On- and off-grid electrification projects in Ethiopia do not yet explicitly prioritize leveraging high productive-use potential. Careful alignment will therefore be needed for Ethiopia to capture the potential synergies between agriculture and electrification.

While there are existing markets for productive use appliances, there is significant potential for further growth in adoption. The markets that do exist are demand led, but a lack of public outreach and training mean that people in rural communities may be unaware of the opportunities or lack the expertise to develop private and cooperative businesses to exploit them. Efficient, reliable appliances are often unavailable and/or unaffordable. There are few loan products available; microfinance institutions that should offer affordable financial packages instead require prohibitive upfront payments or collateral. They are unable to guarantee performance through equipment standards and perceive these investments as high risk. Meanwhile, local manufacturers and importers supply appliances in the tens and hundreds to the few who can navigate the system, but this is negligible compared with the thousands of appliances that would be required nationwide. Explicit support is needed to overcome these barriers and grow the market.

There is an opportunity to establish a **national productive use program** in parallel with the national electrification program to help drive rapid scaling in the sector and capture the opportunities highlighted here.

EXHIBIT 9

Target Areas for a National Productive Use Program



The Government of Ethiopia is well-positioned to lead such a national program, with inter-ministerial collaboration that could include the Ministry of Finance; the Ministry of Water, Irrigation and Energy; the Ministry of Agriculture; and the agencies they oversee. In particular, the Ethiopian Electric Utility and the ATA could play key roles in the implementation of the program.

There are three immediate next steps toward the implementation of a national productive use program. These include:

- Conducting detailed studies to produce market sizing and demand-side analyses, as well as identifying any gender implications or specific barrier, in order to influence program design.
- Implementing pilot projects to test and improve aspects of the program in order to create an evidence base for scaling up (this is especially important where productive uses will be linked to minigrids, as appliance requirements may differ).
- Convening actors across the relevant sectors to pool expertise and jointly create a vision and strategy for a national program. Financial institutions, development partners, and companies involved with agricultural or appliance supply chains should participate actively in this convening alongside government entities.

These three steps will allow the framing and design of an effective, actionable national program that can deliver transformative change in a short timeframe.

Ethiopia has an opportunity to become a regional leader in the well-tailored combination and promotion of productive uses at a national level in close coordination with ongoing electrification efforts, while accelerating progress toward development goals. The scale of the opportunity is immense, as shown by this analysis across just a few areas. Designing and implementing a national productive use program is critical to increasing productivity and improving the livelihoods of smallholder farmers.

ABOUT ROCKY MOUNTAIN INSTITUTE

Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. RMI has offices in Basalt and Boulder, Colorado; New York City; the San Francisco Bay Area; Washington, D.C.; and Beijing.

IFPRI's role in this project was funded with UK aid from the UK government through the Applied Research Programme on Energy for Economic Growth (EEG), led by Oxford Policy Management. The project is being implemented in association with the CGIAR research program on water, land, and ecosystems.

RMI's work is generously supported by Good Energies and the National Postcode Lottery.

Capturing the Productive Use Dividend

Appendix

This Appendix serves as an additional set of explanatory notes and descriptions for the approaches taken in the insight brief analysis. It describes the calculations, cites the reference datasets, and briefly summarizes the assumptions, key inputs, and outputs for each value stream. The full list of references used in this study is also provided.

Irrigating Horticulture—Pump Specifications and Outputs

Irrigation pumping specifications considered, overall projected area breakdown of irrigation in Ethiopia and model outputs

Context and Approach:

This model estimates the water and energy pumping demand for irrigating target regions across Ethiopia. The Growth and Transformation Plan II (GTP-II) proposes a target to irrigate **4.1 million hectares** by 2019/2020, but recent data suggests this target has not yet been met. This analysis focuses on the associated demands for irrigating a subset of **492,000 hectares** to harvest high value crops over the coming five years. These high-value crops consist of fruits and vegetables: tomato, cabbage, red pepper, garlic, onion, avocado, mango, and banana. Irrigation pumping demands vary by crop, region, climate, altitude, and atmospheric pressure. Irrigated areas are spread across eight regions, with the greatest demands in Amhara, Oromia, and Southern Nations, Nationalities, and Peoples (SNNP) regions (Harari and Dire Dawa were not included in the analysis, as they are largely urban areas).

