Productive Uses of Energy in Ethiopia

Agricultural Value Chain and Electrification Feasibility Study

March 2021

Funder:	The IKEA Foundation
Assignment:	This project aims to demonstrate a dramatic increase in the efficacy of rural electrification programs in stimulating local economic development through a community and end-user-centric program design and implementation process that links rural electrification with agricultural productive use.
Reference number:	G-1908-01384
Program Manager:	Shambhavi Sharma

Deliverable:	Project Report: Productive Use of Energy in Ethiopia—Agricultural Value Chain and Electrification Feasibility Study
Developed by:	RMI
Authors:	Scarlett Santana, Zihe Meng, Kester Wade, Patience Bukirwa, Francis Elisha
Date:	31st March 2021

About RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

Table of Contents

Executive Summary

The major institutions in the Ethiopian energy space and the agencies that support them recognize that productive use of electricity is key to achieving national targets of universal electrification.[i] Yet, there is less alignment on which activities to electrify and what support is needed to enable adoption of productive uses throughout rural communities in Ethiopia. This alignment is critical to efficiently support projects and initiatives that successfully push productive uses forward.

This study builds a shared understanding of and a common language to assess opportunities for productive use. Specifically, it identifies opportunities to electrify agricultural productive uses today, how they can be developed through feasible business models, and the strategies and initiatives stakeholders can use to overcome barriers to deployment.

But the approach used is just as important as the questions asked. Productive use initiatives must respond to end-user needs to be successful. Our analytical approach recognizes ground realities to ensure that recommendations connect to end-user needs. To do so, the study explores prevalent activities, community practices, and economic returns that indicate demand and local capacities in and potential benefits for rural communities. We also consult directly with end-users through field surveys as well as through planned field visits and community workshops in the next stage of the project.

Grain-flour milling is economic to electrify today.

There is an immediate opportunity to electrify diesel-fuel milling for various crops in rural Ethiopian communities. Grain flour milling, particularly for maize and wheat, uses inputs that are produced in high volumes and that are already commonly mechanically processed before sale into robust local markets. This opportunity requires little to no market development support to be implemented today and at widespread scale. This potential is further strengthened by the opportunity to use multi-crop milling equipment to broaden the local processor's business opportunity and reduce market risk (see **Section 3**).

This study considered five value chains across Amhara, Oromia, and Southern Nations, Nationalities, and Peoples Region (SNNPR), including more than 250 field interviews with community heads, farmers, processors, and traders in more than 51 rural communities. It also included an extensive literature review and interviews with sector experts (see **Section 2**). Based on this data collection, we evaluated value chain activities with electrification potential for each crop across four dimensions: existing local capacity for the activity, presence of a market for the product, availability of electric equipment and ease of retrofitting electric components, and scalability of the activity.

Considering these factors, prospective productive use activities can be divided into three tiers based on their readiness for electrification and implementation. **Exhibit ES1** shows this prioritization:

---

[i] The National Electrification Program 2.0 (2019), developed by the Ministry of Water, Irrigation, and Energy (MOWIE) explores the agriculture-energy nexus and establishes high-level strategies to explore and develop productive uses. MOWIE and the Ethiopia Electric Utility Company (EEU), with support from the World Bank, will electrify productive uses of energy to accelerate universal electrification through the USD 500 million Access to Distributed Electricity and Lighting in Ethiopia (ADELE) Project.

Tier 1 indicates immediate readiness for deployment, *Tier 2* indicates strong medium-term potential with support to overcome one or more barriers, and *Tier 3* indicates longer-term potential if additional barriers are addressed. Section 3 describes this analysis in greater detail, and Appendix A includes a thorough review of individual crops and their associated activities.

Focus Crops	Priority Value Chain Activities for Electrification with Minigrids					
	Mechanical Threshing and Cleaning	Mechanical Hulling	Flour and Meal Milling	Mechanical Drying	Other	
Maize						
Wheat						
Teff					Injera making	
Barley					Brewing	Malting
Dairy					Butter making	Milk Chilling

Tier 1 Immediate	Tier 2 Medium-Term	Tier 3 Long-Term

Exhibit ES1: Summary of Tier Classifications for Value Chain Activities across Five Crops Analyzed in the Study

The study finds that electrifying grain milling almost halves energy costs and doubles profit margins (Section 4). Although these results are based on reported volumes from field surveys, our research suggests sufficient levels of grain production to meet the break-even threshold within most rural communities in Ethiopia. Electrifying grain milling can also improve minigrid economics, boosting revenues and reducing cost of service by 8%–13% depending on the time of use or seasonality of loads.

A fee-for-service business model connects processors with knowledge and support to seize this economic opportunity.

A fee-for-service business model builds upon widely prevalent practices and brings together actors commonly found in the Ethiopian agriculture space (Section 5). Importantly, it relieves the energy service provider from assuming an additional burden at this nascent stage of the minigrid market. The fee-for-service model is led by a facilitator who enables processors to invest in equipment by educating processors and linking them with finance providers who make an equipment loan (or lease) to the processor. While the processor is ultimately responsible for the credit and operational risk, the facilitator builds awareness about the investment opportunity and provides business development training to support loan applications and equipment selection.

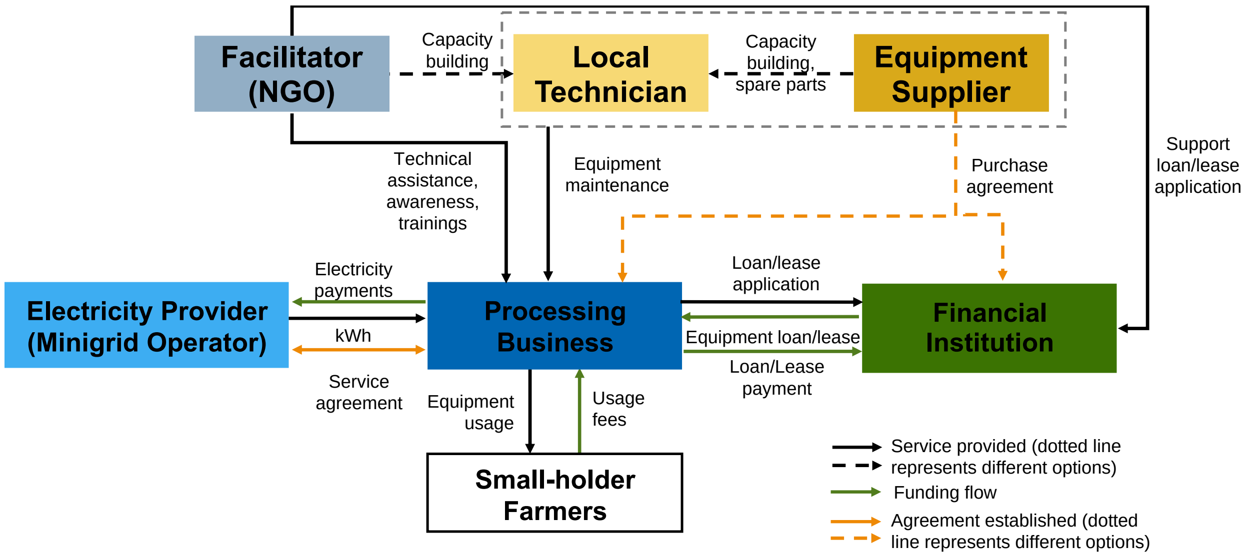


Exhibit ES2: Institutional Arrangements of the Fee-for-Service Business Model

We also explore utility-led and cooperative-based business models. These models may be appropriate to develop new activities that are not yet widespread in rural communities and will require additional development support but may not be suitable for widespread adoption. Nonetheless, the team will further explore, test, and refine this prioritization and specific designs through community consultation.

Although these business models address the capacity and knowledge gaps limiting processors from adopting electric equipment, there are broader systemic barriers and prerequisites that lie outside of the control of community-level actors in the business models. These barriers and prerequisites must be addressed to make these business models feasible.

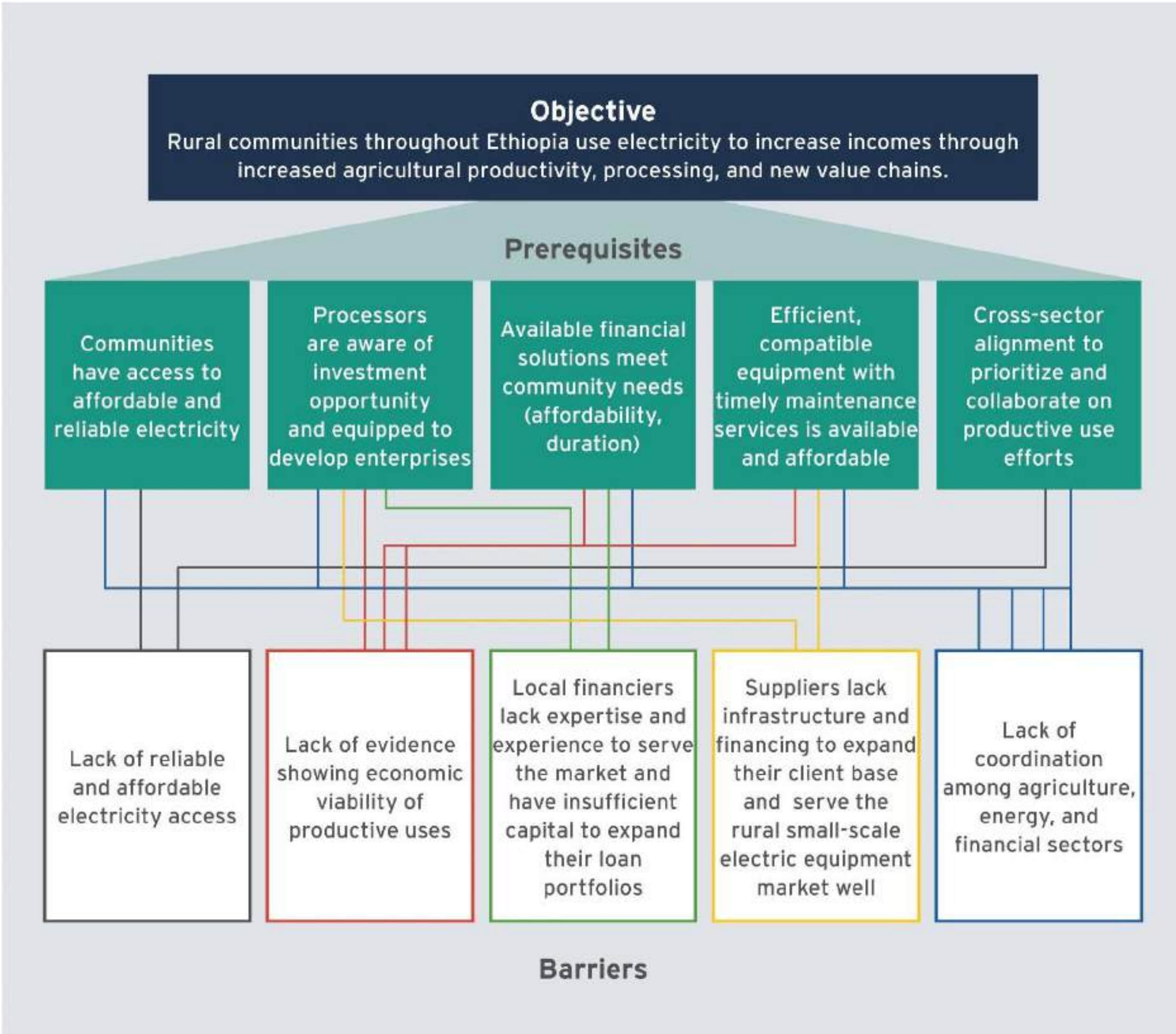


Exhibit ES3: Mapping of Prerequisites and Barriers to Scale Productive Uses

The National Productive Use Program achieves the prerequisites to scale productive uses.

We propose a preliminary design of the National Productive Use Program to achieve the following prerequisites for electrifying productive uses at scale **(Section 6.1):**

Prerequisite 1: Communities have access to affordable and reliable electricity. Affordable and reliable electricity access is the foundation for electrified productive uses. A would-be processor will not be willing to invest in electric equipment if she or he does not think they can sufficiently operate the equipment to recover their investment. Nearly all experts we consulted and over 80% of agro-processors we surveyed noted the lack of reliable electricity to operate equipment as the most or second most important barrier rural entrepreneurs face.

Prerequisite 2: Processors are aware of investment opportunities and equipped to develop enterprises. There is limited precedent to show the economic viability of electrified agro-processing businesses in rural regions. Without robust examples showing the technical and financial viability of electric equipment in rural communities, processors will be unwilling to invest in electric equipment. Beyond the desire to purchase electric equipment, processors also need to be aware of the opportunities available to finance equipment and have the skills to select equipment and develop a business plan.

Prerequisite 3: Available financial solutions meet community needs. About 60% of survey respondents identified lack of access to credit among the top two barriers preventing them from upgrading their business and only 2 of the 63 grain millers we surveyed had obtained a loan in the past. Most local finance providers do not serve the appliance financing market for agricultural productive uses in rural areas.

Prerequisite 4: Efficient, compatible equipment with timely maintenance services is available and affordable. Additional research is needed to test locally available electric equipment to ensure compatibility with minigrid systems, operator requirements for efficiency, and end-consumer product preferences. Equipment suppliers we consulted noted difficulties in providing prompt repairs in remote areas. This risk of delays in repairs and foregone revenues will demotivate would-be processors from purchasing equipment.

Prerequisite 5: Cross-sector alignment to prioritize and collaborate on productive use efforts. As noted previously, there is a lack of awareness and alignment on which opportunities for productive use to prioritize and a lack of coordination among stakeholders in the agriculture, energy, and financial sectors to mobilize investment.

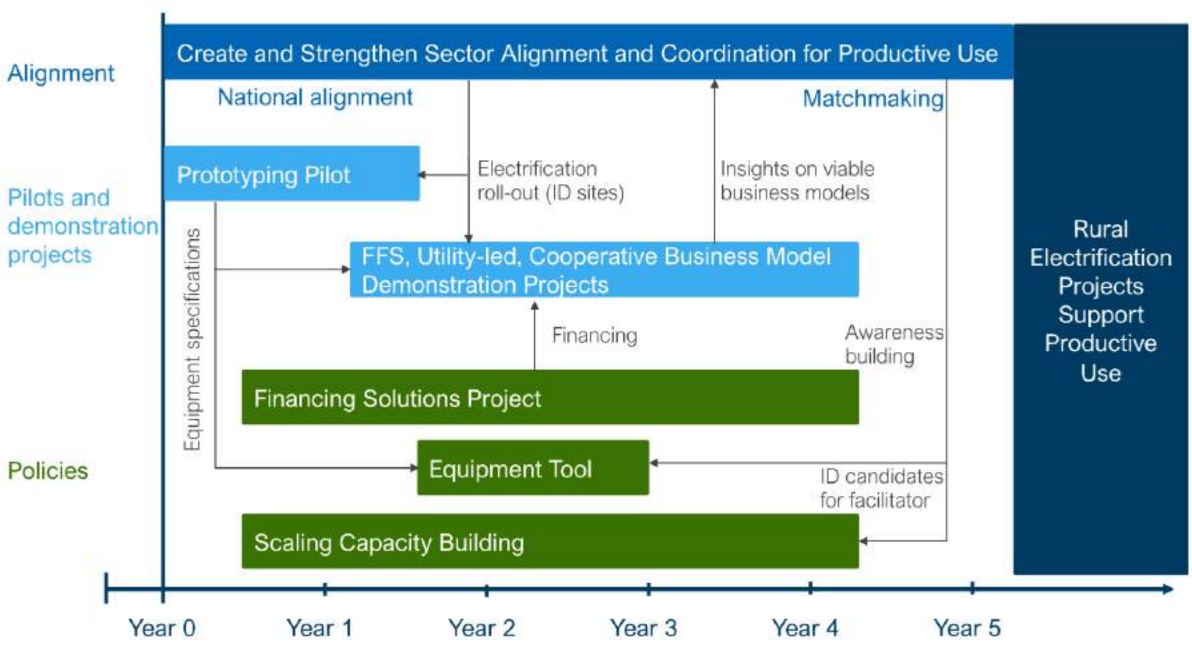


Exhibit ES4: Preliminary Design of National Productive Use Program

We propose a preliminary National Productive Use Program **(Section 6.2)** that ensures these prerequisites are met by aligning cross-sectoral actors, generating an evidence base, and developing supportive policies. The program is made up of the following projects and scaling mechanisms:

Align and connect cross-sectoral actors. The *Create and Strengthen Sector Alignment and Coordination for Productive Use* project will open dialogue across the energy, agriculture, and finance sectors to identify opportunities to develop productive uses. The discussion and coordination between stakeholders will build awareness to oversee the National Productive Use Program and enable partnerships to implement productive use opportunities.

Prove and demonstrate the viability of equipment and business models. A series of pilots and demonstration projects will build the evidence base to show the technical and financial viability of equipment and business models. The *Electric Mill Prototyping Pilot* will fine-tune and field-test equipment in minigrid communities and establish the specifications to ensure equipment compatibility with minigrid systems and equipment operator and end-consumer preferences. The *business model demonstration projects* will recruit private actors to implement recommended business models around Tier 1 activities and demonstrate financial viability. The demonstration projects will seek to de-risk investment in electric equipment by bringing in private actors to understand and gain experience participating in the business models and reduce perceived risks.

Develop supportive policies for an enabling ecosystem. Technical advisory, capacity building, and funding support will lubricate the ramp-up of productive uses in specific hubs through the pilots and demonstration projects and then provide the platform solutions needed to replicate productive uses in rural communities across Ethiopia. The *Designing and Piloting Financial Solutions* project will provide technical advisory and funding to equip finance providers to serve the equipment financing market. The *Electric Equipment Selection Tool* and *Scaling Capacity Building* projects will develop platform tools and materials to support in equipment selection and partnership decisions.

The next steps to finalize the National Productive Use Program focus on ground consultation and field testing.

Going forward, the team will pull in cross-sectoral input and pilot findings to finalize, build consensus on, and propel momentum for the National Productive Use Program, the ultimate deliverable of this project (Section 7). To do so, the team will lead three scopes of work:

1. Carry out community and national consultation (Design Sessions). The Design Sessions will use a three-tiered approach for connecting with end-users. The first two tiers will focus on connecting with end-users to understand the barriers and opportunities at the community level. Together these tiers will lead to the design of highly actionable community solutions and projects rooted on ground realities and priorities. The third tier will convene national level stakeholders to build on and connect these community-level solutions with top-down broader actions to support and scale implementation of community-level projects. Throughout the execution of these tiers, the team will facilitate discussions with end-users and co-producers to build on the preliminary design presented in this study and finalize the National Productive Use Program.
2. Implement a Data Pilot to build a database and insights to estimate potential load and revenue growth for a minigrid system serving milling loads, and better understand milling

profitability and end-consumer preferences. The team will use this information to fine-tune the financial models and design of the pilots and demonstration projects proposed in the preliminary productive use program.

3. **Disseminate study results.** The team will lead cross-sectoral engagement across the agriculture, electricity, and finance sectors to share results, build consensus, and connect projects to actors and funding to prepare for implementation.

1 Introduction

Driving community economic development and sustainable energy access requires rural electrification to be linked with programs that support using electricity for income-boosting activities. Today in Ethiopia there is a recognition of this need, but no understanding of how best to create a national productive use program that effectively links agriculture with electricity provision.

The IKEA Foundation and RMI partnered to build an evidence base for and demonstrate how to link rural electrification with economic development. This study is the first step to achieve that outcome. The study maps value chains at the national scale to pick activities to prioritize for electrification. The main body of the report summarizes the study, and a series of appendices provide much greater depth of analysis, data, and recommendations for policymakers and program implementers to explore.

- **Section 2—Study Scope and Data Collection Approach** provides context on the geographic and topical scope of our research and the approach to data collection.
- **Section 3—Value Chain Analysis** presents an overview of the five agricultural value chains included in the study, the methodology used to prioritize them, and which Tier 1 activities in the value chains are immediately ready for electrification and implementation at scale. The companion **Appendix A** presents an in-depth analysis of all value chains and full assessment of electrification opportunities.
- **Section 4—Economic Viability of Electrifying Tier 1 Processing** evaluates the economic viability of electrifying grain milling from a processor and a minigrid perspective. Although the study assesses the economic impact on minigrid performance, many of the same takeaways would also apply for grid electrification. The companion **Appendix B** presents further economic analysis along with the methodology and assumptions used to prepare the financial models.
- **Section 5—Business Model Design** presents two business models that provide processors and minigrid developers with the knowledge and support to invest in electric processing. The companion **Appendix C** presents a third model that may be suitable for niche opportunities.
- **Section 6—Preliminary Design of the National Productive Use Program** maps the key barriers preventing and prerequisites needed to enable the adoption of productive uses at scale in Ethiopia. The section builds on this mapping and the insights of previous sections to propose a preliminary design of the National Productive Use Program. Companion **Appendix D** presents a more detailed description of the projects included in the preliminary design.
- **Section 7—Next Steps to Finalize and Align Sector on the National Productive Use Program** provides the steps the team will pursue to build consensus on and finalize the National Productive Use Program. This section also describes the Data Pilot that will enable the team to fine-tune the financial models and refine the design of the pilots and demonstration projects in the preliminary productive use program.

2 Study Scope and Data Collection Approach

2.1 Community Engagement

Community consultation plays a significant role in this study and the overall project. Indeed, an effective productive use program must deeply understand and respond to the needs and priorities of end-users who will develop productive uses at the community level. This study has connected with end-users via field surveys to determine the right activities to prioritize for electrification, ensuring we pick activities with proven demand that are prevalent and feasible in local communities. These field surveys also informed our understanding of realities on the ground to identify barriers preventing the adoption of productive uses as well as to design the business model and preliminary projects that can address these barriers.

Going forward, community consultation will continue to form an integral part of the project. We will consult community members via design sessions to test and improve upon our preliminary recommendations. This will help us define highly practical community-based solutions and projects and connect these to wider networks of professionals and support systems via the dissemination seminars.

2.2 Study Scope

This study focuses on five value chains: maize, teff, wheat, barley, and dairy. The Government of Ethiopia identifies these shortlisted value chains as high priority in achieving agricultural development targets.[1] Most of these value chains are prevalent in rural communities.

Exhibit 1 shows that the dairy, teff, maize, wheat, and barley value chains are produced in high volumes nationally. To capture the state of agricultural practices across regions, our study includes survey findings from rural communities across Amhara, Oromia, and Southern Nations, Nationalities, and Peoples Region (SNNPR)—three of the four top-producing regions for each value chain we studied as depicted in Exhibit 1.

Value Chain	Producers (millions)	Annual Production (million quintal)	Top-Producing Regions
Maize	11.5	96.4	1. Oromia 2. Amhara 3. SNNPR
Wheat	4.9	48	1. Oromia 2. Amhara 3. SNNPR
Dairy	N/A	5.7 billion liters	1. Oromia 2. Somali 3. SNNPR 4. Amhara
Teff	7.2	57.4	1. Oromia 2. Amhara 3. SNNPR
Barley	3.9	23.8	1. Oromia 2. Amhara 3. SNNPR

Exhibit 1: Production, Number of Producers, and Top-Producing Regions for Selected Value Chains.

Note: The Government of Ethiopia has prioritized increased productivity for all these value chains in the 2016 National Growth and Transformation Plan.[2] Ethiopia's Agricultural Transformation Agency (ATA) has also prioritized teff, wheat, barley, and maize crops in the Agricultural Commercialization Clusters (ACC) program, which connects farmers to agricultural inputs and markets.[3]

For each value chain, we assess opportunities for electrification that are viable for both minigrid companies and local agro-entrepreneurs. We evaluate the current state of processing activities, and future potential for electrifying these activities. To support our findings, we collected data across specific themes for each shortlisted value chain:

- Production characteristics, including how national production has evolved, and the current state of interventions for increasing productivity. We evaluate the volumes and stability of raw material supplies for processors in the value chain.

- **Processing activities**, in particular highlighting post-harvest processing steps that are necessary for converting raw materials to consumable products. We also determine where processing is concentrated in Ethiopia.[ii]
- **Losses**, including factors that exacerbate losses and potential interventions to limit spoilage. We determine whether processing steps can help mitigate losses by understanding when and where losses occur.
- **Demand**, focusing on the products that rural consumers prefer and corresponding processing requirements in rural communities.
- **Local trade**, using trade flow data in rural communities to evaluate whether processing takes place locally in rural communities.
- **Opportunities for electrification**, identifying and evaluating the processing steps best suited for electrification.

After validating high potential processing activities, we provide an outlook to implementation strategies for testing and capacity building. For shortlisted activities that we find best suited for electrification across target value chains, we assess the economic viability of potential or existing businesses and identify financially viable activities that are ready for further testing. At this point the study switches gears toward determining implementation strategies for testing prioritized activities and designing a national productive use program. We adopt a forward-looking approach to identify strategies that enable an ecosystem that supports productive uses. We design business models and propose a preliminary national productive use program that will serve as the platform for brainstorming with community and national level stakeholders during the next project stage.

2.3 Data Collection Approach

This comprehensive data collection exercise draws upon existing information and incorporates newly collected data. We gathered information in three ways:

- **Field Surveys**—To deeply understand on-ground and local context, we conducted field surveys in rural communities across Amhara, Oromia, and SNNPR. Data was collected in 51 *kebeles* across these regions from November through December 2020.[iii] Local enumerators from the Frontieri Survey Firm conducted 259 field interviews using the Survey Solutions tablet-based interviewing tool. Further details are discussed below.
- **Literature Review**—In designing this study, we leveraged the combined knowledge of existing agricultural value chain research in Ethiopia to understand the national and regional dynamics for each value chain we studied. We performed an exhaustive review of available

[ii] We focus on post-harvest processing activities because they have the strongest potential for electrification in the short term. Based on our survey findings, distances from community centers to farm fields are on average 3.4 km and can range up to 8.4 km. Connecting distribution lines to power minigrid-connected equipment on farm fields is expensive. Electrifying these activities would require developing new or testing early-stage electric equipment that can be charged in the community center and used in the fields. These early-stage opportunities would require more time to develop and are not quick-win opportunities that are already proven commercially viable and can be deployed at scale. So, mechanized farming activities are generally not suitable for electrification in the short term.

[iii] A kebele is the smallest administrative unit of Ethiopia.

literature, including 155 primary literature sources; the **Endnotes** section presents a full bibliography.

- **Expert Interviews**—Experts played a key role in connecting us to resources, validating our findings and observations, and calibrating our analysis and proposed solutions. We interviewed and sought feedback from key stakeholders across Ethiopian agriculture and energy sectors. These included non-governmental organizations, development partners, microfinance institutions, and government agencies.

2.3.1 Survey Details

Field surveys were critical to validate analysis of agricultural value chains in rural Ethiopia. We designed an extensive survey questionnaire to target four types of value chain actors: community champions, farmers, agricultural processors, and agricultural traders.[iv] When we noted the limited prevalence of women in the value chains, we also interviewed women close to but not involved in agricultural businesses to better understand the activities they would be most interested in.

Exhibit 2 shows a count of the interviews conducted along with example questions for each respondent class.[v] The full questionnaire is included in **Appendix G**.

We prioritized collecting data in communities that were representative of prospective minigrid sites and demonstrated potential for productive uses. We reviewed the Least Cost Electrification Plan established in accordance with the National Electrification Program 2.0 to prioritize communities that were classified for medium-term grid extension. These communities are third in priority for grid extension and will not be grid-connected before 2030.

We also identified high production zones of our crops of study using data on crop production at the zone level from the 2020 CSA Agricultural Sample Survey.[4] We then identified *woredas* within these zones that produce significant volumes for at least two of our target value chains using Frontieri's proprietary databank.[vi]

The team then reached out to representatives of Regional Agricultural Bureaus and other local institutions to validate these woreda-level findings and identify recommended kebeles within these woredas to visit. The team selected 51 kebeles to visit based on points of intersection identified by overlapping the geospatial data layers of minigrid-suitable communities and priority agricultural kebeles.

Key characteristics of these communities included:

- **High agricultural production.** We identified communities that were high volume producers of our value chains of study.

[iv] Community champions are defined as leaders or representatives of a community who know the community well and can provide high-level information about residents, issues, and local economic activities.

[v] We prioritized interviewing processors to understand how post-harvest processing activities occur in minigrid-suitable communities. Therefore, enumerators interviewed more processors than any other respondent type.

[vi] A woreda is an administrative unit in Ethiopia that is usually equivalent to a district.

- **Size.** Communities surveyed had a median size of 320 households, with a maximum of 5,000 households.
- **Infrastructure.** Approximately 90% of the communities surveyed had cell phone service, and enumerators prioritized communities with maintained road passageways.[vii]
- **Energy access.** We prioritized minigrid-suitable communities in this study: those that were not grid-connected at the time and were not immediately shortlisted as high priority sites for grid extension. We also visited a few grid-connected and grid extension priority areas to understand both the applicability of our findings in grid extension communities and the presence of processing that is not prevalent in rural communities without electricity access. Of the communities visited, 8% were grid-connected, 4% were minigrid-connected, and 88% were not connected to electricity.

[vii] In communities with cell phone service, 81% had SMS/voice access only and an additional 19% could access at least some data service.

Respondent Type	Number	Sample Questions
Community Champion	52	• Please list the names of the agricultural cooperative, farmer groups, and other groups active in the community within the past 12 months
Agricultural Processor	91	For a given processing activity: • What is the energy source and engine size, if applicable? • What are the operating costs for this equipment? • What is the gender of the operator?
Farmer	69	For a given crop: • What are seasonal yields? • In what form, at what price, and to whom is the crop sold? • What is the demand for mechanical threshing and drying?
Agricultural Trader	65	For a given commodity: • What is the quantity, price, and point of sales? • What are major points of post-harvest loss?
Women not involved in the value chain	7	• What agricultural business activities would you be interested in? • What processing business activity would you be most interested in pursuing?
Total	**259**	

Exhibit 2: Sample Survey Questions from 2020 RMI Survey of Agricultural Value Chain Actors across Amhara, Oromia, and SNNPR
Note: Some community champions participated in the value chain and were interviewed from multiple perspectives. All interviews are captured in the respondent type tallies but the total only captures one interview per respondent.

2.4 Prioritization Methodology

Among the five value chains of study, there are several activities to consider for electrification. We identify the subset of processing activities that demonstrate the highest potential for electrification with minigrid-powered systems. We use a multi-metric framework to sort the high potential activities depending on their appropriateness for electrification in the short term.

2.4.1 Prioritization Criteria

We evaluate each processing activity and assess electrification readiness using four categories: local capacity, offtake market, equipment and electrification, and scalability.

Local Capacity

Processors must have the skills to successfully operate a processing business. Electrifying activities where processing businesses are already prevalent in rural communities and have been operating for a long time will require less support. Otherwise, there would be adoption risks and additional effort required to support the adoption of activities that are unfamiliar and untested in rural communities. We measure the existing capability of processors by assessing the number of processors operating in communities and the longevity of their businesses. We use the following metrics to test this:

- Processors operating in community.
    - *Survey findings show that on average at least one processor operates in each surveyed community.*
- There is more than one processor per community.
    - *Survey findings show that on average at least two processors operate in each surveyed community.*
- Processors have been operating for more than two years.
    - *Survey findings show that the processing businesses surveyed have been operating for at least two years.*

Offtake market

Processors with a robust local consumer base have proven the commercial viability of the activity. The prevalence of local demand for the outputs of a processing activity confirms that customers can afford the product, want to buy the product, and can access processors through established channels.

Rural communities are often isolated from urban and peri-urban markets, so complex supply mechanisms may be required to connect products from a rural community to consumers in larger markets. Setting up these supply mechanisms—beyond requiring additional investment—carries the risk that the demand may not materialize. As such, to score highly, there should be high demand for products in the local communities where they are produced. We assess the strength of offtake markets by analyzing the volume of products traded in the community or within existing trader networks. We use the following metrics:

- Product is consumed at high volumes in Ethiopia.
    - *Literature review shows that there is a significant per capita consumption of product in Ethiopia.*
- Product consumption is high in rural communities.
    - *Literature review shows that there is a significant per capita consumption of processed product in rural communities in Ethiopia.*
- Product is traded in community.

    - *At least 75% of surveyed traders who trade product sell product locally.*
- Those who trade product have little to no wasted product that they are unable to sell.
    - *At least 75% of surveyed traders recorded that no product goes unsold.*
- Consumers are willing to pay for mechanically processed product.
    - *There are operators engaged in the processing activity in rural communities surveyed.*
- There is a waitlist of customers waiting to have crop processed.
    - *At least 75% of surveyed processors observe a waitlist of customers.*

Equipment and Electrification

Agricultural processing activities with electric equipment readily available in the Ethiopian market will be easier and faster to deploy than activities that require developing or importing untested equipment. Retrofitting existing fuel-powered equipment may also be possible, but this will require confirming electric component compatibility with other built-in components. Piloting programs are still needed to field test and debug equipment to confirm minigrid compatibility and that the output meets end-consumer preferences. Processing activities that occur year-round will be more economically viable for the minigrid to serve. We assess the suitability of a processing activity for electrification and the availability of electric equipment with the following metrics:

- Majority of processing is done using mechanized equipment.
    - *Literature describes that processing is currently undertaken using a machine.*
- Electric equipment is available locally.
- Domestic equipment manufacturers already produce or import equipment and thus have expertise to repair equipment.
- Fuel-powered equipment can potentially be retrofit with electric components.
    - *Diesel- or petrol-powered equipment uses action of a mechanical belt or component powered by a fuel engine that an electric motor can likely replace.*
- Crop is available throughout the year with little to no effect of crop planting seasonality.
    - *Marketed crop is widely available year-round from retailers or traders.*
- Product pricing is stable throughout the year with limited spikes from month-to-month.
    - *Processed product is available on the market with little statistically significant price spiking over a year period.*
- Processing activity takes place year-round with no lull period.
    - *At least 75% of surveyed processors state that processing is not seasonal.*

Scalability

The potential for scaling is higher for value chains and activities that are widespread throughout various regions in the country. Processors require stable crop supplies as inputs to sustain high processing volumes each season year to year. Activities with strong scaling potential can be replicated more efficiently in hundreds of communities in Ethiopia, but niche processing activities may not be widespread to attract equipment suppliers. We use the following metrics to test scaling potential of processing activities:

- Processing takes place across multiple regions and kebeles.

- Crop is grown in multiple regions.
- Crop supply is consistent, and yield does not vary widely between seasons.
    - *Quality and quantity of crop yield is consistent between seasons; crop is not known for regular interval seasons of low production.*
- In median community, crop production volume exceeds processing volume required by processors in community.
    - *Median value for the difference between total community production and volume required by all processors in community is positive.*

2.4.2 Scoring Methodology

We evaluate each processing activity using a series of 21 binary true/false metrics described in Section 2.4.1. Data and insights from survey findings, expert feedback, and literature review inform our evaluation of each metric. We use qualitative binary metrics to avoid making significant assumptions required in quantifying metrics, and due to concerns with the reliability and comparability of reported quantitative variables inherent in survey data. Metrics that are "true" score one, while metrics that are "false" score zero. To calculate the electrification readiness score for a processing activity we add the individual scores for each metric. The high-scoring activities are those with stronger electrification potential.

Evaluation Metric	True / False	Score	MAX
Survey findings show that on average at least one processor operates in each surveyed community	True	1	1
Survey findings show that on average at least two processors operate in each surveyed community	False	0	1
Survey findings show that the processing businesses surveyed have been operating for at least two years	True	1	1
Local Capacity Score		2	of 3

Prioritization Criteria	Score	MAX
Local Capacity	2	3
Offtake Market	...	6
Equipment and Electrification	...	7
Scalability	...	5
Total Activity Score	**...**	**21**

Tier 1	80%–100%	max value
Tier 2	60%–80%	max value
Tier 3	< 60%	max value

Exhibit 3: Depiction of the Scoring Methodology for Processing Activities

Note: Each activity is evaluated using a standardized set of 21 true/false metrics. These metrics are divided among the four prioritization criteria (local capacity, offtake market, equipment and electrification, scalability). The sum of the four prioritization scores gives the total activity score, which is then used to rank activities from Tier 1 (immediately suitable for electrification with minigrids) to Tier 3 (requires significant support before electrification becomes possible).

2.4.3 Ranking Activities

Applying the four prioritization criteria allows us to rank activities into three tiers based on their readiness for electrification (as shown in Exhibit 4).

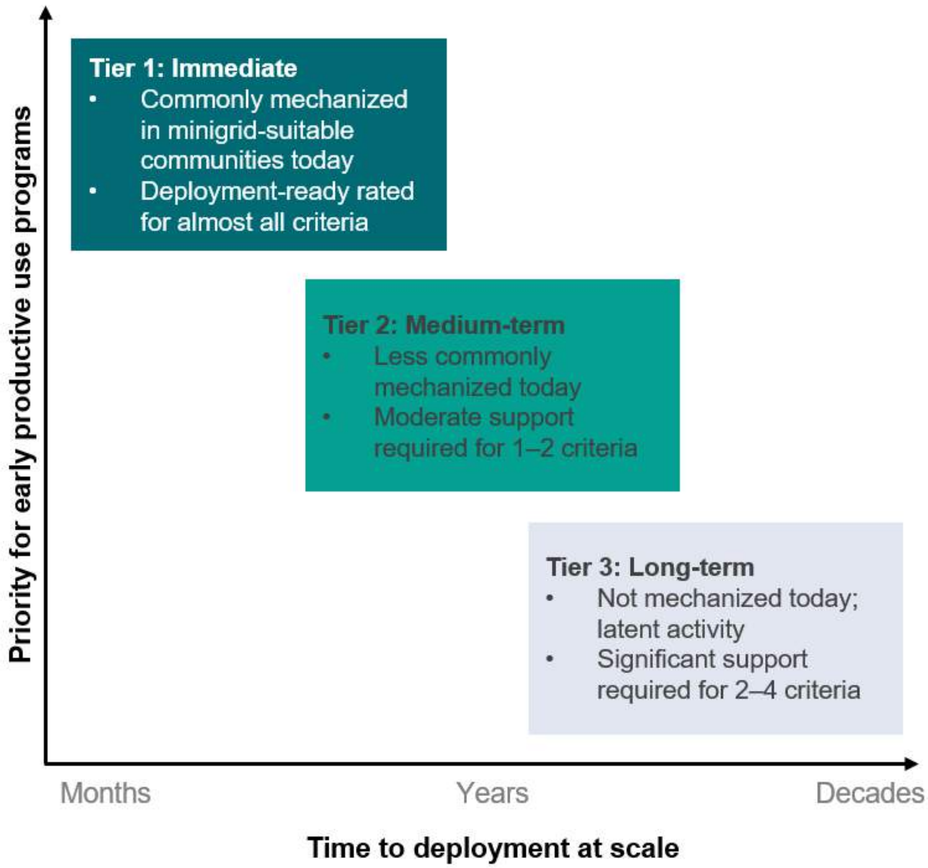


Exhibit 4: Illustration of Tiers Utilized to Classify Productive Use Activities by their Readiness for Electrification

Tier 1—Immediate (at least 80% of maximum readiness score). These activities are viable for immediate electrification in a minigrid context with minimal programmatic support beyond appliance financing and procurement. These activities begin with crops or inputs that are commonly produced in high volumes, and that are already commonly mechanically processed before sale into robust local markets. These are also the activities with the most robust appliance market, where electric equipment is already available for purchase and pilot testing. Integrating these activities could improve minigrid capacity utilization and after field-testing equipment we would recommend incorporating them alongside all new minigrid projects in communities that cultivate these crops.

Tier 2—Medium Term (at least 60% of maximum possible activity readiness score). These activities are not far from being viable for electrification today but will require more program support than the *immediate* activities. Beyond just appliance financing, this support may include strengthening offtake markets, developing suitable appliances, or building local capacity.

Tier 2 activities are not ready for immediate deployment in minigrid communities but have significant potential given community acceptance of new practices, minigrid-compatible electrical equipment, and robust market linkages for processed products. Although these hurdles are surmountable with proper support, the average community-level actor (e.g., community-based organization or minigrid developer) would not be likely to address them alone. We recommend these activities for consideration by larger electrification programs that can include this support, or for local entrepreneurs and off-takers with special sector expertise.

Tier 3—Long Term (less than 60% of maximum possible activity readiness score). These activities may have long-term potential for electrification, but significant support would be required to make minigrid deployment economic and sustainable. This category includes the hundreds of latent agricultural processing activities that could conceivably utilize electricity but would require considerable effort to build adequate local capacity, market linkages, and supply of minigrid-compatible equipment from the ground up.

These are activities which are either rarely conducted in rural communities or are primarily conducted manually. Though we would not recommend incorporation of these activities into a minigrid deployment program today, many may be prime targets for study by agricultural development institutions or corporate actors interested in developing their local supply chains.

3 Value Chain Analysis and Prioritization of Activities

This study applies a productive use lens to post-harvest activities for five target value chains, focusing on opportunities for minigrid electricity to improve the efficiency of the processing steps between unprocessed crops or raw materials and locally marketed products. We find immediate opportunities to electrify currently fossil fuel-powered processing activities particularly for flour milling across key cereal crops in rural Ethiopian communities. This section summarizes these findings, and **Appendix A** provides in-depth analysis on every crop and value chain activity mentioned here.

3.1 Summary of Analysis Findings

As explained in **Section 2.4.1**, we use four criteria—local capacity, offtake market, electric equipment, and scalability—to sort productive use opportunities into three tiers based on their readiness for electrification, captured by the level of support required. **Exhibit 5** shows the ranking for each activity associated with each crop, while **Exhibit 6** shows deployment-readiness across each criterion contributing to this ranking.

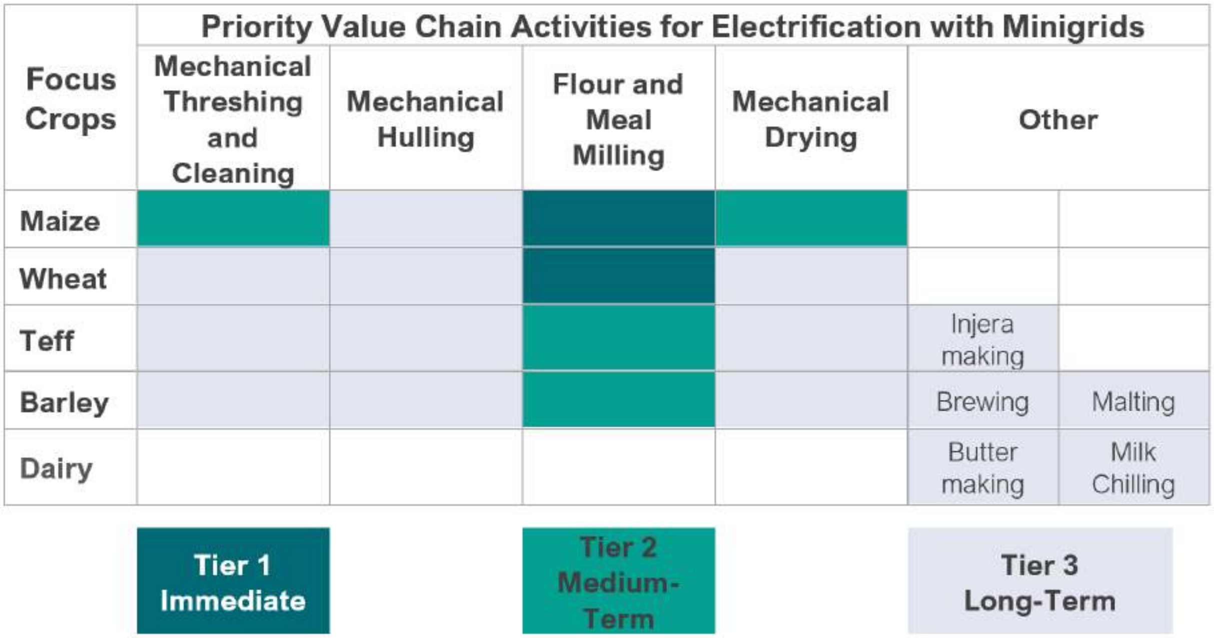


Exhibit 5: Summary of Tier Rankings Based on In-Depth Analyses of 21 Crop and Value Chain Activity Combinations

Grain flour milling is the clear Tier 1 activity primed for immediate electrification and implementation in Ethiopia. Grain flour milling across maize, wheat, teff, and barley has strong fundamental characteristics indicating that electrifying this activity can be straightforward and successful. This opportunity requires little to no market development support to be implemented today and at widespread scale. This potential is further strengthened by the opportunity to use multi-crop milling equipment to broaden the local processor's business opportunity and reduce market risk (see Appendix A.1.1 and Appendix A.1.2 for the potential of multi-crop mills and threshers). Section 4 explores this opportunity further, by assessing whether grain milling is economically viable for processors and boosts minigrid economics.

Tier 2 activities have potential for scaling in the medium term if provided with necessary support. This support must address prohibitive barriers to deployment, particularly regarding the capacity of local actors to adjust to mechanization. Value chain actors may need to change their behavior to adapt to the requirements of mechanized processing. For example, adoption of a centralized multi-crop thresher depends on farmers' ability and willingness to transport their dried cereals to the town center, rather than hiring labor to thresh grains in the field. These adaptations are feasible but may require additional effort. Alternatively, a technological breakthrough or innovation would be needed to adjust the equipment to behavioral practices. For example, developing a battery-operated chargeable thresher that can be charged in the town center and transported to the fields where it is used.

SUPPORT REQUIRED: Deployment-Ready – Minimal – Moderate – Significant

	Activity	Value Chain	Local Capacity	Offtake Market	Electric Equipment	Scalability
TIER 1	Flour milling	Maize	Deployment-Ready	Deployment-Ready	Minimal	Deployment-Ready
		Wheat	Deployment-Ready	Deployment-Ready	Minimal	Deployment-Ready
TIER 2	Flour milling	Barley	Deployment-Ready	Minimal	Deployment-Ready	Moderate
		Teff	Deployment-Ready	Moderate	Minimal	Deployment-Ready
	Threshing	Maize	Significant	Minimal	Moderate	Minimal
	Drying	Maize	Significant	Moderate	Moderate	Deployment-Ready
TIER 3	Threshing	Barley	Minimal	Moderate	Moderate	Significant
		Teff	Significant	Moderate	Significant	Moderate
		Wheat	Minimal	Moderate	Significant	Minimal
	Hulling	Barley	Significant	Moderate	Moderate	Significant
		Maize	Significant	Significant	Moderate	Deployment-Ready
		Teff	Significant	Significant	Moderate	Deployment-Ready
		Wheat	Significant	Significant	Moderate	Minimal
	Drying	Barley	Significant	Moderate	Significant	Significant
		Teff	Significant	Moderate	Significant	Minimal
		Wheat	Significant	Significant	Moderate	Minimal
	Malting	Barley	Significant	Significant	Moderate	Significant
	Beer brewing	Barley	Significant	Significant	Moderate	Significant
	Butter making	Dairy	Significant	Moderate	Moderate	Moderate
	Cheese making	Dairy	Significant	Significant	Moderate	Moderate
	Milk chilling	Dairy	Significant	Significant	Moderate	Significant
	Injera making	Teff	Significant	Significant	Moderate	Deployment-Ready

Exhibit 6: Value Chain Analysis Results by Activity, Including Tier Rankings and Specific Criteria Scoring

Tier 3 activities have longer-term potential if extensive barriers are addressed. Milk pasteurization and teff injera-making both involve applying high heat and are energy intensive and inefficient for electrification (**Appendix A.5** for teff and **Appendix A.6** for dairy). For other activities, business models do not yet exist in rural communities, and may be challenging to develop. For example, cheese-making is common in rural communities, but cheese is not sold for profit. This also applies to injera-making in rural communities, which consumers often offer as gifts to each other.

In the case of milk chilling, demand is not prevalent in rural communities and broader development efforts need to be coordinated to connect rural production to offtake markets in urban areas (infrastructure to conserve and transport milk to urban centers is needed to make milk chilling viable in rural communities). Other activities do not have a demonstrated demand for processing. For example, in maize and wheat value chains most farmers air dry their crops and do not pay for mechanical drying. So, there is insufficient demand to warrant mechanical drying in rural communities.

Key Considerations for Evaluating Productive Use Opportunities

Some key considerations for evaluating productive use opportunities have emerged from our analysis. In addition to the prioritization criteria used to rank activities, applying these considerations can help flag activities that are well-suited to electrification.

Local demand is critical for ensuring volumes and profitability in mechanized agricultural processing. To invest in equipment, processors must be confident they can recover their upfront investment with revenue from their processing businesses. Processors in rural communities typically have limited access to markets in distant communities, so local processing demand must be high because most of their demand will come from within the community. Consumers must already be incentivized to pay for mechanical processing, for example by hiring laborers to conduct processing activities manually, or by regularly purchasing a processed product. Without this steady demand, a processor will not likely offset their investment costs. Multi-crop processing can help processors access demand from various value chains.

Understanding where a value chain activity occurs is critical for understanding which productive uses to support effectively. Location is critical for understanding productive use potential. On-farm processing activities (e.g., threshing) will be limited to high production areas, while end-consumer processing (e.g., grain flour milling) may be viable more broadly if consumption is widespread.

Some crops are consumed widely across Ethiopia, and therefore the demand and potential for end-consumer processing activities is prevalent across the country. But the opposite is also true. For example, since barley is only consumed significantly in the Ethiopian highlands where it is also grown, both on-farm and end-consumer processing activities will be more viable in this region. Planning authorities should consider where agricultural productivity is highest and where processing is concentrated to guide decision-making on which productive use opportunities to prioritize in different sites.

Activities that are already mechanized are less risky. The surest measure of market demand for mechanization is its current prevalence in the target community. Otherwise, productive use programs risk facing insufficient demand or limited capacity among processors to manage businesses. Energy actors who are considering productive use programs to stimulate latent activities must do so with a full understanding of the risks, preferably in partnership with agriculture experts.

Equipment specifications must match processor and consumer preferences. Working with food products means accommodating customers' deeply held preferences for quality, texture, taste, and color. In addition, minigrid power systems and meters pose technical constraints on equipment design (e.g., phase, voltage, inrush current). Only thorough pilot tests can ensure the selected equipment balances customer preferences with these operating limitations.

3.2 Supporting Analysis from Survey Data

Survey data collected during this study confirm that maize and wheat are widely cultivated especially in Amhara and Oromia regions, which supports their prioritization. As shown in Exhibit 7, maize is the most frequently cultivated crop across the three regions based on our survey sample. Teff is also widely cultivated across regions, but teff grains cost almost twice as much as maize and wheat grains and so are not as widely consumed by lower-income rural communities. Throughout the survey sample, dairy production is limited.

Survey data also confirms that grain flour milling is the most prevalently mechanized activity observed in the minigrid-suitable communities visited. Exhibit 8 shows the value chain flows for 91 agricultural processors who have mechanized at least one processing activity in their business. On the ground, mechanized processing activities are dominated by the crops that are most prevalently farmed at large volumes in surveyed communities. Wheat, teff, maize, and barley are threshed mechanically before consumption or further processing; wheat, teff, maize and barley are milled into flour; and barley, teff, and maize are also brewed to make local beer. Other processing activities are also observed but were not reported to be mechanized (e.g., drying and butter churning).

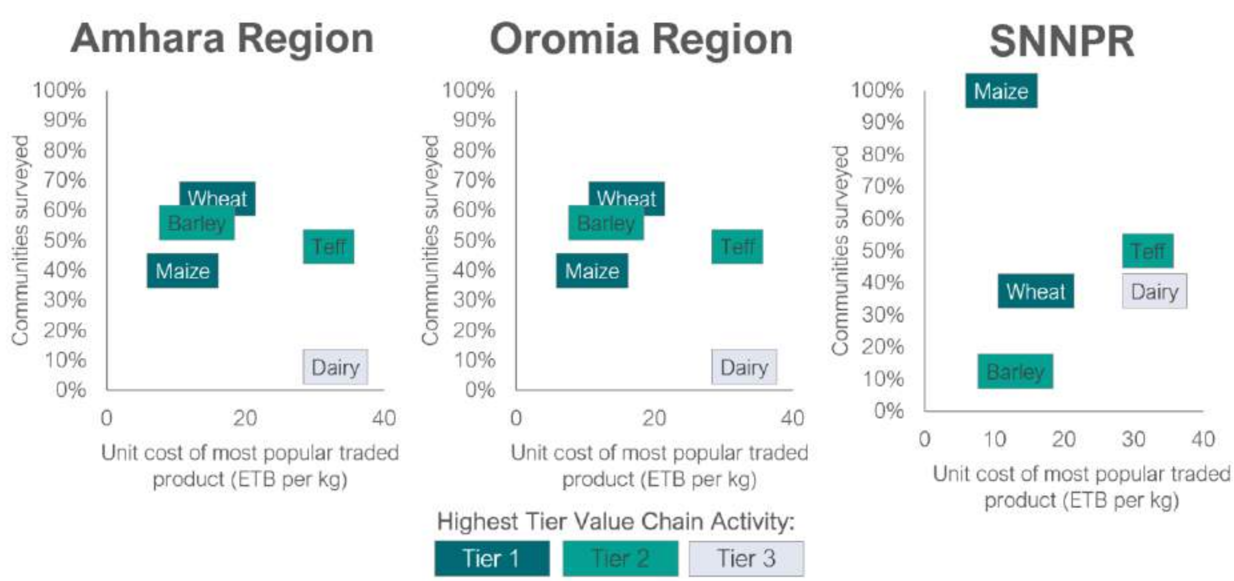


Exhibit 7: Summary of Crop Production at Local Scale

Note: Community observation rates show the percentage of communities surveyed that reported five or more crop farmers or dairy producers for a given value chain. Traded product unit cost shows the median cost in Ethiopian birr (ETB) per kilogram for clean grains (across maize, wheat, barley, and teff value chains) or fresh milk (for dairy value chain), based on 2020 RMI survey findings.

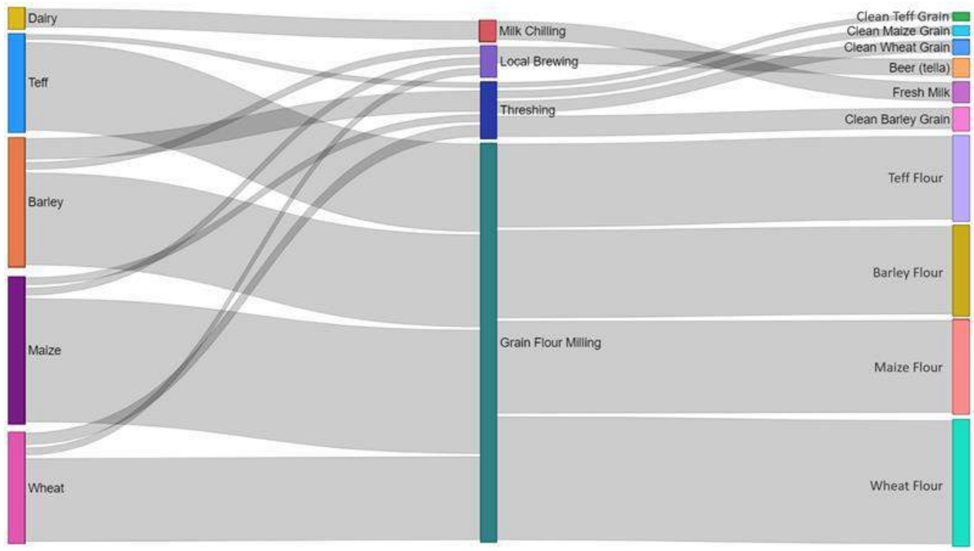


Exhibit 8: Prevalence of Mechanized Processing Activities Observed from 2020 RMI Survey Findings

Note: For each value chain identified on the left, the corresponding product is listed on the right. The size of each flow is proportional to the number of processors we observed that reportedly conduct processing for a particular value chain.

3.3 Gender Considerations Across Activities

Today, men are the primary operators of mechanized processing across most value chain activities. Mechanization of previously manual operations through electrification programs may exacerbate gender income imbalances if not countered with deliberate consideration of gender in program design. Exhibit 9 shows the extent of mechanization and gender representation across the processing activities recorded in field surveys.

Grain flour milling emerges as the most prevalently mechanized activity. This data is based on a limited sample size of 91 processors, but we observe that activities associated with cooking-related work (such as beer brewing and milk chilling) are more likely conducted by women. Yet, the high proportion of women involved in beer brewing and milk chilling is disproportionately skewed by the limited number of observations of these processors. We therefore cannot make definitive conclusions about these patterns with the data available, and further study is required.