Key inputs

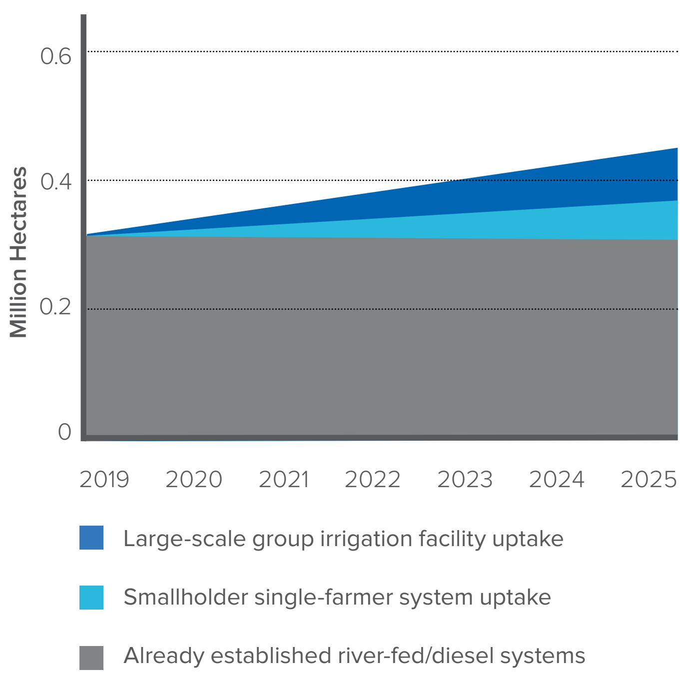
System Description	Single Farmer	Group Irrigation
Percentage of National Area	40%	60%
Distance Pumped	61 m	61 m
Elevation Gain	30 m	30 m
Well Depth	15 m	0 m
Area Coverage	0.4 ha	50 ha
Days of Irrigation Provided	5 days/wk	5 days/wk
Unit Capital Cost	US$140	US$11,000
Energy Required per Unit Mass	0.18 Wh/kg	0.03 Wh/kg
Average Power Requirement	0.03 kW (avg)	0.69 kW (avg)
Total Energy Requirement	0.45 kWh/day	8.96 kWh/day

Outputs	Values Reached by 2025
Value of Production	US$1,169 million
Total Annual Energy Consumption	26 GWh
Potential Utility Revenue	US$0.27 million
Total CAPEX Estimate	US$99 million

The following approach was used:

1. Calculate overall water demands for focus crops (on a per hectare basis for each region, thereby taking into account the effects of different rainfall levels and other conditions in each region; then for the total areas planted across Ethiopia).
2. Scale national irrigation water demand for focus crops to the specific target areas in each region.
3. Determine power requirements for pumping, and use unit irrigation specifications to scale nationally.
4. For the scale-up of crop areas irrigated, calculate increased yields and revenue earning potential.
5. Estimate annual energy demand; use benchmarks to estimate capital cost of appliances and market value of crops.

Growth and Scale-up



Irrigating Horticulture—Crop Growth Assumptions

Inputs and assumptions used for crop water demands, targeted crop areas, and projected changes in crop productivity

It is assumed that only 40% of the 4.1 million hectare irrigation target is viable for high-value crop production. Furthermore, it is assumed that 70% of the target area will be irrigated by river-fed or diesel systems, which is considered outside the scope of our analysis.

Total National Irrigation Area Target (GTP-II)	4.1 million ha
Percentage of Target for High Value Crops	11%
Percentage of Farmland with Already Established River-Fed or Diesel Systems	70%
Focus Target Area for High Value Crops (Value Reached by 2025)	0.14 million ha
Number of Planting Seasons	2 per year

Irrigation Needs Calculation

IWR = (ETc -Pc - GW - dS) / (1-LR)

IWR= irrigation water requirement
ETc = crop rate of evapotranspiration
Pc = effective rainfall = (gross precipitation - runoff and percolation)
GW = groundwater contribution
dS = change in soil water storage between planting and harvesting
LR = leaching requirement

Assumptions	
Runoff and percolation	2%
Groundwater contribution	Negligible
Groundwater contribution	Negligible

Note: Due to lack of data, certain assumptions on parameters may not hold everywhere, but sensitivity analysis shows that the high-level outcomes remain similar while varying the assumptions. For this reason, certain parameters were assumed to be negligible.

Crop	Rain-Fed Yield ton/ha	Irrigated Yield ton/ha	Market Price ETB/kg	Seasonal Water Requirement (average of regional values used) L/ha	Number of seasons with electrified irrigation	2025 target irrigated area thousand ha
Head Cabbage	6	26	5	97	2	3
Tomato	5	30	8	92	2	2
Red Peppers	2	22	12	70	2	71
Onion	9	25	8	66	2	8
Garlic	9	29	150	59	2	9
Avocado	5	5*	15	165	1	8
Banana	8	8*	28	308	1	27
Mango	7	7*	25	21	1	7

*All of the harvested area for these crops already use irrigated systems

Note: following the GTPII trends, it is assumed that the total national cultivated areas for each of these crops will match or exceed these target irrigated areas by 2025.

Bread Baking

Context and Approach:

This model estimates the potential for breadmaking through electric toaster ovens in the rural smallholder population of Ethiopia. Wheat ranks as the second most important food in Ethiopia (after maize) and accounts for 14% of total caloric intake. Ethiopia is the largest producer of wheat in sub-Saharan Africa. In 2018, the country cultivated 1.7 million hectares to produce 4.6 million tons. Yet Ethiopia has faced a national deficit of wheat (900,000 tons in 2016), and therefore national targets push for ambitious increases in national productivity to help meet local demand.

The wheat value chain presents many opportunities for electrification. Some markets are more suited to largescale production, while others are already deeply established (e.g., local beer, bread, and pasta). This analysis considers small-scale breadmaking only. The analysis calculates the overall cost, energy demand, and potential revenue associated with the uptake of small, local bakeries using electric dough mixers and toaster ovens to produce bread for local consumption.

The following approach was used:

1. Estimate overall annual bread demand for Ethiopia's rural population.

2. Use unit electric toaster oven equipment specifications to calculate power requirements, unit of scale for smallholder business.

3. Determine annual national energy demand, total capital expenditure, and market value of the output.

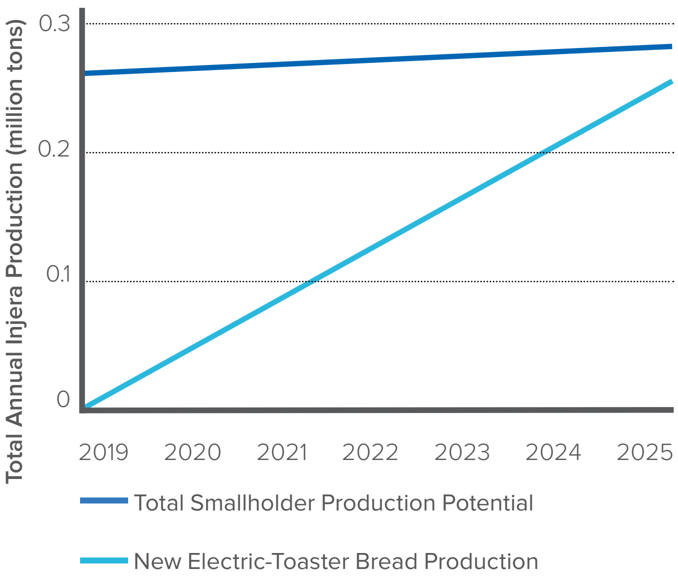
Key inputs

Per Capita Consumption of Bread (rural)	21.26 kg/yr
Bread Unit Value	US$0.85/kg
Bread Ingredients Unit Cost	US$0.32/kg
Toaster Oven And Dough Mixer CAPEX	US$279
Energy demand	0.8 kWh/kg

	2019	2025
Percentage of Target Production Upteke	0%	90%

Assumptions	
Percentage of Bread Purchased (rural)	30%
Percentage of Smallholder Bakers	50%
Annual Equipment O&M	15% CAPEX
Bread Ingredient Ratio Mix	0.83 g Wheat 1 ml Water 1.19 g Bread