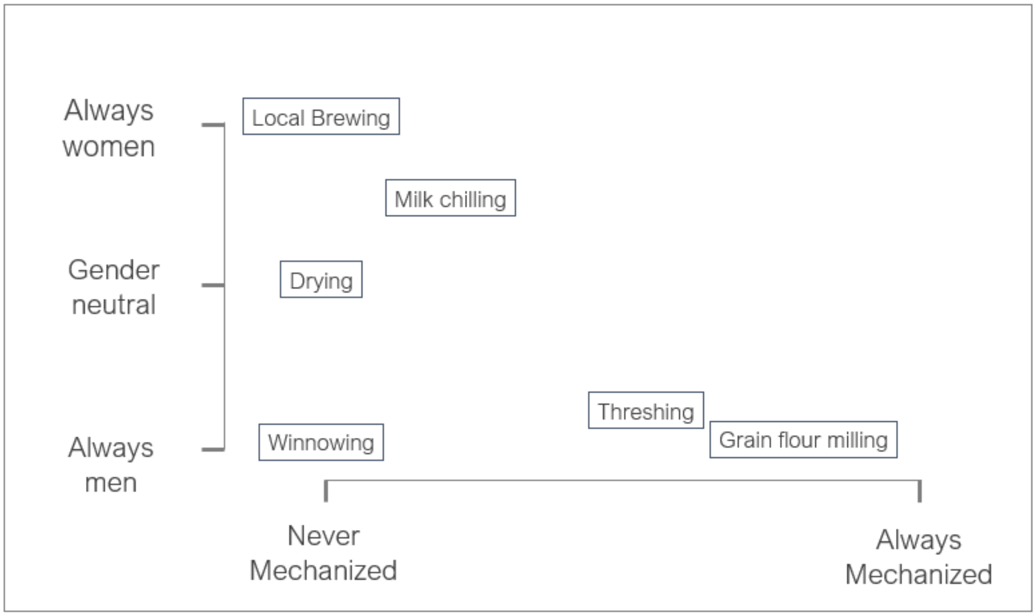


Exhibit 9: Trends in Mechanization and Gender Representation in Value-Add Activities Included in Field Surveys as Reported by Local Processors and Community Champions, with Error Bounds Denoting the 90% Confidence Level Interval for the Trendline

3.4 Value Chain-Specific Findings

This section presents specific findings for each of the value chains studied.

Maize—Maize is the most widely produced crop in Ethiopia (by production volume) and is highly consumed in rural communities. Most people consume maize in flour form and pay processors for milling services. Processors in rural communities use fossil fuel-powered grain mills. Maize milling is a Tier 1 activity that can be scaled across minigrid-eligible communities throughout Ethiopia. See Appendix A.2 for our in-depth analysis of the maize value chain.

Wheat—Wheat is a staple crop in Ethiopia produced at high volumes nationally. Most wheat is used for food purposes and must be processed into flour before consumption. Wheat milling is a Tier 1 activity that can be scaled across minigrid-eligible communities throughout Ethiopia. See Appendix A.3 for our in-depth analysis of the wheat value chain.

Teff—Farmers devote the highest area of farmland to teff cultivation among all crops in Ethiopia because teff can grow in most agroecological zones. Teff is used for food—especially for making the popular national dish, injera. Grain milling produces the raw ingredient for injera: teff flour. But teff is expensive for rural consumers who commonly sell the crop in grain form (unprocessed) and consume cheaper grains like maize. Teff flour milling is a Tier 2 activity due to the limited demand for teff and low prevalence of teff milling in rural communities. See Appendix A.5 for our in-depth analysis of the teff value chain.

Barley—Barley is a staple crop in the Ethiopian highlands (Oromia and Amhara). Many rural consumers use barley flour as a substitute for more expensive teff or wheat flours. Barley is also consumed as a grain and malted to make fermented beverages. Barley hulling and milling are Tier 2 activities because barley consumption is concentrated in highland regions where it is cultivated, limiting its potential to scale nationally compared with other crops that are more widely cultivated and consumed. See **Appendix A.4** for our in-depth analysis of the barley value chain.

Dairy—The dairy sector is still nascent in Ethiopia. Most farmers trade most of the milk they produce within the same day to avoid losses, without value-added processing or preservation. The milk that is not sold is manually processed into shelf-stable products that do not require refrigeration, such as butter and cheese products for household consumption. These products are not sold and have no proven local markets. Similarly, milk chilling is a Tier 3 activity due to low levels of local demand for chilled milk in rural communities, low prevalence of cold storage that would prove its commercial viability, and the need to develop a cold chain to connect with demand centers in urban areas. See **Appendix A.6** for our in-depth analysis of the dairy value chain.

4 Economic Viability of Electrifying Tier 1 Processing

The value chain analysis found that maize and wheat milling offer opportunities for immediate electrification. This section adds an additional layer of analysis to assess the economic viability of investing in and switching to an electric mill from the processor's perspective and to determine the financing needed to afford the upfront cost.

We only model the fee-for-service (FFS) modality because survey results showed and expert consultation confirmed that most processors operate under an FFS modality in Ethiopia.[viii] The analysis captures all types of grain milling since milling fees do not vary significantly between grains.

Crop	Activity	Processor Modality
Maize, Wheat, Barley, Teff	Grain Flour Milling	Fee for Service (FFS)

Exhibit 10: Processing Activity Analyzed

In parallel, we also assess the economic impact on the minigrid operator that serves the load generated by the electric mill. By understanding the economic viability from these two perspectives, the analysis captures the value proposition for the two key decision-makers determining the uptake of electric milling in rural communities: processors and minigrid operators.

4.1 Processor Cash Flow Analysis

Our analysis finds a positive economic case for investing in an electric mill, showing a positive net present value (NPV) and a discounted payback of less than three years. **Compared with diesel-powered mills, electric mills generate savings in operating costs, including a 48% reduction in energy costs and doubled profit margins.**[ix]

[viii] All but one processor in our survey operated under the FFS modality.

[ix] Electricity cost assumption is ETB 13/kWh based on the highest approved tariff in Rensys' solar minigrid pilot, which is much higher compared with the national electricity tariff in Ethiopia. Diesel fuel costs are estimated at ETB 24/liter or ETB 50/quintal of crops processed based on survey median data.

Switching from diesel to electric equipment can generate significant savings. Assuming fixed processing volumes, the discounted value of savings over five years exceeds ETB (Ethiopian birr) 95,000 (US$2,375[x]). The economic case for switching to an electric mill is positive if a processor can replace their mill for a lower net cost. For example, new electric mills can cost ETB 115,000 (US$2,875), and if the processor can sell their used diesel mill for ETB 20,000 (US$500) or more, switching to an electric mill has a positive economic case. This switch to electric milling also offers co-benefits for the processor including displacing the inconvenience of traveling for and transporting diesel fuel and the risk of fluctuating fuel prices.

Investing in an electric mill can generate a positive NPV of ETB 74,600 (US$1,865) and 66% return on investment (equity internal rate of return) over the first five years, and an NPV of ETB 166,000 (US$4,150) over the 15-year equipment lifespan. This analysis uses conservative assumptions from field survey results, literature review, and expert interviews. The methodology for this analysis, including specific assumptions and detailed results, is shown in Appendix B.

Assumptions: ETB 115,000 upfront cost	5-year NPV	15-year NPV	Discounted payback	5-year equity IRR	5-year saving potential[xi]
3 kW, 150 kg/hour electric mill 500 kg/day processing volume ETB 1/kg service charge	ETB 74,600 US$1,865	ETB 166,000 US$4,150	2.4 Years	66%	ETB 95,000 US$2,375

Exhibit 11: Electric Mill Investment Cash Flow Analysis Results

Our research also finds that electric mills sized to meet the processors' capacity needs are cheaper than diesel mills currently available in Ethiopian appliance markets. Box 4-1 presents a summary of a differential analysis comparing the cash flows between an electric mill and a diesel mill that is sized for small-scale needs.

Box 4-1 Differential Cash Flow Analysis

The smallest diesel mill identified through the field survey was 15 horsepower (HP) and the most common diesel mill was 27 HP, despite some processors milling as little as a few quintals of grains per day. This indicates that there is a market gap for smaller diesel mills that match the capacity needs of small-scale rural processors. Despite the market gap, we carried out a differential cash flow analysis using international supplier quotes as a proxy of the cost of a smaller diesel mill.[xii] The analysis captures the comparison that a would-be processor would make to evaluate diesel and electric options if the market gap is ever covered and smaller diesel mills become available.

---

[x] Exchange rate is about US$1 to ETB 40 according to National Bank of Ethiopia data. https://nbebank.com/commercial-banks-exchange-rate/, accessed in March 2021

[xi] Comparing to same processing scale but using diesel-powered mill.

[xii] Selected supplier quotes from Alibaba.com for Ethiopia market.

Results show that even compared with the less expensive smaller diesel mill, there is a compelling positive economic case to invest in an electric mill over a diesel mill. Despite a higher upfront cost, electric mills have lower operating costs that boost profitability and contribute to a positive differential five-year NPV of ETB 67,200 (US$1,680). This means that with the same processing volumes and service charge, electric mills generate additional value for the investor compared with diesel mills. Assuming a lifespan of 15 years, the NPV difference can be as high as ETB 113,900 (US$2,848).

Assumption: 500 kg/day processing volume ETB 1/kg service charge	Upfront cost	Business profit margin	5-year differential NPV of electric over diesel	15-year differential NPV of electric over diesel
New electric mill	ETB 115,000 US$2,875	47%	ETB 67,200 US$1,680	ETB 113,900 US$2,848
New diesel mill	ETB 85,000 US$2,125	23%		

Further analysis suggests that as long as the price difference between electric and diesel mill upfront cost is less than ETB 88,000 (US$2,200), electricity price is below ETB 21 (US$0.53) per kWh, and electricity reliability is above 30%, the five-year differential NPV will be positive, in favor of the electric mill. There are other advantages to an electric mill not reflected in this economic analysis. For example, processors experience less air pollution, enjoy savings in transportation costs, reduce time spent traveling to procure diesel, and have less exposure to fuel price volatility.

While results are positive, the economic returns of investing in an electric mill are sensitive to several factors particularly: **processing volumes, fee-for-service charges, electricity prices, and reliability of electricity supply.** Among these factors, economic viability is most contingent on processing volumes which is also the hardest variable to estimate accurately through field surveys.

To break even (achieve a zero NPV), processors must mill at least 91 tons of grains annually. Survey results and research indicate sufficient levels of grain production to meet this threshold within most rural communities in Ethiopia. Survey results show that the typical community produces 377 tons of maize annually. This indicates that there is enough production to sustain three maize flour milling processors in the median community, even if less than 100% of the production is ultimately processed in the community.

Most processors mill more than one grain type with the same equipment by modifying the sieve size, and so there is an even bigger and more flexible market for processors to serve. In addition, grain yield and production volumes may improve. For example, wheat productivity in Zambia is more than double that of Ethiopia (see **Appendix A.3**) and it is reasonable to assume that with continued government support, yields can continue to improve.

Beyond processing volumes, the sensitivity analysis shows that within reasonable increases or decreases of all variables tested, investing in an electric grain mill remains economically viable. **Exhibit 12** shows the value of variables that will set NPV to zero, when other inputs remain unchanged. These results provide an indication of the "ceiling" or "floor" for the value of each assumption that will make the investment in electric equipment economically viable. For example, if electricity price rises to ETB 27(US$0.68)/kWh (compared with ETB 13/kWh [US$0.33/kWh] "baseline" modeled), or the processors reduce their fees to ETB 700/ton (US$18/ton), the new grain milling business would become unviable.

		New FFS Grain Flour Milling
Processing volume	Baseline	130 ton/year (about 5 quintal/day)
	Floor	91 ton/year
Upfront cost of equipment[xiii]	Baseline	ETB 115,000 (US$2,875)
	Ceiling	ETB 280,000 (US$7,000)
Electricity price	Baseline	ETB 13/kWh (US$0.33/kWh)
	Ceiling	ETB 27/kWh (US$0.68/kWh)
Electricity service reliability	Baseline	94% (about 10 hours of blackouts in a week[xiv])
	Floor	54% (about 80 hours of blackouts in a week)
FFS charge	Baseline	ETB 1000/ton (US$25/ton)
	Floor	ETB 700/ton (US$18/ton)
Debt interest rate	Baseline	20%
	Ceiling	65%

Exhibit 12: Value of Variables that Will Result in a Breakeven NPV of Zero over the Lifetime of the Electric Mill

4.1.1 Financial Implications of Equipment Purchases

Despite the compelling and positive economic case for investing in an electric mill, would-be processors need access to financing to afford the upfront cost. Lack of access to affordable credit is a major barrier rural processors face in upgrading their business. Only 2 of the 63 processors we interviewed noted obtaining loans before. A study by the USAID's Power Africa Initiative shows that about 60% of households in Ethiopia have annual discretionary spending ranging from ETB 2,400

[xiii] Includes equipment capital expenditures (capex) and other upfront costs such as transportation and delivery.
[xiv] From Koftu minigrid site visit data.

(US$60) to ETB 3,000 (US$75), and only about 20% of households have discretionary spending from ETB 14,800 (US$370) to ETB 26,000 (US$650).[5] This means that only 20% of the population can save enough in one year to afford the 20% down payment for an equipment priced at around ETB 100,000 (US$2,500).

The financial assumptions used in the economic viability analysis presented in **Section 4.1** are based on prevailing financing terms and show that a positive business case is possible with these conditions.[xv] See **Exhibit 13** for a summary of assumptions and **Appendix B.1.2** for more details. But more favorable financing terms will be needed to help processors overcome upfront investment costs and de-risk investment until the business case for electric milling in minigrid settings is proven. This section briefly explores how financing support can improve the financial viability of equipment investment.

Financial Assumptions			
Down-payment required	ETB 20,800 (US$520, 20% of equipment price)	Loan tenor	3 years
Debt interest rate	20% (annual)	Installment	Quarterly
Grant support on capex	0	Cost of equity	23% (annual)
Weighted average cost of capital (discount rate)	21% (annual)	Facilitator fee	20% (of loan amount) covered by grant funding

Exhibit 13: Summary of Financial Assumptions in the Economic Viability Analysis

Grant support

Providing grants is a straightforward way for early adopters facing greater uncertainty on investment returns to overcome upfront costs. A 20% grant to cover a portion of the upfront equipment cost shortens the discounted payback period by seven months; A 50% grant shortens the discounted payback to just over one year. **Exhibit 14** shows the impact of changing the grant ratio on business returns.

[xv] Financial assumptions are based on expert interviews with microfinance institutions (MFIs) and capital goods finance companies (CGFC) in Ethiopia.

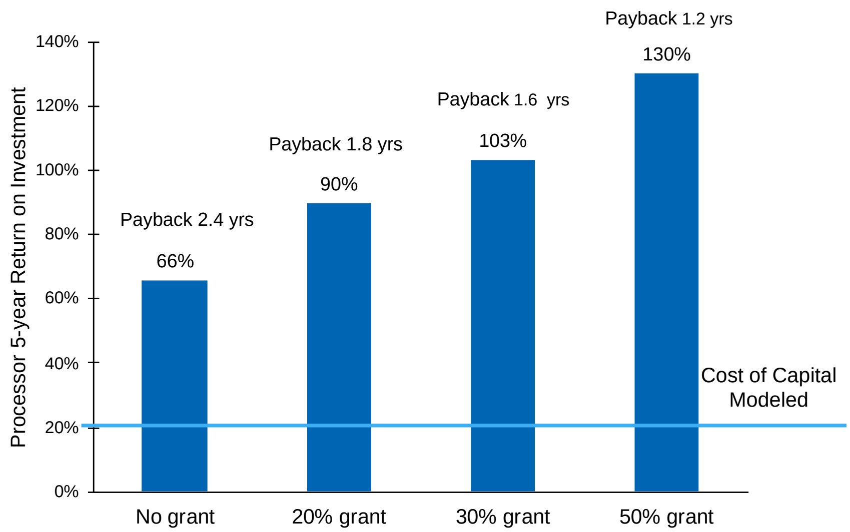


Exhibit 14: Grant Ratio Impacts Payback and the Rate of Returns of the New Processing Business (other assumptions are unchanged)

Favorable loan terms

Reducing the cost of debt and increasing the flexibility of the payment schedule also improves investment economics. For example, reducing the cost of debt from 20% to 15% increases the five-year NPV by 20% and reduces the payback period by two months. Our analysis also suggests that if the finance provider extends the loan tenor to five years, the processor's five-year return on investment would improve by 36% (see **Exhibit 15**).

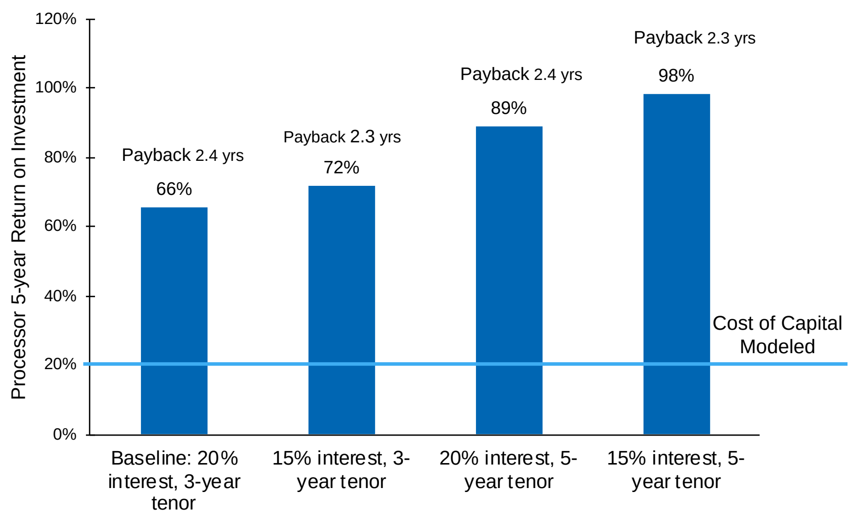


Exhibit 15: Impact of Favorable Loan Terms on Investment Economics

Box 4-2 **Current Financial Offerings in Ethiopia**

Expert interviews and our research indicate that microfinance Institutions (MFIs) offer interest rates ranging from 15% to 24% and provide financing for small-scale agriculture, although this financing is generally provided to fund agricultural inputs (e.g., fertilizer).[6] MFIs provide flexible payment terms for agriculture loans often with a one-time payment to match harvest cycles and seasonality. While one year tends to be the maximum loan tenor offered to smallholder farmers for agriculture loans, MFIs offer three-year tenors for business loans to small- and medium-sized enterprises (SMEs). MFIs generally on-lend savings from active members but can apply for five-year loans from the Development Bank of Ethiopia (DBE), indicating that it may be feasible for MFIs to offer longer tenors.

In contrast, capital goods finance companies (CGFCs) offer lower-cost financing that is less flexible. For example, Oromia Capital Goods Finance Company's equipment lease agreement generally requires a 20% down payment, in monthly or quarterly installments over three years, and a 12% annual interest rate in lease charges.

The size of individual loans may present a challenge for finance providers to finance electric equipment purchases. MFIs cap loan amounts at around ETB 30,000 (US$750), significantly below the cost of a mill of around ETB 100,000 (US$2,500). The collateral required may pose another barrier. Yet, experts consulted suggested using group loans and waiving collateral requirements to achieve the higher loan thresholds.

MFIs commonly use social capital to enforce repayment and waive collateral requirements. Group loans have lower default rates and on average represent over 50% of MFI loan portfolios.[7] Additionally, the MFIs we interviewed indicated interest in exploring using the equipment as collateral, utilizing a similar lease model used by CGFCs.

4.2 Impact on Minigrid Economics

This section assesses the impact of serving grain flour mills on minigrid economic performance. The results of this analysis show that if the equipment is compatible with minigrid design, serving productive use load improves minigrid system utilization and reduces the cost of service (or the cost-reflective tariff minigrid investors need to achieve specified project returns), especially when the productive load matches the solar generation profile.[xvi]

We analyze minigrid economics under four scenarios (**Exhibit 16**) to test how seasonality and time-of-use of the productive load affects minigrid performance. Survey data suggests that while most processors operate their grain mills all year round from 8 a.m. to 6 p.m., some processors report milling seasonally and during the evening.[xvii] We use a combination of HOMER Pro software and custom spreadsheet financial models and develop a community archetype using load data shared

[xvi] Here we define solar generation utilization rate (solar generation to serve load and charge battery divided by total solar generation) as a metric to evaluate system utilization.
[xvii] Over 70% (45 out of 63) grain millers reported milling is not seasonal, and about one-third of (22 out of 63) processors keep businesses running into the evening (past 6 p.m.).

by the Ethiopian Electric Utility (EEU) and our survey findings. We base minigrid cost inputs and assumptions on expert consultation with the EEU, Rensys, and Ethio Resource Group (ERG), to capture prevailing minigrid conditions. The methodology and more detailed assumptions used for this analysis are included in Appendix B.3.2.

Scenarios	Load Description	Minigrid System Design
Base	Load observed in the Koftu minigrid site—with about 162 connections—is used to represent the baseline load in the community archetype.	Optimized hybrid system in HOMER, with 27 kW solar, 150 kWh battery, 30 kW diesel backup, and 16 kW inverter.
Productive use (PU)	Loads from two grain mills added to the baseline load throughout the year. Mills are run from 8 a.m. to 6 p.m.	Same as base scenario. The same system design can support productive load in HOMER simulations.
Seasonal PU	Seasonal loads of two grain mills added to the baseline load from December to June.[xviii] July to November load will be the same as in base scenario.	
Late PU	Loads from two grain mills added to the baseline load throughout the year. Mills are run from 10 a.m. to 9 p.m. but the sum of total productive load equals the total productive load in the base + PU scenarios.	

Exhibit 16: Summary of Scenarios Analyzed for Minigrid Economics

The simulation results find that electric grain milling can improve minigrid economics by generating higher revenue for the minigrid operator and increasing utilization of solar energy generated. Relative to the baseline load, the productive load from the two grain mills increases annual sales by 22% under the productive use (PU) and late PU scenarios and 13% under the seasonal PU scenario. Exhibit 17 shows that, relative to a baseline scenario without added productive use, cost of service in communities with electrified grain milling can be 8%–13% lower while still earning a 15% IRR for minigrid investors.

While the additional revenue is beneficial, the timing of the added load is critical. While the total productive loads of the late PU scenario and PU scenario are the same, the late PU scenario has a smaller impact in reducing the cost of service. This is because about 35% of the grain mill load in the late PU scenario coincides with the evening peak demand (see Exhibit 18). This requires running additional expensive diesel generation in the evening instead of using low-cost solar generation during the day and pushes up operational costs. To take advantage of this benefit,

[xviii] Based on survey results among processors who reported milling activity being seasonal, most reported the processing season beginning around December and ending around June.

minigrid operators can encourage millers and other customers with productive loads to shift loads to daytime hours.

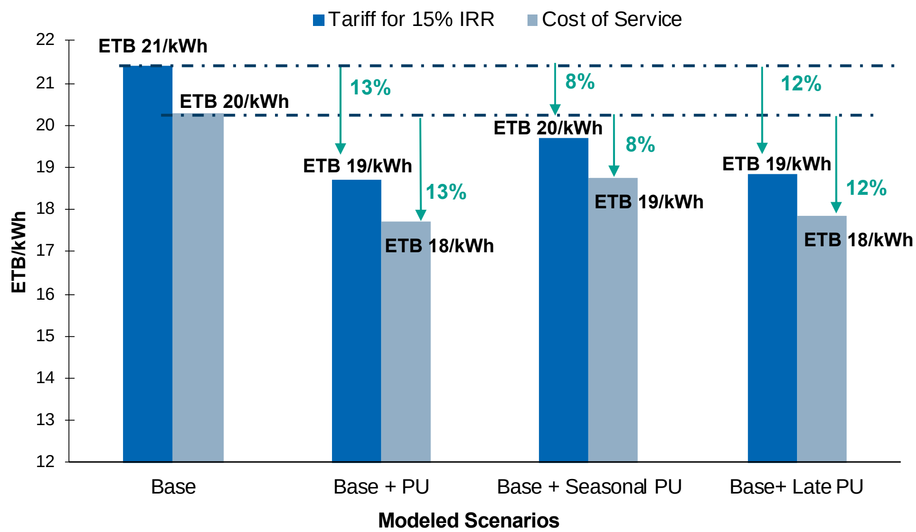


Exhibit 17: Minigrid Cost of Service and Tariff to Achieve 15% IRR for Investors under Different Scenarios

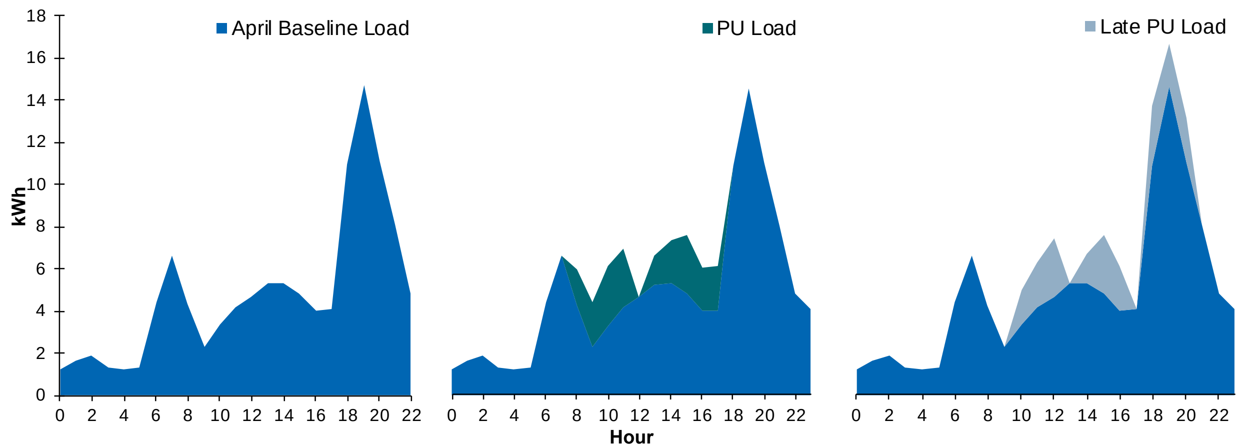


Exhibit 18: 24-Hour Load Profiles in April for the Median Community Modeled (In seasonal PU scenario, April is the month when there is productive use load, and the load profile will be the same as in PU scenario showed in the middle)

Understanding the seasonality of productive use is also critical for optimizing system design and operation. Grain mills that only run seasonally (December to June in our modeled case—seasonal PU) reduce the cost of service by 8% compared with 13% in the PU scenario. This is because fixed operating costs represent a large proportion of total operating costs and the seasonal loads have a similar cost of maintaining the minigrid system while revenue is decreased.

In addition to economic performance, serving productive loads can also affect other aspects of minigrid performance. Minigrid operators will need to manage the voltage upsurge and inrush current (the input surge current drawn when an appliance is turned on) when mills are connected to the system. Analyses of equipment specifications collected from local suppliers suggests that the inrush current of a 3 kW three-phase mill can be around 20 amps. With the modeled system configuration, the inverter would be capable of supporting the inrush current of one mill, but a soft starter may be needed to connect the second mill (see **Appendix B.3.3**).

Our analysis at this point is largely based on reported data through surveys and only indicates early insights. Measured data collected through the Data Pilot (see **Section 7.2**) will provide more robust data to improve the accuracy of these estimates. However, site-specific analysis and field-testing is still needed. Minigrid developers should carefully test assumptions used here to assess their relevance to the conditions found in their specific site.

5 Business Model Design

While the economic analysis shows attractive financial returns for a grain flour milling business with an electric mill, would-be processors need viable business models and access to knowledge and support to seize the opportunity. We define *business models* as the modality of how would-be processors operate their businesses, and the relationships and arrangements between actors to facilitate investment and use of equipment.

Because of their inherent interdependence in promoting rural economic development, the disaggregation of energy, agriculture, and financing sectors results in the inefficient and suboptimal use of resources, limiting the advancement of individual sector efforts. Coordination between agriculture, electricity, and finance will provide the necessary sector-specific knowledge needed to efficiently develop productive uses. Stakeholders who implement these efforts—such as minigrid developers, agricultural processors, and financiers—need to coordinate at the community level. By collaborating and synchronizing their activities, stakeholders can increase their overall efficiency and channel resources to highest priority opportunities.

This section recommends two business models that address the coordination challenge by establishing the arrangements between and the duties and responsibilities of stakeholders and explores potential sources of financing. Through consultation with financiers, community-based organizations, and minigrid operators we found that these two models hold the most promise, so we explore them in further depth in this study.

Between the two models, **we find the fee-for-service model more suitable for scaling implementation of Tier 1 activities.** This is because of the prevalence of organizations to fulfill the facilitator role and the nascent stage of the minigrid market in Ethiopia where minigrid developers are still developing the skills to run utility businesses effectively. We also include a cooperative-based model in **Appendix C** that may be appropriate in communities where there is surplus crop production and the local cooperatives are able to connect to other markets, but may not be suitable for widespread adoption.[xix] Nonetheless, the team will further explore, test, and refine this

[xix] Such as funding, working capital, market linkages, etc.

prioritization and specific designs through community consultation during the design seminars (see **Section 7**).

5.1 Viable Business Models for Tier 1 Activities

5.1.1 The Fee-for-Service Business Model

Fee-for-service (FFS) grain flour milling is already a common practice in Ethiopia. Out of the 63 grain flour millers we interviewed in our survey, 62 reported operating their businesses by charging customers for milling services on a per-kilogram basis using diesel- or petrol-powered mills. Ninety-five percent of them expressed strong interest in improving the profitability of or expanding their business.

As described in **Section 3**, barley, maize, teff, and wheat are generally traded in grain form, and processed before people consume them. A few stakeholders we interviewed, even though living around Addis Ababa, noted that Ethiopians prefer to buy grains in the store, then go to a processing center for milling (especially for pricier teff). As such, the design of the FFS model builds on existing practices and social interactions that reflect local needs and preferences and is more likely to be successful and require less capacity building to implement.

In the **fee-for-service model** a processor invests in electric equipment and provides a processing service for a fee. **Exhibit 19** illustrates the roles and relationships among actors participating in the fee-for-service model. In this model, a **facilitator** connects the processor to capacity building and financing. The facilitator supports the processor throughout the business development process, from building awareness about the opportunity, to equipment selection, to supporting with developing the business plan and applying for financing. As viability of electric processing businesses in rural communities is proven and actors in the model gain experience and capacity, the facilitator role can be removed.

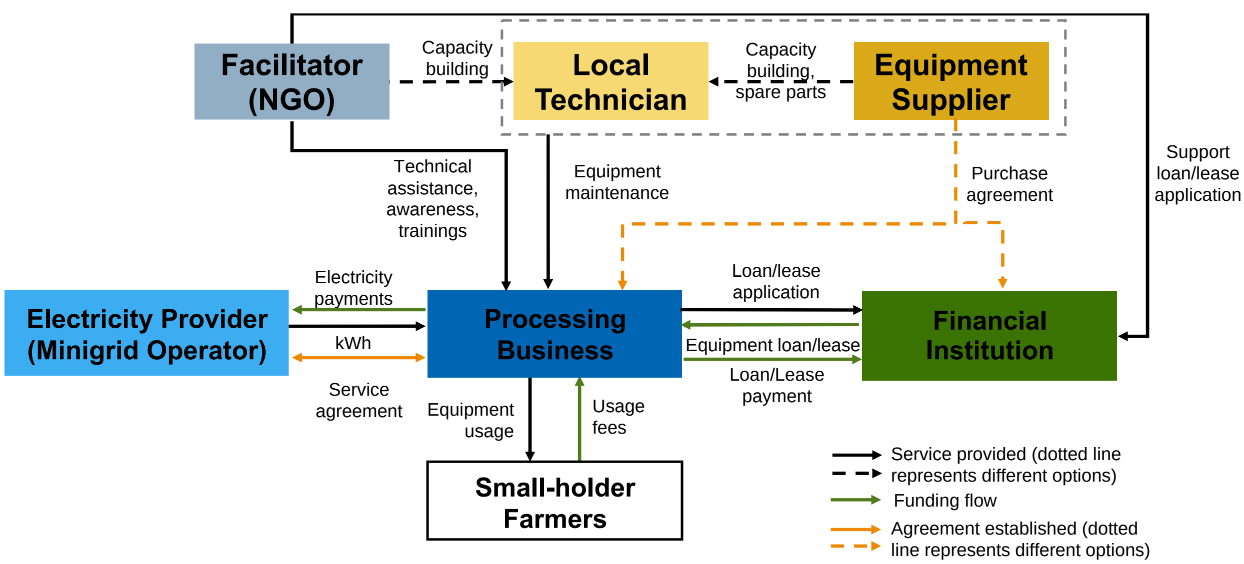


Exhibit 19: Institutional Arrangement for the Fee-for-Service Model

In this model, the processor owns the equipment and can capture a greater portion of the value addition from investing in electric equipment. Other actors also benefit:

- The facilitators fulfill their mission to enhance agriculture sector development in rural areas and can attract additional development funding.
- Electricity providers earn additional revenue from serving the productive load.
- Equipment suppliers increase equipment sales in serving a new market.
- Finance providers increase their agriculture and energy sector portfolios.
- MFIs meet their mandate to support rural income-generating activities (see Box 5-5 MFIs in Ethiopia).

Roles and Responsibilities of Actors in the Fee-for-Service Business Model

This section explains the roles and responsibilities of actors in the fee-for-service model by presenting examples of potential candidates that could fulfill the roles. These examples are meant to illustrate the characteristics of actors and the relationships among them and are not meant to indicate commitment from organizations mentioned to implement the model.

The processor invests and owns the electric equipment and is responsible for managing and operating the processing business, as well as repaying the loan or lease for the equipment. In the short term to leverage quick wins, the processor can be a local entrepreneur or a group of individuals with experience running similar processing businesses with diesel- or petrol-powered equipment to serve smallholder farmers in local and nearby communities[xx] (Box 5-1 presents a profile of the type of candidate targeted). Processors can also include new business owners investing in equipment for the first time, such as organized youth groups. But more training and financial support may be needed during the early stages to support this category of entrepreneurs.

[xx] For example, groups facilitated by Sasakawa, and in AgroBig's mobile thresher pilot (see Box 5-2).

Box 5-1 **Profile of Existing Grain Miller in Rural Ethiopia**

Mr. Eyale Selabat Gessese (pictured) is a processor in Minda kebele in Amhara region. He owns a 27-horsepower diesel-powered mill and processes barley, maize, and teff for households in the community. The community currently lacks access to electricity but is categorized as “minigrid priority” in the Least Cost Electrification Plan.

Mr. Gessese operates the business throughout the year, but peak periods occur from November to June when he operates the mill eight hours, serves about 20 customers, and processes 10 quintals of grains each day for about ETB 70 per quintal. Diesel fuel is the biggest operating expenditure, at about ETB 50 per quintal crop processed.

Mr. Gessese is one of the few processors who managed to access financing for his processing business, securing an ETB 242,000 loan from Amhara Credit and Savings Institution. He expressed strong interest in improving the profitability of his business and noted the challenges around finding reliable and affordable energy sources and access to financing and technical assistance.

Similar conditions prevail in Oromia and SNNPR. The field surveys indicate the presence of processors in rural Oromia and SNNPR who operate similar milling businesses and face similar challenges to invest in their businesses. These are the local entrepreneurs who fit the role of the processor in the fee-for-service model.

Survey results suggest that there is enough local processing demand to justify switching to electric equipment (see Section 4.1). To enable the switch to electricity, financing support as well as technical and business managerial capacity building is needed to support candidates like Mr. Gessese.

The facilitator connects processors with equipment suppliers and financiers, leveraging its agriculture sector expertise, technical knowledge on electric equipment and business management, and trust and relationships with processors. To fulfill this role successfully, the facilitator should be familiar with the farming practices and understand the processing needs and preferences of the community.

The facilitator informs processors of the opportunity to invest in electric equipment and supports processors on selecting suitable equipment for their business needs. The facilitator also provides training and capacity building on proper operation of equipment and reinforces business management skills where and as needed. The facilitator would also work closely with the processors to identify potential financing options and assess the financial feasibility and develop the business plan for the loan or lease application. In more remote regions where equipment suppliers are unable to perform after-sales service, the facilitator would support training a network of local technicians to provide routine maintenance and repairs and coordinate with equipment suppliers for obtaining spare parts.

Candidates that can fulfill the facilitator role need to be embedded within agrarian communities and have experience providing services to these communities. Given the wide-ranging nature of the skills needed, it may be hard in some communities to find one agency to fulfill all facilitator responsibilities. In cases like these, partnerships can be established. For example, the facilitator could connect with equipment manufacturers who would support providing training on equipment use. The facilitator could also leverage local agriculture support offices' networks and expertise in awareness raising and selecting processor candidates to work with.

To place the role in context and further clarify the reader's understanding, Box 5-2 presents examples of AgroBIG and Sasakawa Africa Association serving a similar role promoting agricultural mechanization in rural Ethiopia.

Box 5-2 **Profile of a Facilitator**

The Sasakawa Africa Association (SAA) has experience supporting agricultural mechanization in Ethiopia, including grain milling, threshing, and rice parboiling.[xxi] SAA often partners with woreda officials to select candidates, then helps farmers—especially women—to form small enterprises, supports them to develop business plans, and provides subsidized processing equipment for early adopters. SAA also provides ongoing support to improve the performance of existing agrobusinesses, providing training on equipment operation and business management.

To ensure timely equipment maintenance, SAA identifies technicians in the woreda with some prior experience and basic levels of expertise. The organization then trains and links them to equipment suppliers for spare parts, leveraging the good relationship SAA has established with equipment manufacturers.

The Agro-Business Induced Growth Program (AgroBIG) in Amhara region aims to establish efficient and profitable value chains. AgroBIG supports interventions to develop value chains and provides extension services and access to credit by building local capacity.[8] In Mecha woreda, AgroBIG ran a pilot to test the financial viability of a mobile diesel thresher for maize. AgroBIG provided business development services to organized youth groups and helped them apply for grant funding. AgroBIG supported building linkages with equipment suppliers and trained local operators on operating and maintaining the maize thresher.

Mr. Belayneh is one of the beneficiaries of the program. He and his friends formed a partnership and contributed 15% of the cost of the thresher. His business threshes maize at 10 ETB per 100 kg of maize, providing time and money savings to local consumers. Whereas mechanically threshing 100 kg of maize takes only a few minutes, manual threshing the same amount takes four workers an entire day of labor and can cost farmers 280 ETB. Farmers save money and time and welcome a fee-for-service mechanized threshing business serving their local community.

As these examples illustrate, capable and motivated community-based organizations are already serving similar roles in rural communities in Ethiopia and such prior experience can provide lessons learned to guide implementation of the fee-for-service model.

The equipment supplier provides high-quality electric equipment that meets user preferences and minigrid technical requirements when applicable. The equipment supplier will be responsible for delivering and installing equipment,[xxii] supporting user training, and providing timely service and maintenance. If the community is beyond reach of the supplier's service areas, the supplier supports the facilitator in training a network of local technicians and supplies spare parts when needed.

[xxi] https://www.saa-safe.org/wwd/theme2.html, also from interview with Dr. Fentahun Mengistu, Ethiopia Country Director and Ms. Aberash Tsehay, Post-Harvest Agro-Processing Theme Lead at Sasakawa.

[xxii] In Ethiopia, equipment suppliers often charge extra for equipment delivery and installation, and sometimes customers arrange their own transportation.

The equipment supplier prepares a purchase agreement that stipulates equipment specifications, purchase price, payment terms, estimated delivery date, technical warranty, and terms. The agreement would also align expectations and accountability between the processors (or equipment lessors) and equipment suppliers on training and service and maintenance timeline and arrangements. The signed equipment purchase agreement will serve as proof of purchase to financiers.

AMIO Engineering, a local equipment manufacturer and importer, offers a range of agricultural machinery and processing equipment, including the maize thresher used in AgroBIG's pilots discussed in Box 5-2. Marast, another local manufacturer, has grain mills and threshers in its product catalogue that processes about 200 kg of crops per hour,[9] which fits the small scale of operations found in rural communities. Although already serving smallholder processors, AMIO, Marast, and other suppliers in Ethiopia currently do not offer electric equipment in rural areas and lack the knowledge on equipment specifications suitable for minigrids. Fortunately, these suppliers generally have the ability in-house to design and customize equipment. Several suppliers we interviewed expressed interest in prototyping and testing new electric equipment to better serve the market.

The financial institution provides loans or leases to processors for electric equipment and is responsible to collect loan or lease payments. The scope of responsibilities the financial institution is responsible for varies depending on the strengths and characteristics of the financial organization that fulfills the role.

There are two main categories of financial institutions that can fulfill this role: the MFIs that provide equipment loans, and the capital goods finance companies (CGFCs) that provide equipment leases. Whereas the CGFC is actively involved in reviewing and advising in selecting equipment, the MFI relies on the facilitator to advise the processor in this task. As such, the choice of whether a CGFC or MFI participates in a specific application of the model affects the breadth and depth of the role of the facilitator. Exhibit 20 summarizes the roles of MFI and CGFC, and their current requirements for borrowers or lessees to qualify for a loan or lease.

	MFI	CGFC
Financier role in business model	• Assess loan applications • Disburse financing • Monitor loan portfolio and collect loan payment	• Assess lease applications • Work with applicant and support equipment selection • Party to the purchase agreement with equipment supplier to procure equipment • Monitor processing business and equipment operation and collect lease payment • Provide ongoing technical support and coordinate after-sale service when needed
Down payment requirement	MFIs are not currently providing equipment financing in the agriculture sector	20% of equipment price (Oromia CGFC data)
Collateral requirement	• Individual loan: yes, up to 100% of loan amount often in the form of deeds • Group loan: not required	Equipment serves as collateral, the GCFC recovers equipment if the lessee defaults

Exhibit 20: Summary of MFI and CGFC Roles and Requirements

Box 5-3 presents a deeper look at the role and responsibilities of the financial institution as implemented by MFIs and CGFCs. Section 5.2 compares these financing options in more detail.

Box 5-3 Role and Responsibilities of MFIs and CGFCs in the Fee-for-Service Business Model

The financial institution's scope of responsibilities varies depending on the strengths and operating model of the finance provider. If an MFI is the finance provider, the facilitator plays a bigger role in advising the processor in selecting equipment, developing a business plan, and applying for a loan. The role of the finance provider is limited to reviewing and approving the loan application and collecting payments.

The role of the financial institution is broader with the participation of CGFCs. CGFCs' operating model mandates playing an active role in the selection, purchase, and maintenance of the equipment because in offering a lease, CGFCs are responsible for securing finance to purchase equipment on behalf of processors, often on their own balance sheet. CGFCs own the equipment at least for the period until the lessee pays off its financial commitment. As such CGFCs have a stake in ensuring the proper selection and operation of the equipment. Additional detail on the CGFC's operating model is included below.

Upon receiving the application to lease equipment, the CGFC's appraisal team reviews the business plan and assigns an officer to work with the processor to procure equipment.[10] The officer recommends equipment specifications based on the applicant's needs. The potential lessee then has two options. They can shop around and submit three to four supplier pro forma invoices for the GCFCs review and approval or they can rely on the officer to provide technical assistance and lead in requesting and evaluating quotes and selecting equipment. In both cases the officer reviews the pro forma invoices and specifications and comes to a mutual selection agreement with the lessee, after which CGFCs enter the purchase agreement with equipment suppliers.

Once the lease takes effect, the CGFC will assign officers to monitor business operation and equipment usage, provide technical support when needed, and collect lease payments. With every lease payment, a portion of the equipment ownership transfers from the CGFC to the lessee. In the event of default, CGFC will repossess the equipment, barring the processor of the right to use the equipment and of future ownership.

The CGFC takes over many of the facilitator's responsibilities around equipment selection and capacity building for equipment operation. This operational model requires more active engagement by the CGFC than is required by the MFI, and so the CGFCs' participation will be limited to the geographic regions where their officers can serve this active role.

Currently, most CGFCs serve larger markets and customers where this type of active and ongoing support is paid off by larger equipment purchases and generally have limited presence in deeply rural communities. As such, CGFCs may be more suited to financing larger equipment purchases through the utility-led model (see Section 5.1.2), where they would be working with larger businesses and could explore bundling and funding equipment purchases for the processing center and the energy system.

The electricity provider (minigrid operator) remains in the main business line of supplying and selling electricity and would advise on technical requirements for electric equipment in a minigrid context. If the tariff policy permits and end-consumers are willing to shift their consumption preferences, the minigrid operator could explore tariff structures that encourage equipment operators to shift productive loads to hours when there is excess solar generation. This would reduce costs and create a win-win situation for end-consumers, processors, and the minigrid system.

Given that the minigrid market is nascent in Ethiopia, and that both private sector developers and EEU are still building their experience and expertise developing and operating minigrids, limiting their role in the business model will reduce their managerial burden in these tougher early stages. In the utility-led model introduced below, the electricity provider would take a bigger role, and more risk, in leading productive use implementation.

5.1.2 The Utility-Led Business Model

In the utility-led model (Exhibit 21), the electricity provider (EEU, a private minigrid developer) will first invest and own the electric equipment and charge local farmers a usage fee. The electricity provider may then transfer ownership of the business to local processors. Therefore, the electricity provider is ultimately responsible for credit and operational risks associated with the processing business. This arrangement would work well when larger investment is required or to introduce new productive use technologies to the community.

For this model to be effective in creating value to the local community, the electricity provider must invest time and resources in understanding local market needs and select the suitable technology and service (see Box 5-4 for a case study of Rensys leading productive use in its minigrid pilot). Where possible, the electricity provider should consult with a facilitator to better understand local end-consumer needs and preferences.

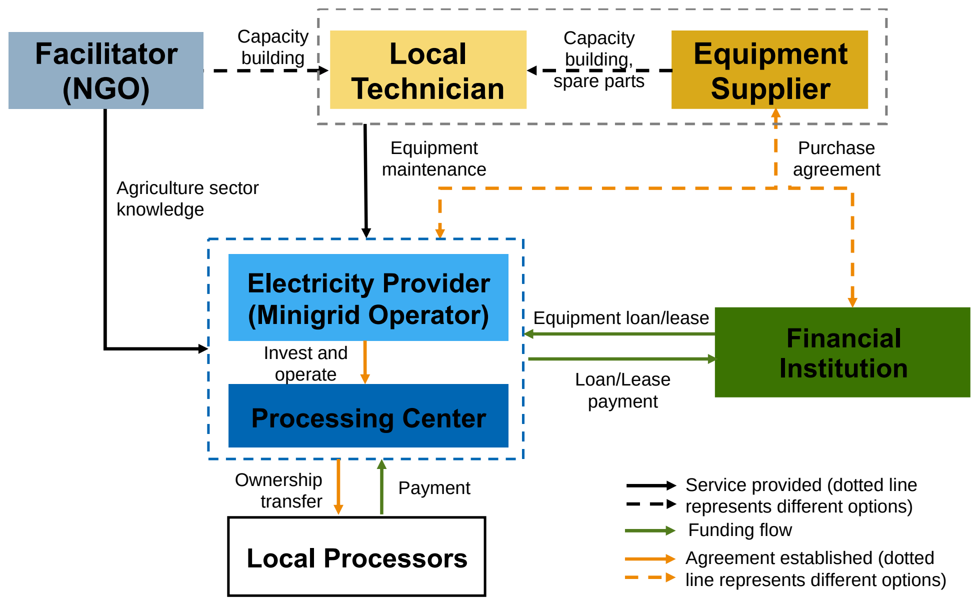


Exhibit 21: Institutional Arrangement for the Utility-Led Model

This model aligns the interests of the electricity provider to supply reliable electricity for the processing center. This model might also be easier for policymakers and development partners in the energy sector to support during early stages, as they can channel their support for productive uses directly to the electricity provider that they are already supporting and use the channels to reach minigrid developers established under the electrification program. As such, minigrid developers in the utility-led model may be able to access additional sources of funding not typically available to small-scale entrepreneurs in rural communities. By integrating the processing center into their site development plans, minigrid developers may be able to access concessional funding and their own project equity.

Additionally, this model does not expose local community members to credit risk at first while providing the local community with a new processing service. As a result, it might be more suitable for earlier stage productive uses that are not yet proven and require more support and concerted effort from development partners to develop.

However, compared to the fee-for-service model, most of the value addition is captured by the electricity provider. One way to share the value captured more broadly in the community is to arrange the gradual transfer of ownership to local entrepreneurs (similar to a lease-to-own agreement), where the electricity provider ultimately serves as the finance provider.

Box 5-4 Case Study of Utility-Led Productive Use Implementation in Ethiopia[11]
With grant support from the United States African Development Foundation (USADF), minigrid developer Rensys Engineering commissioned Ethiopia's first private solar minigrid in 2018 in Dek

island, Lake Tana, Amhara region. The 18 kW solar and 144 kWh battery system provides clean electricity to about 10% of the population on the island.

In the planning phase of the project, Rensys assessed and incorporated productive use in its development plans. Through multiple site visits and door-to-door surveys, Rensys analyzed the fishing value chain and identified an opportunity to support local fishermen with access to cold storage. Rensys now provides cold storage services to local fishermen with the option to own the equipment through a lease-to-own arrangement.

Early success with this model has led Rensys to diversify the productive uses it offers and is now exploring establishing a fee-for-service cold room for smallholder horticulture farmers. This service will enable small-scale farmers to store their perishable produce and gain bargaining power when selling their harvest. Farmers will be charged based on the space and length of storage used.

Roles and Responsibilities of Actors in the Utility-Led Model

Most actors in the fee-for-service model would also participate in the utility-led model. Depending on the electricity provider's capacity, the roles and responsibilities of other actors can vary.

The **electricity provider**, in addition to supplying reliable electricity, will lead the effort in identifying electrification opportunities in the community with support from the facilitator, conduct feasibility analysis, develop a business plan, and introduce suitable technologies to the community by investing and operating the processing center. The electricity provider will also be responsible for securing financing for the productive use equipment and procuring equipment. They will also coordinate with the facilitator, local technicians, and the equipment suppliers to ensure timely service and maintenance of equipment if the electricity provider themselves lack the technical capacity in-house or on-site.

In the alternative arrangement where the electricity provider offers lease-to-own equipment to local entrepreneurs, the electricity provider will take on additional responsibilities of selecting processor candidates, collecting equipment payment, and monitoring operation of the processing center.

The **facilitator**'s main responsibility is to support the electricity provider in identifying productive use electrification opportunities, leveraging the extensive knowledge of agriculture sector and local communities. This support ensures that the technology introduced fits local context needs and creates value for the community members, which will determine the economic viability of the processing center. If the electricity provider lacks knowledge on equipment, the facilitator could advise on equipment selection and support training local technicians to support equipment service and maintenance.

The **equipment supplier** and **financial institution** will perform the same roles as in the fee-for-service model and can be filled by the same candidates. Besides MFIs and CGFCs, the electricity provider may have access to other types of financial institution such as commercial banks and concessional lenders to finance productive use equipment.

5.2 Financing Options for Equipment Purchases

As discussed in Section 5.1, the financier role in both business models can be fulfilled by MFIs providing equipment loans or by CGFCs offering equipment leases. MFIs have more branches and officers to reach a broader client-base, and many already have decades-long experience financing the small-scale agriculture sector and so understand the customer base. CGFCs have technical expertise of and experience with agricultural mechanization but generally have less experience serving small-scale rural entrepreneurs and lack the infrastructure to do so in the short term. Depending on the region of interest, processor profile, and size of the processing business, MFIs and CGFCs may be well positioned to serve different segments of the equipment financing market.

5.2.1 Equipment Loans through MFIs

MFIs provide most formal financing in rural communities in Ethiopia, with extensive networks of branches and officers and ability to serve more remote regions (see Box 5-5 for a brief introduction of MFIs in Ethiopia and Box 4-2 in the economic analysis section for a description of their loan offerings). Many MFIs have provided loans for investments in agriculture for decades, primarily supporting farming inputs such as seeds and fertilizers. More recently MFIs have ventured into financing solar energy projects.

Box 5-5 MFIs in Ethiopia

To date, there are 28 MFIs registered in Ethiopia, and by the end of 2018, the loan portfolio held by MFIs was around ETB 43 billion. The MFI sector in Ethiopia is consolidated, with 15 major MFIs accounting for over 98% of total business.[12]

Public MFIs are limited to serving specific regions, as they are often financially backed by regional and municipal governments. For example, as of April 2019, the Oromia Credit and Savings Share Company (OCSSCO) had 384 branches in all zones in Oromia, covering almost all districts.[13] In contrast, private MFIs have a wider geographical reach but tend to focus on urban markets. Ethiopian MFIs already have a long history of providing a range of financial services, including providing voluntary and compulsory savings, micro-insurance, remittances, and micro-loans.

The legal and regulatory framework governing MFIs establishes their mandate to support the income-generating potential of micro- and small-scale entrepreneurs and aligns closely with supporting productive uses of electricity. *Proclamation No. 40/1996, A Proclamation to Provide for the Licensing and Supervision of the Business of Microfinance Institutions*, and the 17 directives issued by the National Bank of Ethiopia (NBE), constitute the legal and regulatory framework governing MFIs.

The *Micro Financing Business Proclamation (No. 626/2009)* and its *Amendment (No. 1164/2019)* specifies that the main purpose of an MFI is to collect deposits and extend credit to rural and urban farmers and to micro- and small-scale entrepreneurs and to support income-generating projects. Expert interviews indicated that some MFIs receive additional mandates to finance access to renewable energy in off-grid communities.

MFIs' funding sources include savings from active members and loans from the Development Bank of Ethiopia (DBE). DBE usually offers MFIs five-year loans with a one-year grace period, at an 8%–9% interest rate and semiannual installment, requiring no collateral.[14] MFIs apply for funding once a year around June, and the final approval is made by both DBE and NBE.

In recent years, the demand for loans from MFIs has outpaced growth in savings. MFIs indicated that liquidity challenges and loan fund shortages limit their ability to offer more favorable terms for loan borrowers and to extend their existing portfolios and geographical reach. As a result, for MFIs to serve the new market of financing investments in electric equipment, they will need access to funding for capital injections.

Although MFIs are not currently providing large enough loans to afford electric equipment, the MFIs we consulted recognized how serving the productive use market aligns with their mandates (see Box 5-5). They expressed interest in exploring ways to work with policymakers and other actors to define suitable terms and serve this market. However, they also expressed the need for securing additional funding streams with terms that would allow them to serve this market, including longer tenor periods. They also expressed the need for capacity building to identify and understand viable productive uses and equipment and monitor loan repayment.

MFIs rely on a network of officers based close to their clients, and each officer on average works with hundreds of borrowers.[15] To expand their portfolio, MFIs may need support for recruiting and training more qualified officers, for transportation to reach new service regions, and possibly for upgrading IT systems to monitor longer-lasting loans.[16]

The MFIs we interviewed also highlighted the need to ensure that business models covered proper equipment maintenance, noting the difficulties they experienced financing solar home systems. Solar companies failed to follow up after installation and customers were not able to repair solar panels when the systems broke down, leading to customer reluctancy to repay their loans and a significant number of loan defaults. Ensuring that channels for quality and timely repair services are embedded in the design of business models will be a key requirement for getting MFI buy-in and willingness to provide financing for productive use equipment.

5.2.2 Equipment Leases through CGFCs

Processors can also partner with CGFCs to enter a financial lease and gain usage rights of the electric equipment, with the option of eventually owning the equipment (see Box 5-6 for a brief introduction of the equipment leasing market in Ethiopia). CGFCs are already supporting agricultural mechanization in both urban and rural markets, providing farming machinery and agro-processing equipment on lease. But there is no precedent for providing electric equipment for rural customers so far because demand for this type of equipment does not exists due to the lack of reliable electricity access in many rural communities.[17]

Box 5-6 Leasing Market in Ethiopia

In Ethiopia, lease financing is still nascent. The first leasing regulation, the *Proclamation No.103/1998 Capital Goods Leasing Business Proclamation* was issued in 1998. However, little development took place until an amendment (*Proclamation No.807/2013*) of the proclamation came into effect in 2013.[18] The Amendment assigned the National Bank of Ethiopia (NBE) to regulate, license, and supervise the financial lease and hire-purchase market. The main difference between financial lease and hire-purchase is that hire-purchases transfer an equal share of the ownership to the lessee with each payment, and the lessee automatically becomes the owner of the equipment upon last payment. Under financial leases, lessees have the option to buy the capital goods after the lease period ends, subject to agreement with the leasing companies.