Growth and Scale-up



Outputs	Values Reached by 2025
Annual Bread Production Potential	0.3 million tons
Value of Production	US$154 million
Total Annual Energy Consumption	204 GWh
Potential Utility Revenue	US$9 million
Total CAPEX estimate	US$25 million

Milk Cooling

Context and Approach:

This model estimates the value of milk cooling for increasing the flow of milk produced by smallholders into the value chain. The 2017 Ethiopia Livestock Sector Analysis (LSA) identified that the total annual cow and camel production is 5.03 billion liters, of which 80% is cow milk. Total monetary value of milk based on the average farm gate price is estimated to be US$2.8 billion, or 6.9% of the GDP of the country. Traditional smallholder production systems contribute 88% of total national cow milk production, but the LSA estimates that **only 19% of the total cow milk production (780 million liters) entered the value chain in 2013**. There is significant potential for increasing national output and a substantial need for milk collection centers in rural areas to cool the milk before it can be taken for central processing.

This analysis considers the cooling energy needs for milk to enter the value chain. Additional value addition and energy needs for processing (pasteurization, churning, making butter and cheese) are not considered.

Key inputs

Mean Cost of Milk	US$0.47/liter
Increased Production Entering the Value Chain	75%

	2019	2025
Total Milk Production Entering the Value Chain	32%	39%

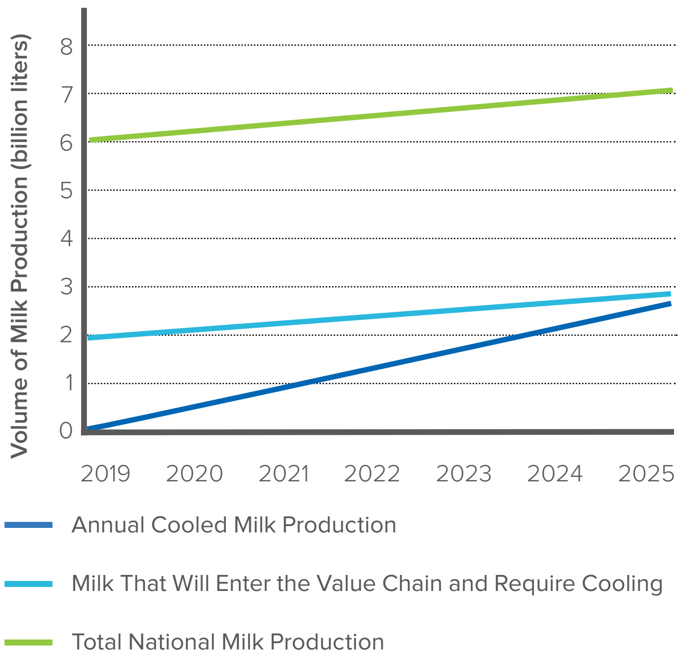
Milk Cooling	
Milk Starting Temperature	35 °C
Milk Final Temperature	4 °C

Milk Cooling Specs	
Daily Collections	2/day
Hours Operational	9 hr/day
Compressor Mean Efficiency (COP)	1.8 W/W
Specific Consumption	22 Wh/Liter
Cost of Milk Cooling Center and Genset	US$26,400
Estimated Cost Without Genset	US$22,400
Cooling Throughput	3,000 liters/day

The following approach was used:

1. Forecast increases in milk production, with an assumption that 75% of increased output can enter the value chain.
2. Calculate milk collection center unit energy demand, and cross-check with international benchmarks.
3. Estimate energy demand and capital expenditure for meeting the full cooling need of the milk in the value chain.
4. Estimate market value of milk in the value chain.