Following the Amendment, NBE issued five licenses to five Capital Goods Finance Companies in early 2014—Addis CGFC (in Addis Ababa), Oromia CGFC (in Oromia), Waliya GCFC (in Amhara), Debub CGFC (in SNNPR), and Kaza CGFC (in Tigray). The five CGFCs soon began providing leasing services in their respective regions. In August 2019, NBE granted the sixth leasing license to Ethio Lease, which finances investments in large-scale machinery and that became the first (and the only thus far) foreign-owned leasing company operating in Ethiopia. MFIs by regulation (*Microfinancing Business Proclamation No. 626/2009 and the Amendment No. 1164/2019*) may provide financial leasing services but the MFIs we consulted indicated they have not entered the space and prefer to leave the leasing business to the GCFCs in the near term.[xxiii]

A closer look at a GCFC suggests that the lease scheme may be more suitable for larger equipment purchases. Oromia CGFC, for example, currently has an ETB 200 million portfolio providing various equipment options including threshers, grain mills, and bread-making machines to 21 zones in Oromia. Their lessees include individuals and limited companies in both urban and rural areas. Grain mills offered in urban regions are usually electric, while in rural areas large-sized (e.g., 45 kW, 2,100 kg/hour) diesel-powered mills are provided due to lack of electricity access. This pattern of selling larger equipment in rural markets suggests that Oromia CGFC works with larger rural customers to justify the greater efforts and resources needed to serve this market segment.

The effort and resources required to serve the leasing market are substantial. Oromia CGFC has a roster of suppliers for the different types of equipment it provides to enable a greater selection of options for customers. They also have knowledgeable officers working across 15 branches to support customers in equipment selection, installation, and training on equipment operation, and to collect lease payments and monitoring business operation (see Box 4-2 in economic analysis section for Oromia CGFC's current terms offered).

[xxiii] Including Amhara Credit and Savings Institution, Oromia Credit and Savings S.C., and VisionFund MFI.

The CGFCs we interviewed expressed interest in expanding their portfolio to include financing for smaller-scale electric equipment for rural customers if the business is proven viable. However, there are many challenges faced by GCFCs in scaling the leasing market to serve this market segment.

For example, lessees in this new market segment may lack capacity and require more support to prepare business plans and properly operate the equipment. This may require additional training for the GCFC staff on evaluating and appraising business plans to make up for these gaps. CGFCs would need to determine whether the additional time and resources needed to serve this new market segment is recuperated in additional revenues. Therefore, early adopters serving this new segment may require support until proving the viability of serving this market segment.

Additionally, because GCFCs do not traditionally serve such small customers, they lack the infrastructure and linkages to access and serve this new and remote market. As such, GCFCs may be more suitable for the utility-led model, in which customers (the minigrid developers) are larger and will generally have a presence in urban centers.

5.2.3 Comparative advantages of MFIs and CGFCs

Introducing CGFCs to fulfill the financier role would spread the credit and operational risk across actors in the business model and in so doing align actors' interest toward ensuring the proper selection and maintenance of equipment. Alternatively, MFIs have a wider presence throughout and more experience working with rural communities. Thus it will be an easier gap to bridge for MFIs to extend their financing services to include equipment financing than it would be for CGFCs to enter a new market segment.

The CGFC operational model assigns a portion of the operational and credit risk to actors with the expertise, experience, and purchasing power to better manage those risks. CGFCs are familiar with agricultural equipment so have the expertise to select the right equipment (see Box 5-3 for details on the leasing operation at CGFCs). Because the CGFC is the owner of the equipment until the ownership is transferred to the processor, the CGFC is motivated to ensure the equipment is well maintained. It does this by collaborating with the equipment supplier on an adequate after-sale service schedule. The CGFC is also motivated to ensure that the processors know how to properly operate the equipment. The equipment suppliers, on the other hand, have a stronger incentive to provide proper maintenance support because they want to maintain a good relationship with the CGFC, which is one of their larger customers.

However, CGFCs have a much smaller number of branches and officers than MFIs and developing this infrastructure will take time. As such, MFIs are better poised to serve small processors in remote rural regions and scale implementation in the short term. That is, due to MFIs' larger customer base and broad geographic coverage, they are currently better placed to expand their portfolio quickly. However, depending on the location and size of the processor seeking equipment financing, a CGFC may be a more attractive option. For example, a CGFC may be well placed to finance a minigrid developer making a larger investment in developing a minigrid system and investing in a processing center under the utility-led model.

6 Preliminary Design of the National Productive Use Program

With this section, we identify the prerequisites to scale electrified agricultural productive uses. We also explore the barriers limiting these prerequisites and use this understanding as a basis to prioritize interventions in the preliminary design of the national productive use program. For an in-depth description of the projects that make up the productive use program see Appendix D.

6.1 Desired Outcomes of and Barriers to Productive Use

There are a set of five prerequisites that must be met to ensure that the use of electricity for agriculture activities will increase incomes across rural communities in Ethiopia. These prerequisites guarantee processors are equipped to invest in electric equipment and operate commercially viable businesses in rural communities. However, as Exhibit 22 shows, five barriers limit these prerequisites. We explore each of these prerequisites alongside their related barriers below.

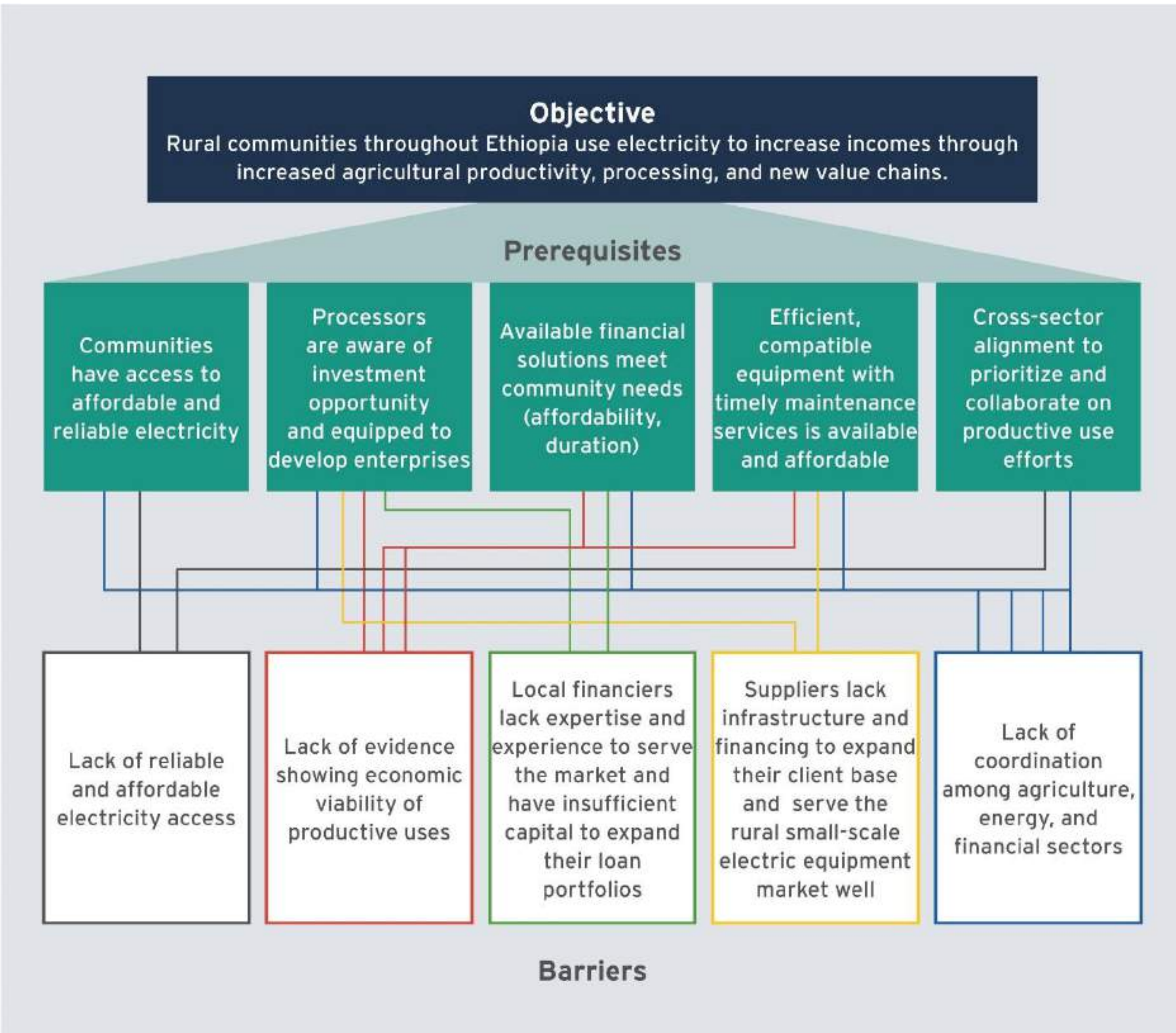


Exhibit 22: Prerequisites and Barriers to Productive Use

Prerequisite 1: Communities have access to affordable and reliable electricity. Affordable and reliable electricity access is the foundation for electrified productive uses. A would-be processor will not be willing to invest in electric equipment if she or he does not think they will be able to sufficiently operate the equipment to recover their investment. Nearly all experts we consulted and over 80% of agro-processors we surveyed noted the lack of reliable electricity to operate machines as the most or second most important barrier rural entrepreneurs face.[xxiv]

Prerequisite 2: Processors are aware of investment opportunities and equipped to develop enterprises. There is limited precedent to show the economic viability of electrified agro-processing businesses in rural regions. The field survey only found two grain millers, two threshers, and two dairy refrigerators among 101 agro-processing business owners who use electricity to power their equipment. Without robust examples showing the technical and financial viability of electric equipment in rural communities, processors will be unwilling to invest in electric equipment.

Beyond the desire to purchase electric equipment, processors need to be aware of the opportunities available to finance equipment. They must also have the skills to select equipment and develop a business plan. Survey results suggest that it is challenging to access extension or business development services in agricultural communities, as 38 out of 69 respondents said it was difficult or very difficult to do so.

Prerequisite 3: Available financial solutions meet community needs. About 60% of survey respondents identified lack of access to credit among the top two barriers preventing them from upgrading their business and only two of the 63 grain millers we surveyed had obtained a loan in the past.[xxv] MFIs consulted identified proven financial viability of the applicant's business as the top factor in determining loan approval. The lack of evidence showing the economic viability of electrified agro-processing businesses in rural regions also limits access to credit.

Most local finance providers do not serve the appliance financing market for agricultural productive uses in rural areas. Even CGFCs that finance agricultural equipment purchases do not target smaller-scale rural customers. As a result, finance providers do not understand market needs and how to serve them successfully. But finance providers also face capital constraints. MFIs lack access to longer-lasting funding to on-lend in the appliance financing market where longer tenors are needed (see Section 5.2.1).

Prerequisite 4: Efficient, compatible equipment with timely maintenance services is available and affordable.

The World Bank ESMAPs review of the appliance market in Ethiopia suggests that existing equipment suppliers can provide or manufacture electric options for Tier 1 activities identified here (see Box 6-1 for an overview of the appliance market in Ethiopia).[19] Nonetheless, additional research is needed to test these locally available electric equipment options to ensure compatibility

[xxiv] In the field survey, 52 out of the 101 agro-processors rated the lack of reliable electricity as the most important barrier they face to grow their businesses, and 31 noted it as the second most important barrier. Among grain millers, 55 out of 63 reported the lack of electricity as the most important or second most important barrier.
[xxv] Out of 101 agro-processors, 40 noted lack of access to financing as the most important barrier and 17 rated it as second most important.

with minigrid systems, operator requirements for efficiency, and end-consumer product preferences.

Equipment suppliers we consulted noted they often face capital constraints that limit the variety and amount of equipment and spare parts they have available in stock. In addition, most equipment suppliers are based around Addis Ababa and lack the infrastructure to provide prompt after-sale service and maintenance for customers in remote rural areas, where demand for productive uses exists. The lack of spare parts and timely repair services leads to lost revenue that limits the profitability of processing businesses.

This risk of delays in repairs and foregone revenues can demotivate would-be processors from purchasing equipment. Similarly, finance providers will be reluctant to finance equipment purchases unless timely maintenance is guaranteed, due to their experience financing solar home systems where lack of after-sale service led to significant loan defaults (see Section 5.2.1).

Box 6-1 Appliance Market in Ethiopia

There are dozens of suppliers that import, manufacture, and distribute agricultural equipment in Ethiopia, offering a selection of equipment including irrigation pumps, threshers, hullers, mills, milking machines, dough mixers, bread ovens, etc. However, the Ethiopian appliance market is opaque, and it is difficult for a would-be equipment investor to make informed decisions.

A market study developed by ESMAP shows that there are significant differences between the price and power rating of the same type of appliance, depending on whether the appliance is domestically made or imported.[20] Locally manufactured mills for example are more expensive than imported mills of the same capacity, while domestic pulpers and dairy pasteurizers are cheaper than the imported alternatives. The underlying design or quality differences causing these price disparities are not immediately clear; therefore, making an informed purchase decision based on the value for money of the different options available is difficult. One reason leading to this situation is the lack of equipment standards. The Ethiopian Standards Agency only has mandatory standards for irrigation pumps and voluntary standards for welding machines.

Equipment supply is concentrated in Addis Ababa and nearby regions and the volume of equipment availability remains low, generally limited to tens or hundreds of appliances produced and available annually. Most suppliers operate on-demand, importing or manufacturing equipment in response to requests from customers, and they often lack equipment or spare parts on stock. The amount of time it takes to respond to customer orders is also difficult to predict, especially if the order requires importing components. This means that a would-be equipment investor must account for this additional layer of uncertainty when making purchase decisions and these additional considerations may demotivate more risk-averse actors.

Without receiving confirmation of demand and prepayment to fund the order, suppliers are unwilling to supply equipment. Equipment suppliers follow this operational model due to constraints on working capital that limit their ability to hold significant levels of inventory.

Commercial loans are also unaffordable, requiring collateral as high as five times the loan value. As a result, suppliers tend to be reluctant to develop new product lines and enter new regions.

Prerequisite 5: Cross-sector alignment to prioritize and collaborate on productive use efforts. There is a lack of awareness and alignment on which opportunities for productive use to prioritize. In addition, there is a lack of coordination among stakeholders in the agriculture, energy, and financial sectors to mobilize investment. Policies and programs aiming to support agriculture and energy sector development are underway, but there are not enough partnerships to leverage cross-sectoral expertise. For example, minigrid developers need to understand end-consumer and processor preferences to integrate agro-processing loads into their planning. Similarly, the connective tissue linking processors to equipment suppliers and electricity providers rarely exists.

Box 6-2 **Other Prerequisites and Barriers to Implement Productive Use**

This study focuses on prerequisites that are tractable and that can be addressed in the short and medium term while avoiding duplicative efforts. However, we recognize that other conditions outside the scope of this study can affect the success of initiatives to support adoption of electric equipment. We summarize those prerequisites, barriers, and their potential impact here.

Agriculture extension services are made available to smallholder farmers to improve farming practices and yields. As the economic analysis suggests, processing volume is the most important factor determining the economic viability of processing businesses. This means that there needs to be sufficient crop volumes produced to support the demand for processing services. As was explored in the value chain research, the lack of quality inputs, irrigation, and access to sufficient training are some of the factors limiting grain production in Ethiopia.

The Ministry of Agriculture, IFPRI, and ATA are supporting efforts to improve agriculture production and farmer capacity building. For example, irrigation is recognized as a key intervention to support the horticulture segment and various organizations including The Rockefeller Foundation, Veritas, and GIZ are exploring how to integrate irrigation into electrification projects.

Foreign exchange (FOREX) policy can streamline and boost equipment imports and attract investment to support productive uses. Ethiopia's restrictive FOREX policies lead to lengthy processes to import equipment and spare parts and can discourage foreign investment. This is a regulatory barrier that is outside the scope of this study but can slow down and affect the ease of procuring electric equipment for prototyping and running field tests. It can also lengthen the process for identifying the specifications of technically viable equipment.

6.2 Preliminary Design of the Productive Use Program

We developed a preliminary design of the national productive use program based on the findings from the economic, business model, and barrier mapping analyses. The program is made up of eight projects and scaling mechanisms that we will continue to build upon and refine through the design sessions (see Section 7). These projects include community-based practical solutions alongside wider solutions to support an enabling ecosystem where community projects can be replicated.

Together these preliminary projects make up a comprehensive national productive use program that aligns and connects cross-sectoral actors, generates an evidence base demonstrating the technical and financial viability of equipment and business models, and develops supportive policies. These three building blocks address the barriers limiting the prerequisites for scaling productive uses in rural communities in Ethiopia. Exhibit 23 shows the projects connected to each of these building blocks.

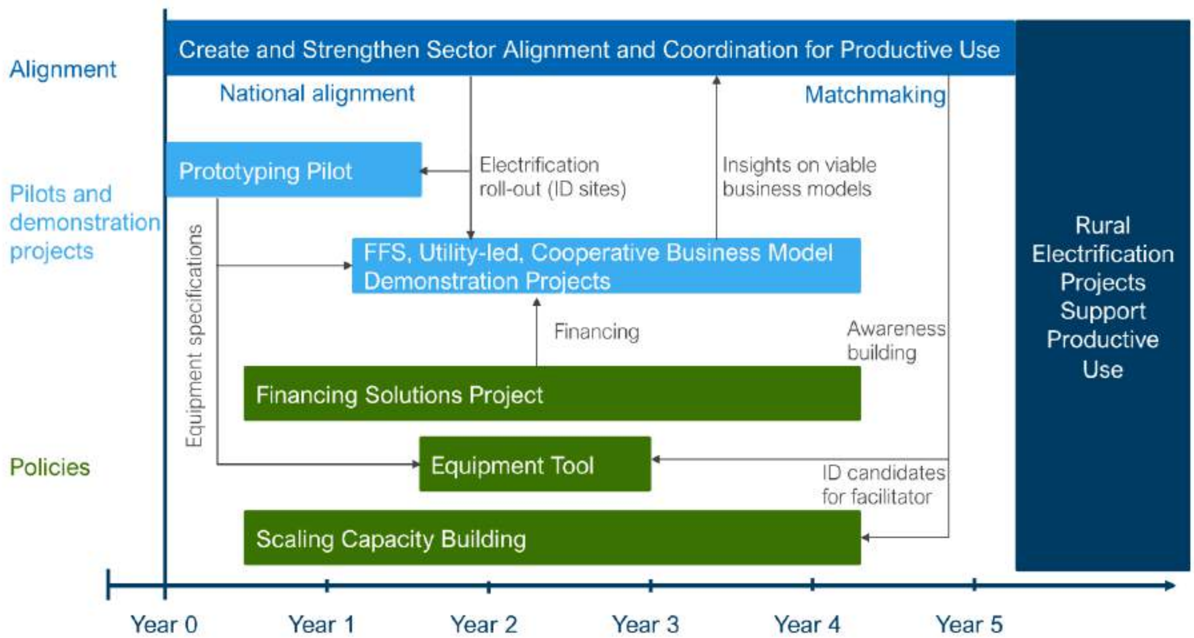


Exhibit 23: Timeline for the National Productive Use Program

These projects categorized by the three building blocks are summarized below. A more detailed description of each project is included in Appendix D.

Building Block 1: Align and connect cross-sectoral actors. The *Create and Strengthen Sector Alignment and Coordination for Productive Use* project (Cross-Sector Alignment Project) will open dialogue across the energy, agriculture, and finance sectors to identify opportunities to develop productive uses. The discussion and coordination between different stakeholders will build awareness to oversee the national productive use program and enable partnerships to implement productive use opportunities.

This alignment will occur at and across the national and community levels and will extend the awareness building and matchmaking efforts planned under this project (see Section 7). Bringing together national-level actors will ensure that electrification efforts connect with agricultural development and ensure reliable and affordable electricity where productive use opportunities are prevalent. Bringing together regional and community level actors will build the connective tissue among actors needed to implement business models in communities.

The Cross-Sector Alignment Project will develop a cross-sectoral committee (the Productive Use Committee) to operationalize this alignment and coordination. The Productive Use Committee will be responsible for overseeing the national level strategy to support productive uses and the implementation of the national productive use program. As the national productive use program is implemented, the Productive Use Committee will identify additional needs that will inform future activities and strategies.

Building Block 2: Prove and demonstrate the viability of equipment and business models. A series of pilots and demonstration projects will build the evidence base to show the technical and financial viability of equipment and business models. The *Electric Mill Prototyping Pilot* will fine-tune and field-test equipment in minigrid communities and establish the specifications to ensure equipment compatibility with minigrid systems and equipment operator and end-consumer preferences. The data captured will be used to identify the right equipment, improve accuracy of the financial model, and refine the design of business models to attract a small group of MFIs and processors to run a series of business model demonstration projects.

The *business model demonstration projects* will recruit private actors to implement recommended business models around Tier 1 activities and demonstrate financial viability, with a primary objective of evaluating whether revenues can recover the costs of operating the business models. The demonstration projects will seek to de-risk investment in electric agricultural equipment by bringing in private actors to understand and gain experience participating in the business models and reduce perceived risks. A secondary objective includes understanding the conditions (e.g., scale, grid vs. minigrid, operator practices) under which one business model is more suitable than others. The demonstration projects will test the fee-for-service, utility-led, and cooperative-based business models.

Building Block 3: Develop supportive policies for an enabling ecosystem. Technical advisory, capacity building, and funding support will lubricate the ramp-up of productive uses in specific hubs through the pilots and demonstration projects and then provide the platform solutions needed to replicate productive uses in rural communities across Ethiopia. The *Designing and Piloting Financial Solutions* project will provide technical advisory and capacity building to MFIs and CGFCs to design financial products suitable for small-scale agricultural electric equipment purchases and equip them to serve the equipment financing segment. It will also provide capital injections to MFIs and CGFCs to on-lend to the productive use market (processors and suppliers).

The *Electric Equipment Selection Tool* (Equipment Tool) and *Scaling Capacity Building* projects will develop platform tools and materials to support equipment selection and partnership decisions. The Equipment Tool will guide processors in identifying suitable equipment that is compatible with minigrids and meets their needs. The Equipment Tool will be built out in stages and will start with electric mills based on the specifications identified in the Prototyping Pilot. The Scaling Capacity Building project will provide standardized materials to support facilitators in fulfilling their role building the capacities of local processors and connecting them to finance opportunities. It will also identify a roster of candidates shortlisted based on their capacity to fulfill the facilitator role to guide community actors in making successful partnership decisions.

Exhibit 23 shows the many connections that exist between projects. Project sequencing was optimized to develop feedback loops that capture insights and lessons available. For example, establishing the Productive Use Committee is one of the first activities planned to ensure that site selection decisions for upcoming electrification projects capture productive use opportunities. This step will be critical to ensure that the pilots and demonstration projects have attractive sites to choose from. Similarly, the equipment selection and capacity building tools will be developed after Year 1, when the pilots and demonstration projects have yielded results to inform tool design.

In next phase of the project, the team will convene and engage stakeholders to ground test and refine these preliminary designs (see Section 7) and finalize the national productive use program.

7 Next Steps to Finalize and Align Sector on the National Productive Use Program

This section defines the next steps to gather local input to finalize the National Productive Use Program (the Program) and move toward a future where all energy access projects in rural communities include a productive use component. Specifically, we will build upon the findings and insights of this study and pull in cross-sectoral input and pilot findings to finalize, build consensus on, and propel momentum for the Program, the ultimate deliverable of this project.

This section is forward looking, describing the ongoing and planned activities and outcomes for the period April to September 2021 in the project timeline. As such, this section focuses on the activities to date and methodology and approach the team will use going forward. By September 2021 when these activities are complete, the team will update the Program (Section 6.2), refine the approach and methodology for community consultation (Section 7.1), and assess the results and outputs of the pilot to date (Section 7.2).

7.1 Process for Community Engagement

This section describes the process for community and national consultation—the design sessions—to finalize the Program. Once the design sessions are complete, the team will revise this section, as needed, to capture the lessons learned through the application of the consultation process described here.

End-User Centered Approach to Program Design

To design the Program, we have adopted an approach centered on the end-user. End-user centered design requires relating with people directly concerned and giving them a voice. Our approach borrows from the capability approach. It requires thinking in terms of actors who express preferences, increase their own capabilities, and participate in the production of value, instead of thinking of beneficiaries as consumers that are passive figures. We also borrow from human-centered design, which brings in actors from different backgrounds to meet and operate in nonhierarchical ways to propose innovative approaches to electrification that are not constrained by agency or sector-specific mandates and thinking.[21]

A user-centered approach is well-suited to designing projects in the productive use space. The nature of productive use opportunities requires understanding ground realities and making connections between and enabling coordination across sectors. For example, grain milling, identified in Section 3 as a Tier 1 electrification opportunity, connects with end-consumer food preferences, which are deeply personal and relate to cultural practices that cannot be easily changed. No one understands consumer preferences better than the end-consumers themselves.

Failure to understand and account for these preferences and behavioral practices will lead to a project design that is unlikely to meet the needs of end-consumers. In addition, it may fail to get community buy-in and adoption once the grant funds supporting early project development run out. Furthermore, because productive use initiatives occur at the nexus of energy and economic development, identifying opportunities in this space requires bringing together a coalition of actors with the needed skills and experience spanning agriculture, energy, and finance sectors.

The project team will implement a user-centered approach to program design through the design sessions. The goal of the design sessions is to create a space to maximize potential for innovation while still being deeply rooted in ground realities. We will bring together actors from different backgrounds to interact, discuss possibilities, and develop projects to test and verify these possibilities. To do so, we have structured the design sessions to start at the community level to first understand needs, barriers, and opportunities. We will then bring in input from community and national actors to design the national productive use program, building on the preliminary design presented in Section 6.2.

7.1.1 Structure and Detailed Methodology of Design Sessions

The Design Sessions will use a three-tiered approach for connecting with end-users to inform the design of the national productive use program. The first two tiers will focus on understanding the barriers and opportunities at the community level. Together these tiers will lead to the design of highly actionable community solutions and projects rooted on ground realities and priorities. The third tier will convene national level stakeholders to build on and connect these community-level solutions with top-down broader actions needed to support and scale implementation of community-level projects.

Throughout the execution of these tiers, the RMI team will facilitate discussions with end-users and co-producers to develop a pipeline of projects that will make up the national productive use program. A more detailed description of each tier is included below.

Tier 1: Conducting community visits and focus groups

Objective: Connect with end-users to understand their needs and priorities and understand ground realities, barriers, and opportunities in rural communities.

Approach: Carry out community visits and one-on-one and group interviews to understand the needs and lives of people we are designing for. During the field visits the team will immerse themselves in the communities, shadowing processors as they work and observing end-consumers as they make decisions to understand their preferences and needs. We will complement these observations with interviews. We will partner with a trusted community-based organization (CBO) to identify communities to visit and connect with end-users while following precautions to mitigate the spread of COVID-19.

Scope and timing: We will carry out two field visits to two agrarian communities with significant post-harvest mechanized processing activity in Amhara, Oromia, or SNNPR in Q3 2021. We will select the communities in collaboration with the CBO we partner with. This will enable us to select communities where our partner CBO has long-standing ties with end-users and leverage that trust to enable buy-in and willingness among community members to engage with the project team.

Tier 2: Designing community-level solutions

Objective: Design community-level projects and viable business models to support adoption of productive uses. The output of Tier 2 will be a pipeline of tangible community projects that address the key needs of rural communities. We will test and build upon the preliminary design of business models (see Section 5.1) and projects (see Section 6.2) included in this study, testing whether these designs appropriately respond to key barriers (see Section 6.1) and whether there are blind spots in these designs.

Approach: Tier 2 will bring together actors with the required expertise and experience to develop and design productive use demonstration projects (i.e., developing an electric milling prototype) at the community level. Tier 2 will target actors that will intervene in the implementation of community-level projects by identifying representatives of the roles included in the proposed business models explored in Section 5.1. Appendix E includes additional detail on the criteria used to select participants. The team will convene these actors and will facilitate discussions to enable the collaborative design of community-level projects. We will keep these convenings small to ensure we can follow precautions to mitigate the spread of Covid-19.

Scope and timing: One multiday session held in Q3 2021. We will select the location based on the needs assessment (see Detailed Methodology below) and in collaboration with our partner CBO.

Tier 3: Scaling solutions and building an enabling eco-system

Objective: Identify top-down actions and broader ecosystem support needed to replicate and scale community-level interventions, building on the results of Tier 2 and preliminary design included in Section 6.2. Topic areas can include funding sources for community-level projects and system-level solutions to attract equipment suppliers and financiers (e.g., bulk equipment purchasing, guarantee funds).

Approach: Tier 3 will adopt a similar approach to Tier 2 of facilitating discussions between cross-sector actors. It will bring together actors at the national and regional levels to connect the grassroots practitioner perspective gathered in Tiers 1 and 2 to national development goals. If this workshop is carried out in person, we will limit the size of the participant list to ensure we can follow precautions to mitigate the spread of COVID-19.

Scope and timing: One multiday session held in Q3 2021. We will select the setting based on the needs-assessment.

Detailed Methodology

To develop the design sessions, the team designed a structured process to achieve the desired outcome of finalizing a national productive use program rooted in ground realities, connected to national development priorities, and bought-into by stakeholders across the energy, agriculture, and finance sectors. Meeting this desired outcome requires a process that is transparent and embeds feedback loops to connect with participant needs and interests.

The team developed a process that identifies participants with the right expertise and experience to lead to meaningful discussions. The process also embeds steps to understand participants needs and incorporate those interests into the design of the workshops to build buy-in for the process and its outputs. **Exhibit 24** illustrates a summary of this process. A deeper description of each step follows.

Exhibit 24: Methodological Approach for Design Sessions

Step 1: Define participant list—A key part of end-user-centered design is building the coalition of actors that will bring the needed skills and experience. But knowing the right things is not enough. In order for these collaborative encounters to be fruitful and effective, participants also need to be bought into the process and want to contribute to and dedicate time to participate fully in the discussions. As such, a key success factor will be identifying the right set of participants. Making sure that each participant carries their weight is important to keep workshop sizes small and manageable and ensure that the team can take adequate COVID-19 precautions.

We defined criteria to propose a preliminary participant list based on our research and stakeholder consultation. These criteria capture the skills and experience needed to meet the target outcomes for each tier. Appendix E includes a description of the criteria and the preliminary participant list categorized by the three tiers. We will next finalize the participant list, identifying potential blind spots and proposing a manageable shortlist of participants. To do so, we are consulting MOWIE, the Ministry of Agriculture, and ATA to receive their feedback and supplement this preliminary list based on their ground-based understanding of the right actors within these organizations to bring in.

Step 2: Conduct Needs Assessment— A key part of building buy-in from participants is early engagement to support awareness and to understand the needs and conditions of potential participants and tying these interests into agenda design. The needs assessment is a prerequisite in answering questions that will determine the detailed agenda planning and logistics of the design sessions (e.g., whether the sessions will be in person or remote). Specifically, the needs assessment will enable the project team to:

- understand the conditions for participants to participate (duration, in-person or remote, location);
- understand what participants want to achieve before we begin designing the facilitation exercises;
- narrow the scope and focus to appropriately reflect what participants are willing to work on;
- build trust with participants; and
- share data with participants ahead of time and build transparency in the initiative.

Some of the basic questions the needs assessment will answer include:

- Would you be willing to participate in a workshop in person during July 2021?
- What is your understanding of the current situation of productive uses in Ethiopia?
- What would make this workshop successful from your perspective?
- What do you hope to have at the end of the initiative (meeting/workshop) that you do not have now?
- What would make the workshop unsuccessful?
- What advice do you have for the design and facilitation team?

Step 3: Define detailed agenda and complete event logistics—We will review the results of the needs assessment to finalize the design parameters and prepare the workshops. This includes determining the physical parameters related to the setting (remote or in-person), location (if applicable), and number of participants that will determine the logistics for conducting the workshops. It will also include finalizing the topical parameters of the content addressed during the workshops. Within reason, the team will incorporate the interests of participants while building on the analysis and findings to date and ensuring the discussions are additive and push toward establishing a national program for productive uses.

Step 4: Carry out workshops and distill lessons learned—The team will carry out the facilitation, identify themes and patterns on barriers and opportunities, and distill insights to translate these findings into opportunities for project design. The team will categorize and order these projects to develop a pipeline that will constitute the national productive use program. The tiered structure of the workshops will allow the team to embed validation of the results of previous tiers in the tier that follows. For example, the design of the community-level projects developed in Tier 2 will be reviewed, refined, and built upon during the Tier 3 workshops. Nonetheless, the team will carry out an additional layer of validation through remote expert consultation and share the results during the dissemination seminar planned for September 2021 (see **Section 7.3** for additional detail on next steps).

7.2 Pilot Design and Implementation

The rural electrification sector lacks evidence for the technical and economic impact of productive loads on isolated electricity systems (minigrids) and income generation for small businesses. There are three actors whose decisions are affected by this knowledge gap: minigrid developers, processors (equipment users), and equipment financiers (e.g., MFIs). Minigrid developers need load data on productive uses to size components of rural electric systems accurately and minimize cost of service, while processors and financiers need proof of the business case to switch from diesel equipment. These data points are also necessary for policy design to support electric equipment ownership needed to scale productive uses of energy.

The team is developing a Data Pilot to gather insights that will improve sector-wide understanding of milling businesses and refine and improve the design of the business model demonstration projects included in the preliminary national productive use program (see **Section 6.2** and **Appendix D**). The Data Pilot will generate measured data on mill usage, minigrid load data, and other metrics that will improve the accuracy of economic viability analysis in this study (see **Section 4**). Specifically, the Data Pilot will collect measured data to answer the following questions:

- Is it economically viable for grid and minigrid systems to serve grain milling loads?
- What is the implication of serving milling loads for grid and minigrid system design and operation?
- Is switching to electric mills from diesel mills an economically viable investment?
- Is there demand for electric mills in communities?

The Data Pilot will not fully answer the following questions, which will be addressed by the business model demonstration projects:

- What are the characteristics of suitable mills that can connect to and operate compatibly with the grid and minigrid systems and are these available locally?
- How can the project mitigate perceived risks of financiers and promote access to credit for equipment purchases?

Feedback loops between the pilot and other project components

We incorporated feedback loops in the design of the pilot, ensuring it uses findings from our research and analysis to date and feeds results back into the project. We leveraged the **findings and insights from the value chain analysis** (see **Section 3**) **to design the pilot**. For example, study results indicate that grain milling has strong potential for electrification in the short term. Therefore, we designed the pilot to further test this finding using measured mill utilization data from grain milling businesses. We will also use pilot results to inform the design of the national productive use program.

Similarly, we **used data from the field survey** to better understand milling businesses and agro-processing in Ethiopia to **shape pilot design**. For example, the survey results provided insights on median community sizes and their average grain processing scale (number of processors, throughput of grain mills and grain harvest quantities of farmers), which we will use to guide selecting sites and processors that are representative of communities and processors found in the country.

Measured data from the Data Pilot will help the team validate insights from field surveys and fine-tune the financial models (see **Section 4**) **in preparation for the demonstration projects** (see **Section 6.2**) Our field surveys found that it is uncommon for rural processors to keep records of their business transactions. Other studies have also found significant differences between estimates and observed values, as was illustrated in Factor[e] Ventures' study which found that observed milling activity varied significantly in timing and duration than that reported by processors via field surveys.[22]

The project team will **feed the early results of the Data Pilot gathered by September 2021 to refine the design of projects proposed in the productive use program**. Mill load profiles (electricity consumption, time, and duration of use) and cash flows (revenues, costs, and their seasonal variations), will help the project team refine the design of and provide baseline data for the Electric Mill Prototyping Pilot and Fee-for-Service Demonstration Project. These projects will then expand the knowledge base on technically viable equipment and commercially viable business models to operationalize productive use initiatives.

This incremental approach to testing best-bet hypotheses will allow us to design more targeted projects. This will help ensure that even if one specific project fails, the sector can distil lessons from it to expand the body of knowledge needed to operationalize productive use initiatives in the national scale electrification efforts.

Pilot Outputs and Activities

By the conclusion of the Data Pilot, the project team will deliver a database and insights to answer key questions that will help processors and minigrid developers make good investment decisions. Specifically, the team will estimate potential load and revenue growth for a minigrid system serving milling loads to better understand milling profitability and end-consumer preferences. **Exhibit 25** presents the data the pilot will collect and the insights the team will develop.

Decision Maker	Insight required	Data provided by the pilot
Minigrid developer	Load increase and impact on system economics	• Mill load profile (energy consumption, time, and duration)
	Impact of connecting electric mills to system power quality (inrush current impact on system and meters, voltage variations)	• Measurement of inrush current upon mill start-up • Measurement of voltage/current at variable mill loading
Processor (equipment operator)	Customer preference for output (flour fineness)	• Product grade purchased by customers • Mill sieve size
	Profitability (revenues minus costs) for equipment available on the market	• Throughput (flour kg/hr) • Product or service selling price • Operating cost • Mill run time and duration (energy costs) • Mill downtime frequency per unit time • Maintenance cost per breakdown
	Energy efficiency (production capacity vs. energy consumption)	• Throughput (flour kg/hr) • Fuel/energy consumption per unit time • Time and duration of equipment use

Exhibit 25: Description of Pilot Output

To collect the data captured in **Exhibit 25** we will use metering and enhanced data reporting. We will install automated sensors to record measured data on grain mill power consumption and time and duration of use in order to develop mill load profiles. We will also install smart meters to capture load profiles of minigrid systems to assess the compatibility of milling loads with minigrids. These meters will help assess when milling loads occur and whether these loads coincide with generation of energy during the times of the day when it is cheapest to produce.

We will use enhanced data reporting (versus a one-time interview approach used during field surveys) to record longitudinal data on revenues and costs of milling businesses. The processors that we partner with will record their daily transactions in a journal designed for ease of use.

We will partner with a community-based organization (CBO) with experience supporting grain processors and providing capacity building for agriculture mechanization and business management, access to finance, and market linkages. The CBO will help engage with processors to boost interest in participating in the pilot, train them on use of data collection tools, and provide periodic gathering of data recorded via journals, sensors, and meters. This collaboration with a partner that has earned community trust will help ensure community buy-in and improve the quality of the data and the reliability of the insights from that data.

Pilot Scope

We will implement the pilot in the regions with the highest grain production volumes: Amhara, Oromia, and SNNPR. We will collect data for one year to understand the full cycle of equipment use and account for variations due to grain production seasonality and its impact on milling activities. Exhibit 26 shows a summary of the pilot scope, which includes collecting data from 24 processors in 12 kebeles and six operational minigrids across the three target regions.

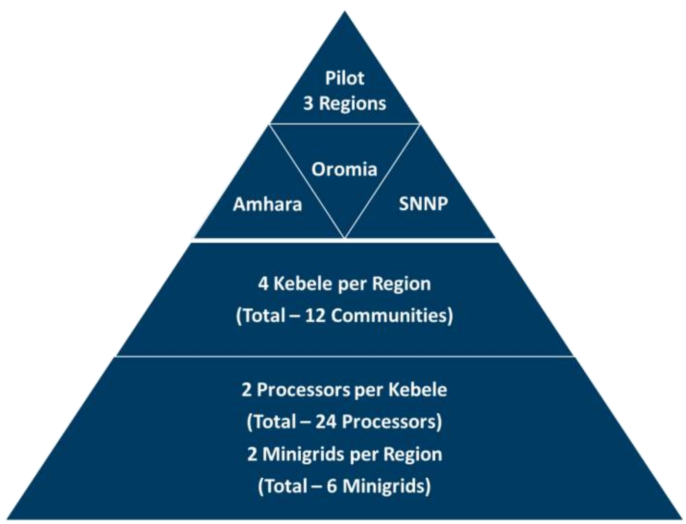


Exhibit 26: Summary of Pilot Scopes

We plan to select sites in coordination with our partner CBO and EEU to ensure the sites are in areas targeted for pre-electrification with minigrids and where the CBO has experience and trusted relationships with community members. Appendix F presents a preliminary selection of woredas that we will consider.

Pilot Workplan and Implementation Timeline

Pilot design activities started in February 2021, with a target of deploying the data collection tools in the communities by June 2021. Periodic data collection will start in June 2021 and end in June 2022. We will analyze data collected between June and August 2021 for preliminary insights that will inform the design of pilot projects under the national productive use program as well as the convenings taking place in September 2021. Exhibit 27 below shows the planned pilot activities and implementation timeline.

Exhibit 27: Pilot Timeline

7.3 Dissemination and Next Steps

This section defines the next steps toward implementing the national productive use program and a future in which all rural electrification projects include a productive use component. By the completion of the design sessions described in Section 7.1, there will be a clear national productive use program developed with and for community and national level stakeholders in Ethiopia. At this point the team will shift focus toward supporting local actors in implementation. To do so, the team will focus on disseminating results, building project consortiums, and connecting the national productive use program with early funding opportunities.

The team will lead cross-sectoral engagement across the agriculture, electricity, and finance sectors to share results, build consensus, and connect projects to actors and funding to prepare for implementation. The next steps include the following:

1. Validate the results distilled from the design sessions through expert consultation to ensure that we accurately captured the insights in the design of the final national productive use program. At this point, the team will update Section 6 and Appendix D of this study, to present the final design of the national productive use program, including cost estimates. As noted, in Section 7.1 the team will also update Section 7 to capture the lessons learned and provide a replicable methodology for community consultation.

2. Convene actors across the agriculture, energy, and finance sectors to **disseminate the results** more widely and align sector actors around the national productive use program. This alignment is a continuation of the awareness and consensus building embedded in the previous steps as many of the actors would have also participated in the design sessions and validation.

3. In parallel and during the dissemination seminars described in step 2, the team will put in motion the **implementation of the productive use program** by matchmaking actors that can lead specific projects identified in the program and connecting these projects with funding opportunities.

The prospects for electrification in Ethiopia are bright. Increased attention from government, development partners, and the private sector is driving increased investment in energy access. However, it is critical that these projects include business models that electrify agricultural productive uses. Failing to do so may compromise project economics and longevity, while an effective national productive use program will unlock local economic development and can serve as a springboard toward realizing the full potential of rural electrification.

Appendices

Appendix A In-Depth Value Chain Assessments

This appendix analyzes five value chains to identify opportunities for productive uses of minigrid electricity using the methodology described in Section 2.4. We focus on post-harvest operations: the processing steps from farm-gate material to the locally marketed product. We analyze each value chain in detail to identify opportunities to electrify value-add activities.

Using four criteria— local capacity, offtake market, equipment and electrification, and scalability— we sort these opportunities into three tiers based on the amount of support required to electrify them. Exhibit 5 presents these classifications for each activity and crop considered. Appendices A.2–A.6 provide in-depth analysis on each value chain, while Appendix A.1 analyzes trends across the target value chains.

A.1 Cross-Value-Chain Analysis

In this section we consider the role of multi-crop processing equipment in enhancing the viability of investments in electrical threshing and milling.

A.1.1 Multi-Crop Milling

Grain milling is already widely mechanized in most communities across Ethiopia. There is strong demand for mechanized milling throughout the year and rural consumers already pay to have their crops processed. Importantly, most grain mills already process multiple cereal crops. As shown in Exhibit 28, most millers process at least three of the focus cereals (66%). This suggests that locally available mills can meet end-consumer preferences of fineness, taste, and consistency across various cereals.

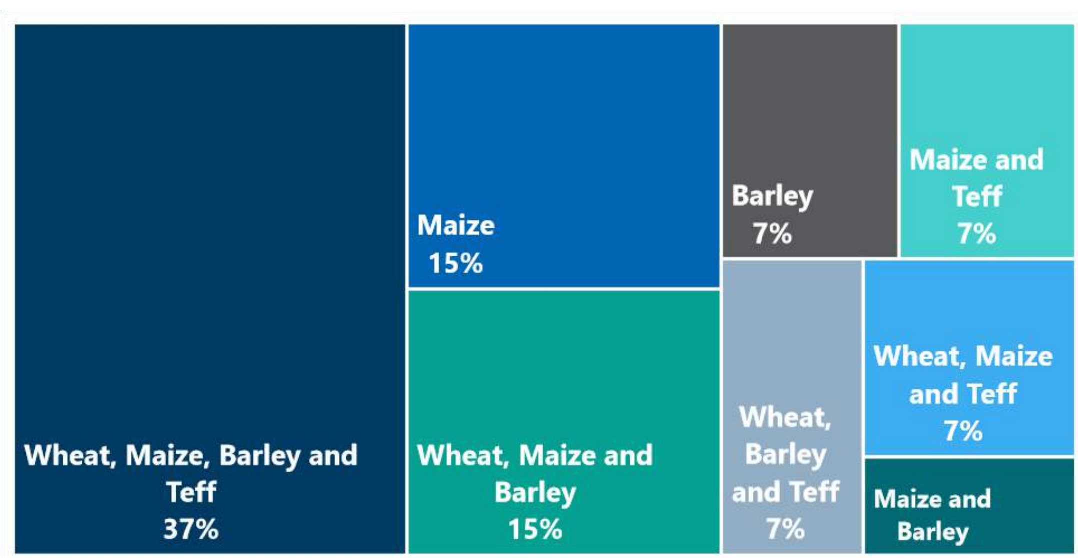


Exhibit 28: Proportions of Grain Milling Processors Based on the Crops that they Process (based on 2020 RMI survey findings: 66% of mills process at least three focus crops, 11% process two crops, and 22% process just one crop)

Today most mills are diesel-powered, typically utilizing old, oversized combustion engines as the prime mover. Electric engines offer clear savings on operation costs over the status quo (see **Section 4**). But further testing is needed to test electric mills in rural communities and compare against measured costs, throughputs, and product quality of diesel-powered engines. For example, processors we interviewed observe throughputs of 2.1 quintal/hour using fossil fuel-powered equipment. A pilot study will need to assess whether electric mills in minigrid settings can meet this threshold.

A.1.2 Multi-Crop Threshing

Across the target cereal value chains, grain threshing is not immediately suitable for electrification. Most grain threshing takes place manually, and farmers in rural communities currently demonstrate limited demand for mechanized grain threshing.

The viability of grain threshing depends on local demand for mechanized threshing. Farmers must be willing and able to pay for mechanized threshing, and the volume of processing must be high enough to offset equipment and business costs. We discuss the viability of grain threshing in the **Maize**, **Teff**, and **Wheat** value chains.

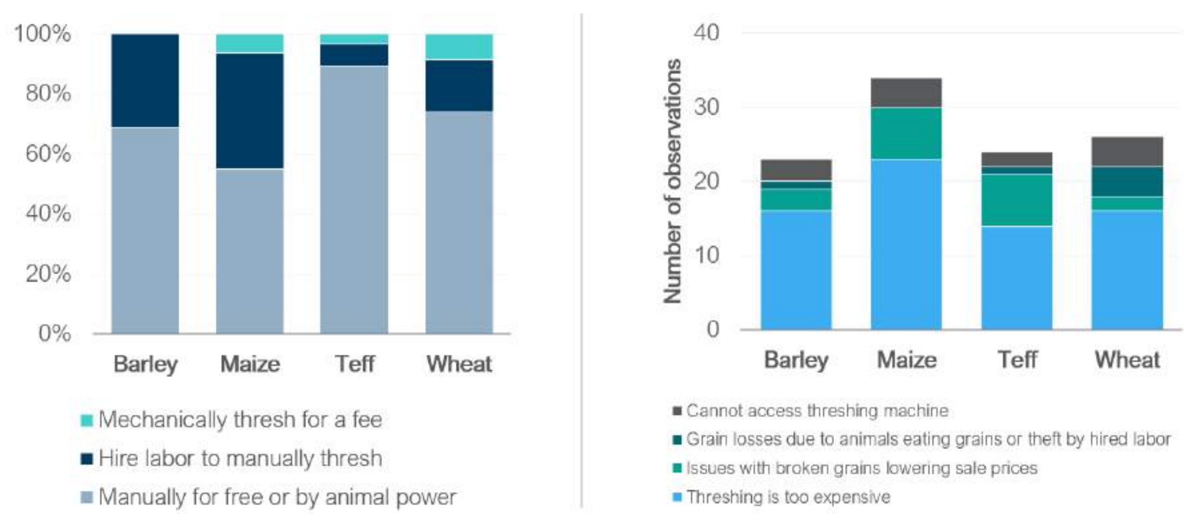


Exhibit 29: Threshing Practices (left), and Challenges Reported by Farmers for Five Surveyed Value Chains (right)

Farmers thresh major cereal crops (teff, wheat, barley, and maize) to separate dry grains from the surrounding grass, cob, or stalk. Threshing is a necessary processing step for farmers before selling or further processing clean grains—except for some maize farmers who trade maize on the cob. Although farmer demand for threshing is high across all target cereals we studied, most farmers across the target value chains manually thresh crops and do not pay for threshing (as shown in **Exhibit 29**). Farmers face issues with broken grains and grain losses across the cereal crops. But **Exhibit 29** shows that the most cited threshing issue among farmers is expense. So, most farmers find paid threshing to be cost-prohibitive.

The few farmers that pay for threshing pay a median threshing labor cost ranging from 51 to 179 ETB per quintal.[xxvi] By comparison, the median mechanized grain threshing cost was 120 ETB per quintal. This indicates that, at these service costs and among those farmers willing to pay for threshing, mechanized grain threshing is affordable for teff and barley but too expensive for maize and wheat.

Muti-crop threshing becomes viable if there is enough farmer demand. Mechanized threshing equipment can handle most grains, although teff grains are notably smaller than wheat, barley, and maize. However, Exhibit 30 shows that most threshing processors we surveyed only thresh one crop (64%). The median farmer who pays for threshing spends 2,000 ETB annually, while a typical multi-crop thresher manufactured by a local supplier costs around 72,000 ETB.[xxvii] If the thresher processes three typical farmers' harvests per year, then the simple payback on the machine is roughly 12 years. If the thresher can serve 18 farmers, then the payback period shortens to around 2 years.

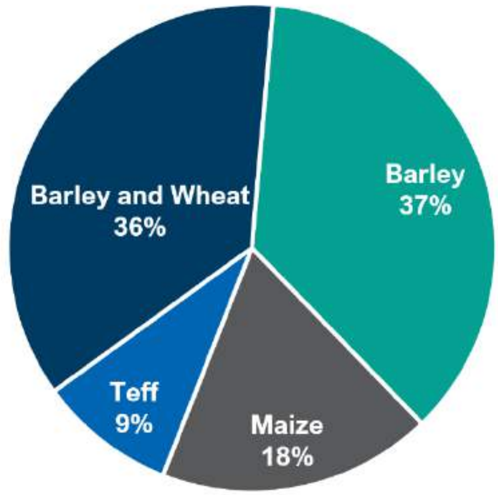


Exhibit 30: Proportions of Grains Processed by Mechanical Threshers

Yet, farming practices limit the viability of electrified threshing. Farmers mainly thresh crop in specified threshing areas in the farm. So, for electric threshing to become viable, farmers must be willing to modify their behavior and transport crops to a stationary minigrid-connected thresher in addition to paying for threshing. Rechargeable mobile electric threshers are not available in Ethiopia. Additionally, Exhibit 31 shows that multi-crop threshing would only increase the peak demand for four months in the year. Economic viability analysis found that seasonable demand like this is less beneficial for minigrid economics (see Section 4.2).

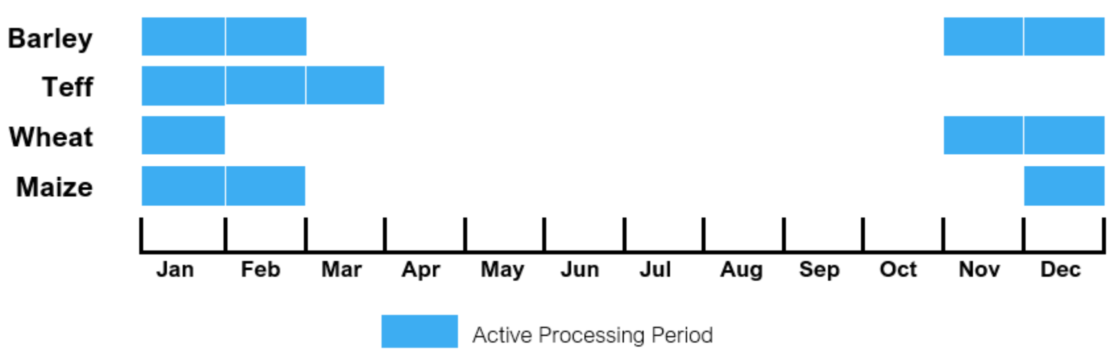


Exhibit 31: Annual Threshing Calendar across Maize, Wheat, Teff, and Barley Value Chains

Note: Threshing demand spans from November through March, depending on the crops processed by a multi-crop thresher.

[xxvi] Median threshing labor costs among farmers were 51 ETB/quintal for maize, 179 ETB/quintal for teff, 73 ETB/quintal for wheat, and 120 ETB/quintal for barley.

[xxvii] Amio Manufacturing produces a tri-phase electric grain thresher with 40 quintal per hour throughput for 72,000 ETB.

A.2 Maize

- **Maize is a staple food in Ethiopia produced at high volumes nationally.**
- **Significant consumption of maize in rural communities makes high-production zones in Amhara, Oromia, and SNNPR strong potential areas for electrified maize processing initiatives.** Approximately 93% of the country's maize is produced in Amhara, Oromia, and SNNPR, and most maize farmers produce maize for subsistence. As such, most maize is consumed in the communities where it is produced. The high demand for local processing within communities of Amhara, Oromia, and SNNPR suggest that these regions have the highest potential for electrifying processing activities.
- **Maize milling is immediately suitable for electrification with minigrids (Tier 1).** Maize milling is a necessary processing step for making maize flour, and processors already operate mechanized milling equipment across Ethiopia. Existing fossil fuel-powered milling equipment can be retrofitted with an electric motor. Based on a 2020 RMI survey of maize farmers across Amhara, Oromia, and SNNPR, 85% of rural communities already have at least one mechanized mill processor operating locally.

A.2.1 Background

Ethiopia is the third largest maize producer in continental Africa—in 2019 Ethiopia produced 96.4 million metric quintals of maize, behind Nigeria (110 million metric quintals) and South Africa (112.8 million metric quintals).[23] In 2019, Ethiopian farmers cultivated 2.3 million hectares of land for maize (22% of all cultivated land dedicated to cereals), the second largest area devoted to any crop behind teff.[24] Since 2000, maize farming has maintained the highest yields in Ethiopia among cereal crops.[xxviii,25] In Ethiopia, more farmers cultivate maize than any other cereal: in 2019, 68% of cereal-producing farmers cultivated maize (11.5 million farmers), ahead of 42% of farmers that cultivated teff (the second most popularly cultivated cereal crop by number of farmers).[26] Farmers typically allocate about a quarter of their land for maize production, which on average corresponds to 0.8 hectare per farm for cultivating maize.[xxix,27]

Sultan Nura's maize crops drying on the cob. Mr. Nura cultivates 0.5 hectares for maize on his farm in the Limu Kosa woreda of the Jima Zone, Oromia. He plants maize once per year and produces 7 quintals of crop each harvest. Mr. Nura sells his crop in the form of dry maize on the cob, and only trades at markets in his and neighboring communities.

---

xxviii Cereal crops include maize, teff, barley, wheat, sorghum, millet, and oats.

xxix Large-scale farmers usually dedicate 60%–80% of their land for maize cultivation, while smallholder farmers only dedicate 20%.

A.2.1.1 Production

High and rising maize production volumes in Ethiopia suggest strong and reliable supply for post-harvest maize processing.

Favorable national maize production trends over the past 10 years suggest there is enough maize supply to sustain high processing volumes. Stable maize supply is critical for processors investing in new electric equipment to recoup equipment costs. National maize production tripled between 2000 and 2019, while maize yields doubled in the same period.[28] Yet, farmers are increasingly dissatisfied with low maize selling prices.[29] This presents a risk of farmers deciding to cultivate more lucrative crops instead of maize, which would affect production and limit crop availability for processors. But this risk has so far had a limited effect on production decisions as maize production volumes (shown in **Exhibit 32**) have been consistently high and farmers predominantly cultivate maize for subsistence purposes.