Growth and Scale-up



Outputs	Values Reached by 2025
Annual Milk Production	2,765 million liters
Value of Production	US$1.29 billion
Total Annual Energy Consumption	60 GWh
Potential Utility Revenue	US$5.84 million
Total CAPEX estimate	US$196 million

Coffee Washing

Context and Approach:

This model analyzes the potential use of electricity for coffee washing in rural areas. Coffee is one of Ethiopia's most important exports, with production of around 441,000 tons in 2019 on an area of 538,000 hectares. The largest producing regions are Oromia (with the bulk of production) and SNNPR. Approximately 30% of coffee is washed, with the remaining 70% sold as natural (unwashed). Most coffee crops are rain fed. National production has major opportunities for growth, with aggressive national targets for increasing both productivity (quintals/hectare) and total area planted. However, climate change is reducing yields and increasing competition; some farmers are switching to drought-resistant khat, for example. Demand is strong and growing in both the national and international markets. The electrification needs for the coffee value chain in rural areas are largely limited to the energy need for coffee washing. Drying is assumed to be carried out with unelectrified sun-drying and turning, while roasting is assumed to occur in urban areas closer to the final demand. This analysis considers coffee washing only.

The following approach was used:

1. Use typical coffee washing station characteristics to build a model of the energy demand for washing and water pumping.
2. Assume national output to grow at 6% annually, with a fixed 30% of coffee washed.
3. Estimate energy demand for meeting the full coffee washing need electrically, along with the value of the output.

Note: capital expenditure was not estimated, as the costs of changing from diesel generators to electric coffee washing are assumed to be low or unknown

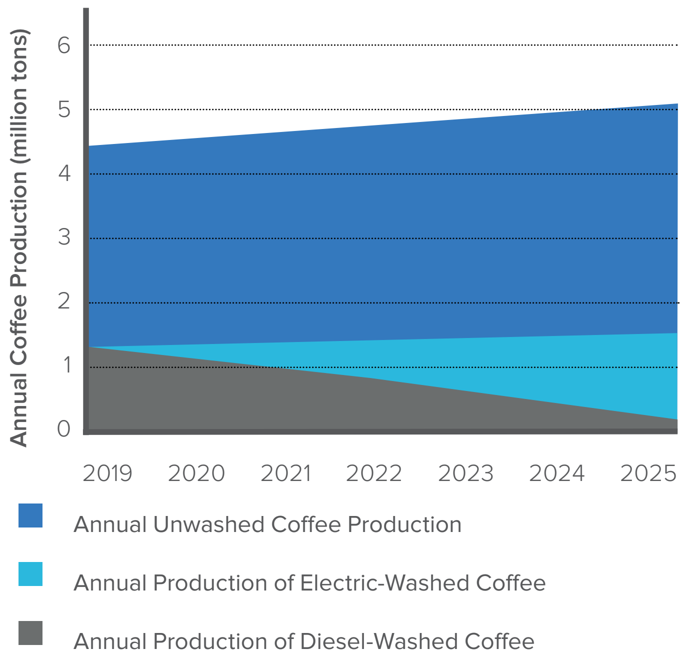
Key inputs

Percentage of Coffee Washed	30%
Production Annual Increase	2%
Annual Production Period	80 days/yr

System Description	Motor for Washing	Generator for Pumping
Peak Power Rating	4.4 kW	2.0 kW
Efficiency of Diesel Generator/Motor	25%	22%
Energy Demand	12.8 kWh/ton-coffee	14.1 kWh/ton-coffee
Production Rate	0.30 ton/hr	
Price Paid to Grower (estimated)	US$0.56/kg	

	2019	2025
Estimated Electrification of Washing	0%	90%
GTP Coffee Productivity Target	11 ton/ha	

Growth and Scale-up



Outputs	Values Reached by 2025
Annual Washed Coffee Production	0.14 million tons
Value of Production	US$541 million
Total Annual Energy Consumption	4 GWh
Potential Utility Revenue	US$0.33 million

Grain Milling

Context and Approach:

This model seeks to estimate the potential for electric milling in the rural smallholder population of Ethiopia, focusing on demand for maize, wheat, and teff. The majority of grains from these crops are milled into flour before being consumed. In rural areas, mills often run on diesel, meaning there is a significant opportunity for direct cost savings through electrified milling. Overall cost and energy demand associated with the uptake of electric milling equipment to meet the rural grain demands are calculated. The overall and specific fuel savings from the changeover to electric mills are estimated over the 2019–2025 period.

The following approach was used:

1. Estimate overall milling demand for focus crops (maize, wheat, teff) in the target rural population of Ethiopia.
2. Use unit milling equipment specifications to calculate power requirements and a unit scale of business.
3. Determine annual national energy demand, capital costs of changing existing systems, savings at scale.

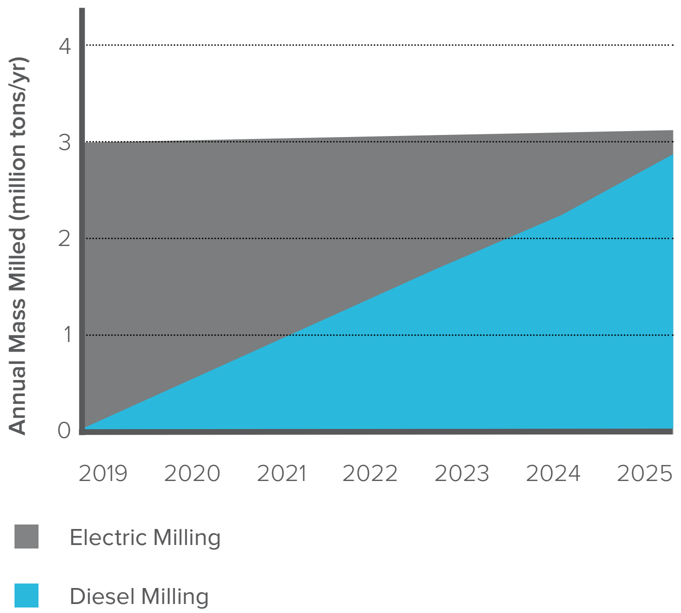
Key inputs

	Diesel	Electric
Capital Cost of Mill	US$6,535	US$5,020
Hourly Throughput	288 kg/hr	1,000 kg/hr
Power Rating	20 kW	18 kW
Efficiency	70%	80%
Fuel consumption	0.02 L-diesel/ kg-milled	0.02 kWh/ kg-milled

Assumptions	
Percentage of Maize Production Milled	80%
Percentage of Teff Production Milled	95%
Percentage of Wheat Production Milled	75%
Percentage of Grain Milled in Rural Areas	20%

	2019	2025
Percentage of Target Production Uptake (percent of all grain milling in rural areas)	0%	90%

Growth and Scale-up



Outputs	Values Reached by 2025
Five-Year Savings per Unit	US$30,238
Annual Production Potential	3.3 million tons
Total Discounted Savings	US$119 million
Total Annual Energy Consumption	67 GWh
Potential Utility Revenue	US$6 million
Total CAPEX Estimate	US$51 million

Injera Baking

Context and Approach:

This model estimates the potential for use of electric cookers (mitads) to make and sell injera in the rural smallholder population of Ethiopia. Teff is one of Ethiopia's most important crops. It is most used for the staple injera bread, which is consumed in households nationwide and generated almost US$10 million in exports in 2015. In 2018, teff accounted for the largest area cultivated at 3 million hectares, and second-largest crop production of 5.3 million tons in 2018. Teff is a key cash crop. Production is centered around middle elevation regions with adequate rainfall. Teff is considered to be a lower risk crop due to its resilience against adverse weather conditions. This analysis considers small-scale injera production, where electric *mitads* can be used to replace wood-burning injera cookers and produce for sale. The analysis estimates the overall cost, energy demand, and potential revenue associated with uptake of electric *mitads* in businesses.

The following approach was used:

1. Determine overall wood mitad usage in rural smallholder injera sellers of Ethiopia.
2. Use unit electric mitad equipment specifications to calculate power requirements, unit of scale.
3. Determine annual national energy demand, annual CAPEX, revenue at scale.

The traditional custom In Ethiopia is to give injera to others rather than sell it. Nonetheless, across urban and peri-urban—and quickly spreading to rural—areas there is a fast-growing market for buying and selling injera. This analysis estimates injera sales in rural areas using the only available injera business data for Ethiopia.