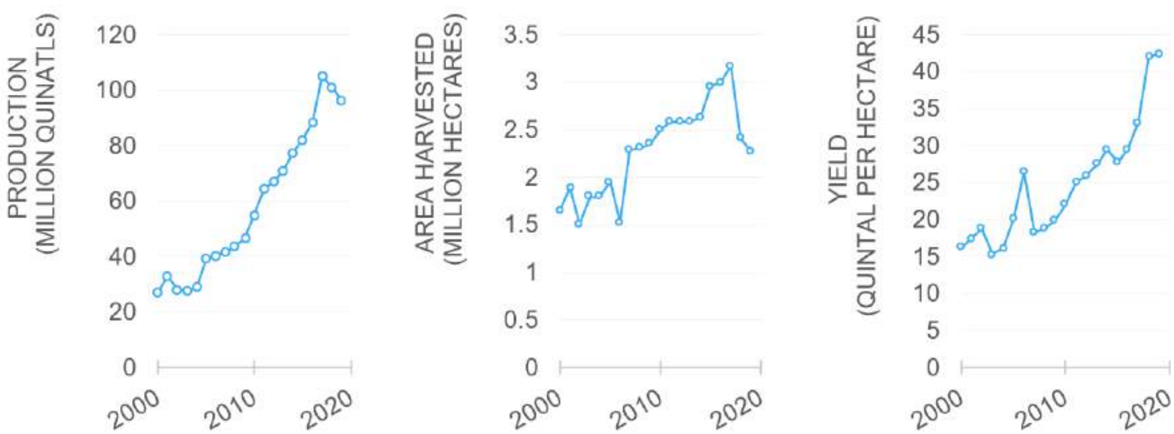


Exhibit 32: Trends of Production, Area Harvested, and Yield for Maize between 2000 and 2019

Note: Maize yields and total maize production are the highest among major cereals (teff, wheat, maize, and barley). In terms of area cultivated among major cereals, maize is second behind teff.[30] (Source: FAOSTAT Production)

Ethiopia successfully transformed its domestic maize sector through local programs to raise national production. As shown in **Exhibit 32**, yields have more than doubled since 2000—national average annual yields increased from 16 to 42 quintal per hectare between 2000 and 2019.[31] During the same period, farmer-cultivated area dedicated to maize expanded from 1.7 to 2.3 million hectares.[32] Beyond favorable growing conditions, this significant improvement was the result of concerted government efforts to increase supply of modern inputs and access to extension services, such as supporting access to improved seeds and mineral fertilizers.[xxx] In 2014, government-run or -owned agencies supplied 63% of improved seeds.[xxxi,33]

Further improvement in maize productivity is still possible as farmers in South Africa had higher yields, averaging national yields of 51 quintal per hectare from 2017 to 2018.[34] In 2013, only 40% of the maize cultivated area in Ethiopia used modern seed varieties because the majority of smallholder farmers could not afford these varieties and instead opted to continue replanting their original seeds.[35] Furthermore, a 2014 study found that the average maize farmer sells only 11% of crop production, equal to about one metric quintal (0.1 metric ton) per farmer each season.[36] Thus, farmers often do not earn enough revenue from maize cultivation to afford the modern inputs that would increase productivity and profits.

A.2.1.2 Processing

Maize processing initiatives can improve rural livelihoods.

Maize flour in a sack that is ready for home consumption.

Maize processing activities can boost revenues for farmers dissatisfied with prevailing crop prices. Maize farmers surveyed in 2015 reported that the per quintal purchase prices they received from traders were 13% lower than the total production cost of maize.[37]

According to a 2016 study in the Mecha District (Amhara), maize farmers break even from selling crops at prices of 417 ETB per quintal.[38] Farmers have limited bargaining power when trading maize grains because they are eager to sell excess grains before they spoil, and traders have the power to find cheaper maize grain in other communities.

The median selling price of maize in communities we surveyed in 2020 was 900 ETB per quintal, which signals improved trading conditions for farmers. Nonetheless, local maize processing activities can provide new and increased revenue streams for farmers. From our survey findings, the median annual revenue of maize farmers is 17,600 ETB.[xxxii] By comparison, the median miller generates 234,000 ETB in annual revenues.[xxxiii] We describe the economic viability of grain milling in **Section 4**.

Maize milling shows significant potential for electrification.

As discussed in **Section A.3.2.1**, the existing state of processing activities in rural communities indicates whether an activity is suitable for short-term electrification with minigrids. We find that maize milling is the only maize processing activity that is already widely mechanized in rural communities.

[xxx] Seed varieties are genetically varied forms of the crop that exhibit favorable traits including resilience to pests and weather conditions, flavor, texture, color, and nutritional value. White flint or dent maize varieties are preferred for human consumption while yellow flint/dent varieties are usually reserved for animal feed purposes.
[xxxi] Pioneer Hi-Bred Seed (an international seed variety supplier operating across Southern Africa) supplied 31%, while the remaining 6% was supplied by community-based organizations and a group of small national seed-producing organizations.
[xxxii] From a farmer that cultivates 1 hectare of land and produces 22 quintals of maize per harvest with one season per year.
[xxxiii] Assuming median grain milling business revenue of 4,500 ETB per week from survey findings over an entire year.

Since processors already have the capacity to manage milling businesses and have experience paying for fuel and upkeep of fossil fuel-powered equipment, they require less support to transition to electric equipment. Furthermore, maize milling is the only processing activity that consistently takes place year-round, which is favorable for minigrids. Maize milling therefore demonstrates strong potential for short-term electrification by minigrids.

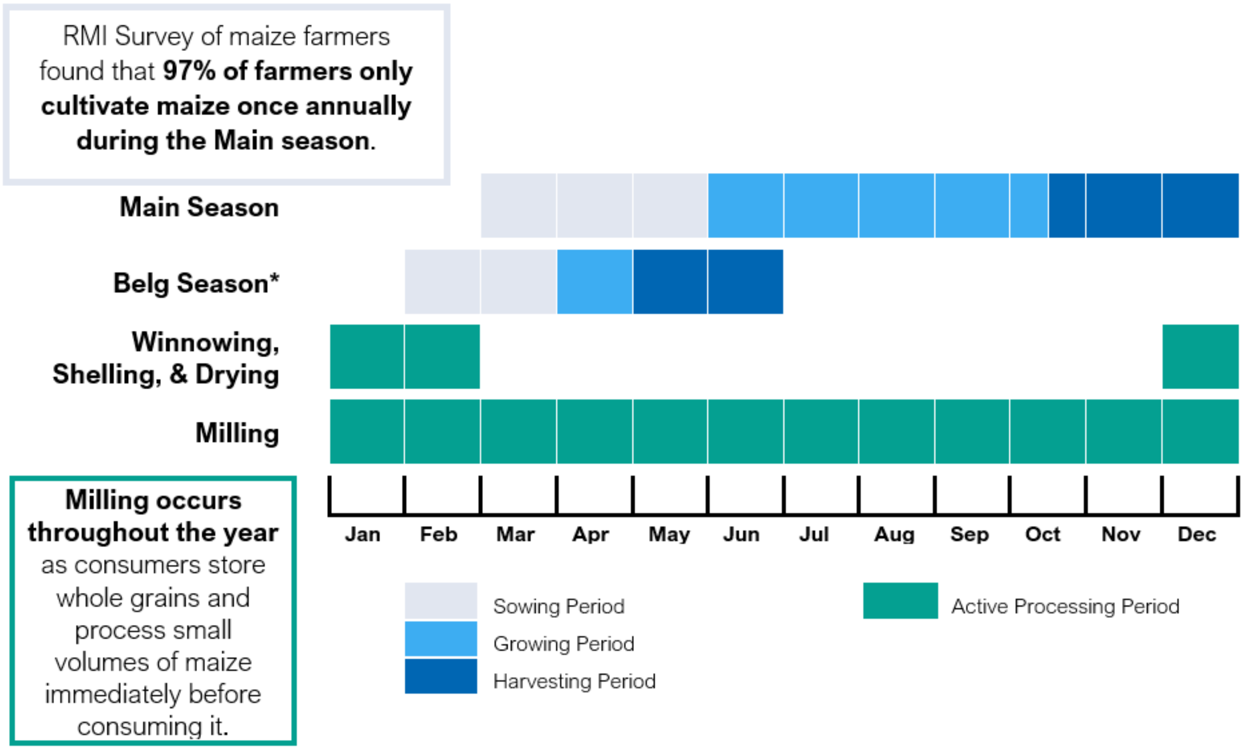
Exhibit 34 shows the flow of processing activities from fresh maize crop to maize flour production.[39] Maize flour is the base ingredient for many popular dishes in Ethiopia—and the most popular form for consuming maize in Ethiopia.[xxxiv] As teff prices continue to rise, Ethiopians increasingly use maize flour to make injera.[40] Drying, shelling, and milling are all necessary steps for making flour. Farmers typically dry maize cobs on the farm before shelling and trading maize grains. Consumers take maize grains to processors within their communities for milling before cooking and consumption.[41] Maize that is consumed on the cob does not undergo any major processing after harvesting, except drying if sold dry. Shelling and drying are important on-farm processing activities, while maize milling is a critical end-consumer processing activity.

The timing of processing activities is important for electrifying activities with minigrids. Processing activities like maize milling that take place continuously throughout the year lead to consistent loads that minigrids can better serve as anchor loads.[xxxv]

Of the maize millers we surveyed, 78% noted that milling activities are not seasonal. Post-harvest processing that takes place on the farm—such as drying, shelling, and winnowing—is seasonal, occurring during a few months of the year. As the processing calendar in Exhibit 33 shows, farmers we surveyed carry out on-farm processing activities such as shelling, winnowing, and drying between December and February—closely following harvesting periods.[42] As a result, nine months of the year, there would be no electricity demand connected to these activities if these activities were electrified. All these activities discussed take place during the daytime hours, which is favorable for solar-powered minigrids that generate lower-cost energy during the daytime.

[xxxiv] The most popular traditional products derived from maize flour include kitta—unleavened flatbread that is typically mixed with barley flour, dabo kollo—a deep fried crunchy snack food that consists of a mix of wheat and maize flours, kurkufa—cooked kale and maize flour sautéed with other vegetables, fossessie—cooked haricot beans and maize flour sautéed in other vegetables, nifro—green whole or cobbed maize, kinche—a porridge made from maize starch, besso—roasted maize (and sometimes other cereals) flour usually made into a drink with water and sugar.

[xxxv] An anchor load is a customer with a constant, predictable energy demand.



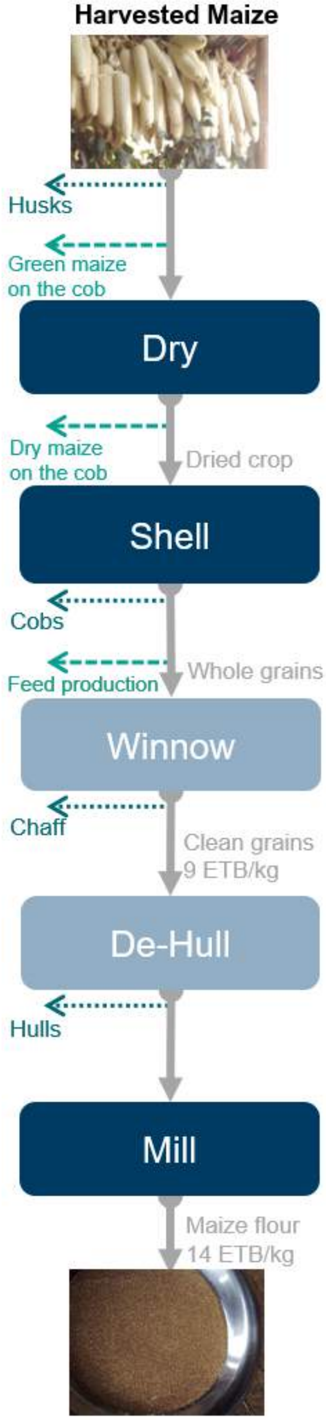
* The Belg season refers to the short rainy season for the Northeast, East, Central, and Southern highland regions during which a few farmers cultivate maize for an additional harvest cycle.

Exhibit 33: Annual Maize Planting and Processing Calendar

Note: Experts consider June through the end of September to be lean grain supply months because in most areas, there are limited harvests during this period for any major cereals.[xxxvi] *(Source: FAO GIEWS, 2020)*

[xxxvi] Major cereals include barley, teff, wheat, maize, sorghum, millet, and oats.

Maize flour production



Description	Mechanization
Harvested maize kernels on the stalk have a moisture content of ~30%.	Farmers typically harvest maize manually using a sharp scythe or sickle blade. They also remove maize husks at this stage.
Cut bunches of maize stalks are hung to dry or left in piles. Farmers dry maize in the field until moisture content drops to between 12% and 12.5%.	Grain dryers are not common in maize processing as most crop is air dried at the farm. More than 80% of maize farmers in communities we surveyed manually dried their crop.
Dry maize is shelled by farmers using animals to stamp crops on an enclosed floor area to release grains from the stalk and cob.	Farmers typically shell maize manually or with animal-powered mashing. Survey findings indicate that 94% of maize was shelled manually, and 6% mechanically.
Farmers separate grains from remaining straw-like chaff at the farm by throwing grains into the air so that the chaff blows away while the grains settle.	Maize winnowing in rural communities takes place manually with a wide thatch plate or basket. Combine machines—though rare—can winnow as well as thresh and hull grains.
Consumers at home may hull maize grains to make cornstarch. They scrape the hull layer off maize grains to leave only the inner bran and germ layers.	Maize hulling is rare in rural communities as maize hulls are soft and edible. Some hulls are shed during threshing or manually removed in households, but most consumers eat hulls.
Processors mill clean, dry grains into a meal or fine flour. From our survey findings, the median grain milling service price was 1 ETB/kg.	All milling processors in surveyed communities used mechanical plate or hammer mills, with 96% using fossil-powered mills and the remaining 4% using electric mills.

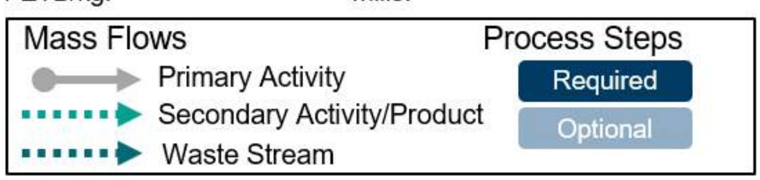


Exhibit 34: The Maize Processing Flow from Harvested Maize to Maize Flour

Note: In rural communities, most maize is sold in the form of dried grain to final consumers. Consumers will typically take their crop to processors for milling. (Source: 2020 RMI Survey)

Electrifying maize processing has the most potential in Amhara, Oromia, and SNNPR.

The robust demand for maize processing within Amhara, Oromia, and SNNPR indicates strong potential for electrifying processing in these regions. In communities within these regions, there is a cumulative demand for end-consumer processing and on-farm processing activities. Since most maize farmers live in Oromia, Amhara, and SNNPR, on-farm maize processing activities (drying, shelling, and winnowing) also occur in these regions. End-consumer processing (maize milling) also occurs in these regions, as these activities are common wherever maize is consumed.

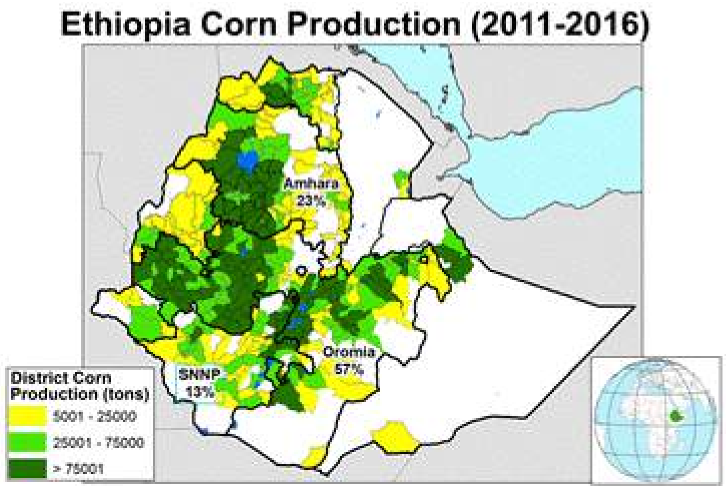


Exhibit 35: Spatial Production of Maize across Ethiopia

Note: Most maize grows across three regions in Ethiopia, with 57% of maize growing in Oromia alone. (Source: USDA Foreign Agricultural Service)

Exhibit 35 shows the spatial breakdown of maize cultivation across Ethiopia. Almost all maize production is rain-fed. This is because most maize in Ethiopia (75% of production) grows in moist and semi-moist agro-ecological zones while the remaining 25% grows in dry zones.[43] So, farmers do not generally irrigate maize-cultivated lands because the crop water requirements are usually met by environmental conditions. Among farmers we surveyed who cultivate maize, only 8% irrigate their fields. The high production agro-ecological zones are clustered in Amhara, Oromia, and SNNPR. Therefore, on-farm processing is most prevalent in these areas where production is concentrated.

A.2.1.3 Losses

On-farm maize losses reduce supply and business potential of maize-processing activities.

Maize crop losses reduce crop volumes available for processing as spoilt crops are discarded before processing. Most post-harvest maize losses are due to improper storage. Harvesting and shelling losses are minimal according to a 2018 FAO study, but on average 7% of maize is lost due to improper farm storage.[xxxvii,44] Traditional storage techniques involve storing maize grains in bags that

[xxxvii] One percent of crop was reported damaged during harvesting due to ear detachment; 2% of crop was damaged during initial crop stacking during harvest because of rats and domestic animals; 0.5% of maize was reported lost in

are piled on the floor, in above-ground cylindrical containers with unplastered walls made from woven plant stems, or in underground storage structures. All these structures are vulnerable to weevil and rodent infestations.[45] Furthermore, these techniques often do not sufficiently keep moisture out of the stored crop leading to crop spoilage. After just three days of improper storage where moisture levels exceed 13.5%, various fungi (most commonly aflatoxins) can multiply up to ten-fold and spoil maize crop stores.[46]

Although improved storage techniques including metal silos or forced-air flow structures modified to keep storage bins above ground have been developed and tested in Ethiopia, uptake is low among farmers.[47] Farmers store grains for household consumption and processing but have limited capacity to properly store grains at home. There could be substantial savings—and increased crop supply for processing—from farmers adopting improved storage techniques for various cereal crops. However, we do not consider them further in this study because these improved storage techniques do not require an energy solution.

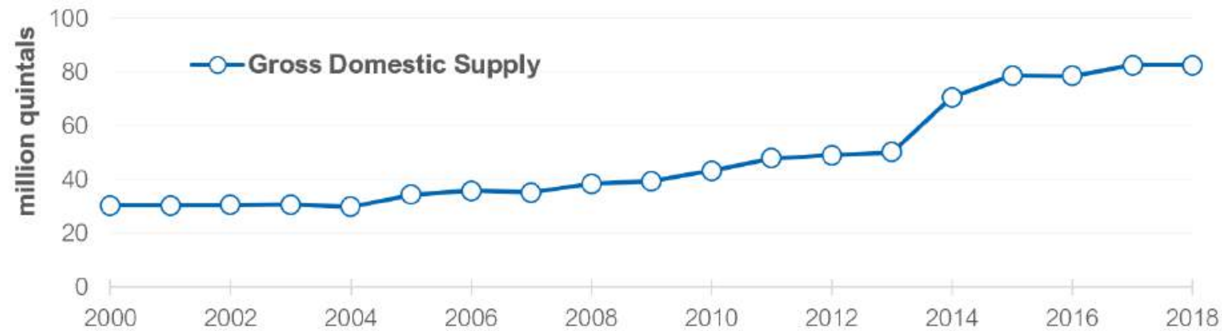
A.2.1.4 Demand

Localized demand for maize products suggests strong potential for electrifying maize processing in rural communities.

The demand for maize flour in rural communities is a strong indicator of the potential for electrifying processing in these communities. Ethiopia's maize demand is high and rising, particularly in rural communities. Rural consumers predominantly consume maize in the form of flour. Most maize flour consumed in rural communities originates from local maize crop cultivated for subsistence or is purchased from traders in whole-grain form. This means that milling grains to flour occurs in rural communities, creating a strong offtake market for small local processing businesses.

---

shelling because of spillage on the floor, and grain breakage when crop is beaten with a stick. Shelling losses are low because farmers more commonly shell by hand which is very time and energy intensive.



	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18
Harvest	27	33	28	27	29	39	40	33	38	39	50	61	62	67	72	79	78	84	84
Imports	.29	.32	.06	.88	.36	.31	.62	.34	.73	.57	.32	.31	.08	.08	.06	.07	.08	.14	.10
Exports	.00	.01	.13	.01	.11	.03	.01	.00	.00	.00	.36	.60	.03	.09	.00	.00	.00	.32	.01
Stocks	3	3	2	2	1	5	5	2	0	0	7	13	13	17	2	.20	0	1	1

Exhibit 36: Gross National Supply of Maize between 2000 and 2018 in Million Quintals

Note: The data table gives a breakdown of gross domestic supply into national harvest, imports, exports, and national stocks. We add production and imports but subtract exports (in red) to determine the gross domestic supply. The Government of Ethiopia contributes national maize stocks toward domestic supply during periods of shortage and subtracts a portion of national production from domestic supply during periods of excess production (as denoted by red values). Maize imports and exports are negligible throughout the period. (Source: FAOSTAT New Food Balances)

Almost all maize produced in Ethiopia is consumed domestically. According to the domestic supply trends in Exhibit 36, domestic maize supply consists mainly of national crop production with small supplements supplied from national crop stocks. Ethiopian exports have been negligible since 2000, so Ethiopians consume all nationally produced maize and maize products within the country.[48]

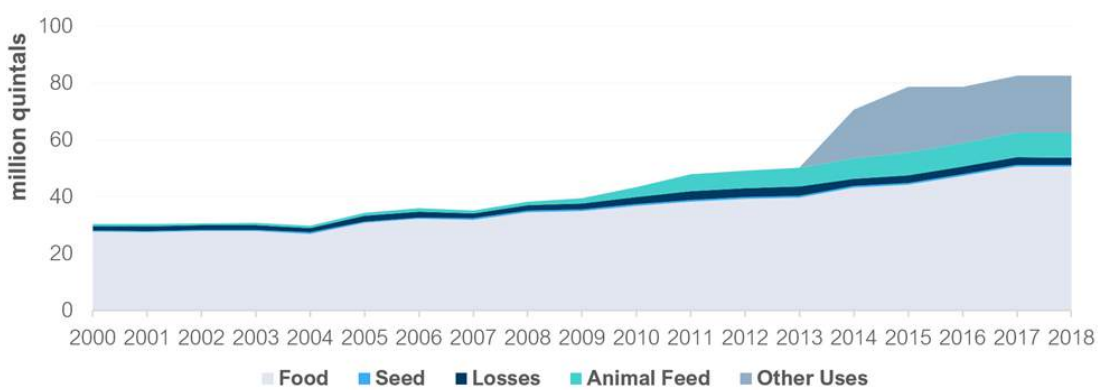


Exhibit 37: Consumption of Maize Domestic Supply by the Major Categories of Food, Seed, Losses, and Animal Feed in Million Quintals

Note: Between 54% and 91% of maize is used for food consumption. Since 2009, an increasing proportion of maize has been consumed for animal feed. There is a growing proportion of maize being consumed for "other uses" that in 2018 account for 25% of all consumption. (Source: FAOSTAT New Food Balances)[49]

Exhibit 37 shows national consumption trends over the past 20 years. Most maize in Ethiopia is consumed for food consumption—in 2018, Ethiopians consumed 61% of maize supply for food.[xxxviii] In Box 1, we discuss the growing demand for animal feed among cereal crops.[xxxix] These trends highlight the strong offtake market for maize products in Ethiopia.

Rural consumers—who accounted for 78% of Ethiopia's population in 2018—consume a significant portion of Ethiopia's maize supply, especially for food.[50] Exhibit 38 shows that almost 60% of rural households nationwide consume maize products, more than twice the proportion of urban households that consume maize. On a per capita basis, rural consumers also eat 8.4 times more maize (843%) than consumers in cities, and 1.5 times more maize (154%) than those in towns. In fact, as household income increases, dependence on maize for nutritional needs decreases. As was already noted, rural households mostly consume maize in flour form. To meet this demand for maize flour, maize crops must undergo the processing steps described in Exhibit 34. This provides evidence to show that demand for on-farm and end-consumer processing is also high.

Melese Sisay with his maize stored in 1 quintal bags. Mr. Sisay cultivates a hectare of land for maize once annually. Each harvest produces 30 quintals of maize. Mr. Sisay's family and friends help him shell maize crops manually for free, but he would be willing to pay to have his crop shelled mechanically.

[xxxviii] In 2018, 11% of maize was consumed for animal feed, 1% for seed, and 24% for other uses.
[xxxix] Between 2000 and 2018, maize demand for animal feed increased with a compound annual growth rate of 12%.

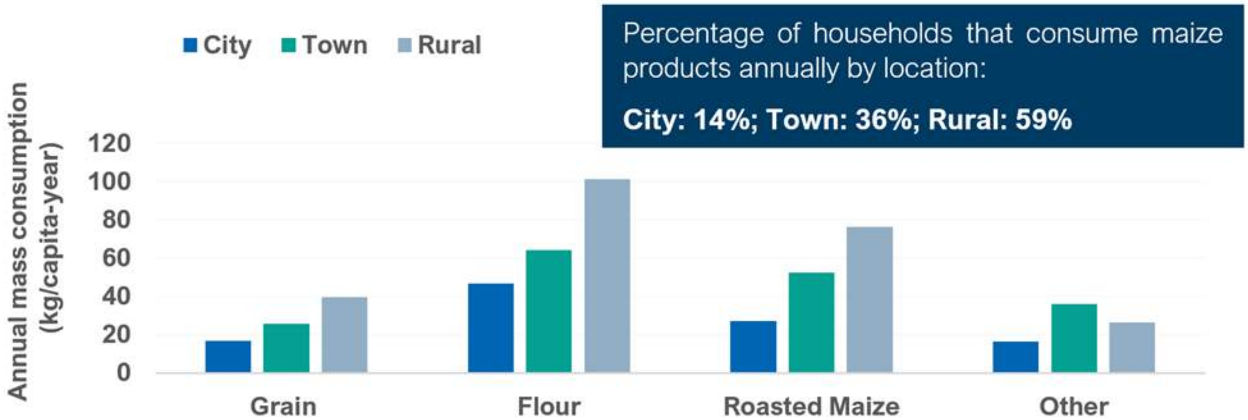


Exhibit 38: Maize Consumption by Location and Type of Maize Product (Source: Abate, et al., 2015)

A.2.1.5 Local Trade

Maize milling has potential for electrification in rural communities in both high and low production zones.

Local trade patterns show that some level of maize processing must take place in rural communities. Traders commonly buy maize from farmers who process harvested maize into dry grains on the farm. Farmers we surveyed also noted they sell around half of the maize harvested and store the rest for household consumption. This is significantly higher than national average of 13% identified in the 2019/2020 Agricultural Sample Survey.[5121] Nonetheless, both data points suggest that a significant amount of production is processed and consumed locally. As shown in Exhibit 39, maize that farmers keep is processed locally and other studies confirm there is significant localized processing and consumption of maize.

Cleaned, dried maize grains ready for trading.

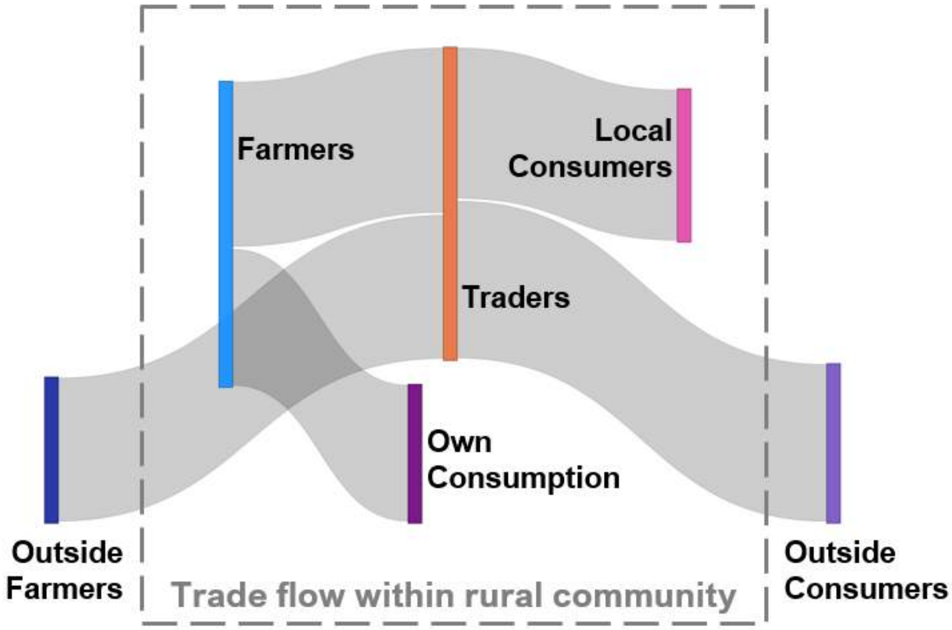


Exhibit 39: Maize Product Flow from Farmers to Consumers Based on RMI Survey Findings from Value Chain Actors in Maize-Producing Communities in Amhara, Oromia, and SNNPR

Note: We measure trade flow proportions by percentage of maize volume traded. (Source: RMI Survey, 2020).

Maize farmers sell 80% of their maize to traders who then distribute that maize across the country.[xl] A network of traders, assemblers, wholesalers, and retailers move maize grains to serve communities in low production zones. End-consumers buy whole maize grains from traders that they then mill prior to consumption. This means that maize milling is found throughout rural communities where maize flour is widely consumed and not just where maize is produced. Survey findings show that most maize traders sold cleaned grains (38%).[xli] By comparison, only 5% of maize traders we surveyed sold maize flour.[xlii]

A.2.2 Opportunities for Electrification

We analyzed several processing activities for maize to identify opportunities for short-term electrification including shelling, winnowing, hulling, drying, and milling. As described in the evaluation framework of Section 2.4.1, we used the metrics of local capacity, offtake market, equipment and electrification, and scalability to shortlist activities that demonstrated strong readiness for electrification in the short term with minimal support.

[xl] Farmers trade their maize with assembling traders, but most consumers buy maize from retailers—traders and retailers trade among themselves before taking the crop to market to the consumer.
[xli] Of maize traders surveyed, 38% sold cleaned grains, 16% sold maize dry on the cob, 22% sold maize green on the cob, 5% sold maize flour, and 19% sold other maize products.
[xlii] In each of the instances where maize traders sold maize flour, we were not able to find a processor that mills crops with mechanized equipment in the communities where those traders operated.

Across the maize value chain, maize milling showed significant potential for short-term electrification. Maize milling and shelling are both critical steps for maize consumption. These activities are discussed further below.

Other activities are not immediately suitable for electrification in minigrid-suitable communities. Farmers naturally air-dry almost all maize produced in Ethiopia because it is free and generally effective. There is little evidence that farmers are incentivized to pay extra for the consistency provided by mechanically drying maize. Likewise, almost all maize storing techniques in rural communities do not involve electric or fossil fuel-powered energy. Lastly, rural consumers rarely hull maize before consumption because maize hull layers are soft and edible. Maize drying, storage, and hulling are not covered in depth because they show little potential for electrification in rural communities and solely involve manual methods.

A.2.2.1 Maize Milling

Maize milling shows the most potential for short-term electrification in rural minigrid communities across all value chain activities.

Maize milling demonstrates strong potential for electrification. The prevalence of maize milling processors in communities shows that processors have the capacity to effectively manage processing businesses and maintain mechanized equipment. Demand for maize milling is consistent and robust because most consumers in rural communities pay processors to mill their maize mechanically. Electric maize mills are available in Ethiopia and milling demand persists year-round throughout Ethiopia—in both high and low production zones.

Abeze Negash with her diesel-powered grain mill. She processes teff, maize, wheat, barley, sorghum, horse beans, and peas. Ms. Negash mills crops into flour for 50 ETB per quintal and operates her business year-round. She typically serves 10 customers per day and earns 8,000 ETB in weekly revenues. Ms. Negash frequently finds that customers bring low-quality grains for milling.

The case for maize milling closely matches the wheat milling discussion in Section A.3.2.1. Most grain milling processors (82%) we surveyed process maize alongside other major cereals.[xliii] As shown in Exhibit 38, end-consumers consume both whole grain and flour-based products. Competing forms of consumption affect the amount of maize that requires milling in rural communities. However, the popularity of maize flour among rural consumers and the prevalence of maize milling indicate that there is a robust offtake market in rural communities.

[xliii] Approximately 64% of grain milling processors mill wheat, 57% mill teff, and 68% mill barley.

Criteria	Support Status	Description
Local Capacity	●	We found **three maize milling processors per community** in the median rural community we surveyed.* The average grain milling business in rural communities has been running for **eight years,** and **82%** of grain milling processors mill maize. Processors have extensive experience as mill businesses are prevalent in rural communities and have been operating for a long time. * Findings based on 2020 RMI survey findings of maize processing in rural communities in Amhara, Oromia and SNNPR regions within Ethiopia.
Offtake Market	●	The average milling service fee in rural communities is high **(94 ETB per quintal)**.* On average, maize milling businesses serve **35 customers daily** and generate significant revenue year-round.** According to **78%** of surveyed maize flour milling processors, demand for milling persists throughout the year—independent of seasons. * By comparison, the average grain shelling service fees we observed were 50 ETB per quintal. ** The median grain shelling business serves 10 customers daily and generates 3600 ETB in weekly revenue during busy periods (3 months of the year). By comparison, the median grain milling business serves 30 customers daily and generates 4500 ETB in weekly revenue year-round.
Equipment and Electrification	◕	Electric mills are available locally—manufacturers produce these mills domestically and have the expertise to offer after-sales servicing.* **100%** of surveyed milling processors own a mechanical fossil-fuel powered or electric mill. * Kalmeks Manufacturing produces a tri-phase electric grain mill with 10 quintal per hour throughput for 140,000 ETB.
Scalability	●	Maize is a staple consumed across Ethiopia—not only in high production regions. Since consumers prefer to purchase whole maize grains and mill small portions of maize before consumption, there is significant scaling potential for maize milling across Ethiopia.

Support Required: ○ Significant ◑ Moderate ◕ Minimal ● Deployment Ready

Electric maize flour milling in rural communities is ready for further testing and piloting. The same equipment can be used to mill maize and wheat mechanically. As discussed in Section A.3.2.1 for wheat flour milling, processors need to test electric mills in their businesses, and pilot studies will need to test whether electric mills can meet the throughput needs of processors while powered by a minigrid system.

A.2.2.2 Maize Shelling (threshing)

Maize shelling is not currently suitable for electrification in rural minigrid communities.

Maize shelling does not show strong potential for electrification in rural minigrid communities. Maize shellers are rare in rural communities as most farmers shell maize manually. As such, there is little evidence that processors have gained experience in managing maize shelling businesses and maintaining mechanical shelling machines. Additionally, most farmers do not pay for shelling and those that do prefer to pay for cheaper labor. This means that there is no proven offtake market for mechanical shelling services. Maize shelling only takes place in high maize-producing rural communities, and farmers only require shelling for three months of the year—farmers also thresh small maize volumes for seeds during cultivation. So, the scalability and electrification potential is also limited.

Criteria	Support Status	Description
Local Capacity		In our survey we only observed shelling processors in **26%** of kebeles, and we only observed one sheller on average within these communities. These shelling businesses have been running for **four years on average,** but only **6% of the threshers surveyed shell maize**. The limited presence of shellers who process maize suggest that capacity is limited in rural communities for maize shelling.
Offtake Market		Maize that is consumed in flour form must be shelled before consumption, so there is a demand for shelling in rural communities. However, our survey findings show that **just over half of maize farmers (55%) do not pay for shelling, so the market that could be served by specialized shelling businesses is limited.** **Only 6% of maize farmers shell crop mechanically**, and average mechanical grain shelling costs are 120 ETB/quintal. This is higher than what maize farmers pay in labor for manual shelling of 39 ETB/quintal. So, maize farmers that do pay for shelling prefer to hire laborers for manual shelling (39% of farmers pay laborers for shelling). Our survey found that most maize farmers already complain of high shelling costs (68%). Given the lower costs and prevalence of manual labor, the market for mechanical and electric shelling is limited.
Equipment and Electrification		Stationary grid-connected electric shelling equipment exists in Ethiopia, but rechargeable mobile equipment is needed to properly serve farmers, who often shell maize in the field.* Furthermore, shelling only takes place for three months of the year (December through February), leading to extended periods in the year where shelling equipment remains unused. * Amio Manufacturing produces a tri-phase electric grain sheller with 40 quintal per hour throughput for 72,000 ETB.
Scalability		Maize shelling is most prevalent in maize cultivation hubs (Amhara, Oromia and SNNPR) because farmers shell crops on the farm. Maize crop that is not consumed on the cob requires shelling.

Most maize is shelled by farmers in a shelling area close to their farms and shelling machines would need to access these areas to cater to these practices. Given the short period when shelling occurs, processors will also want to serve multiple farmers to recoup their investment. Therefore, electric shelling equipment must be mobile and chargeable, and this equipment option is not available in Ethiopia.

Balcha Ambisa with his stationary diesel-powered mechanical sheller. Mr. Ambisa only shells maize for 150 ETB per quintal. During busy periods (November to February), he serves an average of five customers and processes a total of 3 quintals per day. Mr. Ambisa would like to expand his business but faces challenges in accessing finance, and has difficulty advertising his shelling services within the community.

A.3 Wheat

- **Wheat is a staple food in Ethiopia produced at high volumes nationally.**
- **Significant local consumption of wheat in rural communities makes production zones in Amhara and Oromia strong potential areas for electrified wheat processing initiatives.** Eighty-six percent of wheat is produced in Amhara and Oromia, and most farmers produce wheat for subsistence. This means that most wheat is consumed in the communities where it is produced. The high demand for local processing within the communities of Amhara and Oromia suggest that these regions have the highest potential for electrifying processing activities.
- **Wheat milling is immediately suitable for electrification with minigrids (Tier 1).** Wheat milling is a necessary processing step for making wheat flour, and processors already operate mechanized milling equipment across Ethiopia. Existing fossil fuel-powered equipment can be retrofitted with an electric motor. Our survey across Amhara, Oromia, and SNNPR shows that 84% of rural kebeles already have at least one mechanized mill processor operating locally.

A.3.1 Background

Ethiopia is the second largest producer of wheat in continental Africa—in 2019 Ethiopia produced 53.2 million metric quintals of wheat, behind Egypt (90 million metric quintals) and ahead of Morocco (40.3 million metric quintals).[52] Wheat production accounted for 18% of cereal production in the 2019 Meher Season, when 4.9 million farmers cultivated 1.8 million hectares of land for wheat production.[53]

A wheat crop almost ready for harvest on Usmail Feko's farm in the Hitosa woreda of the Arsi Zone, Oromia. Mr. Feko plants wheat once per year. He produces 57 quintals of wheat every harvest and retains 20 quintals for household use. Mr. Feko trades cleaned wheat grains with local traders and the community cooperative.

Domestic wheat supply tripled between 2000 and 2018.[54] In 2014, 98% of wheat farmers were smallholders and only 5.7% of total wheat production (2.24 million metric quintals) came from large-scale commercial farms.[55] Smallholder wheat farmers cultivate small plots of land, with average farm sizes of 0.34 hectares.

A.3.1.1 Production

High and rising production volumes suggest strong and reliable supply for post-harvest processing.

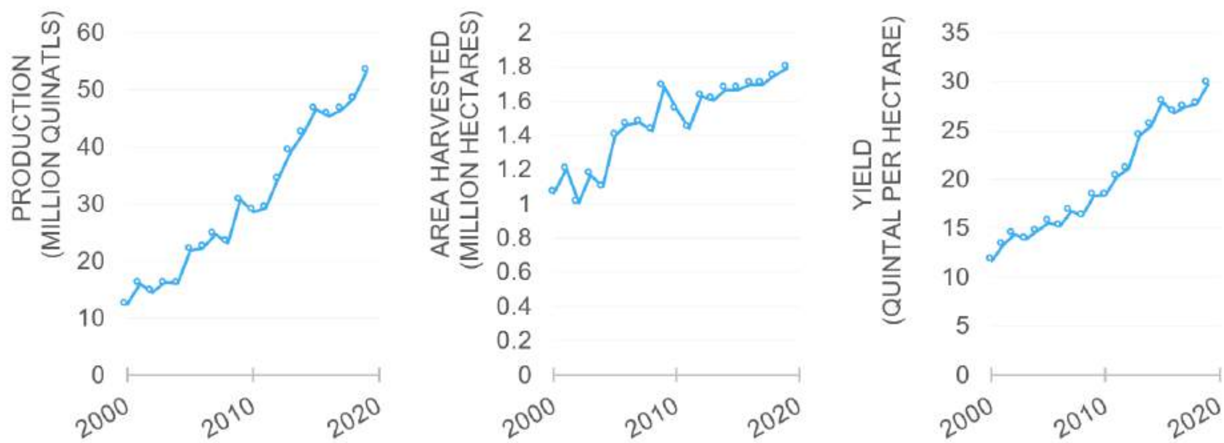


Exhibit 40: Trends of Production, Area Harvested, and Yield for Wheat between 2000 and 2019

Note: Wheat yields are the second highest behind maize when compared among major cereals (teff, wheat, maize, and barley). In terms of area cultivated and overall production of major cereals, wheat is third behind both teff and maize. (Source: FAOSTAT Production)

Consistent and high production volumes indicate strong supplies to sustain processing businesses. Improvement in wheat productivity and expansion in cultivated area have led to consistent increases in production. These improvements (shown in **Exhibit 40**) indicate that processors can confidently expect a stable supply for processing.

Wheat production in Ethiopia increased by 330% between 2000 and 2019. During this same period, area dedicated to wheat production increased by 68% and wheat productivity increased by 155%.[56] These productivity improvements were due to an increased adoption of modern inputs such as pesticides and fertilizers. In 2014, 47.2% of wheat farmers—the highest adoption rate among cereal farmers in Ethiopia—applied pesticides to crops, compared with 30.4% of wheat farmers in 2003.[xliv] As a result, as of 2014 wheat is the most widely fertilized crop among the cereals—farmers fertilized 73% of all cultivated land.[xlv,57]

Yet, wheat productivity can improve further. For example, farmers do not commonly purchase improved wheat seed varieties (only 6% in 2014) and on average farmers only purchase improved varieties every 17 years.[58] In 2019, wheat yields in Zambia and Egypt (highest observed in continental Africa), as well as across Europe, were more than twice those observed in Ethiopia.[59] Government policies, including the National Growth and Transformation Plan, are prioritizing improving wheat productivity going forward. Programs like the Integrated Agro-Industrial Park in Central-Eastern Oromia, and Agricultural Commercialization Clusters by the Ethiopian Agricultural Transformation Agency (ATA), were working to raise average wheat productivity by 27% through 2020.[xlvi, 60]

[xliv] In 2014, 39.5% farmers applied pesticides for teff, 23% for barley, 9.2% for sorghum, and 5.7% for maize.

[xlv] The average fertilizer application rate among the cereals in 2014 was 53.1%. Farmers fertilized 68.7% of cultivated land for growing teff, 50.8% for maize, 42.8% for barley, and 14.7% for sorghum.

[xlvi] The specific targets for this pilot Agro-Industrial Park for production are approximately 25.7 million metric quintals of wheat (11.5 million metric quintal of durum wheat and 14.2 million metric quintal of bread wheat). By 2020, the average

According to the Ethiopian Central Statistical Agency, in 2014 farmers irrigated less than 1% of the field area dedicated to wheat cultivation—similar to irrigation levels observed for other cereal crops in Ethiopia.[xlvii] The Ethiopian Agricultural Transformation Agency is prioritizing irrigation for wheat production to support wheat cultivation outside of moderate rainfall areas.[61] If successful, these interventions would further boost wheat production and increase the overall supply available for processing.

A.3.1.2 Processing

Wheat milling shows significant potential for electrification.

The current state of processing activities in rural communities—if processors currently carry out an activity in rural communities, and if they do so mechanically—can help determine whether electrifying an activity in the short term is viable. If a processing activity is necessary for consuming wheat, higher consumer demand can help sustain mechanizing that activity. Currently mechanized activities—those where processors use fossil fuel-powered equipment—already demonstrate profitability and processor capacity to manage processing businesses.

Andualem Workineh Mengiste shows wheat grains that are ready for trading. Mr. Mengiste pays 120 ETB per quintal to thresh his 50 quintals of wheat every harvest. There are no threshing processors close to his community, Grum Yekez (Misrak Gojjam zone of Amhara). So, Mr. Mengiste transports his crops over large distances to access threshing processors.

Processing activities that are carried out manually in rural communities and do not generate an income do not have evidence to suggest that mechanization is profitable. Would-be processors would need training to build up their management capacity before introducing electric equipment and establishing new processing businesses. Currently, wheat milling is the only required step for wheat processing that is widely mechanized in rural communities and takes place throughout the year. As such, there is compelling evidence to suggest that electric wheat milling is economically viable in rural communities and would require minimal training.

Wheat processors retain more profits than other actors in the wheat value chain, retaining 24% of profits, while farmers retain only 13% of profits from

productivity of wheat is expected to increase to 48 metric quintal per hectare for bread wheat and 44 metric quintal per hectare for durum wheat. The targets also state that the total cultivated land for wheat will increase to 540,000 hectares by 2020.

[xlvii] Less than 1% of the area dedicated to teff and barley production is irrigated in Ethiopia; less than 2% of the area for maize and sorghum production is irrigated. Most farmers cultivate wheat in high rainfall areas and do not need to depend on additional irrigation.

each quintal sold.[xlviii,62] This does not include industrial wheat processing activities like pasta-making.[63] Wheat milling and threshing both have strong offtake markets in rural communities, and rural processors make enough revenues to invest in equipment and cover operational expenses.

Wheat flour is the feedstock of most wheat food products in Ethiopia.[xlix, 64] Both bread and pasta are prepared from wheat flour—the process of preparing wheat flour is the same for both durum and bread wheat varieties. There are few traditional products that require un-milled whole wheat grains instead of flour.[l, 65] Exhibit 42 shows the processing steps in producing flour. Drying, threshing, winnowing, and milling are all necessary activities but among them, only milling uses mechanical equipment in rural communities.

Our survey findings show that farmers carry out drying, threshing, and winnowing manually on the field at the farm before storing or selling grains to traders. In contrast, milling takes place wherever consumers are located because final consumers prefer to mill before consumption. Processors we surveyed provide milling services for a fee of 0.94 ETB per kilogram of wheat grain milled.

The timing of wheat processing informs whether specific activities are well suited for electrification with minigrids. Seasonal processing activities are less optimal for electrification with minigrids because they create fluctuations in energy demand between active and inactive months. Minigrid developers require consistent energy demand throughout the year to recover their investment—fluctuations in energy demand from seasonal activities leads to underutilization of capacity for a portion of the year.

Exhibit 41 shows that wheat milling takes place year-round: throughout the year, consumers store whole grains and carry small volumes of wheat grain to processors for milling before consumption. Post-harvest wheat processing that occurs on the farm (drying, threshing, winnowing) takes place close to harvest and only occurs from November to February.

[xlviii] From a 2018 study of wheat value chain actors in the Arsi-to-Finfinnee (in Addis) market chain, the profits obtained by value chain actors were observed based on the ratio of cost of production to selling price received for product. Farmers had net profits of 13%, collectors 9%, wholesalers 8%, retailers 3%, and processors 24%.

[xlix] The most popular products include injera—thin and spongy fermented bread made from raw flour, water, and previously fermented dough; genfo—popular gelatinous dish made from boiling the flour of lightly roasted grains including barley and wheat; araqe—a high alcohol content distilled beverage made by fermenting a mixture of gesho leaves, water, and bread made of germinated barley or wheat (Selinus, R., "The Traditional Foods of the Central Ethiopian Highlands," and Bunker, M., "Harvesting Wheat by Hand").

[l] Some whole grain wheat products include dabokolo—fried wheat grain and kinche—a porridge made from roasted wheat grain.

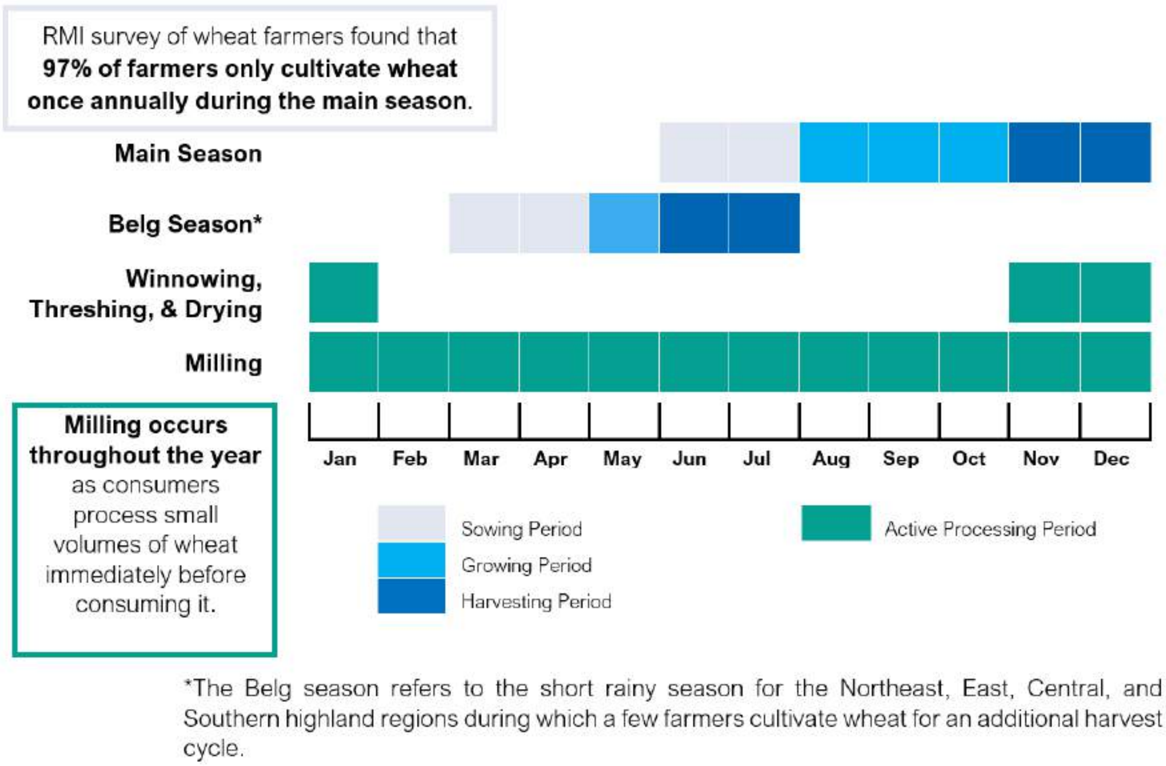
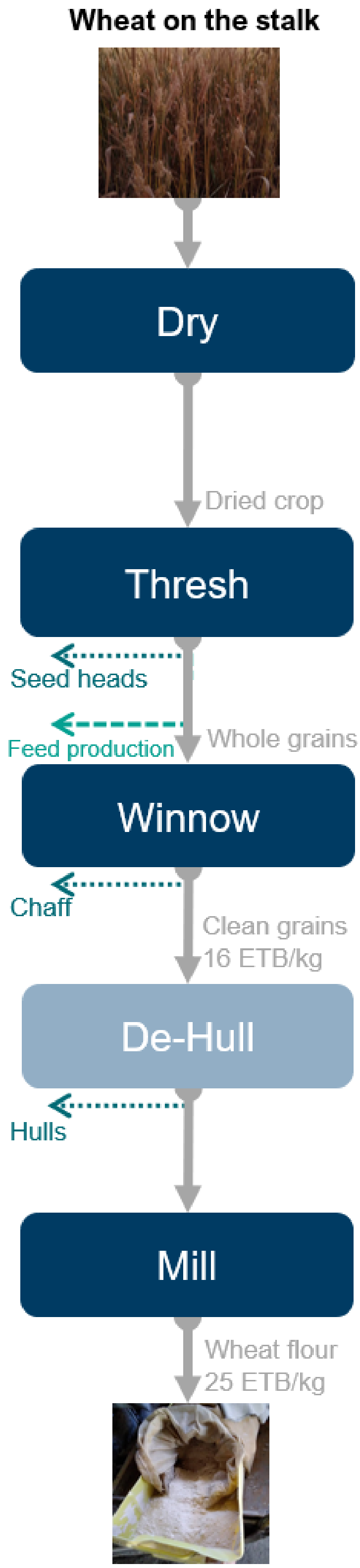


Exhibit 41: Annual Wheat Planting and Processing Calendar

Note: Experts consider June through the end of September to be lean grain supply months because in most areas there are limited harvests during this period for any major cereals. (Source: FAO GIEWS, 2020)

Wheat flour production



Description	Mechanization
Wheat is left to dry to a 14%–18% moisture content before harvesting. Wheat is harvested when golden, bending at the stalk, and berries are hardened.	Farmers typically harvest wheat manually using a sharp scythe or sickle blade.
Farmers further dry wheat until the moisture content drops to 6%–8%.	Grain dryers are relatively common in wheat processing although most crop is air dried. In communities we surveyed, 66% of farmers who cultivate wheat manually dry their crops.
Farmers thresh dry wheat grains in the field to release grains from the stalk and seed heads. This is achieved by beating or shaking crop stalks.	Farmers typically thresh wheat manually or with animal-power at the farm. Survey findings indicate that 74% of wheat was threshed manually, 9% mechanically, and 17% using animal power.
Farmers separate grains from straw-like chaff at the farm by throwing grains into the air so that the chaff blows away while the grains settle.	Wheat winnowing in rural communities takes place manually with a wide thatch plate or basket. Combine machines—though rare—can winnow as well as thresh and hull grains.
Some consumers scrape the hull layer off the wheat grains in their homes before consumption to leave the inner bran and germ layers on the grain.	Wheat hulling is rare in rural communities as wheat hulls are soft and edible. Some hulls are shed during threshing or manually removed in households, but most consumers eat hulls.
Processors mill clean, dry grains into a meal or fine flour. From our survey findings, the median grain milling service price was 1 ETB/kg.	All milling processors in surveyed communities used mechanical plate or hammer mills, with 96% using fossil fuel-powered mills and the remaining 4% using electric mills.

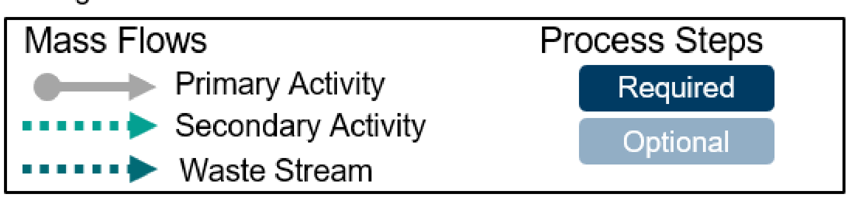


Exhibit 42: The Wheat Processing Flow from Harvested Wheat to Wheat Flour

Note: In rural communities, most wheat is sold in the form of dried grain to final consumers. Consumers will typically take their crop to processors for milling. [28, 29] *(Source: RMI Survey)*

Initiatives to electrify smallholder wheat processing activities will have the strongest potential in Amhara and Oromia.

The prevalence of processing activities in Amhara and Oromia demonstrates strong offtake markets for processed wheat products. The high production volumes in Amhara and Oromia suggest that these regions are significant hubs for on-farm processing activities that occur immediately after harvesting. The potential for electrifying wheat processing is high in rural communities with high wheat production because of the cumulative demand for both on-farm processing and end-consumer milling occurring locally.

Wheat farmers in Oromia and Amhara represent a significant segment of the wheat processing market. Exhibit 43 shows that most of Ethiopia's wheat production (87% in 2019/20) comes from Oromia and Amhara.[66] As discussed in Exhibit 42, wheat farmers must dry, thresh, and winnow wheat on-site before storing or selling the grains. From our survey, we only observed mechanized threshing equipment in kebeles that were among the top 15 producers of at least one major cereal (maize, wheat, teff, barley).[li] Furthermore, most wheat farmers are subsistence farmers who consume substantial portions of harvested crops—farmers consume between 33% to 58% of their wheat harvests in the household and end-consumers prefer to mill immediately before consumption.[67] Therefore, high production communities need both on-farm processing and end-consumer milling.

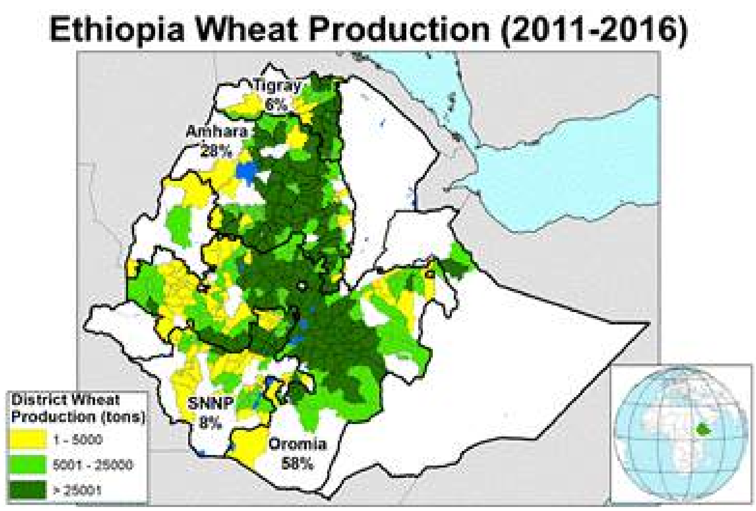


Exhibit 43: Spatial Production of Wheat across Ethiopia

Note: Wheat grows across four regions in Ethiopia, with 58% of wheat growing in Oromia alone. Most wheat in Ethiopia grows in the high-altitude areas (1,500 m above sea level), where temperatures tend to be mild (7°C–21°C) and there is moderate rainfall (750–1,600 mm per year).[68] *(Source: USDA Foreign Agricultural Service)*

[li] Amhara, Oromia, and SNNPR are the top three regional producers of teff, maize, wheat, and barley in Ethiopia by production volume.