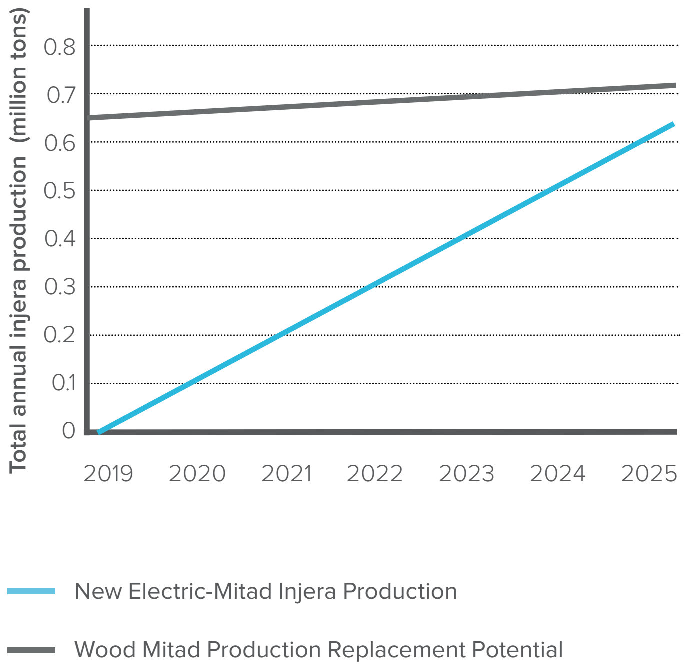
Key inputs

Per Capita Purchase of Injera (rural)	7.44 kg/yr
Injera Unit Value	US$1.72/kg
Teff Unit Cost	US$1.15/kg
Mitad CAPEX	US$30
Energy Demand (high efficiency mitad)	0.17 kWh/kg
Daily Injera Production	17.30 kg/day

	2019	2025
Percentage of Target Production Uptake (percent of all injera produced in rural areas using wood mitads)	0%	90%

Assumptions	
Electric *Mitad* O&M	30%
Lifetime	5 years
Unit Mass	1.15 kg
Injera Ingredient Ratio Mix	100 g Teff 236 ml Water 236 g Injera

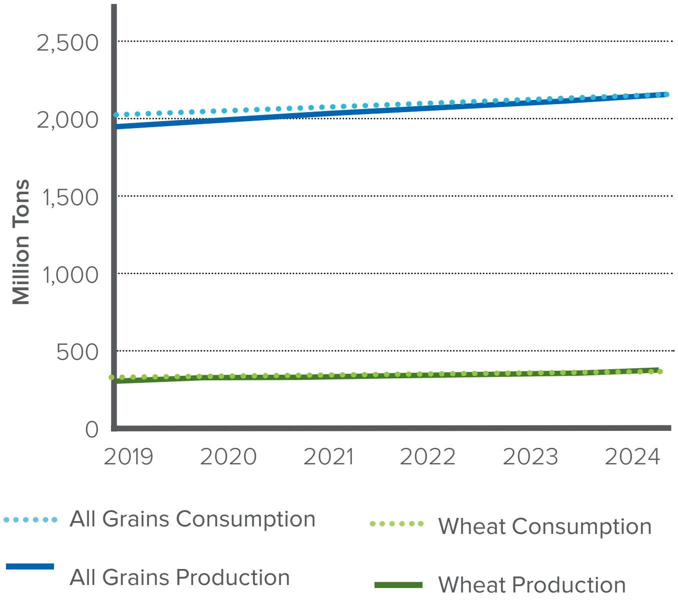
Growth and Scale-up



Outputs	Values Reached by 2025
Annual Injera Production Potential	0.6 million tons
Value of Production	US$776 million
Total Annual Energy Consumption	112 GWh
Potential Utility Revenue	US$1 million
Total CAPEX Estimate	US$4 million