A.3.1.3 Losses

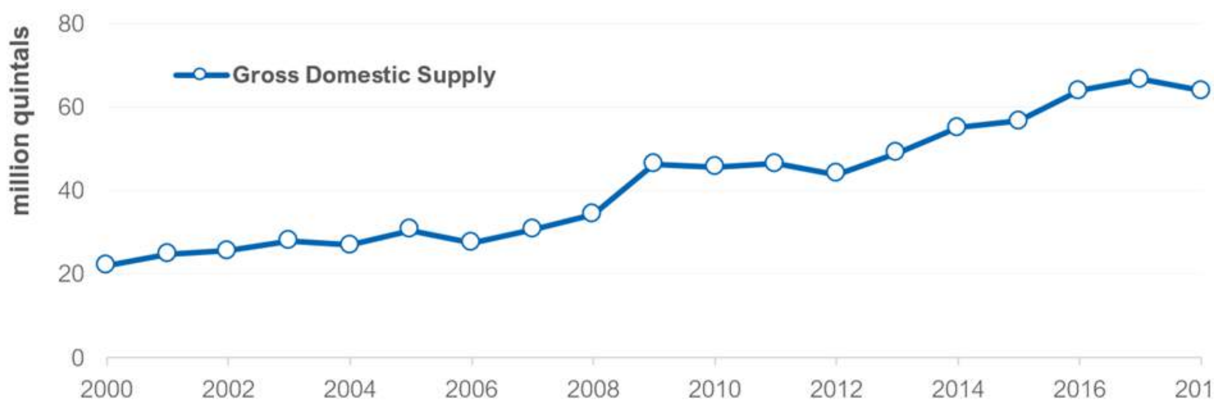
On-farm wheat losses limit the business potential for wheat processing down the value chain.

Post-harvest losses decrease the overall volumes of wheat that are available for processing and consumption. This makes wheat processing activities less viable. Smallholder wheat farmers that RMI surveyed reported average post-harvest losses of 11%. These estimates are consistent with expert estimates of post-harvest losses of 14%–21%.[69]

A case study of wheat losses throughout the steps to produce wheat in Arsi and transport it to Addis Ababa markets noted 6% losses during harvesting due to rainy weather at harvest times. According to this market study, farmers observed negligible losses of 0.25%, 0.35%, 0.5% respectively for drying, threshing, and winnowing.[70] However, the greatest observed losses were reported for improper storage of wheat in the field (8%). Most farmers (66%) store wheat grains in bags, where storage losses drop to 2%, but many farmers (38%) store grains in less secure traditional thatch huts outdoors.[71] Grains are susceptible to storage pests and mold when left in the field or unsealed conditions.[72] These losses demonstrate the need for improved storage techniques. However, these issues can be addressed through non-energy solutions and are not considered further in this study.

A.3.1.4 Demand

High localized demand for wheat in rural communities suggests strong potential for electrifying wheat processing activities in rural communities.



	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18
Harvest	12	16	14	16	16	22	22	25	23	31	29	29	34	40	42	47	45	48	45
Imports	12	11	7	17	6	9	5	6	11	19	17	17	10	9	11	14	26	12	9
Exports	.00	.00	.00	.00	.00	.01	.00	.01	.01	.01	.02	.03	.74	.03	.10	.08	.06	.01	.04
Stocks	3	2	4	5	5	0	0	0	0	3	0	0	0	0	2	4	7	7	10

Exhibit 44: Gross National Supply of Wheat between 2000 and 2018 in Million Quintals

Note: The data table gives a breakdown of gross domestic supply into national harvest, imports, exports, and national stocks. We add production and imports but subtract exports (in red) to determine the gross domestic supply. The Government of Ethiopia contributes national wheat stocks toward domestic supply during periods of shortage and subtracts a portion of national production from domestic supply during periods of excess production (as denoted by red values). Wheat imports account for between 18% (2017, 2013) and 60% (2003) of the gross domestic wheat supply. (Source: FAOSTAT New Food Balances)

Cleaned wheat grains stored inside the household in sacks.

Another indicator of strong processing potential is high local consumption in rural communities. Wheat is a core part of rural diets and the demand for processing in rural communities is also strong.

Domestic wheat consumption is high in Ethiopia given that wheat exports are negligible (as shown in Exhibit 44). Less than 0.2% of domestic wheat supply has been exported since 2000—except in 2012 (1.7%).[73] In fact, Ethiopia imports wheat to meet national demand: in 2018, 18% of the domestic wheat supply was imported. Between 2000 and 2018, imports accounted for between 18% and 56% of the total national wheat supply. [74] Therefore, the domestic wheat supply must be processed within country because Ethiopians consume all the domestic supply.

Wheat imports do not reach rural consumers unless they are directed to specific food-insecure woredas.[75] This means that most rural consumption of wheat is produced locally. Commercial users procure most wheat imports (70% in 2014). Commercial processors import wheat—primarily durum wheat for pasta and macaroni production—because they cannot source the volumes they need domestically.[76]

Thirty percent of wheat imports went toward food aid in 2014, and actual aid volumes ranged between 2 and 14 million metric quintals between 2000 and 2014.[77] Authorities import most of this volume and subsidize wheat to increase the affordability of wheat products for poor urban consumers.[78] Authorities only distribute subsidized wheat to a few authorized large-scale mills and businesses all located near major cities, and most traders and bakers sell subsidized wheat products in marketplaces within major cities.[79] These processors, and any other processors along the value chain handling subsidized wheat, must trade their products at subsidized prices. Only the portions of food aid imports that are prioritized for The Productive Safety Nets Programme (PSNP) and other smaller food aid initiatives are distributed to rural communities.[lii, 80]

[lii] The Productive Safety Nets Programme (PSNP) assists 7 million poor households living in 290 food-insecure woredas with food and crop supplies, as well as funding. In 2009, the PSNP distributed 4.6 million metric quintals of food (which includes food products across various crops) to these communities.

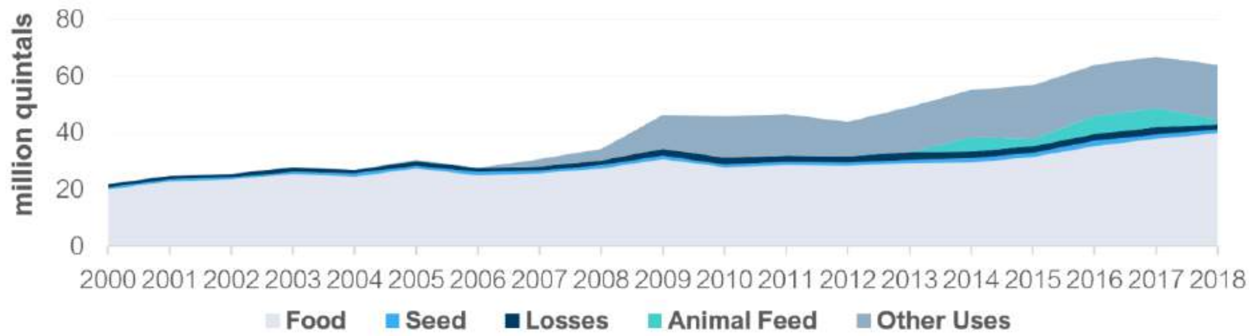


Exhibit 45: Consumption of Wheat Domestic Supply by the Major Categories of Food, Seed, Losses, and Animal Feed in Million Quintals

Note: Food purposes accounts for 54%–91% of wheat consumption in Ethiopia. Since 2014, wheat has been increasingly used for animal feed. Significant portions of wheat are consumed for "other uses," but the actual end use of this category is not well characterized by the FAO or the Ethiopian Central Statistical Agency.[liii] *(Source: FAOSTAT New Food Balances)*

[liii] *Other uses* refer to end-uses other than food, seed, animal feed, losses, tourist consumption, and processing. In 2018, other uses accounted for 30% of all consumption.

Box 1: The Growing Animal Feed Market in Ethiopia

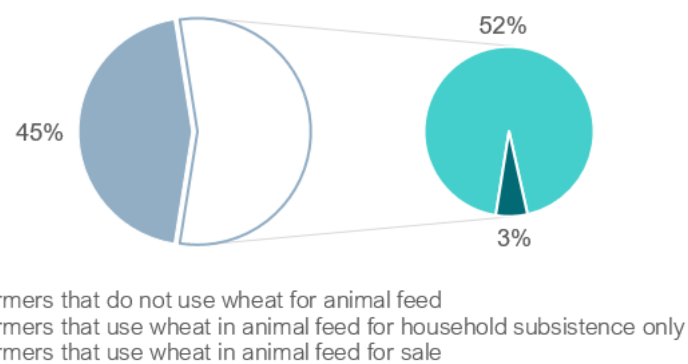
Currently, Ethiopians use negligible portions of wheat production as animal feed.

In the 2019/20 Crop and Livestock Product Utilization Report, the Ethiopian Central Statistical Agency reports that only 0.33% of national wheat production was used for animal feed in 2019 (up from 0.18% in 2016).

Wheat crop residues can be used for animal feed.

The waste streams from threshing and winnowing—wheat seed head and wheat chaff—are useful for feeding livestock. Almost no animal feed processors exist in rural communities.

In surveyed communities, 55% of wheat farmers use wheat for animal feed.



Experts expect animal feed demand to grow to meet the needs of Ethiopia's expanding milk-producing livestock population.

Since 2013, farmers have been using wheat for animal feed (Exhibit 45). Ethiopia's National Livestock Sector Analysis (LSA) predicts that milk production will increase by at least 178% by 2028.* Among initiatives to increase the population and optimize the productivity of milk-producing animals, animal feed will play a key role in realizing these targets. This suggests that demand for animal feed will grow to play an increased role in wheat consumption, and that the animal feed market will see further growth.

* Researchers project milk production of 7.8 billion liters in 2028 without any interventions (this is more than twice the 2018 production of 2.8 billion liters). The LSA also projects that production could even reach 8.8 billion liters by 2028 if interventions to address young and adult stock mortality are implemented. (Shapiro et al., 2017)

Ethiopians consumed 62% of domestic wheat supply for food in 2018. All the wheat consumed for food (shown in Exhibit 45) required processing in Ethiopia.[81] Per capita consumption of wheat is consistent across Ethiopia—annual per capita wheat consumption was estimated at 30 kg in rural communities in 2011.[liv, 82] Consumption is consistent across major cereals, but wheat consumption is slightly below maize consumption in rural communities.[lv, 83] Rural consumers are less likely to purchase pre-made bread and pasta products as they are less affordable. Instead, rural consumers more often make traditional and baked flour-based goods in the household using wheat flour.

[liv] During the same period, annual per capita wheat consumption was relatively equal in towns (39 kg) and urban locations (40 kg).

[lv] A 2011 study compared annual per capita consumption of major cereals in rural communities: 42.2 kg for maize, 31.2 kg for wheat, 20.1 kg for teff, and 14.3 kg for barley.

A.3.1.5 Local Trade

Wheat milling has potential for electrification in both high and low wheat production rural areas as consumers buy and trade wheat grain and process grains into flour before consumption.

Local trade data shows that significant levels of wheat remain in rural communities for local consumption. Farmers we surveyed retain 33% of their harvest for household use. The survey findings presented in **Exhibit 46** also show that traders sell on average 20% of purchased wheat crops within the same community. The literature confirms these findings as our research shows that farmers—having the largest collective wheat storage capacity—collectively store 260 million metric quintals of wheat.[lvi] Farmers primarily store crop for seed use and consumption—this enables them to mill grains throughout the year.

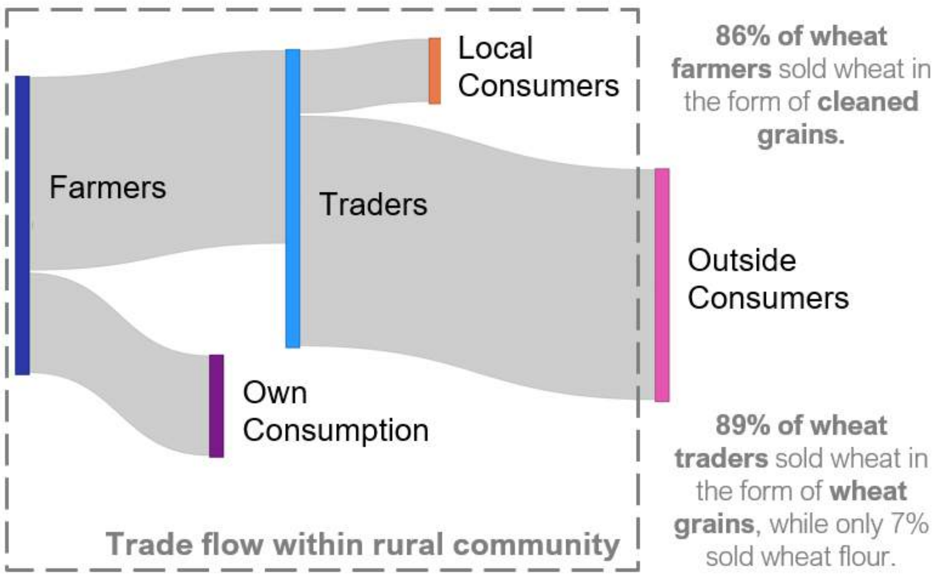


Exhibit 46: Wheat Product Flow from Farmers to Consumers Based on RMI Survey Findings from Value Chain Actors in Wheat-Producing Communities in Amhara, Oromia, and SNNPR

Note: We measure trade flow proportions by percentage of wheat volume traded. (Source: RMI Survey, 2020).

But farmers have limited storage capacity. When farmers reach max capacities during surplus or harvest periods, they sell excess grains they cannot store.[84] Traders sell whole wheat grains to end-consumers in low production regions who mill crops before consumption. This suggests that wheat flour milling takes place in rural communities across Ethiopia.

A.3.2 Opportunities for Electrification

[lvi] According to a 2015 wheat value chain study, the average on-farm storage capacity was 26 metric quintal per farm.

We analyzed threshing, winnowing, hulling, drying, and milling to identify opportunities for short-term electrification. As described in the evaluation framework of **Section 2.4.1**, we used the metrics of local capacity, offtake market, equipment and electrification, and scalability to shortlist activities that demonstrated strong readiness for electrification today or in the short term with minimal support needed.

Abebech Balcha with her diesel-powered mill. She processes teff, maize, and wheat grain into flour for 100 ETB per quintal. Ms. Balcha typically earns 1,000 ETB in weekly revenues and serves eight customers per day.

In the wheat value chain, wheat milling showed significant potential for short-term electrification. Wheat milling and threshing are both necessary for all wheat consumed in Ethiopia. These activities are discussed further below.

Other activities are not immediately suitable for electrification with minigrids. Farmers manually air dry almost all wheat produced in Ethiopia because it is free and generally effective. There is little evidence that farmers are willing to pay for the consistency of electrically dried wheat. Likewise, almost all wheat storage techniques in rural communities do not involve electric or fossil fuel-powered energy. Lastly, rural consumers rarely hull wheat before consumption because wheat hull layers are soft and edible. Wheat drying, storage, and hulling are not covered further because they show little potential for electrification.

A.3.2.1 Wheat Milling

Wheat milling shows the most potential for short-term electrification in rural communities.

The prevalence of wheat millers in rural communities shows that processors have the capacity to effectively manage processing businesses and maintain mechanized equipment. Demand for wheat milling is consistent and robust because most consumers in rural communities pay processors to mill their wheat mechanically. Electric wheat mills are available in Ethiopia and milling demand persists year-round throughout rural communities, suggesting strong scalability.

Criteria	Support Status	Description
Local Capacity	●	On average we found **four wheat milling processors per community**.* The average grain milling business in rural communities has been running for **eight years**. Processors have extensive experience as mill businesses are prevalent in rural communities and have been operating for a long time. * Findings based on 2020 RMI survey findings of wheat processing in rural communities in Ethiopia.
Offtake Market	●	The average milling service fee in rural communities is **94 ETB per quintal**. On average, wheat milling businesses serve **36 customers daily**. According to **78%** of surveyed wheat flour milling processors, demand for milling persists throughout the year—independent of seasons.
Equipment and Electrification	◕	Electric mills are available locally—manufacturers produce these mills domestically and have the expertise to offer after-sales servicing.* **One hundred percent** of surveyed milling processors own a mechanical fossil-fuel powered or electric mill. * Kalmeks Manufacturing produces a tri-phase electric grain mill with 10 quintal per hour throughput for 140,000 ETB.
Scalability	●	Wheat is a staple food consumed across Ethiopia—not only in high production regions. Since consumers prefer to purchase whole wheat grains and mill small portions of wheat before consumption, there is significant scaling potential for wheat milling across Ethiopia.

Support Required: ○ Significant ◐ Moderate ◕ Minimal ● Deployment Ready

As shown in Exhibit 46, most rural consumers purchase wheat grains and take their crop to be milled in small batches throughout the year. From our survey findings, an average processor serving 36 customers per day would generate 1,500 ETB in daily revenues. Processors can expect this demand to remain consistent throughout the year.

Electric wheat flour milling in rural communities is ready for further testing and piloting. Processors need to test electric mills in their businesses to compare costs, performance, and throughputs against those of fossil fuel-driven motors. Surveyed processors observe throughputs of 2.1 quintal/hour using fossil fuel-powered equipment. A pilot study will also need to address whether electric mills can meet the throughput needs of processors while powered by a minigrid system. Otherwise, it would be risky for a processor to invest in an electric mill without the confidence that minigrids can reliably power equipment whenever the processor needs to mill wheat.

A.3.2.2 Wheat Threshing

Wheat threshing is not currently suitable for electrification in rural minigrid communities.

Wheat threshing does not currently demonstrate strong potential for electrification in rural minigrid communities. Wheat threshers are rare in rural communities, so there is little evidence that processors have gained experience in managing wheat threshing businesses and maintaining mechanical threshing machines. Although farmers thresh the wheat they harvest, most farmers do not pay for threshing—74% of wheat farmers we surveyed thresh crops manually or with animal power. Therefore, there is no proven offtake market for mechanical threshing services and the process is not yet widely mechanized. Wheat threshing only takes place in high wheat-producing rural communities, and farmers only require wheat processing for three months of the year.

Nebo Obse Kimo with his mechanical thresher. Mr. Kimo threshes barley and wheat for 90 ETB per quintal. During busy periods (December to February), he serves an average of 10 customers and processes a total of 40 quintals per day. Mr. Kimo also sells wheat and pearled barley grains directly to consumers.

In addition, electric equipment suitable for consumer needs is not available. Most wheat is threshed by farmers in the field, so threshers must be moved to farm fields to cater to farmer practices. Distances from community centers to farm fields average 3.4 km and can range up to 8.4 km. It is not economically viable for a minigrid developer to run distribution lines to connect threshers in the fields. This means that processors need mobile chargeable electric threshers, and these are not readily available in Ethiopia.

Criteria	Support Status	Description
Local Capacity	◕	In our survey we only observed threshing processors in **26%** of kebeles, and we only observed one thresher on average within these communities. These threshing businesses have been running for **four years on average,** but only **30% of the threshers surveyed processed wheat**. The limited presence of threshers who process wheat suggest that capacity is limited in rural communities for wheat threshing.
Offtake Market	◑	All wheat must be threshed before consumption, so there is a demand for threshing in rural communities. However, our survey findings show that **over half of wheat farmers (74%) do not pay for threshing, so the market that could be served by specialized threshing businesses is limited**.* **Only 9% of wheat farmers thresh crop mechanically**, at an average cost of 116 ETB/quintal. That is higher than what wheat farmers pay for manual threshing of 88 ETB/quintal. Thus, wheat farmers that do pay for threshing prefer to hire laborers for manual threshing (13% of farmers pay laborers for threshing). Our survey found that most wheat farmers already complain of high threshing costs (83%). Given the lower costs and prevalence of manual labor, the market for mechanical and electric threshing is limited. * 57% of farmers relied on friends and family for free threshing; 17% of farmers used oxen for threshing.
Equipment and Electrification	◔	Stationary grid-connected electric threshing equipment exists in Ethiopia, but rechargeable mobile equipment is needed to properly serve farmers, who thresh wheat in the field.* Furthermore, threshing only takes place for three months of the year (November through February), leading to extended periods in the year where threshing equipment remains unused. * Amio Manufacturing produces a tri-phase electric grain thresher with 40 quintal per hour throughput for 72,000 ETB.
Scalability	◕	Wheat threshing is likely to be most prevalent in wheat cultivation hubs (Amhara and Oromia) because farmers thresh crops on the field. Since all wheat must be threshed, there is considerable scaling potential for this activity.

Support Required: ○ Significant ◑ Moderate ◕ Minimal ● Deployment Ready

A.4 Barley

- **Barley is not a staple food across Ethiopia and is only produced at high volumes in the Ethiopian highlands.**
- **Significant consumption in barley-producing communities makes high production zones in Amhara and Oromia potential areas for electrified barley processing initiatives.** Eighty-three percent of barley is produced in Amhara and Oromia, and most barley farmers retain portions of their production for subsistence purposes. As such, most barley is consumed in the highland areas where it is produced. The high demand for local processing within communities of Amhara and Oromia suggest that these regions have the highest potential for electrifying processing activities.
- **Barley milling may be suitable for electrification in the medium term (Tier 2).** Barley milling is a necessary processing step for making barley flour and processors already operate mechanized milling equipment across Ethiopia. Existing fossil fuel-powered milling equipment can be retrofitted with an electric motor. Based on 2020 RMI survey findings, 84% of rural communities already have at least one mill processor operating locally. But barley consumption is concentrated in high production zones, so the demand for barley processing has limited scalability across Ethiopia.

A.4.1 Background

In 2018, Ethiopia was the second largest barley producer in continental Africa behind Morocco [lvii, 85] From 2019 to 2020, farmers cultivated 950 thousand hectares of land to produce 24 million quintals of barley.[86]

Karoorsa Mamo Doyo cultivates a hectare for barley on his farm in the Shirka woreda of the Arsi Zone, Oromia. He plants barley once per year and produces 30 quintals of crop each harvest. His crop is threshed manually for free. Mr. Doyo trades with local collectors and at markets in his community and neighboring communities.

Food barley accounts for 90% of barley production in Ethiopia and farmers primarily use it for subsistence purposes.[87] Malt barley accounts for the remaining 10% of national barley production, and farmers primarily sell malt barley to malting factories and breweries.[88]

Barley is the least prominent major cereal crop grown in Ethiopia.[lviii, 89] Only 25% of cereal farmers in Ethiopia produced barley in 2019, and barley made up only 6% of Ethiopia's total cereal production that year.[lix] Most barley production comes from smallholder farmers with plot sizes smaller than 0.5 hectare and

[lvii] Morocco produced 0.75 million quintals more barley than Ethiopia in 2018 (Abate, G. et al., *Maize Value Chain in Ethiopia: Structure, Conduct, and Performance*, 2015, doi:10.13140/RG.2.1.2229.0804).
[lviii] Other major cereals include wheat, teff, maize, and sorghum.
[lix] In 2019, 65% of cereal-producing farmers cultivated maize, 31% cultivated wheat, 31% cultivated sorghum, and 45% cultivated teff. During the same period, maize accounted for 34% of Ethiopia's cereal production in 2018, compared with 17% for wheat, 19% for teff, and 18% for sorghum.

most barley farmers (53%) dedicate only 0.15 hectare for barley production.[lx,90]

A.4.1.1 Production

Relatively low and stagnant barley production volumes in Ethiopia suggest unreliable supply for barley processing.

Barley flour after weigh-in at the grain milling processor.

The inconsistency of barley production volumes signals that barley supplies may be too unstable to support viable processing businesses. Although yields and production volumes doubled between 2000 and 2019, the total area cultivated for barley increased by only 8% within the same period. More importantly, barley production throughout that period was erratic.

IFPRI explored this volatility assessing the coefficient of variation of barley production trends for 2003–2013 against their decade-long compound annual growth curves.[lxi] On average, the actual annual production value differed by 40% from the expected value for that year. This average variation was 38% for barley yields and 25% for area cultivated.[91]

A 2019 survey of 180 farmers in the North Gondar highlands of Amhara (a barley production hub) found that only 2.2% of farmers consistently produce barley each year. In fact, 82% of respondents indicated that they are reducing the area devoted to barley.[92] Farmers cited a move to cultivate cash crops, the low productivity of available barley seeds, and soil erosion as reasons for this shift. These findings reflect that year-to-year barley trends in Ethiopia are volatile and on a downward trend, thereby increasing the risk for processors investing in new equipment to access sufficient volumes to recover their investment.

[lx] From the 2012/2013 Agricultural Sample Survey: 29% of barley production comes from (0.5–1 hectare) farmers with average cultivated area of 0.68 hectares, 15% from (1–2 hectare) farmers with average cultivated area of 1.3 hectares, and 4% from (more than 2 hectares) farmers with average cultivated area of 2.8 hectares.

[lxi] Coefficient of variation (CV) is defined as the quotient of the standard deviation and the mean for a dataset. This measures how much the data points generally differed from expected values (Mohammed, J., Seleshi, S., Nega, F. & Lee, M., "Revisit to Ethiopian traditional barley-based food," *Journal of Ethnic Foods 3*, 135–141, 2016.). While the compound annual growth rates were calculated over the period, the actual values for each year would be expected to fall slightly above or below the expected values on the growth rate curves. The CV is a measure of the degree of variation, compared with the actual expected value.

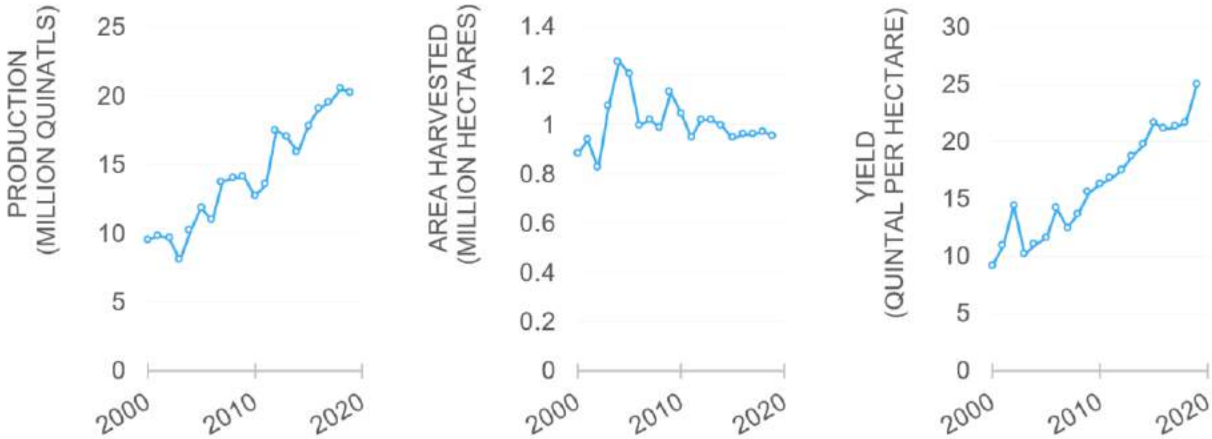


Exhibit 47: Trends of Production, Area Harvested, and Yield for Barley between 2000 and 2019

Note: Barley is consistently the lowest performer among the major cereals (teff, wheat, maize, and barley). For production and area harvested, barley also shows the least growth between 2000 and 2019. Barley yields lag wheat and maize yields but stay higher than teff yields. (Source: FAOSTAT Production)

Despite improvements during the past decade, barley yields in Ethiopia have significant room for improvement, compared with other African countries: in 2018, Ethiopia's overall barley yields ranked sixth in continental Africa at 21.6 quintal per hectare.[lxii] Ethiopia's barley farmers are the least likely among cereal farmers to adopt modern inputs. In 2014, of all fertilizers applied to cereal crops in Ethiopia, farmers only used 4% for barley cultivation.[lxiii,93] Less than 1% (0.6%) of barley farmers used improved seed varieties in 2014, even though a study shows that adoption of improved seed varieties could double barley yields. The public resources to disseminate barley inputs have been scarce. Regional seed enterprises, the major government-authorized distributors of improved barley seed varieties, only designated 4% of their total seed supply for selling barley.[lxiv, 94] Low barley yields compound the risks of unstable barley supplies for processors.

A.4.1.2 Processing

Milling shows potential for electrification within the barley value chain.

The existing state of processing activities in rural communities helps indicate whether an activity is suitable for short-term electrification with minigrids. We find that barley milling is the only barley processing activity that is already widely mechanized in rural communities. Since processors already have the capacity to manage milling businesses and have experience paying for fuel and upkeep of fossil fuel-powered equipment, they require less support to transition to electric equipment. Furthermore, barley milling is the only processing activity that consistently occurs year-round, which is favorable for minigrids. Barley milling therefore demonstrates potential for electrification.

[lxii] The top three barley yields in continental Africa were 1.6–2.5 times the yields observed in Ethiopia. Yields of 54.9, 39.0, and 35.4 quintal per hectare were observed in Zimbabwe, Kenya, and South Africa, respectively.
[lxiii] By comparison, in that year 22% of fertilizers were applied for wheat and 16% for teff.
[lxiv] Regional seed enterprises marketed 18% of their supply for teff, 63% for wheat, and 13% for maize in 2014.

Exhibit 50 shows the flow of processing activities for making barley flour.[95] As shown in **Exhibit 53**, barley flour is the most popular form for consuming barley particularly in rural communities. Barley flour is a popular substitute for other types of flour in numerous traditional food products.[lxv,96] Farmers dry, thresh, winnow, and de-hull barley crops on the farm before trading barley grains to traders who sell to end-consumers. Similar to other cereal crops, end-consumers take grains to processors within their communities for milling before cooking and consumption.[97] Drying, threshing, winnowing, and hulling are important on-farm processing activities, while milling is a critical end-consumer processing activity.

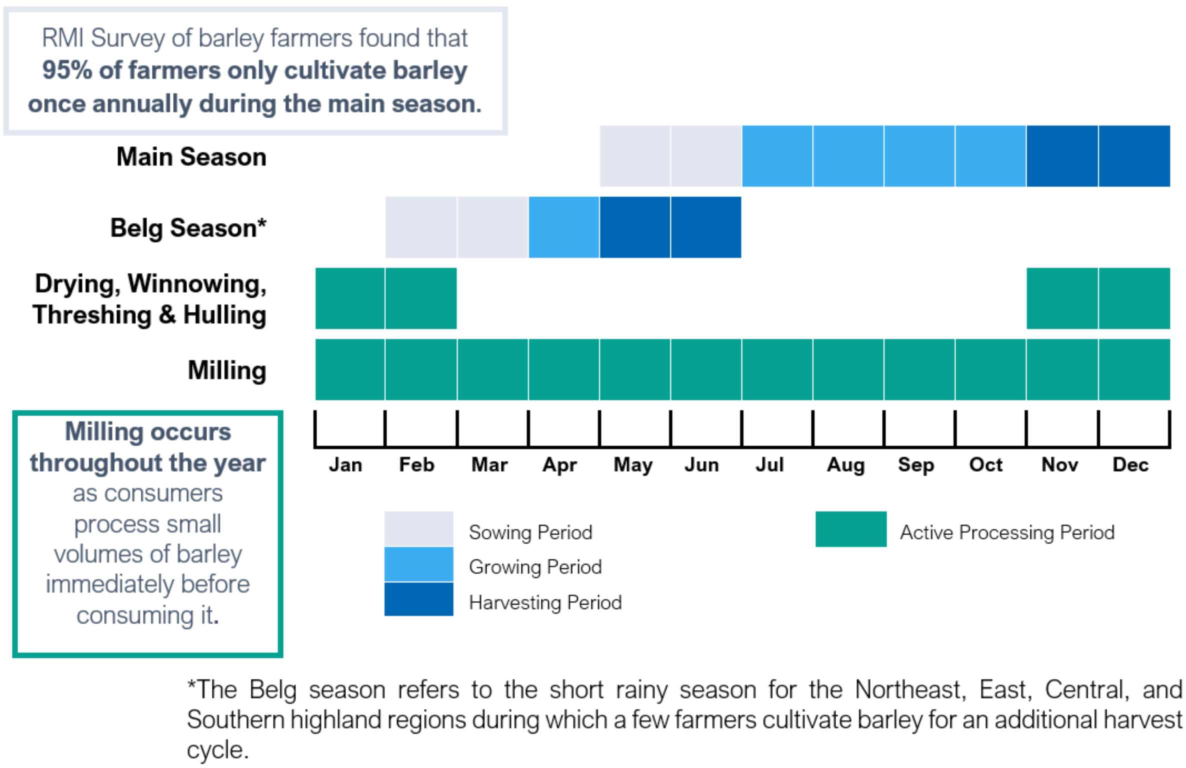


Exhibit 48: Annual Barley Planting and Processing Calendar

Note: Experts consider June through the end of September to be lean grain supply months because in most areas, there are limited harvests during this period for any major cereals.[98] (Source: FAO GIEWS, 2020)

The seasonality of barley processing throughout the year is critical for determining if specific processing activities are suitable for electrification with minigrids. As discussed in **Section A.3.1.2** for the wheat value chain, seasonal processing activities are less optimal for electrification with minigrids because fluctuations in energy demand from seasonal activities leads to underutilization of capacity

[lxv] The most popular traditional products derived from barley flour include injera—thin and spongy fermented bread made from raw flour, water, and previously fermented dough; kita—dry, thin, chewy unleavened flatbread that is typically mixed with barley flour; dabo—soft and salty leavened bread that is typically mixed with barley flour; genfo—popular gelatinous dish made from boiling the flour of lightly roasted barley minus the hulls; beso and chuko—roasted barley (and sometimes other cereals) flour usually made into a drink with water, sugar and spices; tihlo—balls of boiled barley flour prepared similarly to beso.

during the year. Inconsistent energy demands affect the earning potential of minigrid developers trying to recoup investment costs. As the processing calendar in Exhibit 48 shows, farmers we surveyed carry out on-farm processing activities such as threshing, winnowing, drying, and hulling between November and March—closely following harvesting periods.[99] Therefore, if these activities were electrified there would be no electricity demand for eight months of the year. In contrast, milling takes place year-round.

Barley processing is a niche opportunity for high production communities in Amhara and Oromia.

There is a cumulative demand for end-consumer processing and on-farm processing activities in Amhara and Oromia. As shown in Exhibit 49, farmers in Amhara and Oromia contribute most (85% in 2020) of the national production—twenty-three of the top twenty-four barley-producing woredas are located in these regions. Barley crops grow best in the highlands, and farmers in these areas favor barley because (compared with other grains' performance at high altitude) it is more resilient against frost, water logging, diseases, and pests. Most barley production in Oromia comes from the Arsi-Bale and West Shewa zones, while the production hubs in Amhara are in the North Shewa and North Gondar zones.[100] Because consumption is coupled to production, these production hubs present a niche opportunity for barley processing

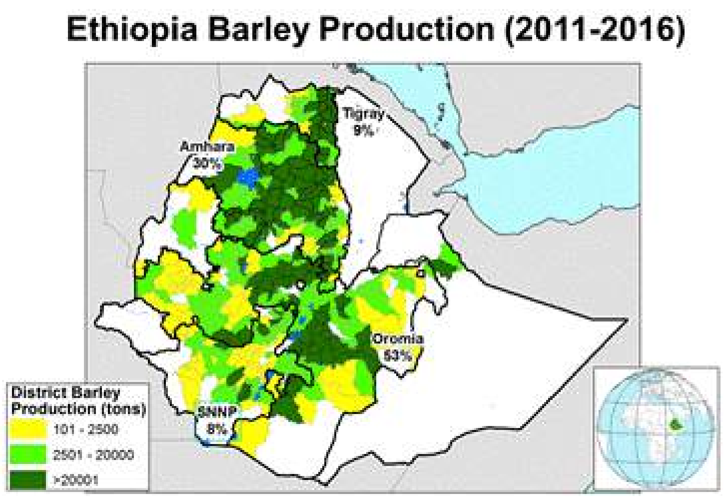
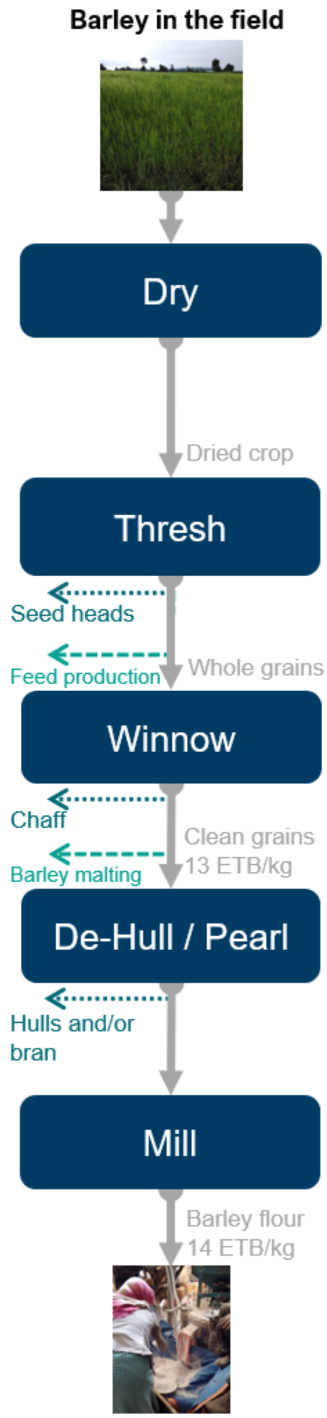


Exhibit 49: Spatial Production of Barley across Ethiopia

Note: Barley grows optimally in the highlands of Ethiopia, and cultivation is only split among four regions. (Source: USDA Foreign Agricultural Service)

Barley flour production



Description	Mechanization
Barley is left to dry to a 16%–18% moisture content before harvesting. Barley is harvested when the entire crop turns yellow and is bending at the stalk.	Farmers typically harvest barley manually using a sharp scythe or sickle blade.
Farmers further dry barley until the moisture content drops to between 12% and 12.5%. To do this manually, farmers lay out bunches of barley stalks in interwoven rows to dry.	Most barley farmers in Ethiopia sun dry their crops. Yet, mechanized grain drying is common among the subsets of barley farmers we surveyed, particularly in Amhara.
Farmers thresh dry barley grains in the field to release grains from the stalk and seed heads. This is achieved by beating or shaking crop stalks.	Farmers typically thresh barley manually at the farm. Survey findings indicate that 94% of barley was threshed manually, and 6% using animal power.
Farmers separate grains from straw-like chaff at the farm by throwing grains into the air so that the chaff blows away while the grains settle.	Barley winnowing in rural communities takes place manually with a wide thatch plate or basket. Combine machines—though rare—can winnow as well as thresh and de-hull grains.
Inedible barley hulls must be removed before consumption. De-hulling removes the hull layer only, while pearling also shaves some inner bran layer.	De-hulling can be mechanized with a combine thresher but is typically carried out manually. Most farmers and consumers do this with a grinding stone or by further threshing and winnowing.
Processors mill clean, dry grains into a meal or fine flour. The median grain milling service price we observed was 1 ETB/kg.	All milling processors we surveyed used mechanical plate or hammer mills, with 96% using fossil fuel-powered mills and the remaining 4% using electric mills.

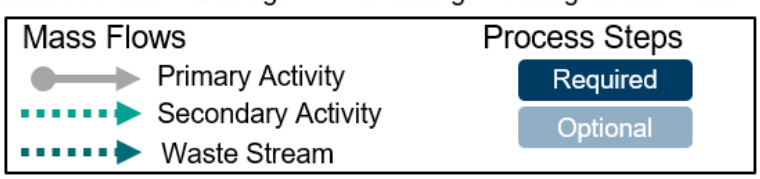


Exhibit 50: The Barley Processing Flow from Harvested Barley to Barley Flour

Note: Most marketed barley is sold in the form of dried grain to final consumers. Consumers typically take their crop to processors for milling.

A.4.1.3 Losses

Losses restrict the business potential for barley processing activities along the value chain.

Post-harvest losses decrease the overall volumes of barley that are available for consumption and processing. This makes barley processing activities less viable. Improperly dried barley grains are prone to rot. Losses from improper storage also affect crop supply as deteriorated grains used as seeds have lower crop yields. Proper drying and storage techniques can decrease losses and increase supplies in the barley value chain.

Experts in 2019 estimated barley crop losses in Ethiopia at approximately 10%.[101] Improper drying and storage techniques particularly affect post-harvest losses. Barley grain that is not dried to below 12%–12.5% moisture content levels is susceptible to rot.[102] Farmers often use tarpaulins or plastic sheets to separate crops from the soil, but unpredictable rainfall affects the drying process and increases losses. Half of all barley farmers we surveyed air-dry their barley, and among them 33% reportedly faced challenges drying their crops at least 10 days every harvest.

Meanwhile, most farmers store barley primarily for future household consumption and secondarily for future seed use.[103] Farmers store barley as dried grain or flour, which are both shelf stable with proper storage conditions. But they typically store barley in bags on the ground in the house.[lxvi,104] Improper storage techniques significantly increase crop deterioration and spoilage. Effective drying and storage techniques could help reduce losses and improve crop supplies.

A.4.1.4 Demand

Localized demand for barley in producer communities suggests limited scalability for electrification.

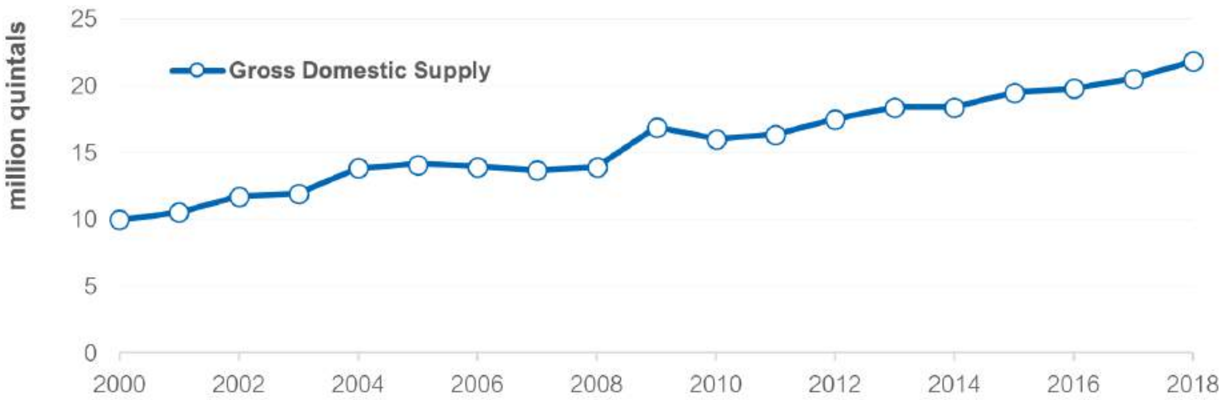
Barley is not a central part of rural household diets outside of the Ethiopian highlands where farmers cultivate it. This indicates that the processing activities described in

Exhibit 50 predominantly occur in rural communities where barley grows.

Most of the barley produced in Ethiopia is consumed in the country, as shown in **Exhibit 51**. Ethiopia has not exported barley since 2000.[105] In fact, Ethiopia imports barley to meet national demand: in 2018, 8% of the domestic barley supply was imported. Therefore, the domestic barley supply must be processed within the country.

Dereje Lema piling large grain barley flour on a tarpaulin. Mr. Lema uses his grain mill to process barley grains.

[lxvi] Fifty-eight percent of farmers store barley in bags in the house, 29% use other forms of storage in the house, 7% heap barley in the house, 6% use unprotected piles, and no farmers use metallic silos in the house.



	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18
Harvest	8	10	12	11	14	14	14	13	14	18	17	16	18	19	20	20	20	20	21
Imports	.13	.15	.08	.08	.08	.16	.39	.46	.43	.32	.49	.49	.70	.57	1	1	1	1	2
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stocks	2	.20	.20	1	0	0	1	1	0	1	2	0	1	2	2	2	2	1	1

Exhibit 51: Gross National Supply of Barley between 2000 and 2018 in Million Quintals

Note: The data table gives a breakdown of gross domestic supply into national harvest, imports, exports, and national stocks. We add production and imports but subtract exports (in red) to determine the gross domestic supply. The Government of Ethiopia contributes national barley stocks toward domestic supply during periods of shortage and subtracts a portion of national production from domestic supply during periods of excess production (as denoted by red values). Barley imports account for up to 8% of the gross domestic barley supply. (Source: FAOSTAT New Food Balances)

Barley imports do not reach rural consumers and small-scale rural processors because local breweries and malting factories import malt barley for large-scale commercial use. The malt barley sector growth discussed in Box 2 has increased the demand for high-quality malt barley. But industrial malting and brewing companies are unable to procure high volumes of high-quality malt barley in Ethiopia and therefore import crops to supplement their demand.

Around the world, barley is widely used for animal feed, but as shown in Exhibit 52, this is not the case in Ethiopia.[lxvii,106] Farmers prefer the high quality of barley straw for thatching roof, beds, and baskets. But, as discussed in

[lxvii] In 2012/13, 65% of global barley production was used for animal feed (Kifle, S. W., "Review on Barley Production and Marketing in Ethiopia," 2016).

Box 1, the market for animal feed is growing and barley may help to meet this demand alongside other cereal crops in the future.

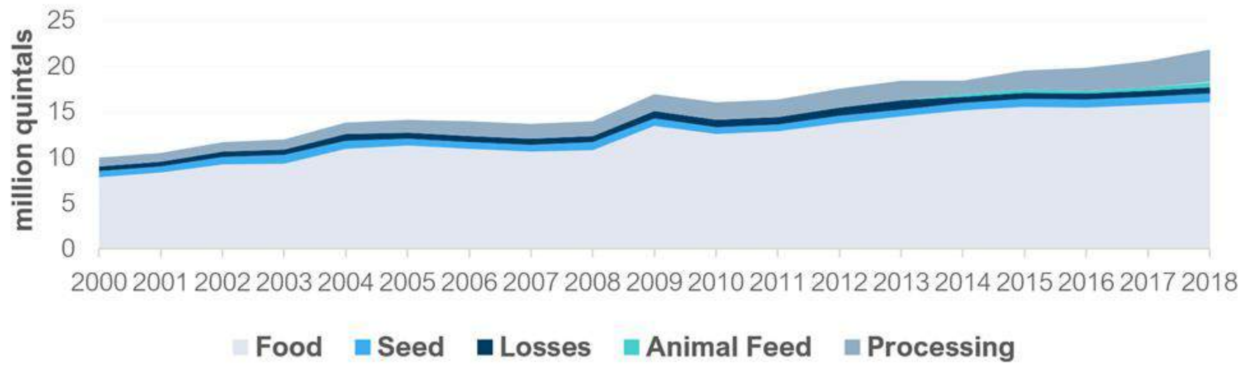


Exhibit 52: Consumption of Barley Domestic Supply by The Major Categories of Food, Seed, Losses, and Animal Feed in Million Quintals

Note: Barley consumption for seed has remained almost static over the years, but food consumption has steadily increased. Since 2014, a small portion of barley has been consumed for animal feed. (Source: FAOSTAT New Food Balances)

Ethiopians primarily consume barley for food (74% of domestic barley supply in 2018). All the barley consumed for food (shown in Exhibit 52) required processing in Ethiopia.[107] But 60% of barley food intake occurs in highland regions where it is grown.[108] Per capita consumption of barley is highest in rural communities as shown in Exhibit 53—annual per capita barley consumption was estimated at 15 kg in rural communities in 2011.[lxviii, 109] Yet, barley consumption is the lowest across major cereals.[lxix,110] Nonetheless, for rural households that consume barley, it is a staple crop and significant source of calories. Most barley consumers use barley flour to make traditional and baked flour-based goods.

[lxviii] During the same period, annual per capita barley consumption was significantly lower in towns (6 kg) and cities (3 kg).
[lxix] A 2011 study compared annual per capita consumption of major cereals in rural communities: 42.2 kg for maize, 31.2 kg for wheat, 20.1 kg for teff, and 14.3 kg for barley.

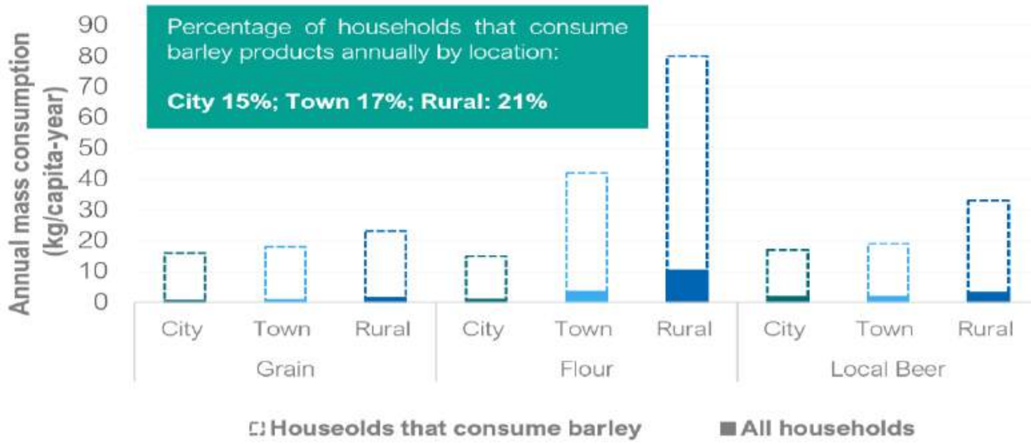


Exhibit 53: Barley Consumption by Location and Type of Barley Product

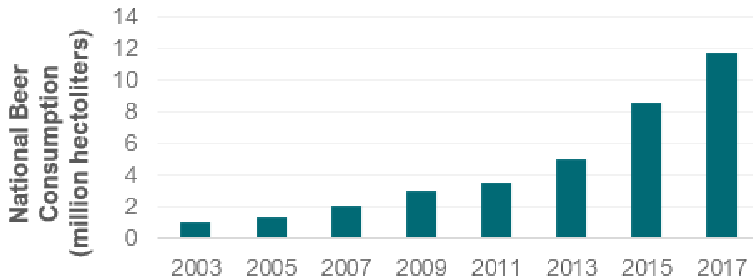
Note: Barley consumption in flour form (e.g., as injera or other baked goods) is most popular among all types of households. Rural consumers use greater volumes of barley across all product forms. Relatively low proportions of households consume barley on an annual basis. (Source: Rashid et al., 2015)

Box 2: Rising Malt barley Demand for Beer Production

Brewing plants in Ethiopia have high and growing demand for malt barley.

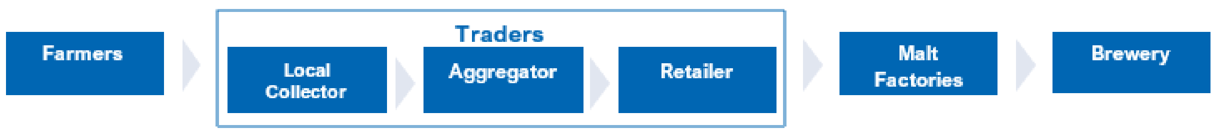
Twelve brewing plants in Ethiopia had a cumulative demand of 1.3 million quintals for malt barley in 2015. While significant portions of this malt barley demand is met by imports, brewing companies aim to eventually source their barley domestically: Heineken has a goal to source 60% of raw materials within Africa.

National demand for bottled beer—a malt barley product—is growing rapidly in Ethiopia.



Malt barley farmers attain higher revenues through more direct trading mechanisms with industrial factories and breweries.

Traditional barley supply chain involving multiple intermediate traders



Modern barley supply chain where breweries directly purchase crops from producer organizations

In the modern supply chain shown above, beer brewing companies pre-negotiate crop prices with lead farmers, farmer unions, and cooperatives to secure crop production from farmers. As farmers gain access to increased channels for selling their crops (through lead farmers, cooperatives, or traders), they gain increased power to negotiate trading prices and sell barley to the highest bidders. In a 2020 study, farmers observed up to 100 ETB per quintal increases in barley trading prices after entering into purchase agreements. Empowered farmers would have increased income, training, and potential capacity to invest in local barley processing.

Largescale brewing companies are supporting domestic malt barley farmers to improve crop production quality and quantity.

Brewing companies enter into purchase agreements with cooperatives, unions, and even lead farmers in communities to buy malt barley from farmers at a pre-negotiated price. Brewing companies also partake in public private partnerships to supply farmers with improved seed varieties, fertilizers, pesticides, and training for improving cultivation techniques.

Sources:

Tefera, D. A., Bijman, J. & Slingerland, M. A. Multinationals and Modernisation of Domestic Value Chains in Africa: Case Studies from Ethiopia. The Journal of Development Studies 56, 596–612, 2020.
Heineken Ethiopia. Best practice- barley in Ethiopia, 2017.

A.4.1.5 Local Trade

As of 2015, Ethiopian farmers only sold 12% of their barley production. [111] In 2020, farmers we surveyed in producer communities reported selling 70% of their barley harvest. These data points from different sources cannot indicate precise changes, but they can suggest trends. Our research (See Box 2) suggests that an increase in barley trade is reasonable as a response to the increasing demand from industrial malt barley processing discussed in Box 2. Nonetheless, the prevalence of processors in the communities surveyed indicates that enough barley remains in producer communities to sustain these processing businesses.

Pearled barley grain ready for trading.

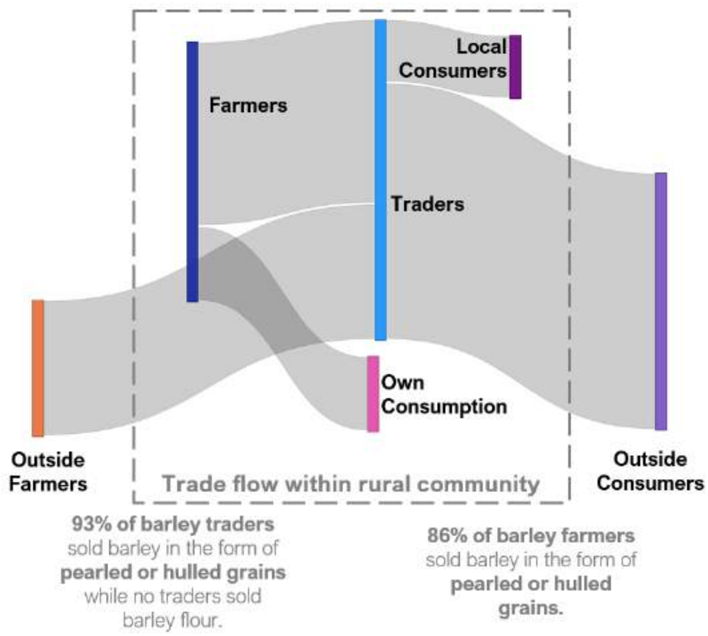


Exhibit 54: Barley Product Flow from Farmers to Consumers Based on RMI Survey Findings from Value Chain Actors in Barley-Producing Communities in Amhara, Oromia, and SNNPR

Note: We measure trade flow proportions by percentage of barley volume traded. (Source: RMI Survey, 2020).

A.4.2 Opportunities for Electrification

We analyzed several processing activities for barley to identify opportunities for short-term electrification including threshing, winnowing, hulling, drying, and milling. As described in the evaluation framework of Section 2.4.1, we used the metrics of local capacity, offtake market, equipment and electrification, and scalability to shortlist activities that demonstrated strong readiness for electrification today or in the short term with minimal support needed.

Barley milling shows potential for short-term electrification in niche areas but holds less potential to scale compared with other crops studied. We also explore barley hulling but find it is not immediately suitable for electrification with minigrids.

Other activities show less potential, and we do not consider them in depth. Traditional malting and brewing involve numerous steps that do not require mechanical energy. Electric equipment for these activities would be costly. This is because both malting and brewing involve heating across several steps (dough-making, roasting, soaking, and incubation). Heating is not a cost-effective use of electricity particularly to replace fossil fuel-powered cook stoves prevalent in rural communities.

Barley drying does not currently demonstrate strong potential for electrification in rural minigrid communities. Barley drying processors are rare in rural communities, so there is little evidence that processors have gained experience in managing barley drying businesses and maintaining mechanical drying equipment.

Although threshing is necessary, 94% of farmers we surveyed threshed their barley manually and most of these farmers did not pay for threshing. Therefore, there is little evidence that farmers are willing to pay for electric threshing. Similarly, almost all barley storage in rural communities does not require energy. These activities show little potential for electrification in rural communities and we do not explore them further.

A.4.2.1 Barley Milling

Barley milling is a niche opportunity that shows potential for short-term electrification in producer communities but not at scale across Ethiopia.