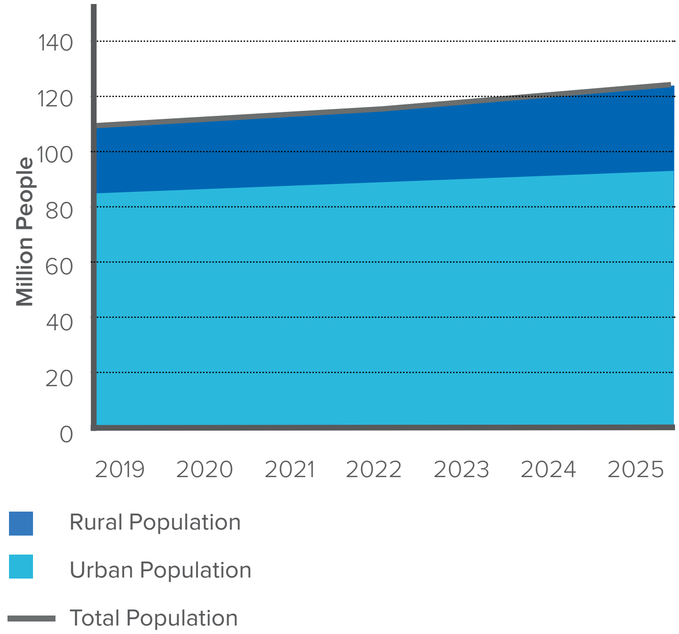
Overarching Assumptions

Global Grain Supply/Demand 5-year Projections



Source: IGC five-year baseline projections of supply and demand, 2019

Ethiopia Population Trends



Source: UN Population Dynamics Database, 2019

Tariff Rates

	Monthly Consumption kWh	2018 ETB/kWh	2019 ETB/kWh	2020 ETB/kWh	2021 ETB/kWh	Annual Rate Increase ETB/kWh
Domestic Tariff Classes						
1	50	0.27	0.27	0.27	0.27	0.00
2	100	0.46	0.56	0.66	0.77	0.10
3	200	0.78	1.06	1.34	1.63	0.28
4	300	0.91	1.28	1.64	2.00	0.36
5	400	0.98	1.38	1.79	2.20	0.41
6	500	1.04	1.50	1.95	2.41	0.45
7	500	1.14	1.59	2.03	2.48	0.45
General Tariff Class (flat rate tariff)						
8	n/a	1.04	1.40	1.76	2.12	0.36

http://www.eeu.gov.et/index.php/current-tariff

Notes

- Annual rate increase is assumed through 2025
- For the domestic tariff classes, individual customer energy costs are calculated in the following way: Out of the total energy units (kWh) used in the month, the first 50 kWh are charged at the Tariff 1 rate; the next 100 kWh are charged at the Tariff 2 rate; the following 200 kWh are charged at the Tariff 3 rate… and so on up to Tariff 7, or until all of the remaining energy units are covered.

Discount Rates

This analysis assumes a discount rate of 6% for all calculations.

The last recorded discount rate for Ethiopia (1995) was 14.28%. More recent discount rates were found for sub-Saharan African neighbors Kenya (7% in 2010) and Uganda (14% in 2010), as well as for Nigeria (4.25% in 2010) as benchmarks. Accounting for Ethiopia's aggressive economic growth, we assume that a representative discount rate would lie near to the median of the benchmarks listed. Furthermore, given that all monetary calculations are quoted in US dollars (the United States' discount rate of 2.25% in 2019 signals that this currency is less prone to fluctuation), a slightly lower-than-median value within the range of benchmarks was adopted.

Diesel Costs

In order to provide conservative savings estimations, this analysis assumes that diesel costs remain constant through 2025 at US$0.62 per liter.

CAPEX Estimates

Capital outlays quoted reflect 2019 RMI survey findings for equipment prices in Ethiopia. Yet, Ethiopia's appliance landscape is still nascent and equipment prices will continue to respond to increasing demand and supply chain growth.

Overview of Crop Types Considered for Prioritization of Value Chains

Crop	Area Planted million ha	Number of Planters million	Production million quintals	Export Earnings million US$
Cereals	**9.7**	**30.4**	**255.4**	**18.5**
Teff	3.0	6.8	52.8	-
Barley	1.0	3.5	20.5	-
Wheat	1.7	4.2	46.4	6.6
Corn	2.1	10.6	84.0	11.4
Sorghum	1.9	5.4	51.7	0.5
Pulses	**1.6**	**8.3**	**29.8**	**116.6**
Soybeans	0.0	1.0.1	0.9	20.7
Oilseeds	**0.8**	**3.3**	**8.6**	**352.0**
Coffee	**0.7**	**5.0**	**4.5**	**704.0**
Vegetables	**0.2**	**6.7**	**7.4**	**4.9**
Red Pepper	0.2	2.3	2.6	1.1
Cut Flowers	**-**	**-**	**-**	**206.8**
Chat	**0.3**	**2.9**	**2.4**	**unknown**

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