The prevalence of barley milling in producer communities shows that processors have the capacity to manage processing businesses and maintain mechanized equipment. Demand for local barley milling only exists in producer communities signaling low scalability. Furthermore, even in producer communities barley volumes are erratic. Therefore, most millers (68% of survey respondents) process barley alongside other cereals to reduce supply risk, and would-be millers are unlikely to invest in a mill to solely mill barley.[lxx]

Habib Demicha with his diesel-powered grain mill. He processes barley, horse beans, and yellow peas. Mr. Demicha mills crops into flour for 20 ETB per quintal and operates his business year-round. He typically serves 10 customers per day and earns 600 ETB in weekly revenues. Mr. Demicha has trouble accessing the necessary financing to expand his business and cannot purchase electric equipment as he does not have electricity access.

[lxx] Of grain milling processors surveyed, 64% mill wheat, 57% mill teff, and 82% mill maize.

Criteria	Support Status	Description
Local Capacity	Minimal	We found **four barley milling processors per community** in the median rural community we surveyed.* The average grain milling business in rural communities has been running for **eight years,** and **68%** of grain milling processors mill barley. Processors have extensive experience due to mill businesses being prevalent in rural communities and operating for a long time. *Findings based on 2020 RMI survey findings of barley processing in rural communities in Amhara, Oromia and SNNPR regions within Ethiopia.
Offtake Market	Minimal	The average milling service fee in rural communities is **94 ETB per quintal**. On average, barley milling businesses serve **36 customers daily**. According to **68%** of surveyed barley flour milling processors, demand for milling persists throughout the year—independent of seasons.
Equipment and Electrification	Deployment Ready	Electric mills are available locally—manufacturers produce these mills domestically and have the expertise to offer after-sales servicing.* **One hundred percent** of surveyed milling processors own a mechanical fossil-fuel powered or electric mill. * Kalmeks Manufacturing produces a tri-phase electric grain mill with 10 quintal per hour throughput for 140,000 ETB.
Scalability	Significant	Barley consumption is concentrated in the Ethiopian highlands where barley is cultivated. Consumers prefer to purchase whole barley grains and mill small portions of barley before consumption, but there is limited scaling potential for barley milling across Ethiopia.

Support Required: ○ Significant ◑ Moderate ◕ Minimal ● Deployment Ready

A.4.2.2 Barley Hulling

Barley hulling is not immediately suitable for electrification with minigrids. We found no processors focused on barley hulling in the rural communities surveyed. There is no willingness to pay for barley hulling as most farmers and consumers hull their grains manually at home. Electric barley hulling equipment is available in Ethiopia but uncommon.

Barley hulling is necessary for consumption, but the stage at which barley hulling occurs—and the corresponding hulling method—varies by barley product. Consumers hull barley grains immediately after threshing for products like *kinche* or *shorba*, while they roast and mill whole barley grains before sieving hulls for products like *genfo* or *beso.* Some farmers hull barley grains before trading. In fermentation activities like malting, barley hulls are left intact to maintain optimal conditions for seed germination but are easily removed after soaking. The variety of methods directly impacts the demand for mechanical barley hulling. Since steps before and after hulling occur in the household, consumers are less incentivized to go to a barley processor for hulling.[112]

Criteria	Support Status	Description
Local Capacity	○	We found **no barley hulling processors** in the rural communities we surveyed.* The lack of hulling businesses indicates that processors do not have extensive experience with operating hulling businesses. * Findings based on 2020 RMI survey findings of barley processing in rural communities in Amhara, Oromia and SNNPR regions within Ethiopia.
Offtake Market	◑	Barley must be hulled to pearl or mill grains due to the fibrous indigestible nature of the hull. This suggests there is demand for mechanical barley hulling in rural communities. Yet, farmers and consumers primarily hull their barley grains manually at the farm or at home, so there is little evidence of their willingness to pay for mechanical de-hulling.
Equipment and Electrification	◑	Electric hulling equipment is available domestically in Ethiopia.* But hulling is traditionally carried out manually, especially because the hull is removed at different stages—either by farmers or by consumers. * Amio Manufacturing imports a tri-phase electric huller from China with a 15 quintal per hour throughput for 180,000 ETB
Scalability	○	Barley consumption is concentrated in the Ethiopian highlands where barley is cultivated. Given the uncertain demand even in high production and consumption areas for mechanized hulling, there is limited scaling potential for barley hulling across Ethiopia.

Support Required: ○ Significant ◑ Moderate ◕ Minimal ● Deployment Ready

Further support is necessary before barley hulling can be suitable for electrification. The business case for mechanized barley hulling must first be demonstrated in rural communities. Only if consumers demonstrate a willingness to pay for hulling barley, will it make sense to explore further the viability of electrifying this step.

Abeyot Ayenew Asres with his diesel-powered mechanical thresher. Mr. Asres uses his equipment to pearl barley grains for 30 ETB per quintal. During busy periods (November to April), he serves an average of three customers and processes a total of 3 quintals per day. Mr. Asres would like to expand his business but faces challenges in accessing finance and has limited land resources for new worksites.

A.5 Teff

- **Teff is a staple food in Ethiopia produced at high volumes nationally.**
- **Significant local consumption of teff indicates strong potential for electrifying processing in production zones of Amhara and Oromia.** From 2019 to 2020, 87% of teff was produced in Amhara and Oromia. Most teff farmers retain portions of teff crops for subsistence and so significant volumes of teff are consumed in the communities where it is produced. The high demand for local processing within communities of Amhara and Oromia suggest that these regions have strong potential for electrifying processing activities.
- **Teff milling is suitable for electrification but the future of this opportunity is less clear (Tier 2).** Teff milling is a necessary processing step for making teff flour, and processors already operate mechanized milling equipment across Ethiopia. But demand for teff in rural communities is falling due to high prices. However, milling teff alongside other grains will continue to be viable. Existing fossil fuel-powered milling equipment can be retrofitted with an electric motor. Eighty-four percent of rural kebeles from our survey already have at least one mechanized mill processor operating locally.

A.5.1 Background

Teff is a species of lovegrass native to the Horn of Africa and known for its small grain kernels.[113] Ethiopia is the primary teff producer around the world—in 2019 Ethiopia produced 57.4 million metric quintals of teff and as of 2016, Ethiopia produced 90% of the world's teff.[lxxi, 114] International teff demand continues to grow among the Ethiopian diaspora—which was estimated at 2 million in 2016—and consumers worldwide seek teff's nutritious and gluten-free properties.[115]

Teff is central to Ethiopia's national identity because Ethiopians use teff to make *injera*—a staple that is widely consumed with traditional Ethiopian dishes.[lxxii] Yet, the demand for teff—and lagging improvements in productivity discussed below—make it relatively expensive in Ethiopia. In 2011, teff made up 30% of average daily caloric intake in urban communities, but only 8% in rural communities. Teff is considered a luxury grain, and rural consumers generally opt to sell the teff produced so they can purchase cheaper grains like maize, sorghum, wheat, or barley.[116]

Smeneh Gashe standing in his field of teff crop in the Guangua woreda of the Awi Zone, Amhara. Mr. Gashe plants teff once per year on 1 hectare of land. He produces 35 quintals of teff every harvest and retains 10 quintals for household use. Mr. Gashe manually threshes his teff for free with friends and family before trading.

[lxxi] Teff is now grown marginally in the Netherlands, Spain, Australia, and within the United States—in Idaho, California, Texas, and Nevada. (O'Connor, A., "Is Teff the New Super Grain?" *Well,* 2016 https://well.blogs.nytimes.com/2016/08/16/is-teff-the-new-super-grain/; and Fortune, A., The Globalisation of Teff: Implications for Ethiopia, https://addisfortune.news/the-globalisation-of-teff-implications-for-ethiopia/.)

[lxxii] Injera is a thin and spongy fermented bread made from raw flour, water, and previously fermented dough.

Researchers in 2011 found that smallholder farms produced 99.8% of teff, while large-scale farms produced the remaining 0.2%. As of 2011, most (80%) smallholder farmers cultivated less than 1.5 hectares per farm.[lxxiii,117]

A.5.1.1 Production

High and rising teff production volumes in Ethiopia suggest strong and reliable supply for post-harvest teff processing.

Stable and high production volumes indicate sufficient volumes to sustain viable processing businesses. Improvements in teff productivity and expansion in cultivated area have led to consistent increases in production and stable annual supplies. These improvements shown in **Exhibit 55** indicate that processors can have confidence in the stability and availability of annual teff supply.

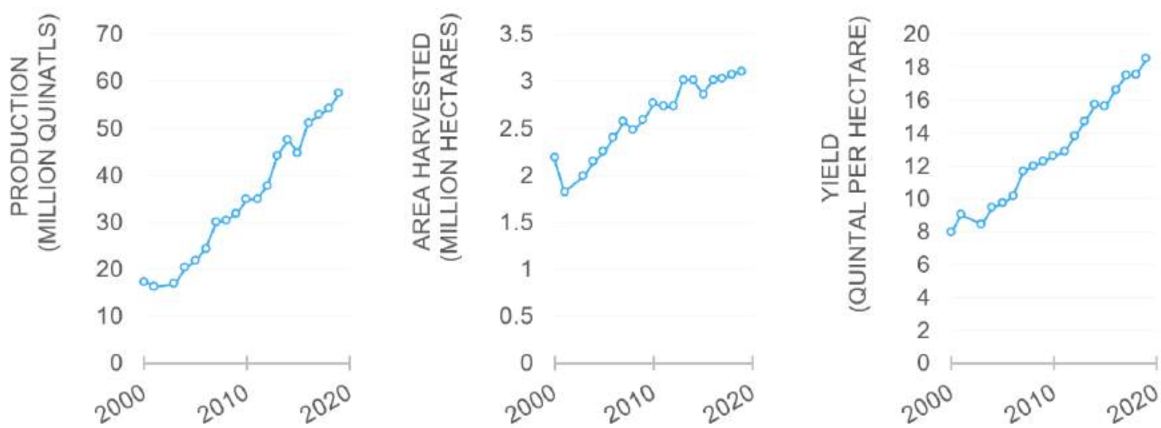


Exhibit 55: Trends of Production, Area Harvested, and Yield for Teff between 2000 and 2019

Note: Compared with other cereals, the largest area of land is dedicated to teff cultivation. Yet, teff yields are consistently the lowest among the major cereals. Teff yields also show the least growth with a compound annual growth of 4.3%.[lxxiv,] (Source: Ethiopian Central Statistical Agency Agricultural Sample Survey 2000-2019)

Teff is the second most widely cultivated crop in Ethiopia behind maize—7.2 million farmers cultivated teff in 2019.[lxxv] As shown in **Exhibit 55**, teff production in Ethiopia increased by 230% between 2000 and 2019. During this period, area dedicated to teff production increased by 42% and teff productivity increased by 132%.[118] These productivity improvements were due to an increased adoption by farmers of modern inputs such as pesticides and fertilizers. In 2014, 39.5% of teff farmers—the second highest adoption rate among cereal farmers in Ethiopia behind wheat—applied pesticides to

---

[lxxiii] In Ethiopia, smallholder farmers are split evenly among these farm sizes (20% each): 0–0.25 hectares, 0.25–0.52 hectares, 0.52–0.90 hectares, 0.90–1.52 hectares, and 1.52–25.20 hectares.

[lxxiv] Compound annual growth rates of grain yields between 2000 and 2019 were 4.9% for maize, 5.2% for barley, and 4.8% for wheat.

[lxxv] Maize, the most highly cultivated crop among farmers in Ethiopia, was cultivated by 11.5 million farmers in 2019.

crops, compared with 11.5% of teff farmers in 2011.[lxxvi,119] Teff was also the second most widely fertilized cereal crop in Ethiopia behind wheat in 2014—farmers fertilized 68.7% of land dedicated to teff cultivation that year.[lxxvii,120]

Yet, teff yields are consistently the lowest among maize, wheat, and barley. Although a relatively high proportion of teff farmers use improved seeds (35% of teff farmers in 2017 compared with 6% of wheat farmers in 2014), teff farmers are not able to maximize yields because of specific farming practices.[121] Researchers find that teff farmers excessively till their land as they prepare soil: farmers in 2013 were tilling teff fields more than four times per harvest despite government agency recommendations to reduce tilling.[lxxviii,122] Excessive tillage decreases teff yields by preventing crop root elongation and accelerating the decomposition of soil nutrients.[123] Production, area harvested, and yields have also slightly stagnated since 2016.[lxxix,124] Farmers can improve teff farming practices and further increase crop supply for processing.

A.5.1.2 Processing

Teff milling shows significant potential for electrification among teff processing activities.

As discussed in **Section A.3.1.2** for the wheat value chain, the existing state of processing activities in rural communities helps indicate whether an activity is suitable for short-term electrification with minigrids. We find that teff milling is the only critical teff processing activity that is already widely mechanized in rural communities. Since processors already have the capacity to manage milling businesses and have experience paying for fuel and upkeep of fossil fuel-powered equipment, they require less support to transition to electric equipment. Furthermore, teff milling is the only processing activity that consistently takes place year-round, which is favorable for minigrids. Teff milling therefore demonstrates strong potential for short-term electrification by minigrids.

Teff flour in a canvas after milling. In this form, teff is ready for consumption.

Teff flour is the main ingredient in injera, the primary product that Ethiopians make with teff.[125] Consumers also use low-quality teff grain to make local alcoholic beverages like *tela* and *araqe*.[lxxx,126] **Exhibit 57** shows the processing steps involved in producing teff flour. Drying, threshing, winnowing,

---

lxxvi In 2014, 47.2% farmers applied pesticides for wheat, 23% for barley, 9.2% for sorghum, and 5.7% for maize.
lxxvii The average fertilizer application rate among the cereals in 2014 was 53.1%. Farmers fertilized 73% of the land cultivated for growing wheat, 50.8% for maize, 42.8% for barley, and 14.7% for sorghum.
lxxviii Tillage is the process of mixing and displacing soil to integrate organic soil components and break apart soil for easier seed germination. This is important for circulating soil components and loosening hardened soil to support germination of tiny teff seeds.
lxxix The compound annual growth rate for yield between 2000 and 2019 is 4.3%, compared with 2.7% between 2016 and 2019; compound growth for area harvested between 2000 and 2019 is 1.8%, compared with 0.7% between 2016 and 2019; compound growth for production between 2000 and 2019 is 6.2%, compared with 2.9% between 2016 and 2019.
lxxx *Araqe*—a high alcohol content (22%–50%) distilled beverage made by fermenting (and then distilling) a mixture of gesho plant leaves, water, and bread made of germinated barley, wheat, or teff; *tela—a local beer made by fermenting the same ingredients as araqe.*

and milling are all necessary activities but among them, only milling processors predominantly use mechanical equipment for processing crops in rural communities. Teff flour milling takes place wherever consumers are located because final consumers take their grain to a processor for milling before consumption. Processors we surveyed mill teff as a service for a fee of 0.94 ETB per kilogram of teff grain milled.

The timing of teff processing in the year informs whether specific activities are well suited for electrification with minigrids. Seasonal processing activities are less optimal for electrification with minigrids because they create fluctuations in energy demand between active and inactive months. Minigrid developers require consistent energy demand throughout the year to recover their investment—fluctuations in energy demand from seasonal activities lead to underutilization of capacity for a portion of the year.

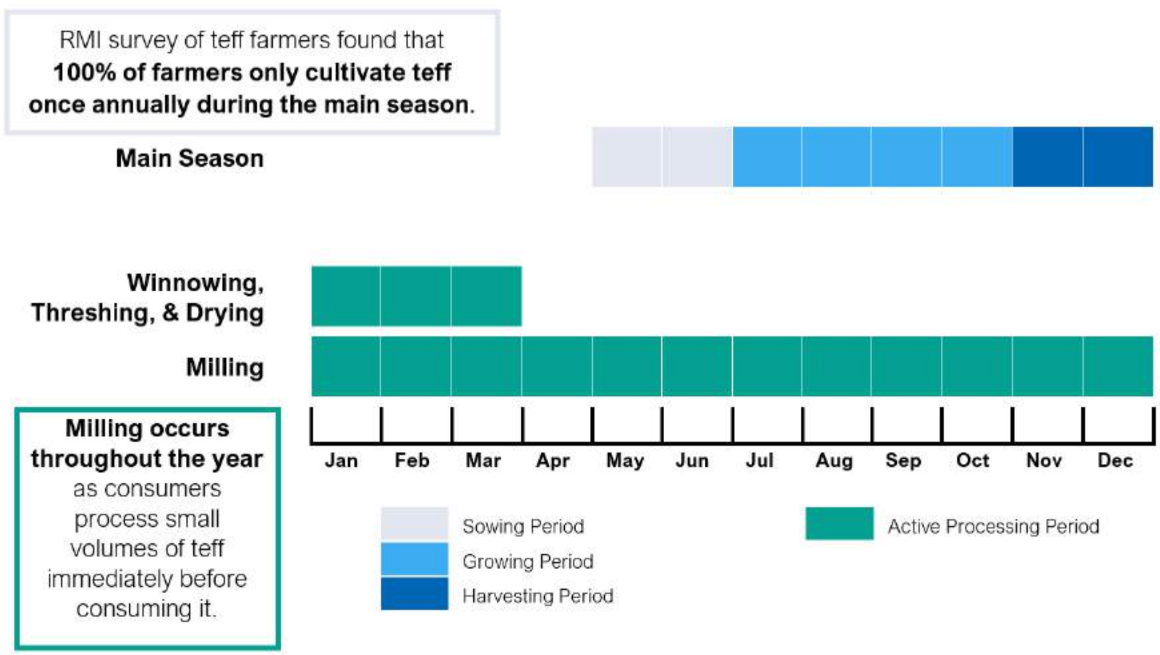


Exhibit 56 : Annual Teff Planting and Processing Calendar[lxxxi]

Note: Experts consider June through the end of September to be lean grain supply months because in most areas, there are limited harvests during this period for any major cereals. (Source: FAO GIEWS, 2020)

Exhibit 56 shows that teff milling takes place year-round: throughout the year, consumers store whole grains and carry small volumes of teff grain to processors for milling before consumption. Post-harvest teff processing that occurs on the farm (drying, threshing, winnowing) take place immediately following harvest times and only occurs from January through March with some variation—in lowland areas, threshing starts as early as November.

[lxxxi] The Meher planting season is split into two weather seasons: Bega (October to January) and Kiremt (June to September). Bega typically corresponds to dry and cold weather across the country. Kiremt is the main rainy season across the country, except for the South and Southeast areas (Fikadu, A. A., Wedu, T. & Derseh, E., *Review on Economics of Teff in Ethiopia*, 2019, http://doi:10.31031/OABB.2018.02.000539).

Teff flour production

	Description	Mechanization
Teff crops 	Teff is left to dry to a 20%–30% moisture content before harvesting. Teff is harvested when the entire crop is golden, and teff kernels are hardened.	Farmers typically harvest teff manually using a sharp scythe or sickle blade.
Dry (→ Dried crop)	Farmers further dry teff until the moisture content drops to 12%–12.5%.	Grain dryers are relatively common in teff processing although most crop is air dried. In communities we surveyed, 62% of farmers who cultivate teff manually air dry their crops.
Thresh (→ Seed heads; Feed production; Whole grains)	Farmers thresh dry teff grains on the farm to release grains from the stalk and seed heads. This is achieved by beating or shaking teff stalks.	Farmers typically thresh teff manually or using animal-power. Our survey findings indicate that 96% of teff farmers threshed crop manually, and 4% threshed crop mechanically.
Winnow (→ Chaff; Clean grains 32 ETB/kg)	Farmers separate grains from straw-like chaff at the farm by throwing grains into the air so that the chaff blows away while the grains settle.	Teff winnowing in rural communities takes place manually with a wide thatch plate or basket. Combine machines—though rare—can winnow as well as thresh and hull grains.
De-Hull (→ Hulls)	Some consumers scrape the hull layer off the teff grains in their homes before consumption to leave the inner bran and germ layers on the grain.	Teff hulling is rare in rural communities as teff hulls are soft and edible. Some hulls are shed during threshing or manually removed in households, but most consumers eat the hull layer.
Mill (→ Teff flour 43 ETB/kg) 	Processors mill clean, dry grains into a meal or fine flour. From our survey findings, the median grain-milling service price was 1 ETB/kg.	All milling processors in surveyed communities used mechanical plate or hammer mills, with 96% using fossil-powered mills and the remaining 4% using electric mills.

Mass Flows: Primary Activity; Secondary Activity; Waste Stream

Process Steps: Required; Optional

Exhibit 57: The Teff Processing Flow from Harvested Teff to Teff Flour

Note: In rural communities, most marketed teff is sold in the form of dried grain to final consumers. Consumers will typically take their crop to processors for milling.[55] (Source: FAO, 2018)

Initiatives to electrify smallholder teff processing will have the highest potential in Amhara and Oromia.

High production volumes in Amhara and Oromia indicate that these regions are hubs for on-farm processing activities that occur immediately after harvesting. In 2019, 87% of teff production came from Oromia and Amhara.[lxxxii,127] Teff is known for adapting to numerous conditions including varied humidity and rainfall levels, a range of altitudes, and different temperature and soil atmospheres.[128] This explains why teff is widely cultivated in so many areas across Ethiopia as seen in **Exhibit 58**. Nonetheless, teff yields are highest when cultivated at altitudes between 1,800 and 2,200 meters above sea level with adequate rainfall. This is why Oromia and Amhara are predominant teff producers.[129]

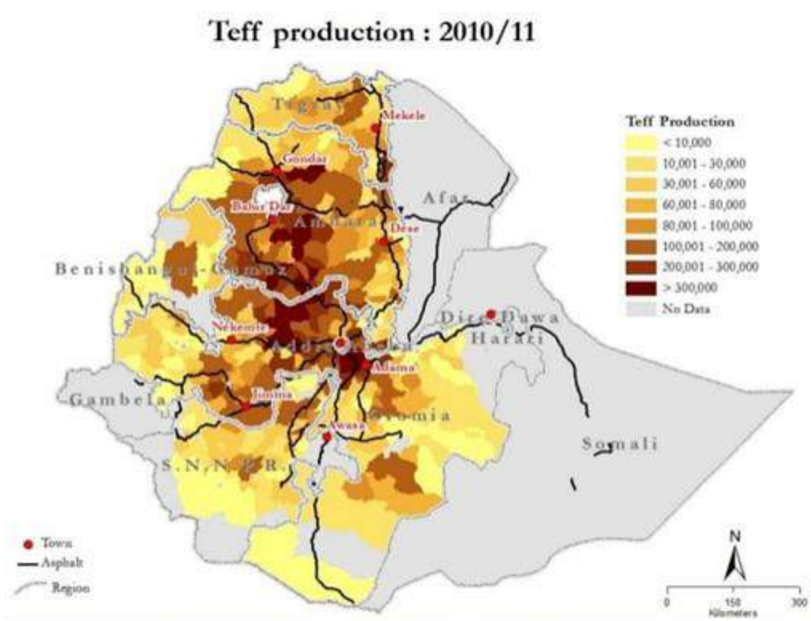


Exhibit 58: Spatial Production of Teff across Ethiopia

Note: Teff grows across four regions in Ethiopia, with 49% of teff growing in Oromia alone. (Source: IFPRI, 2013)

A.5.1.3 Losses

On-farm teff losses restrict the business potential for teff processing activities along the value chain.

Losses affect processing volumes across the value chain as spoilt crops are discarded before getting processed. Experts estimate that on-farm post-harvest losses average 13% but losses can significantly exceed this level.[130] A 2015 study found that farmer losses (in harvesting, drying, storage,

[lxxxii] In 2019, 49% of Ethiopia's teff production came from Oromia (28.1 million quintals), 38% from Amhara (21.9 million quintals), 5% from Tigray (3.1 million quintals), 7% from SNNPR (3.8 million quintals), and less than 1% from Benishangul-Gumuz (0.4 million quintals).

and transportation) in the Workima kebele of Amhara were 25%. Threshing accounted for the highest proportion of losses (8%), followed by teff stacking during drying (6.3%).[lxxxiii, 131]

Reported losses during storage are relatively low (3%) because teff grains are resistant to storage pests like weevils, and can remain edible for years.[132] Most farmers store teff grains in bags inside the home and improved storage techniques across cereal crops would have limited impact on teff grain losses. Mechanized threshing would reduce crop losses, but our survey findings indicate that 94% of farmers thresh teff manually. We discuss the opportunity for electrifying teff threshing and drying below.

A.5.1.4 Demand

Fluctuating demand for teff in rural communities suggests limited potential for electrifying teff milling.

The demand for teff flour in rural communities is a strong indicator of the potential for electrifying smallholder processing activities in these communities. Ethiopia's teff demand is high and rising, but not in rural communities. As teff prices rise, rural consumption falls. Rural consumers that use teff predominantly use teff flour. Demand for processing in rural communities exists but is sensitive to teff prices and the success of processing businesses depends on a stable local demand for flour.

Cleaned teff grains stored inside the household in sacks.

Most teff produced in Ethiopia is consumed domestically. Official teff exports have been limited and peaked at 1.5% of national production in 2005.[133] During 2006–2015, the Government of Ethiopia banned all teff exports to support the domestic teff market and increase the availability and affordability of teff in Ethiopia.[134] Since 2015, the Government has allowed limited exports of processed teff products from authorized dealers who must source their teff from authorized farmers.[135] Yet, some researchers cite that there is significant teff smuggling from Ethiopia to neighboring countries.[136] This indicates high international demand for teff that further increases local teff prices.

[lxxxiii] Farmers also reported losses of 5.6% from harvesting, 2.2% from farmer transportation, and 3.2% from farm storage.

Metoaleqa Tlahun Tesfaye shows teff grains that are ready for trading. Mr. Tesfaye threshes his 15 quintals of teff for free through friends and family every harvest. He often faces problems of broken teff grains that lower the sale price of his crops.

Teff is a cash crop that rural farmers cultivate and sell instead of consuming themselves. We found that teff grain prices were significantly higher than that of any other major cereal flour at 32 ETB per kg—twice the price of wheat grains at 16 ETB per kg.[lxxxiv] As a result, rural consumption per capita of teff flour is a third of urban per capita consumption—in 2011, per capita demand was 20 kg in rural communities compared with 61 kg in urban communities. As teff prices continue to rise, researchers estimate that rural consumption will continue to fall.[137] Demand for milling in rural communities is sensitive to the price dynamics of teff and may continue to fall going forward. Nonetheless, demand for on-farm processing activities (drying, threshing, and winnowing) is high and will continue to rise with increasing teff production.

A.5.1.5 Local Trade

Teff milling has potential for electrification in rural areas, for now.

Local trade patterns show that some teff processing must take place in rural communities although increasing prices may continue to decrease the size of this market. Our survey findings show that on average, farmers surveyed retain 37% of their teff harvests for household use (**Exhibit 59).** We also found that that traders sell on average 40% of teff crops within the same community. This portion of crops that remains in these communities is milled locally.

[lxxxiv] 2020 RMI survey results found the following median grain prices: 11 ETB per kg for maize, 16 ETB per kg for wheat, 13 ETB per kg for barley, and 32 ETB per kg for teff.

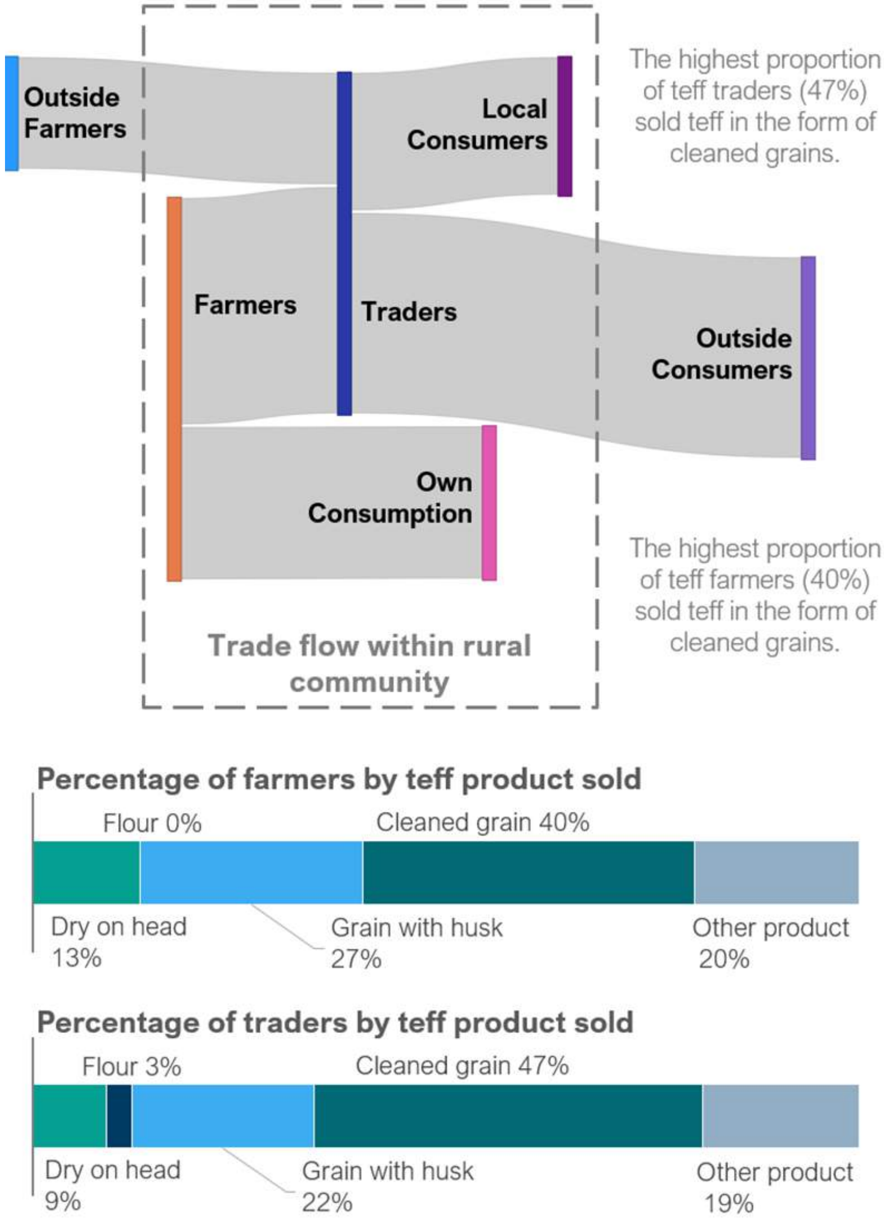


Exhibit 59: Teff Product Flow from Farmers to Consumers based on RMI Survey Findings from Value Chain Actors in Teff-Producing Communities in Amhara, Oromia, and SNNPR

Note: We measure trade flow proportions by percentage of teff volume traded. (Source: RMI Survey, 2020).

A.5.2 Opportunities for Electrification

We analyzed several processing activities for teff to identify opportunities for short-term electrification including threshing, winnowing, hulling, drying, milling, and injera-making. As described in the evaluation framework of **Section 2.4.1**, we used the metrics of local capacity, offtake market, equipment and electrification, and scalability to shortlist activities that demonstrated strong readiness for electrification today or in the short term with minimal support needed.

Across the teff value chain, teff milling showed potential for short-term electrification but it was unclear how long this opportunity will last. As teff prices continue to rise, the demand for teff flour in rural communities will fall. Therefore, the demand for milling services in rural communities is also at risk. Teff milling and threshing are critical processing steps. These activities are discussed further below.

Other activities in the value chain hold less potential and are not considered further. For example, despite the growing popularity of injera-making businesses in urban markets, they are not yet viable in rural communities. Researchers estimate that the market size of ready-made injera in 2015 was 9.8 billion ETB.[138] But, rural consumers do not typically pay for ready-made injera. Public attitudes in rural communities do not yet support injera-making as an income-generating activity: consumers in rural communities make injera at the home for household consumption and customarily gift each other with injera. In addition, in rural communities injera is almost exclusively made using mitads over a fossil fuel cookstove or wood fire. [62] Electric mitads will require further testing to ensure compatibility with minigrids.

Other activities are also not immediately suitable for being electrified with minigrids in Ethiopia's rural communities. Almost all teff storing techniques do not require energy. Since teff losses from storage are small and existing storage techniques are generally effective, the potential impact and viability of modified teff storage is also limited. Most teff is air dried by farmers in the field, and we found no drying processors that dry teff. Lastly, rural consumers rarely hull teff before consumption because teff hull layers are soft and edible.

A.5.2.1 Teff Milling

Teff milling shows the most potential for short-term electrification in rural minigrid communities, but its future is limited.

Kass Teshome with his diesel-powered grain mill. He processes teff, wheat, maize, and sorghum from grains into flour for 200 ETB per quintal. Mr. Teshome typically earns 2,300 ETB in weekly revenues and serves 15 customers per day. His milling business operates year-round.

Teff milling demonstrates strong potential for electrification right now. The prevalence of teff milling processors in communities shows that processors have the capacity to effectively manage processing businesses and maintain mechanized equipment. Demand for teff milling is robust right now because most consumers in rural communities pay processors to mill their teff mechanically. But teff prices have continued to rise as the increasing national demand for teff is met with limited improvements in crop production.

If rural consumers cannot afford to buy teff, they will have limited demand for teff milling. This future demand risk in rural communities is most significant for teff among major cereals because teff grains are already twice the price of other grains.[lxxxiv] Electric teff mills are available in Ethiopia and grain milling demand persists year-round and already takes place throughout the country. This suggests strong scaling potential if processors can mill other grains alongside teff.

Criteria	Support Status	Description
Local Capacity	Deployment Ready	We found **three teff milling processors per community** in the median rural community we surveyed.* The average grain milling business in rural communities has been running for **eight years,** and **57%** of grain milling processors mill teff. Processors have extensive experience due to mill businesses being prevalent in rural communities and operating for a long time. * Findings based on 2020 RMI survey findings of teff processing in rural communities in Amhara, Oromia and SNNPR regions within Ethiopia.
Offtake Market	Moderate	The average milling service fee in rural communities is **94 ETB per quintal**. On average, teff milling businesses serve **33 customers daily**. According to **94%** of surveyed teff flour milling processors, demand for milling persists throughout the year—independent of seasons.
Equipment and Electrification	Minimal	Electric mills are available locally—manufacturers produce these mills domestically and have the expertise to offer after-sales servicing.* **One hundred percent** of surveyed milling processors own a mechanical fossil fuel-powered or electric mill. * Kalmeks Manufacturing produces a tri-phase electric grain mill with 10 quintal per hour throughput for 140,000 ETB.
Scalability	Deployment Ready	Teff is a staple consumed across Ethiopia—not only in high production regions. Since consumers prefer to purchase whole teff grains and mill small portions of teff before consumption, there is significant scaling potential for teff milling across Ethiopia.

Support Required: Significant Moderate Minimal Deployment Ready

A.5.2.2 Teff Threshing

Teff threshing is not currently suitable for electrification in rural minigrid communities.

Teff threshers are rare in rural communities, so there is little evidence that processors have gained experience in managing teff threshing businesses and maintaining mechanical threshing machines. Although many farmers thresh their harvests, 89% of surveyed teff farmers do not pay for threshing, so there is no proven willingness to pay for mechanical threshing services. Farmers also thresh teff manually, so the process is not yet widely mechanized. Teff threshing only takes place in high teff-producing rural communities, and farmers only require teff processing for three months of the year.

Kebede Tadese using his mechanical thresher, with which he only processes teff. Mr. Tadese threshes his own teff crops and then sells threshed teff grains for 3,200 ETB per quintal. During busy periods (January to March), he sells his grains to an average of 25 customers every day and earns a total of 4,000 ETB each week.

The same threshing equipment discussed for wheat threshing in Section A.3.2.2 is used for teff threshing. Most teff is threshed by farmers in the field, so threshing machines would need to access farm fields to cater to these practices. Electric threshing equipment must be mobile as it is not economically feasible for a minigrid developer to run distribution lines to connect stationary threshers in distant farming fields. Electric threshing equipment that is mobile and rechargeable is not readily available in Ethiopia.

Criteria	Support Status	Description
Local Capacity	◔	In our survey we only observed threshing processors in **26%** of kebeles, and we only observed one thresher on average within these communities. These threshing businesses have been running for **four years on average,** but only **8% of the threshers surveyed processed teff**. The limited presence of threshers who process teff suggests that capacity is limited in rural communities for teff threshing.
Offtake Market	◑	Teff must be threshed before consumption, so there is a demand for threshing in rural communities. However, our survey findings show that **most teff farmers (89%) do not pay for threshing, so the market that could be served by specialized threshing businesses is limited.** **Only 4% of teff farmers thresh crop mechanically**, and average mechanical grain threshing costs are 250 ETB/quintal. This is higher than what teff farmers pay in labor for manual threshing of 179 ETB/quintal. So, teff farmers that do pay for threshing prefer to hire laborers for manual threshing (7% of farmers pay laborers for threshing). Our survey found that 50% of teff farmers already complain of high threshing costs. Given the lower costs and prevalence of manual labor, the market for mechanical and electric threshing is limited.
Equipment and Electrification	◔	Stationary grid-connected electric threshing equipment exists in Ethiopia, but rechargeable mobile equipment is needed to properly serve farmers, who thresh teff in the field.* Furthermore, threshing only takes place for three months of the year (January through March), leading to extended periods in the year in which threshing equipment remains unused. * Amio Manufacturing produces a tri-phase electric grain thresher with 40 quintal per hour throughput for 72,000 ETB.
Scalability	◑	Teff threshing is likely to be most prevalent in teff cultivation hubs (Amhara, Oromia) because farmers thresh crops on the field. Since all teff must be threshed, there is considerable scaling potential for this activity.

Support Required: ◔ Significant ◑ Moderate ◕ Minimal ● Deployment Ready

A.6 Dairy

- **Dairy products are not staple foods in Ethiopian diets and production volumes vary significantly across communities.**
- **Limited local consumption of dairy products limits the potential for dairy processing in rural communities. Niche areas in high production communities—especially those near urban markets—have potential for electrified dairy processing.** From 2019 to 2020, 90% of milk was produced in Somali, SNNPR, Amhara, and Oromia. Dairy producers sell most of the fresh milk they collect to traders and so limited volumes of products are consumed and processed in rural communities. Most dairy processing takes place in urban markets, so there is currently limited potential for electrifying dairy processing in rural markets. Niche opportunities for dairy processing exist for high dairy-producing peri-urban communities near urban markets.
- **Milk chilling is not suitable for electrification (Tier 1).** Milk chilling is not a necessary processing step in rural communities because rural producers sell fresh milk and process remaining milk into shelf-stable products within hours of collection. The rural demand for fresh milk is also low, so consumers are not willing to pay for refrigerated milk. Only 4% of rural kebeles from our survey sample across Amhara, Oromia, and SNNPR have mechanized milk chilling.

A.6.1 Background

In 2019, Ethiopia was the fourth largest milk producer (3.54 billion liters) in the African continent behind Kenya (5.37 billion liters), Egypt (4.51 billion liters), and Sudan (4.49 billion liters).[139] That year, Ethiopia's livestock population was the eighth largest in the continent at 12.7 million animals and mostly consisted of cows (68%).[lxxxv,140] Almost all milk production in Ethiopia comes from cows

Seid Yifredegn with his cows in the Dessie Zuriya woreda of the Debub Wello Zone, Oromia. Mr. Yifredegn milks one of his cows to produce milk throughout the year. He produces 900 liters of milk each year, sells half of this as fresh milk, and retains the other half for household use. Mr. Yifredegn would like to expand his business but lacks finance and is interested in learning more about business management first.

[lxxxv] Ethiopia's 2019 livestock herd consisted of 68% cows, 21% sheep, 10% goats, and 2% camels.

(91% in 2019).[lxxxvi,141] The scale of dairy production is small—the median dairy producer in milk production zones owns two cows.[142]

A.6.1.1 Production

Limited milk production volumes in rural communities suggest an unreliable supply for post-harvest dairy processing.

Volatile milk production volumes may signal instability for would-be milk processors. Milk production trends fluctuated between 2000 and 2019 (as shown in Exhibit 60).[143] During this period, milk production increased by 244% and the animal population dedicated to milk production (dairy animal population) increased by 115%, but the yield per animal only increased by 60%. More importantly, milk production is volatile, and would-be processors therefore face higher risks of insufficient milk supply.

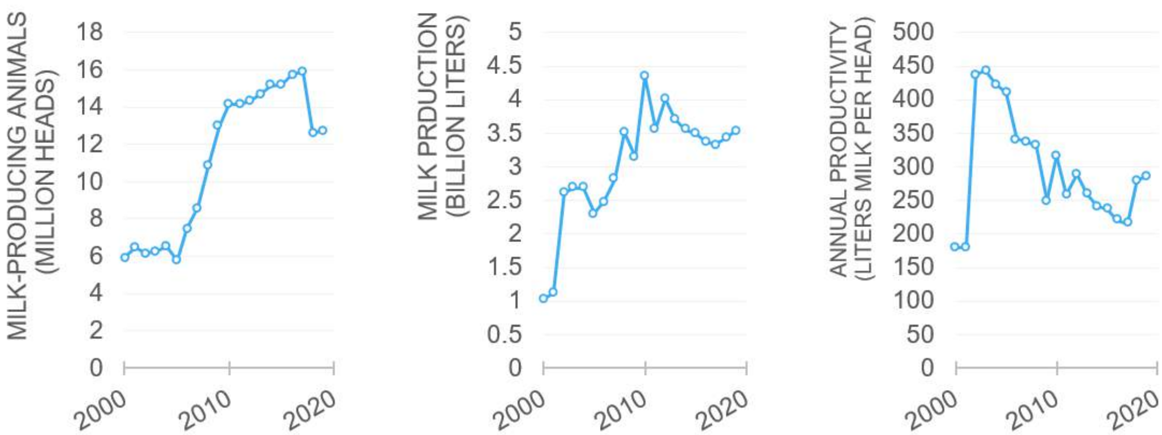


Exhibit 60: Trends of Producing Animals, Production, and Annual Animal Productivity for Milk between 2000 and 2019 (Source: FAOSTAT Livestock Primary)

Between 2000 and 2010 alone, milk production increased by 322% (increasing consistently for the first time since 1993) in direct response to increases in the dairy animal population. However, most of this growth occurred in commercial production in urban areas. During this period, the expansion in the commercial dairy market enabled urban and peri-urban dairy producers to access modern inputs and trade channels. As commercial dairy processing companies began to establish operations in Ethiopia, demand for high quality fresh milk to serve urban markets boosted sale prices.[lxxxvii,] Dairy producer associations directed resources to serve this urban market, developing animal feed markets and cross breeding cows to improve milking yields. After government authorities relinquished control of the dairy market and transitioned to an advisory role, newly empowered cooperatives and dairy companies extended milk collection services that allowed dairy producers to access formal trade

---

[lxxxvi] In 2019, cows provided 91% of milk production, camels produced 5%, and sheep and goats produced 2% each (Abate, G. et al., *Maize Value Chain in Ethiopia: Structure, Conduct, and Performance*, 2015, http://doi:10.13140/RG.2.1.2229.0804).

[lxxxvii] For example, the Sebeta Agro-Industry processing firm set up operations in the late 1990s.

markets.[144] By 2010, robust urban and peri-urban dairy markets had formed around Addis Ababa and other cities.

Despite growth in the dairy animal population, milk yield per animal has remained low. In 2019, the annual milk yield per animal in South Africa—the highest recorded productivity in the African continent—was 3,360 liters compared with 278 liters in Ethiopia.[145] The decline in average annual productivity from 2002 to 2017 shown in Exhibit 60 is attributed to the steep increase in Ethiopia's livestock herd during the same period. Despite recent efforts by producer associations, only 32% of milk-producing cows in 2019 were genetically bred to optimize milk production.[146] The average cow in Ethiopia lactates for six months and produces 1.4 liters of milk per day while a cross-bred cow can yield an additional 5.3 liters per day.[147]

Despite the growth in production led by urban and peri-urban producers, production in rural areas remains low. IFPRI researchers surveyed 870 producers surrounding Addis Ababa and analyzed how travel time to urban markets affects rural producer operation and performance.[lxxxviii,148] This study found that the greater the distance to urban markets, the lower the financial viability for milk production. Remote dairy producers cannot access demand for their product, and so do not invest in improved production practices and inputs. Therefore, yields and production remain low.

For example, no producers with four hours or more travel time to Addis Ababa own cross-bred cows.[lxxxix] Producers with three hours or more travel time to Addis Ababa also do not invest in animal feed and rely on grazing.[xc] As such, producers in remote communities (four hours or more travel time to Addis) have significantly lower yields—observed daily yields of producers in remote communities were on average 2 liters (1 liter per cow), significantly below the daily yields of 15 liters (5 liters per cow) achieved by producers located nearby Addis.[149] At six-hour travel times from Addis, producers no longer consider dairy production an income-generating activity due to lack of access to market channels and instead focus on milk production for subsistence.

A.6.1.2 Processing

No dairy processing activity shows immediate potential for electrification in remote rural communities.

The existing state of processing activities in rural communities helps indicate whether an activity is suitable for short-term electrification with minigrids. We find that currently no dairy processing activity is widely mechanized in rural communities. Processors do not currently have capacity to manage dairy processing businesses or the experience paying for fuel and upkeep of fossil fuel-powered equipment, so they would require significant support before transitioning to electric equipment.

[lxxxviii] Travel time for respondents varied from 0–6 hours and was measured in terms of straight-path walking commutes. Even within this range, populations shifted drastically from urban near Addis Ababa to rural after multiple hours of travel time from Addis. This study sought to investigate groups with some form of access to a larger market, but also to understand how the thresholds of distance affected producer marketing and production behavior.

[lxxxix] By comparison, for producers near Addis Ababa, half of their herds are the higher-yielding cross-bred cows and sixty percent of them own at least one cross-bred cow.

[xc] Meanwhile, producers near the city spend 2,030 ETB every month on animal fodder for milking animals.

Exhibit 62 shows the flow of processing activities involved in making butter from fresh milk. Among dairy products, rural consumers prefer butter and cheeses, particularly because of their acidic flavor and longer shelf-life.[150] Although milking is a necessary step to produce these products, activities that occur in rural communities are generally not mechanized.

Producers do not generally pasteurize or refrigerate milk in rural communities. Instead, they ferment fresh milk to increase shelf-life, which does not require mechanization.[xci] In producing butter, which is not a commercial activity and occurs at the household level, consumers extract milk fats from milk, and these milk fats are shelf-stable for weeks. Local cheese, made by heating fermented milk with acid, is also shelf-stable for up to a week and so does not require refrigeration.[151] Rural consumers generally make butter and cheese manually with little effort and at low cost, so there is limited awareness of and incentive for mechanizing—and then electrifying—these processing activities.

The seasonality of dairy processing throughout the year is critical for determining if specific processing activities are suitable for electrification with minigrids. As discussed in Section A.3.1.2 for the wheat value chain, seasonal processing activities are less optimal for electrification with minigrids because fluctuations in energy demand lead to underutilization of capacity during a part of the year. Fluctuating energy demand limits the earning potential of minigrid developers trying to recoup investment costs.

Seasonality of milk production therefore varies by location depending on rainfall. Cows require sufficient water and feed to produce milk, so production depends on rainfall and crop production for animal feed. Although the dairy producers and processors we surveyed stated that milk production and processing are not seasonal, our research indicates (as shown in Exhibit 61) that the average cow in Ethiopia lactates for only seven months of the year.[xcii] This means that for five months of the year, there would be limited electricity demand connected to dairy processing.

Initiatives to electrify smallholder dairy processing activities will have the highest potential near cities in Oromia, SNNPR, and Amhara.

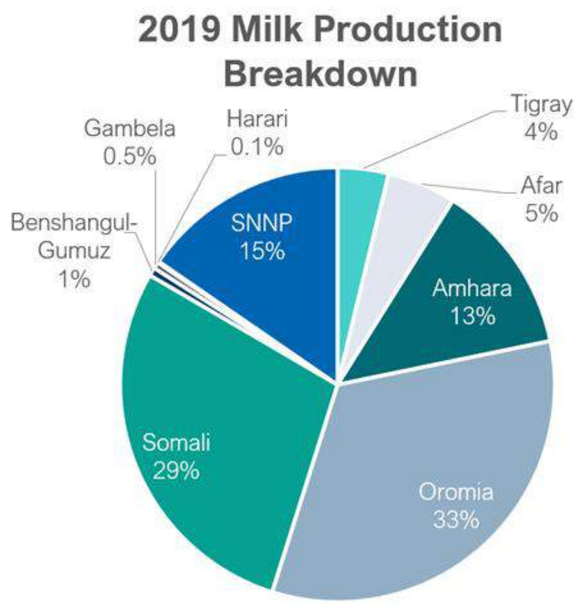
Electrified dairy processing activities will have the highest potential near urban markets, where dairy processing activities are already prevalent. As we discuss below, paying dairy consumers are concentrated in urban communities. To access consumers and deliver products without risk of spoilage, dairy processors operate in peri-urban communities that are nearby cities. So, proximity to urban markets is the key indicator for the prevalence of dairy processing.

In 2019, producers from Oromia, SNNPR, Somali, and Amhara produced 90% of Ethiopia's milk production (as shown in Exhibit 61). However, dairy processing and consumption was mostly concentrated in the peri-urban and urban areas in each of these regions. Dairy producers in rural communities carry out on-farm processing activities (milking) and use small portions of their own milk to carry out end-consumer processing (fermenting, butter churning, cheese making) primarily for subsistence purposes. But dairy processing activities do not take place in remote rural communities

---

[xci] Consumers ferment raw milk into more acidic milk products like *irgo* (fermented milk) or *arrera* (sour buttermilk), particularly because their acidity inhibits bacterial growth.
[xcii] Since cows require animal feed and water to produce milk, lactation periods depend on the crop growth cycles and weather patterns of a particular area.

for income generation purposes. Therefore, there is limited potential for productive uses connected to dairy processing in rural communities.



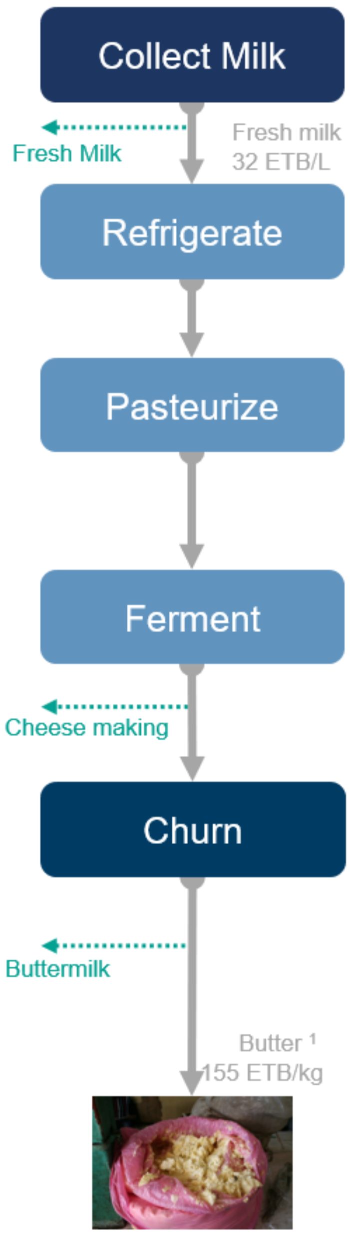
Average Cow Lactation Period	Region
5 months	Dire Dawa Gambela
6 months	Afar Harari Somali
7 months *	Amhara Oromia SNNPR Tigray
8 months	Benishangul-Gumuz

* In Ethiopia, the average cow lactates for 7 months of the year

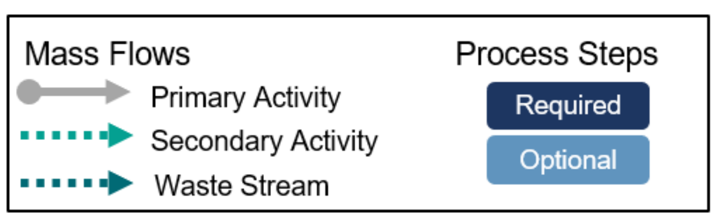
Exhibit 61: Regional Production Statistics from the 2019 Agricultural Sample Survey Data

Note: The pie chart shows the proportions of total milk contribution by region in Ethiopia based on milk production from 2019 to 2020. The table shows the number of months that cows produced milk over the year in each region. The average lactation period across Ethiopia was seven months. (Source: CSA, 2019)

Butter production



Description	Mechanization
Farmers milk animals daily in the morning (few farmers milk again in the evening) and deliver milk within two hours of milking to a collection center.	All farmers we surveyed milk their animals manually. We observed no milking machines in communities surveyed.
Raw milk must be cooled to below 4°C to limit bacteria growth. Refrigerated milk stays fresh for 7–10 days.	Farmers quickly sell milk rather than chilling it. We found a mechanized milk chiller in only 4% of communities surveyed.
Processors heat milk briefly at high temperatures to kill bacteria and milk-spoiling enzymes. Pasteurized milk stays fresh for weeks (or up to months) when stored properly.	Rural consumers rarely pasteurize milk. Instead, they make butter or cheese. We found no processors in surveyed communities.
Farmers ferment milk by sealing fresh (raw) milk and heating it at 30°C–40°C. The milk sugar (lactate) changes into lactic acid, thereby increasing the shelf life of the milk.	Consumers ferment milk manually with a sealed container and sunlight or cookstove heating. They do this manually in the household for free.
Farmers leave milk untouched for a cream layer (20%–30% fat content) to emerge at the top. They skim this layer and mix it with air so that fat and air particles coagulate into butter.	Consumers churn butter (for home consumption) using hand-powered tools. We did not observe any mechanized butter churns.



[1] Photo: goorsha.net

Exhibit 62: The Dairy Processing Flow from Raw Milk to Butter

Note: Most milk is sold in the form of fresh milk to rural consumers who then make one of the many potential dairy products including butter and cheese.

A.6.1.3 Losses

Dairy product losses restrict the business potential for dairy processing activities along the value chain.

In peri-urban communities, dairy losses displace potential revenues. However, in rural communities, where the market for fresh milk is smaller, losses lead to displaced household consumption. Fresh milk spoils within hours without refrigeration, pasteurization, or fermentation. And so rural producers are motivated to sell fresh milk supplies quickly. Most consumers then ferment fresh milk or make butter to prevent spoilage. Pasteurization and milk chilling would significantly reduce milk losses but are less viable in rural communities because of low consumer demand for fresh milk and the lack of a cold chain to connect rural producers to urban markets.

Fresh cow milk stored in clay containers. Producers typically transport milk in these containers for trading.

Experts estimate that milk losses across sub-Saharan Africa are as high as 40% due to spoilage or contamination despite the minimal reporting shown in Exhibit 64.[152] Spoiled milk has an unpleasant flavor and can be deemed unsafe to consume due to bacterial growth and presence of contaminants. Contaminated milk collection equipment, hands or cow teats, and improper milk storage, can introduce dust or chemical contaminants into milk.[153] Dairy producers aiming for high quality milk and to reduce losses due to contamination must clean these surfaces—sometimes just with clean water.

Milk can only be left at room temperature for up to two hours following milking as bacteria growth remains slow during this initial period. After that cutoff period, bacteria growth is exponential and doubles every 20–30 minutes unless milk is stored under 4°C or pasteurized.[xciii, 154] Exposure to light and excessive agitation during handling also oxidize milk fats, which affects overall flavor.[155]

Rural producers struggle to control these variables without adequate storage or pasteurization technology, but accessing these conservation technologies is unfeasible when they lack a market to sell to. Because milk spoilage leads to lost income, rural producers typically sell their milk immediately after collecting.

Milk cooling and pasteurization could be transformative for Ethiopia's dairy sector by reducing milk spoilage rates, but these processes are not yet feasible in rural communities. Below, we discuss the low demand for fresh milk in rural communities—rural consumers do not widely use fresh milk. In fact, after generations of relying on fermenting to create shelf-stable products, rural consumers prefer the taste of acidic dairy products over fresh milk products.[156]

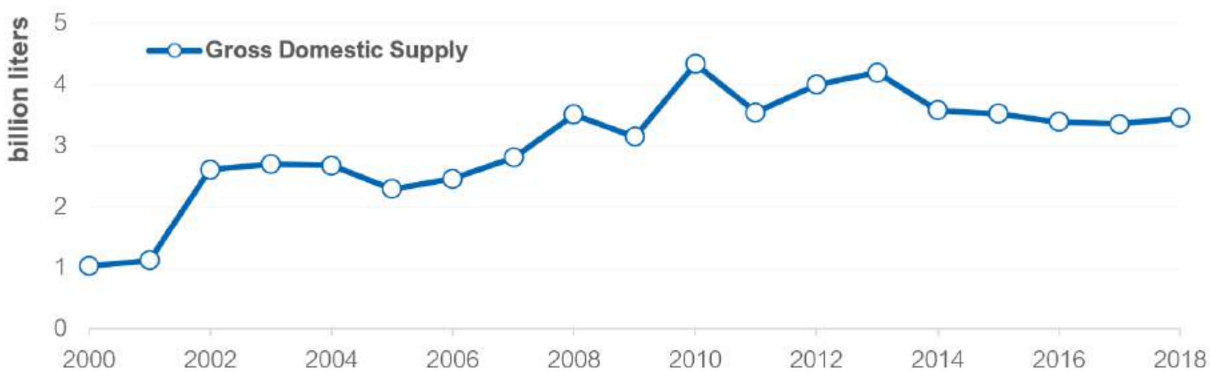
[xciii] Ultra-high temperature (UHT) pasteurization involves heating milk to 280°C–300°C for two to six seconds to kill all present bacteria. UHT-pasteurized milk is shelf stable at room temperature for up to six months when stored in sterile, sealed, dark containers.

The business case for milk cooling depends on strong consumer demand to offset refrigeration costs. Since urban consumers demonstrate a willingness to pay for fresh milk, milk refrigeration in rural communities would require accompanying refrigerated transportation networks to distribute milk from rural communities to consumers in urban markets. Concerted efforts—beyond providing access to electricity and financing in rural communities—are necessary to develop and ensure the feasibility of a cold chain connecting remote rural producers to demand in urban markets.

Pasteurization is also energy intensive and expensive and rural smallholder dairy producers cannot afford to buy equipment. More importantly, rural consumers who already cannot afford to pay for fresh milk do not have the ability to pay for locally pasteurized milk at the rate needed to offset processing costs.

A.6.1.4 Demand

Lack of localized demand for dairy products suggests limited potential for electrifying dairy processing activities in remote rural communities.



	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18
Local	1	1	3	3	3	2	3	3	4	3	4	4	4	4	4	4	3	3	4
Import	.010	.004	.013	.026	.011	.011	.017	.017	.014	.019	.022	.012	.013	.013	.003	.002	.002	.002	.002
Export	0	0	0	0	.001	.004	.007	.002	0	0	.006	.005	.005	.005	0	0	0	0	0
Stocks	0	0	0	.001	0	0	0	.001	0	0	0	0	0	0	0	0	0	0	0

Exhibit 63: Gross National Supply of Milk between 2000 and 2018 in Billion Liters

Note: The data table gives a breakdown of gross domestic supply into national harvest, imports, exports, and national stocks. We add production and imports but subtract exports (in red) to determine the gross domestic supply. The Government of Ethiopia contributes national dairy stocks toward domestic supply during periods of shortage and subtracts a portion of national production from domestic supply during periods of excess production (as denoted by red values). National milk stock variations are negligible in Ethiopia during the period shown. Both imports and exports are generally limited and insignificant. (Source: FAOSTAT New Food Balances)

Until cold chains connecting rural remote producers to existing demand in urban hubs are established, potential for dairy processing will depend on local consumption in rural communities. But milk is not a central part of rural household diets, so there is limited demand for processing in rural communities across Ethiopia. This trend indicates that even in rural communities where milk is produced, the processing activities described in **Exhibit 62** are not frequent and occur at the household level and not for commercial pursuits.

Awareness about and demand for dairy products is increasing in Ethiopia, primarily in urban areas. **Exhibit 63** shows that national supply has gradually increased between 2000 and 2018. The national per capita demand for milk almost doubled from 17 kg in 2011 to 31 kg in 2017.[157] While per capita demand is consistent with other countries in sub-Saharan Africa, they are far below the 200 kg that the World Health Organization recommends for a balanced diet.[xciv] Experts anticipate that milk demand will increase in line with Ethiopia's growing population and as more Ethiopians migrate to urban areas for work opportunities and gain spending power to afford dairy products. These projections estimate that national milk consumption will reach 10–11 billion liters by 2028, more than three times the 2018 level (for food consumption) observed in **Exhibit 64**.[xcv,158]

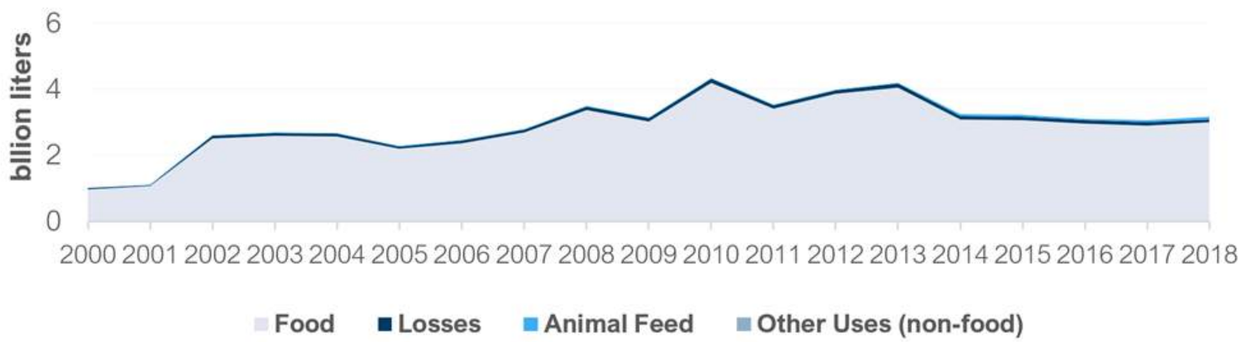


Exhibit 64: Consumption of Milk Domestic Supply by the Major Categories of Food, Losses, and Animal Feed in Billion Liters

Note: Milk consumption peaked in 2010 and after a steep decrease in 2011 has remained mostly stagnant at 2014 levels. Reported losses have remained minimal, but experts estimate milk spoilage losses to be much larger than quoted (closer to 40% across sub-Saharan Africa). (Source: FAOSTAT, New Food Balances)

Across Ethiopia, dairy demand is limited and irregular. Devout subgroups of the Orthodox Christian faith, who are estimated to make up 62% of Ethiopians, abstain from dairy on fasting days.[159] Between 140 and 250 days of the year, adult Orthodox Christians avoid dairy products in observance of religious customs with the longest continuous fasting period lasting 55 days. This directly affects the marketing of milk products in rural communities where dairy producers cannot store and retain products to sell when demand recovers. Only 54% of smallholder dairy producers report that customers continue to buy products on these days.[160] Dairy product prices react to these dips in demand: in August 2018, Zagol Milk Factory reported milk prices of 13 ETB per liter during fasting periods compared with 20 ETB per liter in non-fasting periods.[161]

[xciv] Average annual milk consumption in sub-Saharan Africa was 25 kg per capita in 2011.
[xcv] Projections of milk consumption by 2028 without any interventions is 10.9 billion liters. And 10.4 billion liters of milk consumption by 2028 is projected with the deployment of interventions to address young and adult stock mortality.

Fresh milk is considered too expensive among rural consumers, and dairy producers opt to sell their milk production and buy cheaper food for household consumption. Dairy producers reserve rejected milk and small volumes of leftover milk to make butter, cheese, and fermented products that are more shelf stable than raw fresh milk.[162] This aligns with dairy expenditure patterns shown in **Exhibit 65**, as lower-income consumers spend more annually on butter than any other dairy product.[163] This is especially true for lower-income rural consumers who prefer to consume dairy as butter.

Ahimed Teyib Mohammed with containers of fresh milk that are ready for trading in the Seweyna Woreda of the Bale Zone, Oromia. Mr. Mohammed sells both fresh cow's milk and goat's milk throughout the year. He pays 25–35 ETB per liter for cow's milk and sells it for 35–40 ETB per liter. Likewise, he pays 30–40 ETB per liter for goat's milk and sells it for 40–45 ETB per liter. Mr. Mohammed sells 108 liters of milk each week.

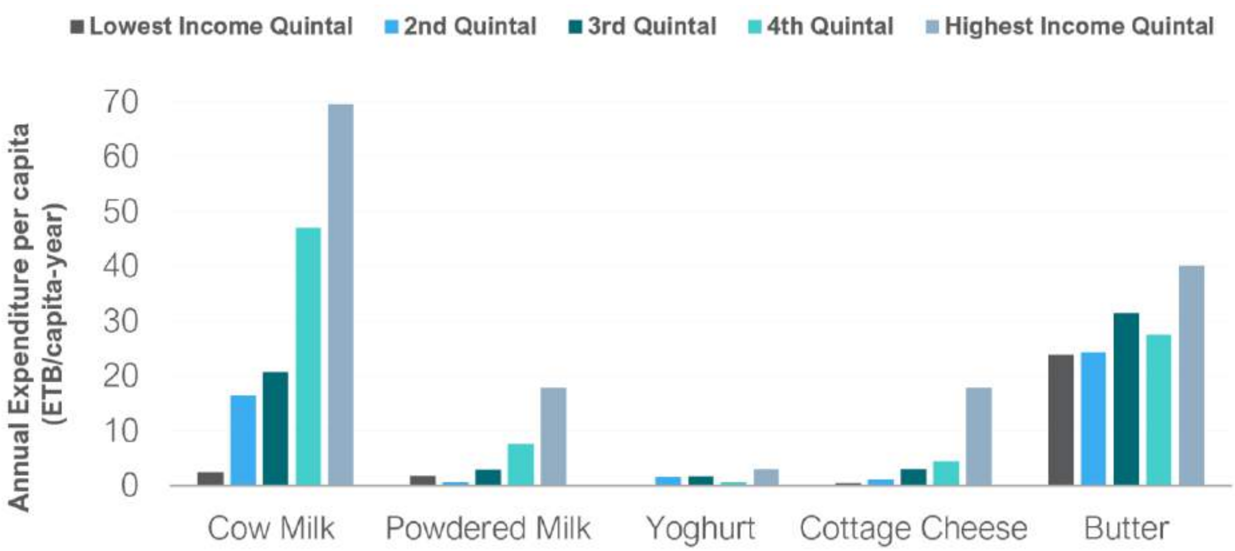


Exhibit 65: Dairy Product Expenditure by Income Quintile and Type of Product

Note: We use the 2016 Household Income Consumption and Expenditure Survey (HICES 2016) to provide a representative depiction of dairy consumption in Ethiopia. Consumption among Ethiopia's lowest income quintiles provide context of rural population spending, while the highest income quintiles illustrate urban community expenditure. Across all quintiles, consumer expenditure is high for butter. (Source: Minten et al., 2018)

A.6.1.5 Local Trade

Across Ethiopia's dairy market, commercial milk processing facilities have significant demand for fresh milk. These companies—typically based in Addis Ababa and other cities—are critical off-takers that buy rural producer milk. They deploy traders and milk collectors, and make arrangements with producers and traders for easier local collection.[164]

Commercial processing companies that set up out-grower schemes develop relationships with dairy producers and ensure that milk production meets their quality standards.[165] But commercial processing facilities are concentrated in urban areas and the dairy producers that serve this demand for fresh milk are in the areas surrounding urban markets. A study found that milk producers in communities with distances of four hours or more of travel time from an urban market (Addis Ababa), sell butter instead of fresh milk or cheese because of its increased shelf-life.[166] This means that the dairy offtake arrangements for fresh milk do not extend into rural communities that are not located close to urban markets.

Butter churning has longer term potential for electrification in dairy-producing rural areas.

Dairy processing is limited in rural communities, but there is some small-scale butter churning for commercial purposes. Of the rural dairy producers we surveyed, 63% sold fresh milk, and the remaining 38% sold butter (shown in Exhibit 66). This indicates that rural dairy producers engage in butter churning for both household consumption and commercial purposes. However, butter markets in rural communities are small. Overall, milk is the most common form in which dairy is bought and sold. The highest subset of dairy traders we surveyed sold fresh milk (45%), and most dairy products leave the community primarily in milk form.

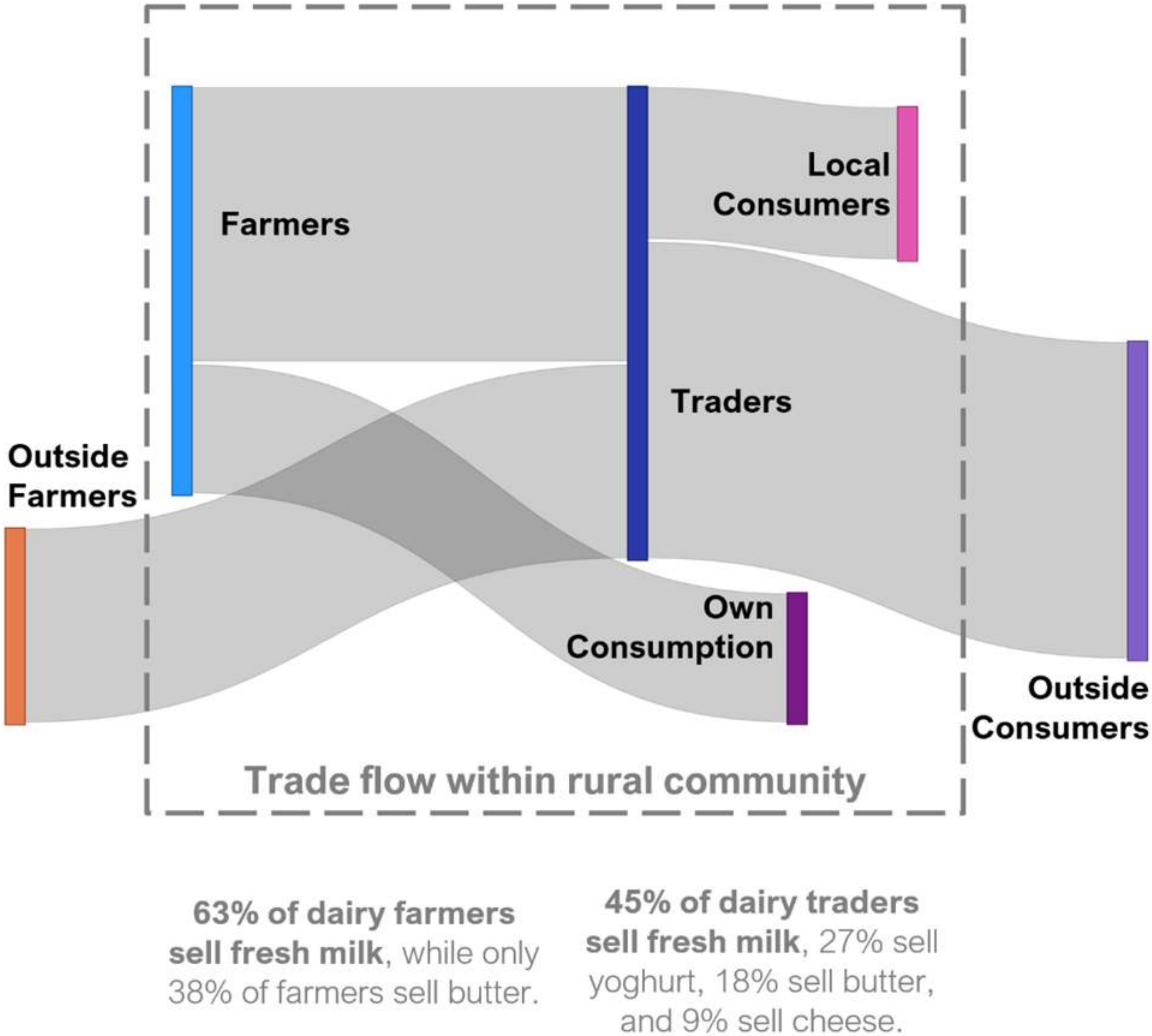


Exhibit 66: Dairy Product Flow from Producers to Consumers Based on RMI Survey Findings from Value Chain Actors in Dairy-Producing Communities in Amhara, Oromia, and SNNPR

Note: We measure trade flow proportions by percentage of dairy volume traded. (Source: RMI Survey, 2020).

A.6.2 Opportunities for Electrification

We analyzed several processing activities in the dairy value chain to identify opportunities for short-term electrification including mechanical milking, milk chilling, pasteurization, fermentation, butter churning, and cheese making. As described in the evaluation framework of Section 2.4.1, we used the metrics of local capacity, offtake market, equipment and electrification, and scalability to shortlist activities that demonstrated strong readiness for electrification today or in the short term with minimal support needed.

In the dairy value chain, no processing activity showed significant potential for short-term electrification in rural communities. There are niche opportunities for electrifying dairy processing activities in peri-urban communities that are close to urban markets and have access to paying customers. But opportunities in peri-urban communities are outside our scope since they do not extend to rural communities.

Butter churning and milk chilling may have longer-term potential for electrification but would require significant support to develop. Butter churning is a popular processing step for dairy consumed in rural communities and milk chilling has significant potential to transform the dairy value chain in rural communities if connected to a cold chain. These activities are discussed further below.

Other activities prevalent in rural communities are not immediately suitable for electrification with minigrids. Fermenting milk requires no energy input. As such, fermenting is not an energy end-use activity and so we do not explore the potential for electrification any further. Likewise, consumers make cheese for household consumption and are not likely to pay for this product. Cheese is cooked by heating milk using a fuel- or wood-powered cookstove. Since consumers do not make cheese for sale, there is no evidence that cheese revenues can offset the upfront and maintenance costs associated with electric cook-plates or dedicated cheese-making equipment.

One hundred percent of dairy producers we surveyed manually milk their cows. Rural dairy producers manually milk animals because it is free and generally effective. There is no evidence to suggest that rural dairy producers are willing or able to pay for electric dairy milking. Milking, cheese-making, and fermenting are not covered further because they show little potential for electrification in rural communities and are primarily carried out manually.

Habte Xagnawe with his hand crank butter churn machine in the Andabet woreda of the South Gonder zone, Amhara. Mr. Xagnawe is a dairy producer who milks his two cows every day throughout the year. Over the year he produces 1,080 liters of milk, keeping 250 liters for household use. Mr. Xagnawe sells butter for 225 ETB/kg.

Pasteurization is an uncommon processing activity in rural communities. We found no pasteurization in any of the dairy-producing communities we surveyed across Amhara, Oromia, and SNNPR. Due to equipment costs and energy requirements, pasteurization is concentrated in urban communities and takes place in production at large industrial scale.[167] As discussed above, rural dairy producers sell or ferment their fresh milk to avoid spoilage. As a result, the rural demand for pasteurization is limited. We do not consider pasteurization any further in this study.

A.6.2.1 Butter churning

Butter churning is not suitable for short-term electrification in rural minigrid communities.

Butter churning is not suitable for electrification with minigrids. Churning does not require energy in rural communities because dairy producers and consumers easily produce small volumes through manual mixing. Furthermore, most consumers in rural communities buy milk and make butter at home for household use instead of buying butter. As a result, the demand for butter among rural consumers is not big enough to justify investing in mechanical butter-churning equipment. Butter churning also does not take place across Ethiopia—processing is concentrated in high production areas, suggesting limited scaling potential.

Criteria	Support Status	Description
Local Capacity	◑	We found **no mechanized butter-churning processors** in the rural communities we surveyed.* Many dairy producers sell their dairy products in the form of butter, but this represents a small portion of the butter consumed in rural communities. Most consumers make butter from leftover milk for household use, not commercial pursuits. Since the purchased butter market is limited in rural communities, there are no dedicated butter production businesses in rural communities beyond the dairy producers who sometimes trade parts of their dairy produce as butter. * Findings based on 2020 RMI survey findings of barley processing in rural communities in Amhara, Oromia and SNNPR regions within Ethiopia.
Offtake Market	◑	We found that butter costs **155 ETB per liter** in rural communities. Rural consumers sometimes buy butter from dairy producers, but more often make butter at home. In rural communities there is limited demand for buying butter, and not enough paying customers to warrant investing in mechanized butter churners that would enable processors to make high volumes of butter.
Equipment and Electrification	◑	Electric butter churners are available domestically, and local churner manufacturers should have the technical expertise to support equipment repair.* Yet butter churning is almost solely done manually in rural communities using hand-crank equipment. This is because it is not energy intensive, and hand-cranking is generally effective for the scale of the market. Producers who make butter cannot afford electric equipment because they do not sell enough butter to offset costs. * Marast Manufacturing produces a tri-phase butter churner with 40-liter capacity for 35,350 ETB
Scalability	◑	Butter making is prevalent across Ethiopia but is more concentrated in rural communities in milk production zones. Butter churning will first need to become a paid processing activity before becoming suitable for electrification.

Support Required: ○ Significant ◑ Moderate ◔ Minimal ● Deployment Ready

Manual butter churning is easy and can be carried out in only 31 minutes. Electrified churning would introduce electricity and maintenance costs which cannot currently be recovered through higher revenues.[168] Butter churning is predominantly done at the household level for personal consumption and those few consumers who do purchase butter have an easy substitute by making their own. In addition, processors do not have experience or expertise operating dedicated businesses for butter churning, so they may require training to build sales as well as to maintain and operate electric equipment.

Despite the popularity of butter in rural communities, there is limited evidence that rural demand for butter is high enough to make electrified butter churning viable. Ability to pay for churned butter has not been proven and consumers may not be willing to pay for a service they can perform at home for free. Trade channels to sell to new markets do not exist and would require developing new supply chains—identifying transport and storage—which is unlikely to happen without considerable effort and without identifying an attractive market that could make this investment worthwhile.

A.6.2.2 Milk chilling

Milk chilling is not suitable for short-term electrification in rural minigrid communities.

Milk chilling is not suitable for electrification with minigrids. Demand for fresh milk is low in rural communities because most consumers do not consume fresh milk and therefore will not pay processors to refrigerate milk. Electric milk-chilling equipment is available in Ethiopia. But milk chilling is not prevalent across Ethiopia—chilling is concentrated in urban areas particularly because it requires electricity.

Milk chilling can reduce milk production losses by up to 8%. A 2019 study of milk chilling methods for milk delivered to Zagol Milk Factory (an hour north of Addis Ababa) found that refrigerating milk in community collection centers was viable.[xcvi] Milk chilling enabled producers to carry out a second daily milking on evenings and significantly boost production volumes—refrigeration reduced the rejected portion of evening milking yields from 96% to under 20%.[169] On-farm cooling also significantly improved losses when producers stored milk in metal cylinders rather than plastic

Buzayo Tariku Leka showing her electric chiller in the Dasenech woreda of the South Omo zone, SNNPR. Ms. Leka buys fresh cow milk, then sells chilled milk for 30 ETB per liter. She usually sells milk to five customers every day and earns 750 ETB weekly. Typically, she sells 57% of the milk she buys and keeps 15% for household use—10% of the milk usually spoils before sale or consumption. Ms. Leka operates her business throughout the year.

[xcvi] Researchers evaluated three milk cooling scenarios from producers to community collection centers before delivery to Zagol Milk Factory: 1) no cooling at the farm or collection center, 2) small-scale on-farm cooling units, and 3) cold storage units at collection centers. For the on-farm cooling scenario, researchers also varied the type of on-farm chiller used and the frequency of milk deliveries from producers. On-farm electric refrigerators with 10–20 liter capacities were either

containers.[xcvii] However, without investing in a cold chain, these opportunities only exist for production areas close to processing plants and would not be viable for remote rural communities.

Milk chilling in rural communities would require a considerable development effort. The study described above was a significant effort funded and managed by Zagol Milk Factory. The Zagol Factory paid for all infrastructure, purchased all the milk from collection centers, and arranged transportation to transport milk from collection centers to its factory.[170] Producers also required awareness raising and capacity building to ensure sufficient milk aggregation and production quality and yields.[171] Milk chilling in collection centers was just one aspect of a holistic effort that addressed production, collection, preservation, transportation, and market linkages. These requirements require considerable efforts that are beyond the scope of the independent actions of minigrid developers and smallholder producers but may be suitable for niche opportunities if the right actors and conditions were identified.

In some situations, solar technologies are also not fully compatible with the timing of milk chilling loads. As discussed in the study above, milk cooling technologies are most critical for overnight operation to preserve evening milk yields for collection the following day. This does not coincide with the cheaper sources of power from solar generation. Nonetheless, solar-powered refrigerators could enable consumers in rural communities to increase the shelf-life of their milk and other perishable items during the daytime hours.

Milk chilling is not viable in minigrid communities in the short term. Electrifying milk cooling in rural settings will only become viable after introducing an off-taker that can train—and coordinate milk intake from—disparate smallholder producers, as well as manage milk storage and transport to consumers in urban centers. Even if rural communities invest in local milk cooling, the lack of a cold chain still presents a barrier to accessing urban consumer markets. None of these solutions will be addressed by facilitating access to electricity or electric equipment in minigrid communities. These solutions therefore require significant support and are unlikely to be replicated at scale across most minigrid-suitable communities in the short-term.

---

powered by solar panel systems or biogas digestors, while community collection refrigerators were electric 1000-liter capacity chilling systems. To accommodate producer unwillingness in making evening milk deliveries, researchers hired delivery-people to transport milk to collection centers with scooters.

[xcvii] A full 96% of milk collected during evening milking without overnight refrigeration and delivered to the collection center at eight o'clock the next morning was rejected. This rejection rate decreased to 21% with on-farm overnight refrigeration using plastic containers, 0% with on-farm overnight refrigeration using metal containers, and 6% with collection center overnight refrigeration. Metal cylinders are better conductors of heat than plastic containers, which would allow them to require less of a temperature difference in refrigerators to cool milk—this makes them more efficient for milk cooling.

Criteria	Support Status	Description
Local Capacity	◐	We found that only **4% of rural communities we surveyed had mechanized milk chilling processors**.* Processors have experience handling fresh milk, but no experience operating cold storage. * Findings based on 2020 RMI survey findings of barley processing in rural communities in Amhara, Oromia and SNNPR regions within Ethiopia.
Offtake Market	◐	We found that fresh milk costs **32 ETB per liter** in rural communities. Demand for fresh milk in rural communities is low and so there is no evidence that consumers are willing to pay for chilled milk. As discussed above, the current demand for fresh milk is concentrated in urban markets. So, the success of milk chilling in rural communities depends on connecting cold storage in rural communities to cold supply chains that transport milk to urban markets.
Equipment and Electrification	◐	Milk cooling machines are available domestically and local manufacturers producing this equipment should have the technical expertise to support equipment repair.* Yet most milk producers solely use insulated containers to keep milk cool without refrigeration prior to sale to traders, consumers, or commercial dairy producers. Small-scale milk chilling would be most critical during overnight periods before next day transfer to collection centers. This timing would drive up nighttime load, which would coincide with more expensive generation sources of electricity in solar minigrid communities. * Marast Manufacturing produces a tri-phase milk chiller with 2000-liter capacity for 333,982 ETB
Scalability	◐	Milk cooling can boost the dairy sector across Ethiopia but only if cold storage in communities is connected to a cold chain connecting remote dairy producers to urban markets. However, this coordination requires concerted effort from regional and/or national actors and is beyond the scope of decisions made in rural communities by smallholder producers and minigrid developers.

Support Required: ○ Significant ◐ Moderate ◕ Minimal ● Deployment Ready

Appendix B Economic Modeling Assumptions

This appendix explains in more detail the methodology and assumptions used in assessing the economic viability of the Tier 1 activities. Detailed cash flow analysis and sensitivity analyses results are also included.

B.1 Methodology for economic analysis

B.1.1 Selecting processing activities and equipment

We select processing activities that are identified as Tier 1— maize flour milling and wheat flour milling (see Section 3). Because most processors we surveyed perform milling on multiple grains including maize, wheat, barley, teff, and others (e.g., sorghum), we combine these activities as grain flour milling and analyze the economics of such processing business.[xcviii] From the survey we also learn that grain flour milling is already a mechanized activity using diesel-powered machines in surveyed regions, and that a fee-for-service (FFS) modality is common across Ethiopia. Therefore, we model introducing an electric mill while operating the processing business to match the status quo.

Although existing diesel-powered mills are relatively large in capacity (20 HP is the most common size), our study aims to test minigrid-compatible electric equipment that could meet processors' needs. So instead of modeling electric motors that are of a similar size to the diesel ones, we size the equipment based on processing demand (i.e., throughput that meets daily processing volume) and compatibility with minigrid (e.g., power rating, inrush current). We defined these specifications in consultation with equipment suppliers and experts.

B.1.2 Analytical tools and assumptions

The economic viability analysis consists of a cash flow model that examines the revenue and cost that a processor can expect by investing in an electric mill. The model also calculates the net present value (NPV) and discounted (and simple) payback period of the investment. We include the following cost categories in the analysis: capital cost of equipment (capex), financing cost, energy cost, maintenance cost, and facilitator fee. On the revenue side, revenue comes from the FFS charge.[xcix]

We base many of the model inputs on survey results, including daily processing volume, FFS charge, and maintenance cost. We use the median value of all responses from grain milling processors to capture the central tendency of the data, except for the daily processing volume. Instead for daily processing volume we adopt the 25th percentile to be extra conservative, given the wide range of processing volumes observed. We cross reference these inputs with our literature review and test assumptions with field experts when possible.

For input fields not included in the survey, such as debt interest rate, loan tenor, and electricity price, our assumptions are based on literature review, RMI's previous research and analysis, and

---

[xcviii] Thus, this analysis would also apply to barley milling and teff milling, which are identified as Tier 2.

[xcix] The calculation in the cash flow model is in ETB, and the exchange rate used is US$1= ETB 40 (rate accessed in March 2021 on National Bank of Ethiopia data)

expert interviews. **Exhibit 67** below summarizes key assumptions used in the analysis. Please note that these inputs are specific to the Ethiopian context, particularly to our surveyed regions. To replicate this analysis for different scenarios these assumptions must be revisited.

Inputs	Assumption	Explanation/Data Source
Energy data		
Minigrid electricity tariff	ETB 13/kWh	This reflects the tariff level in Rensys' solar-battery minigrid pilot in Ethiopia; sensitivity analysis of tariff is conducted.
Electricity service reliability	94%	This is based on Koftu site visit data. The operator reported that the minigrid experiences breakdown about five times a week. We assume each breakdown lasts two hours on average. (5*2)/(24*7) = 94%.
Diesel cost	ETB 0.5/kg (ETB 250/day)	Median value of fuel cost per kilogram of grain processed based on survey results.
Equipment data		
Equipment sale price	ETB 101,400	Quote from Amio Engineering (US$2,600). The price is also within the range from ESMAP productive use appliance study, price per unit output for smaller mills (e.g., less than 500 kg/hour throughput) is about ETB 800/kg for locally manufactured mill. [6]
Other upfront cost	10% (of equipment price)	It Includes other upfront costs such as the delivery of equipment and installation. Transportation cost is often by distance. At Afesol for example, it can cost up to ETB 3,500 for 100 kilometers.
Throughput	150 kg/hour	The throughout is based on median hourly processing demand (calculated using survey results), with consultation with equipment suppliers and experts to confirm technical feasibility.
Power capacity	3 kW	From consultation with equipment suppliers and experts to confirm technical feasibility.
Lifespan	15 years	From consultation with equipment suppliers and experts.
Service and maintenance cost	ETB 10,800/year	Median value based on survey results.

Service and maintenance cost saving	0%	Some suppliers mentioned while electric motor tends to be cheaper to repair (sometimes even five times cheaper), breakdowns can happen more frequently due to unreliable electricity supply. We assume service and maintenance cost for electric and diesel mills remains the same to be conservative.
Processor data		
Daily processing volume	500 kg/day	The 25th percentile based on survey results.
FFS charge	ETB 1/kg	Median value based on survey results.
Equipment usage	Between 8 a.m. and 6 p.m.	Assumed usage profile of new electric equipment—hours of operation and equipment capacity level will remain the same as reported in survey.
Non-energy cost	ETB 94/day	Median value, which includes labor cost, transportation cost, and others as reported by processors in the survey.
Financing data		
Down payment requirement	20% (of equipment price)	Based on literature review and expert interviews.[c] In the baseline analysis, we assume down payment is contributed by the processors. We also tested the scenario in which down payment is contributed by a grant, which has very similar results (see Section 4.1.1)
Grant support	0%	We model the unsubsidized scenario in the baseline analysis. We later tested how a grant can support early adoption of electric mill (see Section 4.1.1).
Debt/lease interest rate	20% (annual)	Based on interviews with microfinance institutions (MFIs).
Loan tenor	3 years	Based on interviews with MFIs and CGFCs. A three-year tenor is the longest MFIs would offer to businesses.
Installment	Quarterly	Based on interviews with MFIs and CGFCs.
Cost of equity	23% (annual)	We use the profit margin of existing diesel processing business as the minimum desired return for equity.

[c] For example, AgroBig's maize thresher pilot requires a 15% contribution from processors, and Oromia Capital Goods Finance Company requires a 20% down payment for equipment hire-purchase.

Facilitator fee	20% (of loan amount)	Currently facilitators are supported by donor grants and will continue as such in the early stages of productive use projects. Eventually it will be rolled off.
Weighted average cost of capital (WACC)	21%	Calculated with debt interest rate, cost of equity, and debt ratio. The WACC is used as the discount rate in the NPV calculation.
Others		
Seasonality	Not seasonal	The majority (>70%) of respondents reported grain flour processing as not seasonal.
Tax rate	15%	This is a rough average number according to the tax rate ladder in Income Tax Proclamation No. 979/2016, considering the annual income level of grain processors.

Exhibit 67: Overarching Assumptions

B.1.3 Sensitivity analysis approach

To examine which variables, if changed, would most impact the economics of the electric equipment investment and how significant the impact would be, we conduct sensitivity analysis for key variables. To isolate the impact of each specific variable, other model inputs remain fixed in the analysis. The following is a summary of the variables and the range tested.

Sensitivity Variables	Range of Change	Description
Energy data		
Minigrid electricity tariff	-50%, +100%	This is to test how a minigrid tariff will impact the economics of the investment.
Electricity service reliability	-30%, +6%	This is to understand how the reliability of electricity supply affects the economics of the business.
Equipment data		
Equipment capex	-50%, +50%	This is to test how changes in equipment capex impact the economics of the investment.
Lifespan	-5 years, +5 years	This is to test how equipment lifespan impacts the economics of the investment.
Processor data		
Daily processing volume	-50%, +50%	This shows how the economics of the equipment investment are affected if production drops due

		to poor harvest, weather, or other crop-related issues, or if production grows due to business expansion.
FFS charge	-50%, +50%	This is to test the FFS charge needed to make the business profitable.
Financing data		
Grant support	0 grant, 50% grant	This is to test the impact of a grant/subsidy.
Debt interest rate	-50%, +50%	This is to test the impact of cost of capital on returns and the cost of debt that processors can afford

Exhibit 68: Summary of Sensitivity Variables

B.2 Economic Viability Analysis: Fee-for-Service Grain Flour Milling

Across the communities we surveyed in Amhara, Oromia, and SNNPR, the most prevalent processing of grains (including maize, wheat, barley, teff, and sorghum) is grain flour milling. The activity happens all year-round, and customers prefer to bring crops to a processing center and pay a fee for the milling service.

Grain flour milling is already mechanized in rural communities. Processors we surveyed use oversized diesel-powered mills. Electric mills are available in the Ethiopian appliance market, both imported and manufactured locally by domestic suppliers[172] .When selecting the electric equipment to model, instead of trying to match the size of existing mills, we model "right-sized" equipment that can meet local processing needs without having to extend operation hours. **Exhibit 69** shows a selected list of available electric grain mills in Ethiopia (as reported by survey or equipment suppliers). We consulted with equipment suppliers and technical experts and confirmed that the 3 kW mill with 150 kg/hour throughput that we model can be found or customized in market.

	Power Source	Manufac turer	Imported (Yes/No)	Capacity	Throughput	Efficiency
Existing mill (from survey)	Diesel	Chinese brand	Yes	20 kW	Unknown	Unknown
Horizontal flour mill	Diesel	Amio	Yes	15–18 kW	5 ton/day	Unknown
Grain mill 1	Electric	Amio	No	16 kW	900 kg/hour	99%
Grain mill 2	Electric	Marast	No	3 kW	200 kg/hour	85%
Grain mill 3	Electric	DYD	Yes	11 kW	300 kg/hour	Unknown

Grain mill 4	Electric	Tsion	No	11 kW	2,000 kg/hour	85%
Mill quoted for pilot	Electric	Amio	No	3 kW	<200 kg/hour	Unknown

Exhibit 69: Available Mills in Ethiopia[8]

Our analysis finds that there is a compelling economic case for processors to invest in electric multi-grain mills. With electric mills, processors can recoup the investment within three years, and generate a positive NPV of ETB 166,000 over the 15-year lifespan of the equipment. Compared with processors using diesel-powered mills, processors save ETB 31,200 annually in energy cost alone, and the profit margin is improved by 105%.

Assumptions:	5-year NPV	15-year NPV	Discounted payback	5-year equity IRR	5-year saving potential[ci]
ETB 115,000 upfront cost 3 kW, 150 kg/hour electric mill 500 kg/day processing volume ETB 1/kg service charge	ETB 74,600 US$1,865	ETB 166,000 US$4,150	2.4 Years	66%	ETB 95,000 US$2,375

Exhibit 70: Economic Viability of Grain Flour Milling

Under reasonable assumptions (see **Exhibit 67** above), a discounted cash flow analysis of the grain flour milling business shows that processors can generate strong profits and recoup investment in about three years (see **Exhibit 71**). In our analysis, we choose the processing volume corresponding to the 25th percentile to be conservative. At this processing volume, investment in electric equipment is economically viable. The equipment utilization is only at 31% and can technically process more grains if there is demand.[cii]

[ci] Compared with the same processing scale but using a diesel-powered mill.
[cii] Calculated based on a 10-hour per day operation, with the maximum processing volume being 10 hours * 150 kg/hour.

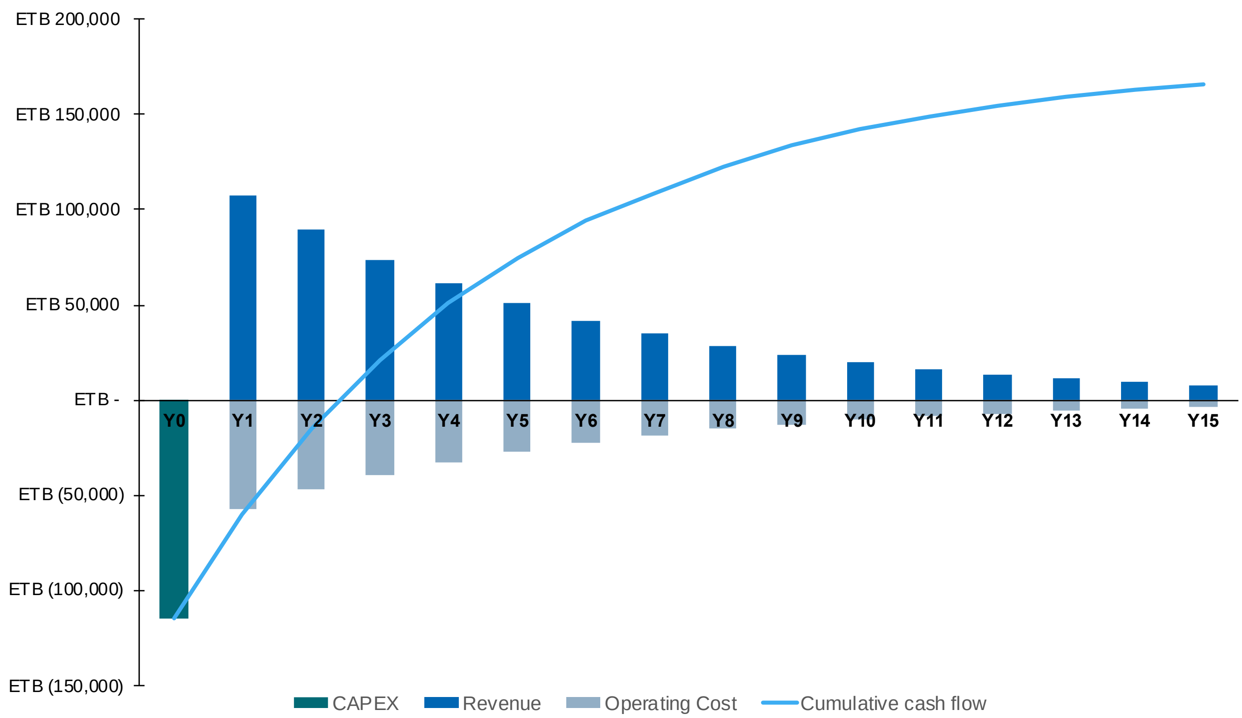


Exhibit 71: Discounted Cash Flows of Electric Equipment Investment in FFS Grain Flour Milling

The economic viability of an electric grain flour mill depends on a number of variables. In the sensitivity analysis, we find that the processing volume, the FFS charge, electricity price, and reliability of electricity supply most significantly affect the financial results (see **Exhibit 72**).

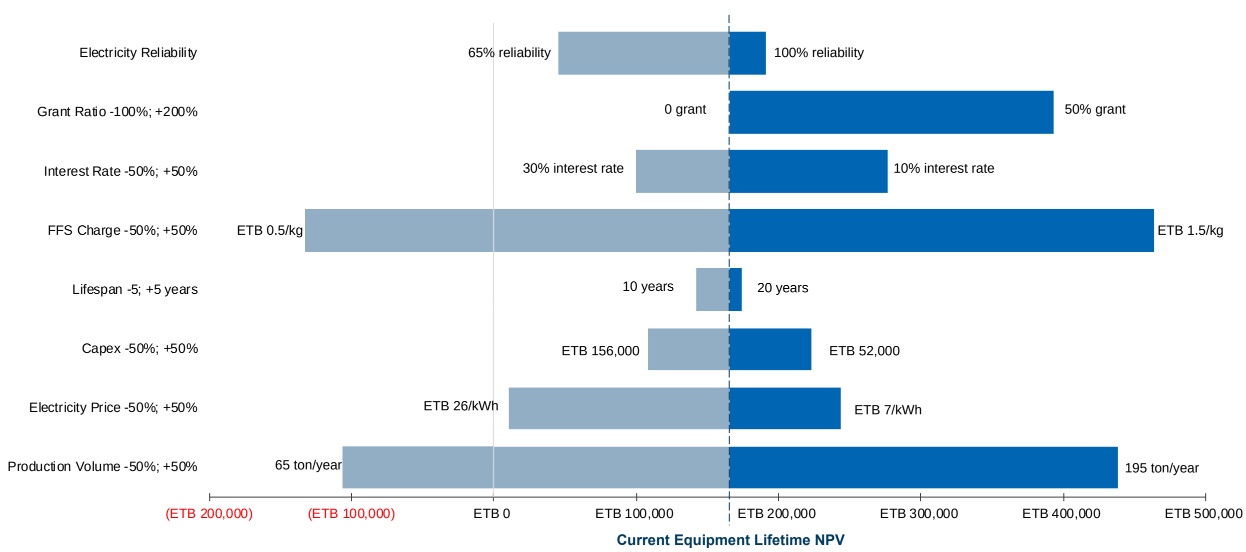


Exhibit 72: Processing Volume, Electricity Price and Reliability, and FFS Charge Have the Largest Impact on Expected Returns for Fee-for-Service Grain Flour Miller

Processing volume is one of the most volatile variables because crop production cannot be guaranteed and is dependent on exogenous variables such as rain and locusts. We assess the grain volume the miller requires to break even (where NPV equals zero) and find that the volume is feasible in communities where grains are the main crops for cultivation. This means that it is reasonable to assume that processors will have access to sufficient grains to make an electric mill a viable investment on most years.

Exhibit 73 shows that the break-even volume of grain (maize as an example) is about 91 tons per year. This amount roughly equals the harvest of 29 smallholder farmers in Amhara regions.[ciii] Survey results show that the median number of maize farmers in maize farming communities in Amhara is 120. In addition, almost all communities have other grains such as wheat, barley, and teff that can also be processed by the electric mill, representing additional milling demand. Therefore, it is highly feasible for a miller to process enough grains to sustain a profitable business.

However, the exact number of processors that a community can sustain will vary significantly by location as we observed a wide range in number of farmers and their grain production levels in surveyed communities. For instance, in Oromia, a median maize farming community produces about 317 tons of maize per year. In SNNPR, while both farming one hectare of maize, one farmer reported 3 tons of annual harvest while the other reported 2 tons.

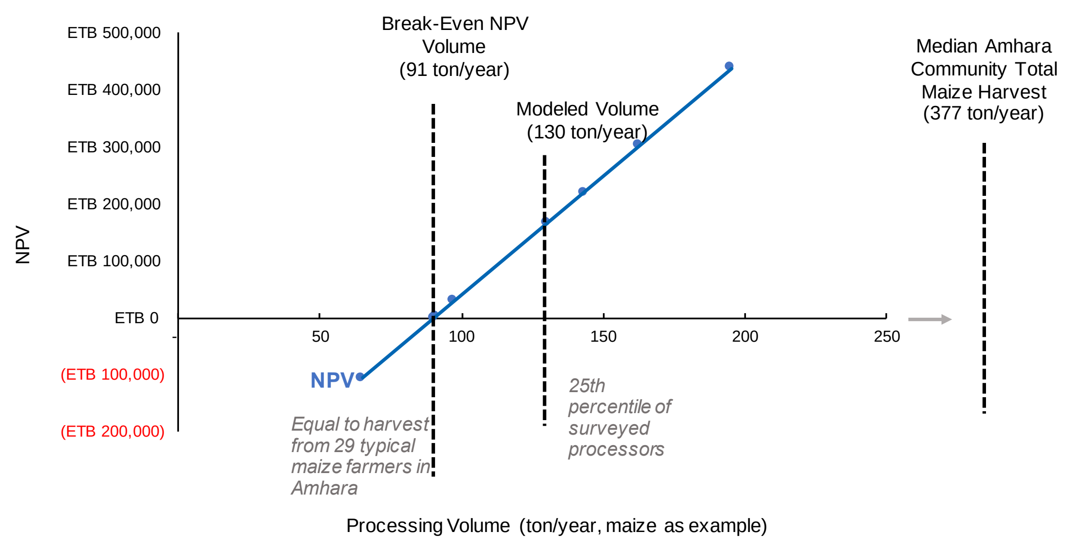


Exhibit 73: FFS Grain Flour Millers Can Break Even Processing Relatively Low Volume (Maize as Example)

With above analyses, we conclude that grain flour milling has high potential for electrification. In communities where there is sufficient processing demand, affordable and reliable electricity supply, and some financial support for early adopters, investment in electric mills can yield attractive economic returns for processors within a reasonable payback period.

[ciii] According to our survey, the average harvest of maize in Amhara is about 3.7 tons per hectare per year, and farmers farm 0.85 hectares of maize on average.

B.3 Minigrid Economic Analysis

B.3.1 Establish community archetype and load profile

We reference the load data from the Koftu minigrid site shared by the EEU to construct the annual baseline load for the baseline community. A 24-hour grain mill load profile is developed using processor survey responses (reported time of operation, equipment running capacity, etc.). We consider processing seasonality and days of operation to estimate different demand scenarios for productive loads. We run a HOMER simulation with the baseline load profile to size the minigrid system (the base scenario) and then run another HOMER simulation with load profiles of the other demand scenarios to make sure the same system configuration can support additional productive loads.

B.3.2 Key inputs and assumptions

We keep many of the default values in the HOMER modeling, including maximum annual capacity shortage of 0%, and 10% load plus 80% solar output required as the system operating reserve requirement.

We assume a single tariff is applied to all loads in the community, and that existing electricity consumption will not change with the introduction of productive loads. Key cost inputs and assumptions used in the minigrid economic analysis are summarized below.

	Model Input/Assumption	Explanation/Data Source
Minigrid Hardware Costs		
Solar CAPEX	US$588/kW	Includes pane and mounting structure, from minigrid in Ethiopia.
Battery CAPEX	US$117/kWh	Includes battery, rack, and housing, from minigrid in Ethiopia.
Diesel CAPEX	US$800/kW	Includes diesel genset and housing, from cost benchmark in Electrifying Economies Initiative.[173]
Converter/Inverter	US$143/kW	Cost data from minigrid in Ethiopia.
Distribution CAPEX	US$6,449/km	Cost data from minigrid in Ethiopia.
Metering CAPEX	US$48/meter	Cost data from minigrid in Ethiopia.
Grant support	100% for minigrid hardware cost and project development cost (excluding distribution)	In this nascent stage of the minigrid market in Ethiopia existing minigrids rely heavily on grant support. For EEU sites, generation assets are covered by grant or concessional loans, while EEU self-finances distribution cost. Rensys' pilot relied on 100% grant

		funding for CAPEX. We mirror the grant support in our analysis here to reflect current practices.
Project Development Cost		
Project design	US$10,500/project	Includes engineering, financial modeling, and system integration, from cost benchmark in Electrifying Economies Initiative.
Project preparation	US$9,537/project	Includes community engagement, site preparation, and other support (e.g., legal), from cost benchmark in Electrifying Economies Initiative.
Ongoing Cost		
Fuel	US$0.6/L (ETB 24/L)	Median from survey reported diesel cost.
Site O&M	US$10,500/year	From an expert interview, EEU's operating cost at the Koftu minigrid site (so far not running diesel) is about US$9,500/year, and operating cost of another minigrid system (no diesel genset) is about US$12,000/year. We used the average number here.
Financing Assumptions		
Debt interest rate	10%	According to the recent average loan interest rate at the Commercial Bank of Ethiopia (9.8%).[174]
Cost of Equity	15%	We assume minigrid developers' targeted return rate is 15%.
WACC	11%	Calculated with debt interest rate, cost of equity, and debt ratio. The WACC is used as the discount rate in minigrid project NPV calculation.
Project timeline	20 years	Typical lifetime of a minigrid project.

Exhibit 74: Key Inputs and Assumptions Used in Minigrid Economics Analysis

B.3.3 Inrush current calculation

We use equipment specification collected from suppliers to calculate the inrush current of a 3 kW, 220V three-phase grain mill. We assume start-up current is four times the normal running current of the motor,[civ] the motor efficiency is 90% as reported by equipment manufacturers, and a 0.86 power factor, which is common for induction motors with full load. The inrush current of the grain mill is calculated:

[civ] For an electric motor, the start-up current can be 4–10 times greater than the normal running current, and a soft starter can often reduce that by half, so we choose to model 4 times as the middle ground.

$$3\ kW \div 90\% \div 0.86 \div 220V \div 3\ (three - phase) * 1{,}000 * 4\ times = 23\ Amps$$

With the system inverter size of 16 kW as the HOMER result shows, the maximum single line current is calculated to be:

$$16\ kW \div 220V \div 3\ (three - phase) \div 0.86\ (power\ factor) \times 1{,}000 = 28\ Amps$$

Hence, the inverter can manage the start-up current from one modeled mill, and with the help of soft starters, a second mill should be able to be connected to the system without causing upsurge issues. Minigrid developers could also consider larger inverters in sites with significant productive loads to allow for higher current. The analysis here only provides directionally correct insights based on reported data. Site-specific analysis and field-testing are still needed. Minigrid developers should carefully test assumptions used here to assess their relevance to the conditions found in their specific site.

Appendix C Alternative Business Model

The cooperative-led business model is an alternative to the fee-for-service model and the utility-led model, where agriculture cooperative unions (the cooperative) own and operate the processing business.

In the cooperative-led business model, the cooperative acts as an off-taker, owns and operates the processing business, and sells to bigger markets. The cooperative brings agriculture sector expertise, member networks, and market linkages to develop the processing business. A facilitator supports the cooperative in developing a business plan, selecting equipment, and capacity building as necessary. The cooperative can mobilize funding through selling shares of the processing business to members, who will later receive dividends from the business. Other actors involved in the cooperative-led business model (the equipment supplier, the electricity provider, and the financial institutions) perform similar tasks to those included in the fee-for-service model.

There is precedent for this business model in Ethiopia. For example, the Raya Wakena Farmers' Cooperative Union in Oromia region developed a wheat flour processing facility. With support from Self Help Africa and Agriterra, the cooperative developed a business plan and mobilized capital by selling shares of the processing business, obtaining a bank loan, and accessing its own equity.[175] The Union buys wheat grain from its members, mills it into flour, sells the flour for a premium, and distributes dividends to its shareholders. The cooperative guarantees an off-taker market for its member smallholder farmers and generates profits for shareholders. The processing business faced working capital limitations; therefore future applications of this model may need access to more flexible sources of financing.

Despite this example, most agriculture cooperatives in Ethiopia focus on supporting farmers with access to inputs and extension services and lack the administrative capacity that implementing this model will require. In addition, the financiers (MFIs, CGFCs) we interviewed prefer working with individuals and small enterprises to cooperatives. As such, the cooperative-led business model may have limited scalability and may only be suitable in niche situations where the conditions are just right—surplus grain production, prevalence of a cooperative with the required expertise experience, and market linkages.

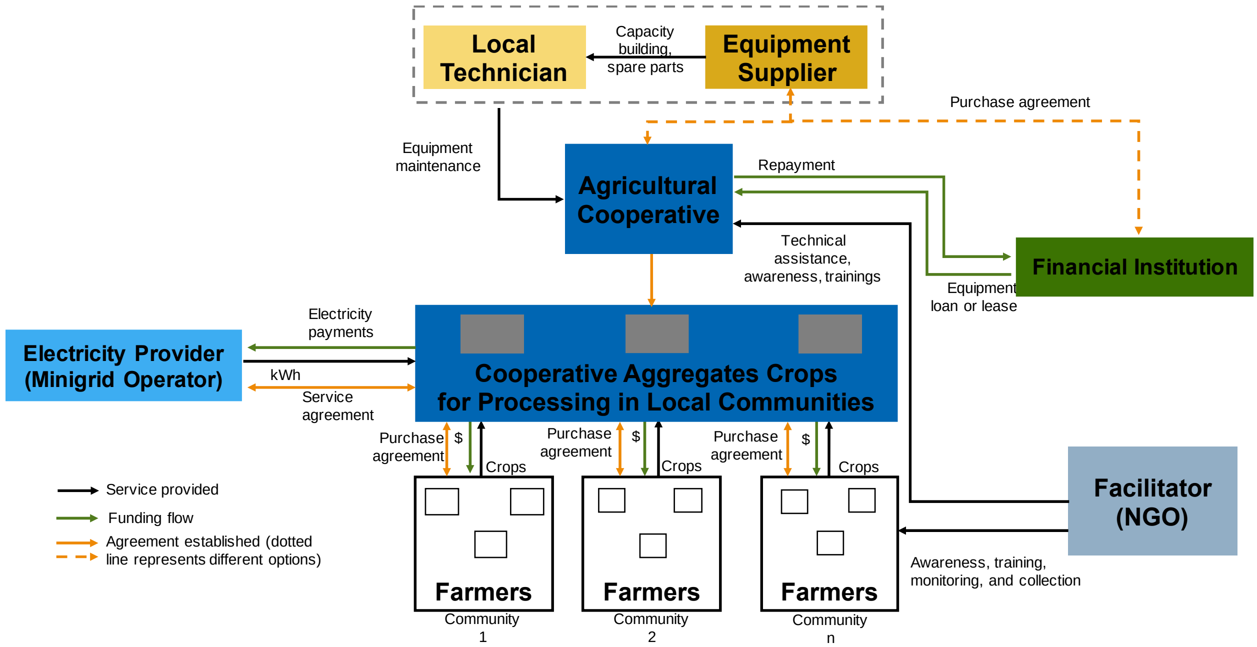


Exhibit 75: Institutional Arrangement for the Cooperative Model

Appendix D Detailed Design of Preliminary National Productive Use Program

This appendix presents a more detailed description of the eight projects constituting the preliminary design of the National Productive Use Program. These projects are categorized into the three building blocks summarized in **Section 6.2**. This project design will be ground-tested, refined, and finalized during the next phase of the project described in **Section 7.**

D.1 Align and Connect Cross-Sectoral Actors

Create and Strengthen Sector Alignment and Coordination for Productive Use

Context—The lack of collaboration and understanding of ongoing efforts, priorities, and challenges across energy, agriculture, and finance sectors restricts adoption of productive uses. The design sessions and dissemination seminars (see **Section 7**) will be the first step for establishing sector alignment, but these efforts need to be continued and home-grown to enable long term cross-sector coordination, and foster knowledge-sharing to integrate efforts in productive use.

Target insights—The objective of the project is to facilitate dialogue among stakeholders in energy, agriculture, and finance sectors to identify and mobilize cross-sectoral opportunities to implement productive use. Bringing together stakeholders that rarely coordinate will build awareness and a shared knowledge base of productive use opportunities. The project will offer stakeholders a platform for information exchange, to listen and learn from each other's' experience, and to identify productive use interventions that reinforce each other's' efforts. This sector alignment and coordination is essential to test the right things and establish an enabling ecosystem for productive use. The workshops will also enable sharing and learning from the results of the projects implemented through the National Productive Use program and support replication.

Project description—The project will support developing a Productive Use Committee, a cross-sectoral committee that supports the design, implementation, promotion, and dissemination of productive use projects and initiatives. The Productive Use Committee will be responsible for overseeing national-level strategy to support productive uses and the implementation of the Program. The Productive Use Committee will be comprised of a set of core members representing the key sectors. Participants in workshops can be expanded to include additional actors beyond the core members, to meet the needs in experience and skills required for achieving the specified outcomes of a workshop.

The first step will be establishing a committee charter defining member roles and responsibilities, frequency of meetings, and reporting and communication plans. The Productive Use Committee will then define the planning for the year in support of the Program, defining outcomes, themes, and topics, and selecting working groups that provide the skills and experience needed to address the specific theme. The Productive Use Committee (or a smaller team delegated to do so) will then plan the workshops.

These workshops will be designed to achieve specified outcomes. Different working groups will be assembled around targeted productive use themes (initial topics could emerge from the design sessions) involving actors across sectors and functions (e.g., leadership, technical staff). For example, one of the workshops can focus on identifying ongoing agriculture sector projects with energy needs and determining the opportunity for productive use. As the implementation of the Program advances, updates and revisions will also become necessary and one of the workshops can focus on revising the pipeline of projects to address new challenges and opportunities.

Project Team—A trusted organization that understands the Ethiopian context will first lead the effort to present the initiative to and get buy-in from top leadership of core member organizations in energy, agriculture, and finance sectors. The organization can then help identify participants that will form the productive use committee. The Productive Use Committee would include representatives of MOWIE, the Ministry of Agriculture, ATA, the Ministry of Economic Planning, and the Ministry of Finance. Then, based on the planning for the year, the Productive Use Committee will select working groups. Examples of working groups and themes could include:

- National-level Policymaker Group: to identify and address regulations and policy gaps and align national-level strategies and programs to implement productive use projects.

- Agency Technical Staff and Community Group: to share project experience and identify opportunities within ongoing projects to include productive use components. For example, EEU can overlay the Least Cost Electrification Plan with the ATA agriculture survey to identify potential sites for minigrid-powered productive use projects. The Ministry of Agriculture could identify energy needs within ongoing projects in the agriculture space, and the cohort can brainstorm how to develop projects to address those energy needs. These discussions can bring in community-level stakeholders to connect these projects to local user and regional needs and priorities.

Timeline—The project will start in Year 0 and continue throughout the timeline of the Program. The **preparation and development stage of the project will occur in the first six months**. This stage will include the following activities:

- Activity 1. Establish the Productive Use Committee

  - *Activity 1a. Introduce initiative.* Present initiative to and get buy-in from top leadership in core member organizations.
  - *Activity 1b. Define participants*. Define specific participants within core member organizations that will form part of the Productive Use Committee
  - *Activity 1c. Agree on initiative*. Develop and approve a committee charter defining roles, duties, and responsibilities of core members.

- Activity 2. Plan Cross-Sectoral Workshops.

    - *Activity 2a. Define high-level programming.* Determine the goals to achieve and themes to address and develop a workshop schedule and annual plan. Define the number of workshops to be held and their timing, and determine specific outcomes for each workshop. The workshops can be held on a quarterly or monthly basis depending on the need.
    - *Activity 2b. Carry out detailed planning of individual workshops*. In preparation for each workshop, carry out the detailed planning of the event, including designing the agenda, defining participants, and determining the timing needed to achieve the desired workshop outcomes.

During the **following six months of the year**, the productive use committee will **hold the cross-sectoral workshops** and carry out the planning for the next year.

- Activity 3. Hold Cross-Sectoral Workshops. As specified under Activity 2, the cross-sectoral workshops will be designed to achieve specified outcomes.

Scaling strategy—Over the long term, the Productive Use Committee will oversee and develop opportunities to extend productive use from specific hubs (e.g., projects implemented in the Program) to the full country. In doing so, the Productive Use Committee will evaluate new concepts demonstrated—like the feasibility of pairing agricultural and electricity programming for more robust development outcomes. Then, the Productive Use Committee will engage other regional stakeholders to disseminate knowledge on and support replication of successful business models throughout the country.

The pilot and demonstration projects implemented in the first few years of the Program will also reduce the risk (or risk perception) of potential investors in the productive use and electrification space. To maintain and continue scaling the successes achieved thus far, the Productive Use Committee will create promotional materials attracting investors to financing opportunities. Through support from development partners like the World Bank, GIZ, and the African Development Bank, the pilot demonstrations from the Program will be used to promote additional fundraising and investor education.

Outputs:

1. Educational materials to stimulate financing for commercial agricultural productive use projects.
2. Dissemination and awareness-building activities to share the findings from the projects implemented in the Program.

D.2 Demonstrate the Technical and Financial Viability of Equipment and Business Models

This section includes the following preliminary projects:

- Electric Mill Prototyping Pilot
- Fee-for-Service Demonstration Project
- Utility-Led Demonstration Project
- Cooperative-Led Demonstration Project

Electric Mill Prototyping Pilot

Context—Minigrids have limited power supply compared with the main grid, and their power supply is contingent on component sizing (e.g., inverter power rating, which will vary from system to system). Therefore, ensuring equipment compatibility with the power source is a harder challenge to address in isolated minigrid settings compared with areas served by the national grid.

Target insights—The pilot will determine the performance requirements to ensure equipment compatibility with equipment operator and end-consumer preferences and minigrid systems.

Project description—The pilot will debug and field-test prototype equipment in minigrid communities. Equipment testing and fine-tuning will occur in the supplier workshop and at minigrid sites that are representative of high grain production communities across Ethiopia. The team will aim to select sites based on representative values of community size, grain production volumes, mill processing capacity, and throughput gathered from the field survey (see **Section 2**) and the Data Pilot (see **Section 7.2**). This dual-stage testing approach will ensure that equipment performance is finetuned for ground realities.

Planned activities will include:

- Assessing equipment performance against specified international standards and modifying equipment design to ensure performance meets those standards (in the lab setting).
- Installing equipment in minigrid sites and training processors on equipment use and data recording.
- Assessing equipment performance against end-consumer and equipment operator needs and minigrid compatibility requirements. This step will include finetuning equipment design to those needs and requirements.
- Providing servicing and maintenance of equipment to ensure proper operation for the duration of the pilot.

The pilot will test equipment performance on:

- Ability to produce products that meet end-consumer quality requirements (e.g., flour fineness, consistency, taste).
- Capacity to meet the equipment operator's needs like energy efficiency and production speed.

- Meeting minigrid compatibility requirements including limiting power quality impact (e.g., voltage variations) and preventing damage (e.g., burning meters, wires, and other components).

Project Team:

- **The equipment supplier imports or manufactures the electric mill.** The equipment supplier will test equipment performance against specified international standards and finetune equipment design to meet those standards. They will also help install equipment in sites, train the equipment operator to use the equipment, and test equipment performance on-site. They will compare equipment performance against end-consumer and operator needs and finetune equipment to ensure compatibility with those needs, preferences, and minigrid requirements. The equipment supplier will also provide spare parts to local technicians for repairs and maintenance.
- **The local agriculture mechanization expert works closely with the equipment supplier and operators, providing technical expertise for equipment testing and data collection.** This technical expert will advise in developing equipment specifications, translating equipment operator and end-consumer needs into equipment specifications that the equipment supplier will use to manufacture equipment or redesign imported equipment. The technical expert will lead the training for the equipment operator on using equipment and collecting data, and provide support in troubleshooting and debugging the equipment during field tests. They will also conduct periodic data collection to assess pilot results.
- **The minigrid operator (e.g., EEU) ensures the supply of reliable electricity.** The electricity provider will support equipment connection to the minigrid by advising on the due process and any fees due. They will provide technical support for equipment connection to the minigrid, ensuring minigrid and operator safety. They will also provide the minigrid data required to assess the impact of connecting the equipment on minigrid performance.
- **The processors operate the electric mills.** Individuals or groups selected as processors for the pilot will have basic business and finance literacy as well as a good track record of operating processing businesses. The processors will carry out data collection on daily business transactions like grain quantities milled as well as frequency of equipment maintenance and breakdowns.

Timeline—The Prototyping Pilot will begin in Year 0 of the timeline of the National Productive Use Program and last for 1.5 years. Workshop equipment testing against international standards and field equipment testing will each last three months. Processors will then operate the equipment for a full year to ensure data collection covers a full cycle of grain production seasons and incorporate the potential impact of seasonality on equipment operation.

Scaling strategy—The specifications of equipment compatible with end-consumer and operator needs and minigrid requirements will be shared with the Ethiopian Standard Agency (ESA), equipment suppliers, and equipment financing institutions. It will serve as a baseline for performance assessment of milling equipment on the market. The insights on operator and end-consumer needs and minigrid requirements can serve as a starting point to categorize and eventually standardize milling equipment performance to increase transparency for making equipment selection decisions. More immediately, the specifications of technically viable equipment will be used for equipment selection in the business model projects (see *Fee-for-Service*, *Utility-Led*, and *Cooperative-Led Demonstration Projects*)

Fee-for-Service Demonstration Project

Context—The economic analysis presented in **Section 4** indicates that fee-for-service electric milling is economically viable. But these results are based on reported data from field surveys and information gathered from our literature review. Fee-for-service electric grain milling in rural communities has not been ground-tested and proven commercially viable. Evidence showing that project revenues are high enough to cover expenses of the business model and pay back loans is necessary to attract adopters.

Target insights—The goal of the pilot is to test whether the electric fee-for-service milling business model is economically viable and assess the impact on minigrid economic and operational performance. The project also aims to reveal the conditions and characteristics wherein this model is viable, to guide replication in suitable rural communities in Ethiopia.

Project description— Electric mills will be introduced to replace diesel-powered mills, or as a new business opportunity for willing entrepreneurs. Processors will run the processing business on a fee-for-service basis with support from the facilitator providing capacity building and linkages to financing (see *Designing and Piloting Financial Solutions*). The project will also gather information from the diesel-operated mills as a baseline to compare the performance of the electric mills.

The project will collect measured data of processor revenues, operating costs, processing volumes, time-of-use of equipment, capacity utilization, and efficiency, while documenting any technical and managerial challenges processors encounter. Analyzing this data will reveal the viability of the electric milling business compared with diesel-run alternatives, and more importantly, the drivers (such as processing volume and electricity cost) and enabling conditions (such as reliable electricity supply and business management capacity) for business success.

In this way, even if this pilot fails to prove the commercial viability of the electric milling businesses, it will increase and deepen understanding on key success factors. For example, if processing volume is the main driver determining profitability and these levels were too low in the selected communities, future projects would prioritize selecting communities with more processing demand or re-designing equipment for smaller-scale operations.

The team will select sites with prevalent demand for grain milling and electricity access. For example, the Kogo Ashebeka kebele in the Arsi region of Oromia could be an attractive site for the pilot. Kogo Ashebeka has over 200 wheat farmers, over 200 barley farmers, and other farmers growing maize, peas, and other crops. This 2,000-household agrarian community is home to four millers providing processing services to local households. The kebele does not have access to electricity yet, but it is targeted for minigrid electrification in the National Electrification Plan. The team will coordinate site selection with the EEU.

Project Team:

- **The processors own the electric mills and are responsible for operating the processing business.** Individuals or groups selected must have basic business and finance literacy, and preferably a track record of operating successful milling businesses. The candidates must be committed to support project success by participating in trainings, monitoring and reporting data diligently, and contributing to a portion of the equipment cost (e.g., 20%). Existing processors with diesel mills in the community who are interested in testing electric mills are well positioned to fulfil the processor role as they are already familiar with the business model and serving customer needs.

  Sasakawa Africa Association and AgroBIG have experience organizing women and youth groups who graduated to equipment ownership and operate successful agro-processing businesses (see Box 5-1). Such women and youth groups could be candidates for the processor role.
- **The facilitator works with the processors, providing capacity building and connecting them to financing.** The facilitator will have experience supporting rural agriculture mechanization—introducing technologies, providing capacity building around business development and equipment operation, and facilitating access to financing. Most importantly, the facilitator needs to have relationships with and trust from local community members.

  Sasakawa Africa Association may be an attractive candidate to fulfill the facilitator role, given its experience developing post-harvest agro-processing projects, including grain milling across different regions in Ethiopia. In previous projects, Sasakawa collaborated closely with local agriculture bureaus and support offices, delivered equipment to rural communities, organized trainings for women groups on equipment operation and business management, and trained local technicians to properly maintain equipment. This substantial experience would be relevant for the project.
- **The electricity provider ensures the supply of reliable electricity.** The electricity provider will be a minigrid developer with experience serving productive use loads and proven willingness to test productive use business models. The electricity provider will advise on equipment specifications suitable for minigrid system configurations, will support assembling and calibrating the sensors and meters, and will train the facilitators on how to connect the sensors to the mills to ensure accurate data collection. Rensys Engineering, for example, provided lease-to-own cooling appliances to local fishermen in the Dek Island minigrid pilot and is assessing and developing projects exploring productive use opportunities in other minigrid sites.
- **Donors channel funding through local MFIs to finance equipment purchase.** In this proof-of-concept project, donor support is necessary. The Designing and Piloting Financial Solutions project will be executed in parallel and will focus on designing financial solutions that meet processor needs and mitigate financier perceived risks. That

financing will be channeled through this and the other demonstration projects (see *Utility-Led and Cooperative Demonstration projects*). See *Designing and Piloting Financial Solutions* for a more detailed description on potential candidates to fulfill this role.

- **The equipment supplier coordinates with the processor and the facilitator to supply electric mills and provide repair services.** This project will build on the findings of the Electric Milling Prototyping project, and those project results will guide the facilitator and supplier on the equipment specifications to use. The supplier will train equipment operators and local technicians and will provide spare parts for repairs. AMIO Engineering may be a suitable candidate to fulfill this role because it has experience prototyping equipment for small-scale agro-processing and in supporting after-sale services.

Timeline—The pilot will start in Year 1 (after the electric equipment has been field tested) and end in Year 4.5. Although this project will subsidize a portion of equipment loans, capturing performance for the full duration of expected loan tenors will ensure the project can capture data to assess whether the processor is able to generate enough revenues to repay full equipment loans (without subsidies). As such, the duration was set to cover the development stage and the estimated payback period of around 2.4 years presented in **Section 4**.

Scaling strategy—Results on the financial viability of the fee-for service business model will be shared to attract investor interest and replicate its application in other communities. Proof points on the business case of electric milling will reveal conditions of where and when the business model can be successful and guide the design of future initiatives. For example, the break-even processing volume can be used to shortlist geographies with sufficient processing demand in the roll-out of minigrids and grid extension under the National Electrification Plan 2.0. Additionally, the cost of service can inform tariff setting and the timing of cash flows can be used by finance providers to fine-tune repayment schedules.

Utility-Led Demonstration Project

Context—Most investments in rural electrification today are not accompanied by a surge in income -generating activity and most electricity providers find that electricity demand is too low to sustain a business case for electricity systems. Agriculture and electricity actors rarely coordinate to understand which agricultural activities to electrify (and where) to generate win-win opportunities for both sectors. Many electricity providers lack the content knowledge and financial resources required to support productive uses.

Target insights—The goal of the pilot is to test whether the utility-led business model is feasible and economically viable, and to assess the impact on minigrid economic and operational performance. The project also aims to reveal the conditions and characteristics wherein this model is viable, to guide replication in suitable rural communities in Ethiopia.

Project description—The minigrid developer will develop an appliance financing program, providing mills to processors on a lease-to-own basis. The appliance financing program can offer other equipment if other studies identify viable opportunities. For example, Veritas and Rockefeller are exploring the viability of small-scale irrigation and cold storage for horticulture production. This project design is tailored to supply grain mills, but a similar design can be used for supplying other types of equipment.

There is early precedence for the utility-led model in Ethiopia. For example, Ethio Resource Group (ERG), a minigrid developer in Ethiopia, is partnering with an associated equipment manufacturer to prototype a minigrid-compatible electric grain mill. If successful, they will work with local processors to replace existing diesel mills. The Utility-Led Demonstration Project will capture and build on the results of this early experiment.

Project Team:

- **The minigrid developer develops and manages the appliance financing program.** The developer (e.g., Rensys, ERG, EEU) will lead, with facilitator support, assessing the prevalence of milling demand in their site, understanding end-consumer and operator preferences, and collaborating with equipment suppliers to supply compatible mills to processors in their community. The minigrid developer will oversee connecting the mill to the minigrid, collecting lease payments from the processor and liaising with equipment suppliers to enforce warranty and maintenance terms of the lease. The minigrid developer will also oversee the monitoring and evaluation system to capture and share the results or the project.
- **The facilitator supports the minigrid developer in identifying productive use interventions and understanding processor needs.** The facilitator will connect the minigrid developer to processors and where necessary, may advise the minigrid developer on end-consumer and operator preferences and the productive use opportunity on the site. The FFS demonstration project notes candidates for the facilitator role that may also be a good fit here.
- **Processors acquire equipment and operate milling businesses.** The processor will contribute a portion of the equipment cost (e.g., 20%). The processors will fulfil the lease terms and be responsible for correct operation of the mill to ensure its safeguarding, reporting issues to the developer who will coordinate maintenance and enforce the warranty as needed. They will also record revenue and cost data for periodic collection by the minigrid developer.
- The **equipment supplier and local finance provider** play similar roles to those specified in the FFS Demonstration Project.

Timeline—The pilot will start in Year 1 (after the electric equipment has been field tested, and in parallel to the FFS and Cooperative-Led Demonstration Projects) and end in Year 4.5. This project will subsidize a portion of equipment loans. However, capturing performance for the full duration of expected loan tenors will ensure the pilot can capture data to assess whether the minigrid developer can recover loans made to the processor and recover the expenses of operating an appliance financing program. As such the duration of the pilot was set to cover the development stage and the estimated payback period of an electric mill of 2.4 years.

Scaling strategy— Results on the financial viability of the utility-led business model will be shared to attract investor interest and replicate its application in other communities, where suitable. The project will provide tools and templates documenting the process and agreements used to simplify the replication of the model.

Cooperative-Led Demonstration Project

Context—Agriculture cooperatives play a key role in helping smallholder farmers access farming inputs and extension services in Ethiopia. Cooperatives offer a way for members to pool resources and improve farming practices (e.g., purchase better seeds, access capacity building) and achieve better market conditions (e.g., gain more bargaining power). Some cooperatives already have experience providing processing services and market linkages to members.

The Raya Wakena Farmers' Cooperative Union in Oromia for example, established a wheat flour processing facility that buys raw crops from members and sells flour to bigger markets. Although most rural farmers mill their grains in small quantities immediately before consumption, there are offtake markets for maize and wheat flour in bigger communities close to major cities. Nonetheless, electric cooperative-led processing has not been proven viable yet, especially in rural unelectrified regions.

Target insights—The project tests the financial viability of electric milling via the cooperative based model and determines the conditions where the cooperative-based model is appropriate. For example, the project will explore the minimum trade volumes and economic returns needed to cover the expenses and justify the efforts of this more complex model, including establishing a new business line, training cooperative members, and marketing products.

Project description—The cooperative, with support from a facilitator, invests in electric mills to start a new business line, aggregates and offtakes grains from surplus communities, and sells flour to consumers in other regions. The project will target larger-scale processing than in the fee-for-service model and will require working with a cooperative with established trade channels and market linkages.

The project will evaluate the economic viability and feasibility of the cooperative-led processing business. To do so the project will gather information on the purchase price of grain, sale price of flour, electricity consumption and cost, operating and administrative expenses, time of use of equipment, and equipment performance, along with procedures to establish the business and engage with different stakeholders involved.

The project will target locations where local farmers have surplus grain production. For example, more than 90% of the 900+ households in Yedengora kebele grow maize, wheat, and teff. There are two grain millers in the kebele meeting local processing needs for subsistence, but more than half of the grains are traded to outside consumers. The local cooperative could invest in a processing center to offtake surplus production, process it into flour, and sell it to urban or peri-urban consumers. The kebele is categorized as Grid Priority in the National Electrification Plan, suggesting that there is infrastructure (e.g., roads) in place or planned that will allow grid extension, that would also facilitate access to broader markets. This model has the additional benefit of creating additional value for the community.

Project Team

- **The cooperative identifies market opportunity and owns and operates the processing business.** The cooperative is responsible for securing member buy-in and the financing needed for investment and working capital. The cooperative will source grains from local smallholder farmers at market competitive prices, process and sell flour, and distribute dividends to shareholding members. The cooperative should have a track record that indicates strong administrative capacity.
- **The facilitator supports the cooperative with technical assistance and capacity building**. The facilitator will work with the cooperative to develop a business plan (including assessing offtake market potential), recommend equipment, build awareness among members, and facilitate market access. The facilitator will organize training covering business management, equipment operations and maintenance, data collection and reporting. A qualified facilitator must have experience working with cooperatives, a deep understanding of the sector, and the ability to connect cooperatives to markets and finance.

  Self Help Africa could be a potential candidate for this role. Self Help Africa has decades of experience in Ethiopia designing and implementing interventions to support agricultural development through cooperatives. Self Help Africa has supported the Raya Wakene Cooperative, along with other primary cooperatives, to get access to mechanization, finance, and strengthen market linkages.
- **The electricity provider supplies electricity to the processing business.** The electricity provider will support installing and calibrating the sensors and meters on the equipment and the processing business to ensure accurate data collection. The electricity provider will ensure reliable electricity supply and share electricity consumption data on a timely basis. Given the processing facility is likely to be a larger customer, the cooperative model has a higher chance of success if it is located in a grid-electrified area or connected to a larger minigrid system.
- **The cooperative can mobilize equity and debt to finance equipment purchase to establish the processing business.** The cooperative will cover a portion of the cost to establish the processing business. In this early-stage pilot where the business is not proven viable yet, donor funding will be necessary to encourage cooperatives to take on the operational and credit risk to establish and operate the business. The financial solutions and funding in the Designing and Piloting Financial Solutions project will be channeled here.
- **The equipment supplier coordinates with the cooperative and the facilitator to deliver a suitable electric mill for the pilot.** Similar to other business models, the equipment supplier will support equipment operation training and provide spare parts to local technicians when equipment service and maintenance is required.

Timeline—The timeline will be similar to the timeline for the other demonstration projects.

Scaling strategy— Results on the economic viability and feasibility of the cooperative-led business model will be shared to attract investor interest and replicate its application in other communities, where it is suitable.

D.3 Develop Supportive Policies

This section includes the following preliminary projects:

- Designing and Piloting Financial Solutions
- Electric Equipment Selection Tool
- Scaling Capacity Building

Designing and Piloting Financial Solutions

Context—Access to affordable financing is a top barrier for would-be processors to invest in electric equipment (see **Section 6.1**). Although our analysis indicates electric grain milling is economically viable with prevailing market terms, microfinance institutions (MFIs) in Ethiopia do not offer loan products specifically designed for financing small-scale agro-equipment and lack the knowledge to properly serve the market. Unlocking the financing market for electric equipment requires supporting finance providers in understanding productive use, designing suitable financing products, and de-risking productive use investment.

Target insights—The key objective of the project is to de-risk financing in the small-scale agro-processing market.

Project description—The project will develop and backstop financing products to fund equipment purchases in the demonstration projects included in the National Productive Use program. In doing so, the project will build comfort and experience among participating finance providers in serving the electric agro-equipment market.

A small set of finance providers will receive technical advice to assess the results of the Data Pilot (see **Section 7.2**), understand electric milling businesses, and determine their financing needs. The team will then design the characteristics of loan products that will be tested in the demonstration projects (the FFS, Utility-Led, and Cooperative-Led Demonstration Projects presented in this Appendix) including defining the interest rate, tenor, and payment schedule. The loans will be backed by a partial guarantee to encourage MFIs and capital goods finance companies (CGFCs) to participate in the project. The technical advisory component will also equip the finance providers to continue financing the electric agro-equipment market by providing training on evaluating loan applications and other needs identified through the project.

Project Team—The project team will be led by a technical advisory firm that collaborates closely with participating finance providers and donor partners. The MFIs and CGFCs will then coordinate with equipment investors in the demonstration projects.

- **The technical advisory firm provides guidance to design financial products and capacity building.** The firm must have strong financial sector expertise and understand the Ethiopia context. It will lead the assessment of financing needs, design the financial solutions, and provide capacity building for MFIs and CGFCs. The firm will closely coordinate with the facilitators in the demonstration projects to monitor the performance of the milling businesses and flag issues with loan repayment that may require finetuning loan design.
  - BFA Global for example, has experience working on development projects focusing on financial services in Africa, designing financing products, conducting financial analysis, creating credit scoring metrics, and offering technical assistance to small enterprises and MFIs. SELCO Foundation also has extensive experience with the design of financial solutions, within the context of rural energy service delivery and it recently launched its program in Ethiopia. Organizations like BFA Global and SELCO Foundation may be candidates to consider for this role.
- **The MFIs and CGFCs finance equipment loans in the demonstration projects.** Participating MFIs and CGFCs need to commit to project success and assign dedicated staff and focal points for the project. These staff will collaborate closely with the technical advisory firm to design and launch products and attend training sessions. MFIs and CGFCs will also monitor loan and lease performance, tracking and documenting loans disbursed, end uses, and repayment rate and noting any issues equipment investors encounter during application, repayment, and any follow-up process.
  - The Amhara Credit and Savings Institution (ACSI) and Waliya CGFC serving Amhara, and the Oromia Credit and Savings Share Company (OCSSCO) and Oromia CGFC serving Oromia already have experience collaborating with international donors and organizations on development projects and may be candidates to consider for this role.
- **Guarantee facility backstops equipment loans.** The facility will offer partial credit guarantees to reduce credit risk and serve as an alternative to collateral requirements. The facility will rely on donor funding at the early stage while the demonstration projects are tested. DBE has experience managing guarantee facilities and may be well-positioned to administer the facility. For example, the Global Environment Facility, together with UNDP and UNCDF, provides a guarantee facility at DBE, supporting small and medium enterprises working on renewable energy technologies.

Timeline—The project will start in Year 0 so that the loans can be disbursed around Year 1 through the demonstration projects. The project ends in Year 4.5 and will cover the full tenor of the loans and/or leases offered.

Scaling strategy—To ensure that the findings and lessons learned on viable business models and characteristics of viable financial solutions are replicated beyond the specific hubs defined in the National Productive Use Program (the three demonstration projects) and adopted by more MFIs and GCFCs serving rural communities throughout Ethiopia, two initiatives are needed:

- **Awareness raising and dissemination**. The project will generate evidence and data on viable business models and financial solutions. Data and training materials illustrating viable financing terms, pilot results, and lessons learned will be shared with other MFIs and CGFCs to generate interest and draw more participation and capital to support the sector. This scope of work will be included in the dissemination activities that the Productive Use Committee is responsible for (see *Create and Strengthen Sector Alignment and Coordination for Productive Use*).
- **Establishing the infrastructure and support systems.** For productive uses to scale, MFIs and CGFCs need to serve the appliance financing market. This may require taking the lessons from the project to understand the financier needs and determining the infrastructure needed to provide that support at a wider scale. For example, this may include setting up a fund of funds that addresses the lack of liquidity identified by MFIs as a challenge to expand their portfolios and serve new markets, expanding the guarantee mechanism developed under the project, or both. The exact support and infrastructure needed to provide this support at a broader scale will be defined based on the results of the project. These actions can be rolled into a new project as the National Productive Use Program is revised and updated.

Electric Equipment Selection Tool

Context—Selecting electric equipment that can be used in minigrid communities requires triangulating compatibility requirements between the minigrid system, the equipment operator (or processor), and the end consumer (e.g., the person procuring milling services). The lack of market information indicating which equipment options can safely connect with minigrid systems without impacting power quality, and meet operator and end-user needs for energy efficiency, throughput, and product quality makes equipment selection difficult. For example, determining minigrid compatibility requires understanding requirements for startup current, current, and voltage, which vary depending on the minigrid system. This is information that processors lack. Processors need guidance in selecting equipment that meet their needs and system requirements.

Target insights—This project aims to develop an equipment selection tool to help processors (equipment operators) select minigrid-suitable equipment that meets their needs. The project will generate a database with tested and certified equipment performance specifications and minigrid profiles providing location and component data and defining the equipment requirements to ensure compatibility with the system. The database will be linked to a user-friendly interface to help users select equipment. This tool will simplify and streamline equipment acquisition by eliminating the need for technical support in equipment selection, helping scale purchases of equipment in rural communities in Ethiopia.

Project description—The project will include four stages of implementation as described below:

- **Phase 1: Generating a database of productive equipment and performance specifications.** This will include testing equipment to verify key parameters that affect minigrid power quality (e.g., startup current for heavy motored equipment like grain mills, current and voltage fluctuation with loading/use variation, energy efficiency etc.). The testing outcomes will generate a certification label to attach to the equipment as a performance reference point for the equipment seller and buyer.
- **Phase 2: Developing minigrid profiles.** Minigrid developers will compile data on the precise location of their minigrids and the territory/zone served by each minigrid. They will also include technical specifications of the minigrid system and its components including inverters, meters, distribution network cable sizes, etc. This minigrid specification data, in combination with the equipment performance data, will serve as the reference database for the equipment selection tool.
- **Phase 3: Developing a data referencing algorithm and user-interface for the tool.** To use the equipment selection tool, the equipment supplier will input the site location where the processor plans to install the equipment and scan the certification label attached to the equipment the processor wants. The tool will then generate a confirmation (or rejection) of compatibility between the processor's power source and their desired equipment. This phase will involve creating the algorithm that the tool uses to compare the specifications of a scanned equipment label to the power supply of a minigrid located where the processor plans to install the equipment. It will also include developing a user-friendly interface that the equipment supplier accesses to input location data, scan the equipment label, and receive compatibility results.
- **Phase 4: Tool testing, awareness raising, and training.** This stage will include testing the tool with an equipment supplier, minigrid developer, and processors for ease of use and accuracy of compatibility results. Once any identified issues are solved, the project team will carry out awareness raising for the tool with equipment suppliers, minigrid developers, and processors. Awareness-raising activities will be accompanied with training on using the tool appropriately to ensure accurate results.

Project Team

- **Expert on equipment performance and standards carries out equipment testing and develops the equipment certification label.** The expert will lead equipment testing and developing the database of productive equipment and its performance specifications. They will also develop the certification code for labeling tested equipment. This role is best suited to an organization with "performance testing and standards" experience. The International Electrotechnical Commission (IEC) could fulfill this role in collaboration with the Ethiopian Standards Agency (ESA), since the ESA does not currently test or enforce standards for most productive equipment like grain mills. In addition, the IEC already has plans to pursue a similar approach to provide guidance in selecting equipment for households using solar home systems.
- **The minigrid operators compile minigrid location and technical specification data.** Minigrid developers will provide minigrid data for the tool's database, which is required for cross

referencing with equipment specifications in comparing compatibility of equipment and power supply. EEU, which owns the majority of minigrid systems planned for the short to medium term, will play a key role in providing this information.

- **The equipment supplier to applies the tool while supporting a processor in selecting equipment.** The equipment supplier is the core user of the tool, and will input the equipment buyer's location information, scan the equipment label, and generate the compatibility report for the buyer.
- **The tool developer designs the tool.** The tool developer will develop the tool's back-end algorithm that will evaluate equipment specifications against power supply at the buyer's chosen location. They will also develop the front-end user interface that the equipment supplier will access when they use the tool. This role is suited to a software development expert or organization with experience in developing back-end algorithms as well as front-end graphic design, for a user-friendly tool interface.

Timeline—The tool will be developed targeting one type of equipment to start with. Based on the analysis presented in **Section 3**, we suggest prioritizing grain mills. This stage will start in Year 1.5 and last for approximately 15 months. Phase 1 will start in Year 1 and last approximately six months. Minigrid developers can implement Phase 2 (minigrid data compilation) in parallel with Phase 1. The tool developer, with access to the database, will require at least six months to design and test the tool. When the tool is operational, raising awareness and training users will require an additional three months.

Scaling strategy—The tool will require continuous promotion to minigrid developers to ensure they update the minigrid location and technical specification database as they commission new minigrids. Expanding the database to include more types of equipment will require additional testing and certification labelling. We recommend aligning the order of equipment captured in the database to the electrification potential of activities based on this (see **Section 3.1**) and other studies.

Scaling Capacity Building

Context—The business models (see **Section 5.1**) are designed to embed capacity building to prepare for and during project implementation. This capacity building is channeled through the facilitators who are responsible for training the processor or equipment operator to select the right equipment, access financing, and develop their businesses. The proposed business models (especially the FFS model) place a strong weight of responsibilities on the facilitator. Executing these responsibilities successfully will require significant expertise and experience.

The biggest risk in proving the commercial viability of business models and then scaling their adoption is not finding adequate candidates to fulfill the facilitator role. We should expect that the level of expertise and experience will vary across would-be facilitators in Ethiopia. Support is needed to assess the relative strengths of would-be facilitators and support those facilitators that pass a minimum benchmark to fulfill the role effectively.

Target insights—Support facilitators in curriculum development by providing a starting point and templates offering a floor level of quality for training and support provided. Connect shortlisted facilitators with project opportunities.

Project description—The project provides tools and guidance to help facilitators carry out their responsibilities. The project will develop a standardized curriculum and training materials including manuals and guidelines that processors need to develop and operate an agro-processing business with electric equipment.

The materials will cover technical, financial, and managerial aspects to strengthen the expertise of processors and entrepreneurs. For example, the materials can include a business development and management guide (e.g., to improve business management and financial literacy), an economic and financial analysis template to assess equipment investment, and a user manual to help with basic troubleshooting and maintenance of common types of electric equipment. However, facilitators will still be expected to adapt the curriculum based on the specific needs of the processors or entrepreneurs found in their community.

The project will also create and host a one-stop depository for easy access to materials (e.g., a website). The depository will include additional information to help connect project opportunities to shortlisted facilitators. This includes a roster of would-be facilitators that have been shortlisted based on their capacity to fulfill the role effectively. The depository can also advertise project opportunities in specific communities (e.g., a minigrid developer is looking for a facilitator to support with implementing a specific productive use initiative) to connect with interested shortlisted facilitators.

Project Team—A project lead will oversee developing the depository and its components. The project lead will develop and manage the depository and recruit and shortlist facilitators to be included in the roster. The project lead will also oversee developing the standardized curriculum and training materials. They may choose to hire the services of a consultant to prepare these materials. For example, the project lead may choose to hire the services of a community-based organization with content expertise and experience on agro-businesses and capacity building events for rural communities. Similar candidates for the facilitator role described in the FFS demonstration project can also provide support here. The project lead could be the Productive Use committee described in *Create and Strengthen Sector Alignment and Coordination for Productive Use*, or a team hired or delegated by them.

Timeline—The components of the project are needed at different points during the implementation period of the national productive use program and so the depository will be developed in stages to meet needs as they materialize. The standard materials and tools need to be developed first, in Year 0, to ensure they are ready for facilitators to use during the implementation of the business model pilots (see FFS, Utility-Led, and Cooperative-Led Demonstration Projects).

The depository to make the training materials widely accessible and the roster of shortlisted facilitators will support the replication of business models in more communities. As such, these components can be developed when enough evidence has been gathered through the demonstration projects to prove the viability of the business models, around Year 3 of the timeline.

Scaling strategy—The depository is a scaling strategy to help replicate the business models tested in the early stages of the national productive use program. As projects in the National Productive Use program are completed and results gathered and assessed, findings and insights can also be shared through the depository. The tools included in the depository can also be expanded as new needs arise. For example, a shortlist of equipment suppliers may be added to indicate which suppliers provide quality equipment. The project team will carry out awareness raising to ensure the depository is known and accessible to would-be entrepreneurs and processors, facilitators, and other actors.

Appendix E Criteria and Preliminary Participants List for Design Sessions

The design sessions will bring together actors from different backgrounds to interact, discuss possibilities, and develop projects to test and verify these possibilities. As such, a key part of end-user centered design is building the coalition of actors that will bring the needed skills and experience. This requires understanding who these actors are. But knowing the right things is not enough, participants also need to be bought into the process and must want to participate and contribute to the discussions. As such, bringing in participants with the required disposition, expertise, and skills is a key requirement to ensure that discussions are meaningful and contribute to highly practical projects anchored on end-user needs and ground realities.

This appendix **provides the criteria used to identify the organizations and people within these organizations to populate the participant list**. This appendix also presents the preliminary participant list.

E.1 General Criteria

A set of **general criteria** should guide the selection of **participants throughout all tiers:**

- Actors must be **bought-in** and **want to participate** in the design sessions
- Actors must have an **open mind, positive attitude** toward others, and **willingness to listen to new ideas**, other people and organizations, and different approaches.

E.2 Criteria for Target Participants in Tier 1—Community Visits and Focus Groups

The key decision for Tier 1 is selecting the appropriate CBO to partner with as co-producer to select communities and to connect with end-users during the community visit. The following criteria will guide our selection of the CBO to partner with as well as end-users to shadow and interview during the community visit.

Co-producers—Thse should be CBOs that work with micro, small, and medium enterprises (MSMEs) in small-scale agriculture development particularly in agro-mechanization pilots (priority on milling pilots). They should support these enterprises with capacity building for business management, provide awareness building to introduce new technologies, and connect processing MSMEs with finance. The CBO should have at least two years' experience operating community development programs to suggest the existence of strong, trust-based relationships with end-users. Ideally the CBO will have ongoing programs in the three regions of interest: Amhara, Oromia, and SNNPR.

End-users—There are two categories of end-users we will target during the field visit:

- Processors—MSMEs engaged in mechanized post-harvest processing that have been running processing businesses for at least one year and/or been recipients of CBO services in the past and have higher capacity levels as demonstrated by their ability to access credit and operate successful processing businesses (priority on milling).

- End-consumers (customers) of processing services.

E.3 Criteria for Target Participants: Tier 2—Design of Community Solutions

We will target actors that would intervene in implementing community level solutions, are immersed in ground realities, and understand end-user needs. Based on our secondary research, field surveys, and expert interviews assessing existing business practices and models, the fee-for-service business model (see Section 5.1.1) is the most prevalent business model in rural communities. We are using the roles established in the fee-for-service business model to guide our identification of participants in Tier 2 discussions. We have structured the criteria to identify participants based on the roles and the required expertise needed to fulfill those roles:

- **The processing Business** will meet the same criteria listed for processors in Tier 1. The team with support from the partner CBO will select the processor(s) based on the community visit and interviews held in Tier 1.
- **The facilitator** connects processors with equipment suppliers and financiers, leveraging its agriculture sector expertise, technical knowledge on electric equipment and business management, and relationships with other actors. The actors to represent the facilitator role will meet the same criteria listed for CBOs in Tier 1.
- **The electricity Provider** supplies and sells electricity in rural communities. The actors to fulfill this role should have rural minigrid systems in operation and have experience testing productive use initiatives in their areas of service so that they can bring this practical knowledge to the discussion.
- **The equipment supplier** should already be providing post-harvest processing equipment to small-scale rural end-users, including milling equipment.
- **The financial Institution** can be a microfinance institution (MFI) and/or the capital goods finance company (CGFC) with existing loan or lease portfolios targeting small-scale agricultural entrepreneurs.

E.4 Criteria for Target Participants: Tier 3—Design of Solutions for Scaling and Building an Enabling Ecosystem

In addition to the actors identified in Tier 2, Tier 3 will also bring in national and regional level policymakers, development partners, and research institutions that have a broader vantage into the national and regional level goals and barriers to address and resources available.

To effectively bridge gaps between energy, agriculture, and other sectors that support rural development, the key ministries representing these sectors would participate. Key stakeholders, including **the ministries of energy, agriculture, economic planning, and finance** would be invited. Specific participants within these organizations should include **sector specialists with experience in project design and implementation.** They can then bring the required knowledge of ongoing projects and identify opportunities for collaboration. They can also leverage cross-sectoral initiatives and make recommendations on how to channel those collaboration opportunities into programmatic recommendations.

E.5 Preliminary Participant List

Exhibit 76 presents the preliminary participant list. The project team, with partner support, will refine this list to identify blinds spots, define in which tier specific actors will intervene, and ensure that the final participant list leads to manageable workshops that bring together the required set of expertise and experience in each tier. This may require reducing the number of participants included in the final participant list.

Organization Name	Geographical Focus	Contact Name and Position
Expertise: Agriculture and Community Development (Community Based Organizations)		
Sasakawa	National	Dr. Fentahun Mengistu, Country Director
Electricity Planning and Delivery		
EEU (Planning Dept)	National	Lemlem Misganaw, Off -grid Unit Head Samuel Shawel, Head of Projects
Rensys	Amhara, Oromia, SNNPR	Samuel Alemu, Deputy GM
ERG	Amhara	Hilawe Tesema, CEO Getnet Tesfaye, co-Founder
Solar Village Ethiopia	Amhara	Lebeza Alemu, MD SinShaw Alemu, Biz Dev Manager
Green Scene Energy	Somali, SNNPR, Oromia, Amhar	Rekik Bekele, CEO
Hello Solar Ethiopia	National	Bart Minsaer, CEO
Manufacturing and Equipment Supply		
Amio	Addis	Mr. Ibrahim
Tsehay	Addis	Mr. Teshome
Marast	Addis	Mr. Mareg
Afesol	Addis	Mr. Teshome
Financing		
OCSSCO (Oromia MFI)	Oromia	Mekonnen Biru, DEMD Strategy & Transformation (one of their executive management)
Oromia CGFC	Oromia	Yonas Geleta, CEO
ACSI (Amhara MFI)	Amhara	Mekonnen Yelewemwessen, Tewabe Aysheshim Wudineh (Mekonnen's deputy)
VisionFund MFI	Amhara, Oromia, SNNPR (but m	Hailu Leta, Deputy CEO
Development Bank of Ethiopia		
Omo MFI	SNNPR	Alemayehu H/Giorgis Bramo
Debub CGFC	SNNPR	Tarekegn Bache, Managing Director
UNCDF	National	Seifu Teshome
Agro Mechanization Technical Expertise (Research Institutes)		
IFPRI	National	Dawit Mekonnen; Bart Minten (VC expert)
CIMMYT	Amhara, Tigray, Oromia	Ephrem Tadesse
National Agriculture Research Institute	National	
MELCASA Research Institute	Regional	
Ethiopia Institute for Agricultural Resear	National	Daniel Muleta
Mekelle University	National	Asfafaw Tesfay
College of Agriculture and Veterinary Me	National	Chemeda Abedeta Garbada

Organization Name	Geographical Focus	Contact Name and Position
Agriculture Sector Policies and Planning (and Support)		
		Chimdo Anchala
ATA	National	Kebede Teshome
ATA	Regional	Muluneh Alemneh
ATA	Regional	Andale Mekuria
ATA	Regional	Endale Lemma
Ministry of Agriculture	National	Esayas Lemma
GIZ (Ag team)	National	Dr. Andrea Rüdiger (seed and mechanization project--ongoing) Heinz Loos (training centre project--completed in 2014),
Feed the Future	National	Ian Chesterman
FARM Africa	National	Asaye Asnake
Gates Foundation	National	Amsale Mengistu
JICA		
Ethiopian Rural Energy Development ar	National	Mr. Yisehak Seboka
Energy Sector Policies and Planning (and Support)		
MOWIE	National	Yiheyis Esthetu Director of Energy
World Bank (Country and ESMAP)	National	Jon Exel, Tatia Lemondzhava
GIZ (Energy team)	National	David Otieno (programme manager) Samson Tolessa (deputy) and Jannik Moller (minigrids)
AfDB	National	Fekede Sahele Tamiru
Veritas	National	Omer Bomba

Exhibit 76: Preliminary Participant List

Appendix F Preliminary Woredas for Data Pilot

Exhibit 77 shows the woredas we are considering for the Data Pilot. Our review indicates that these woredas include communities targeted for pre-electrification with minigrids with significant grain production. However, this selection is not final. We will consult with our partner CBO to determine the final list of woredas and communities.

Region	Zone	Woreda
Amhara	Maekelawi Gonder	Gonder Zuriya
Amhara	Mirab Gojjam	Burie Zuria
Amhara	Misrak Gojjam	Enarji Ena Enawuga
Amhara	Misrak Gojjam	Awabel
Oromiya	Buno Bedele	Chora
Oromiya	Mirab Arsi	Gadeb Asesa
Oromiya	Mirab Shewa	Dendi
Oromiya	Misrak Shewa	Adea
SNNPR	Gurage	Sodo
SNNPR	Yem Liyu	Yem Liyu

Exhibit 77: Woredas for Data Pilot

Appendix G Survey Tool

Generated by kwad, Mar 29, 2021 23:25
Questionnaire created by kwad, Aug 10, 2020 09:43
Last modified by kwad, Nov 05, 2020 17:38

Shared with:
sssantana (never edited)
zihemeng (never edited)
felisha (never edited)
pbukirwa (never edited)
bdscdr (never edited)
ameha (never edited)

Sections: 9, Sub-sections: 44,
Questions: 387,
Questions with enabling conditions: 201
Questions with validation conditions: 43
Rosters: 21
Variables: 12

Survey Solutions

Ikea_ProdUseFieldSurvey_200810

SURVEY IDENTIFICATION INFORMATION
QUESTIONNAIRE DESCRIPTION

COVER IDENTIFICATION
Sub-sections: 2, No rosters, Questions: 11, Static texts: 3.

A - RESPONDENT DATA
Sub-sections: 2, No rosters, Questions: 16, Static texts: 2.

B - COMMUNITY INTERVIEW
Sub-sections: 6, Rosters: 8, Questions: 62, Static texts: 3.

C - AGRIC PROCESSOR INTERVIEW
Sub-sections: 12, Rosters: 6, Questions: 133, Static texts: 6, Variables: 3.

D - FARMER INTERVIEW
Sub-sections: 11, Rosters: 3, Questions: 80, Static texts: 2, Variables: 3.

E - AGRIC TRADER INTERVIEW
Sub-sections: 6, Rosters: 2, Questions: 46, Variables: 2.

SIZE REFERENCE
No sub-sections, No rosters, No questions, Static texts: 7.

Z - CROP APPENDICES
Sub-sections: 5, Rosters: 2, Questions: 35, Static texts: 4, Variables: 4.

Y- FEMALE RESPONDENT
No sub-sections, No rosters, Questions: 4.

APPENDIX A — INSTRUCTIONS

APPENDIX B — CATEGORIES

LEGEND

SURVEY IDENTIFICATION INFORMATION QUESTIONNAIRE DESCRIPTION

Basic information

Title	Ikea_ProdUseFieldSurvey_200810

Survey data information

Study type	Enterprise Survey
Kind of data	Census/enumeration data [cen]
Mode of Data Collection	CAPI

Survey information

Country	Ethiopia
Year	2020

COVER IDENTIFICATION

A. COMMUNITY IDENTIFIERS (FOR ENUMERATOR)

STATIC TEXT

This section is meant to be filled out by the enumerator ahead of carrying out the interview with the respondent.

Select region	SINGLE-SELECT cover_region 01 O Tigray 02 O Afar 03 O Amhara 04 O Oromiya 05 O Somali 06 O Benishangul 07 O SNNP 08 O Gambela 09 O Harari 10 O Addis Ababa 11 O Dire Dawa
Name of Zone	SINGLE-SELECT: CASCADING cover_zone 001 O Central Tigray 002 O East Tigray 003 O North West Tigray 004 O South Tigray 005 O South East Tigray 006 O West Tigray 007 O Mekele (special zone) 008 O Zone 1 - Awsi Rasu 009 O Zone 2 - Kilbet Rasu 010 O Zone 3 - Gabi Rasu 011 O Zone 4 - Fantena Rasu 012 O Zone 5 - Hari Rasu 013 O Argobba 014 O Agew Awi 015 O East Gojjam 016 O North Gondar And 83 other symbols [10]

Name of Woreda	SINGLE-SELECT: CASCADING — cover_woreda 001 O ABERGELE 002 O ADWA 003 O ENTICHO 004 O KOLA TEMBIEN 005 O LA'ILAY MAYCHEW 006 O MEREB LEHE 007 O NAEDER ADET 008 O TAHTAY MAYCHEW 009 O WERIE LEHE 010 O ATSBI WENBERTA 011 O GANTA AFESHUM 012 O GULOMAHDA 013 O HAWZEN 014 O IROB 015 O SAESI TSAEDAEMBA 016 O KILTE AWULAELO And 844 other symbols [2]
Kebele name I If possible, check spelling with community champion.	TEXT — cover_kebele ....
Community name I If possible, check spelling with community champion.	TEXT — cover_com_name ....
Is this your first entry for this community?	SINGLE-SELECT — com_new_community 01 O Yes 02 O No
Is this community connected to a minigrid?	SINGLE-SELECT — com_mg_connected 01 O Yes 02 O No

COVER IDENTIFICATION

B. COMMUNITY BACKGROUND OBSERVATIONS (FOR ENUMERATOR)

com_background

E com_new_community == 1

STATIC TEXT

This section is meant to be filled out by the enumerator ahead of carrying out the interview with the respondent. Please use your observations of the community to fill out this sub-section.

STATIC TEXT

The next question will ask about the community electrification profile...

Not Connected: Minigrid Priority This is a community with the following characteristics: this area is more than 10km from the nearest national high voltage grid infrastructure; there is a dense community with relatively large population; lots of existing domestic and commercial loads (including agro-processing eg. 3+ mechanized productive use activities); existing use of generators or larger standalone systems shows ability and willingness to pay; the community is close to roads and relatively easy to access.

Not Connected: Grid Extension Priority This is a community with the following characteristics: this area is less than 10km from the nearest national high voltage grid infrastructure; there is a dense community with relatively large population; lots of existing domestic and commercial loads (including agro-processing eg. 3+ mechanized productive use activities); existing use of generators or larger standalone systems shows ability and willingness to pay; the community is close to roads and relatively easy to access.

Not Connected: Electrification Low Priority This is an area with the following characteristics: small community with very low population; very limited commercial activity (no mechanized productive use activities); the community is far to roads and difficult to access.

Grid Connected This is a community with the following characteristics: already connected to the national grid infrastructure.

Minigrid Connected This is a community with the following characteristics: already connected to a minigrid project.

Describe the community's electrification connectivity profile.	SINGLE-SELECT cover_locality_type 01 O Not Connected: Minigrid Priority 02 O Not Connected: Grid Extension Priority 03 O Not Connected: Electrification Low Priority 04 O Grid Connected 05 O Minigrid Connected
Record GPS coordinates at the interview site.	GPS cover_com_gps _________________ N _________________ W _________________ A
Is there a woreda office in this community?	SINGLE-SELECT com_wereda_presence 01 O Yes 02 O No
What is the type of main access road surface in this community?	SINGLE-SELECT com_road_mat 01 O TAR/ASPHALT 02 O GRADED GRAVELED 03 O DIRT ROAD (MAINTAINED) 04 O DIRT TRACK

A - RESPONDENT DATA

form_a

A - RESPONDENT DATA
INTRO

Please record the date and time of the interview.	DATE: CURRENT TIME interview_starttime

STATIC TEXT

Enumerators please read the following:
My name is (enter name), I'm working with Rocky Mountain Institute (RMI) to understand how electricity can be used in agriculture in communities like yours.

We invite you to participate in the study by providing information on your community, agricultural production and processing activities and the use of electricity in your community. Your perspective as a community member and a farmer/businessowner/trader is very valuable to us.

Kindly note that your participation in this survey is voluntary. You will not be given any money or other compensation for participating. All the information that you provide to me will be taken with utmost confidentiality and will be used for research purposes only. However, photos taken may appear in published material about our study.

In case you need more information about the survey, you may contact the Principal Investigator, XOXOXOXOOX on +251-XX-XXX-XXX

Do you have any questions? [PAUSE & ANSWER ALL QUESTIONS]

May I begin the interview now?

STATIC TEXT

IMPORTANT: Determine Respondent Type
Community Champions: community leaders, elders, government workers, respected members of the community etc, who have a strong knowledge of what's happening in the community and has lived in the community for at least 2 years. The authority of the respondent is less important than the degree to which they understand the activities and businesses in their community.

Agric Processor: value chain actors who perform mechanized post-harvest processing activities. This includes farmers who are preparing their crop for sale, fee-for-service processors, or offtakers who buy raw material and sell value-added products.

Farmer: value chain actors who cultivate focus products (including Maize, Wheat, Teff and Dairy) as a primary or secondary occupation. An eligible farmer includes land owners and land renters.

Agric Trader: value chain actors who buy and sell agricultural products without performing processing in-between: brokers, "middlemen", cooperatives.

Select the type of respondent. Maximum of two responses allowed.	MULTI-SELECT respondent_type
I Please select according to how the respondent spends the majority of t heir time.	01 ☐ Community Champion
V1 `self.Length > 0`	02 ☐ Agricultural Processor
M1 If none of the above apply to the respondent, consider interviewing so meone who is either a community champion or value chain actor.	03 ☐ Farmer
	04 ☐ Agricultural Trader
	05 ☐ Not a value chain actor

A - RESPONDENT DATA
RESPONDENT DETAILS

	What is your full name?	TEXT	respondent_data_name
I	Enter full name of the person being interviewed.	....	
W1	`self.Length>6`		
M1	Name is very short. Please ensure you've recorded the first and last name of the respondent		
	(for enumerator) Gender of main respondent	SINGLE-SELECT 00 O Male 01 O Female	respondent_gender
	What is your phone number?	TEXT	respondent_phone
I	Enter the number of the person being interviewed. Leave blank if he/she does not have a number to give.	....	
	Do you work for a particular organization?	SINGLE-SELECT 01 O Yes 02 O No	respondent_org_yn
	What organization do you represent?	TEXT	respondent_org
E	`respondent_org_yn == 1`	....	
	Do you consent to be interviewed for the purposes of this study?	SINGLE-SELECT 01 O Yes 02 O No	consent_interview
V1	`self == 1`		
M1	If the respondent does not consent to being interviewed, move to another interviewee.		
	Do you consent to have photos taken of yourself and your farm or business, where applicable?	SINGLE-SELECT 01 O Yes 02 O No	consent_photos
W1	`self == 1`		
M1	If the respondent does not consent to being photographed, consider proceeding if this is a unique perspective to capture.		
	Please sign here to indicate your consent.	PICTURE	consent_sig
E	`consent_interview == 1`		
	Please take a good quality photograph of the respondent. If the respondent is made very nervous by the personal photo, it is ok to skip.	PICTURE	respondent_photo
I	If possible, include in the photo the respondent's business or fields or holding some of their crop, etc		
E	`consent_photos == 1`		

(for enumerator) What is the relationship of %respondent_data_name% to the household head?	SINGLE-SELECT respondent_relation 01 O head 02 O wife/husband 03 O child/adopted child 04 O grandchild 05 O niece/nephew 06 O father/mother 07 O sister/brother 08 O son/daughter-in-law 09 O brother/sister-in-law 10 O grandfather/mother 11 O father/mother-in-law 12 O other
(for enumerator) Which of the following describes the respondent's household business category? E `respondent_type.Contains(2) || respondent_type.Contains(4)` W1 `self != 1` M1 If the respondent is in a household with no business, reconfirm whether you have selected the right respondent type for this entry.	SINGLE-SELECT respondent_class 01 O Household with no Business 02 O Household with small Business in-home 03 O Household with small Business out-of-home 04 O Medium Business/Cottage Industry 99 O Other
If "Other", please describe E `respondent_class == 99`	TEXT respondent_class_other ....
If you could instantly improve three things in %cover_com_name% by tomorrow, what would they be? Please rank. I Allow respondent to answer before showing or suggesting response options, if possible.	MULTI-SELECT: ORDERED dev_priority 01 ☐ education for my children 02 ☐ education for myself, to do a new business or improve my current work 03 ☐ clean running water 04 ☐ reliable power (light) 05 ☐ less government corruption 06 ☐ higher household income 07 ☐ better healthcare services 08 ☐ good road network 99 ☐ Other
Please describe: E `dev_priority.Contains(99)`	TEXT dev_priority_other ....

B - COMMUNITY INTERVIEW

form_b

E respondent_type.Contains(1)

STATIC TEXT

Enumerator: try to limit the answers to the area that could be served by a minigrid (i.e. people that live and work within about 15 minutes' walk of the town center)

B - COMMUNITY INTERVIEW

BASIC INFORMATION

i_basic_info

About how many households are contained in %cover_com_name%? W1 (self >= 50 && self <= 5000) || self >10000 M1 Is %cover_com_name% within the target size for minigrids (50-5,000 households)? Consider relocating to a different nearby community if available. V2 self <= 10000 M2 %cover_com_name% is too large to be considered for a minigrid. Please probe respondent's answer and relocate if necessary.	NUMERIC: INTEGER community_hh_estimate --------------------------------
(for enumerator) What level of cell service is available from this location?	SINGLE-SELECT cell_service_status 01 O no cell service available 02 O SMS/voice service only 03 O slow data speeds available - can send Whatsapp but little else 04 O 3g+ data connection, can browse internet
(for enumerator) Is there a cell tower (mast) visible or within walking distance of the community?	SINGLE-SELECT cell_tower 01 O Yes 02 O No
What is the nearest town to this community?	TEXT community_nearby ....
How many minutes would it take to walk to this town from this community center?	NUMERIC: INTEGER com_nearby_distance --------------------------------

B - COMMUNITY INTERVIEW

COMMUNITY ENERGY

com_energy_status

STATIC TEXT

Respondent: Now, the next questions will ask about power (light) sources in the community.

How many households and businesses own <u>solar home systems</u> that can provide light and power small appliances? I Note: a solar home system is defined as a solar system supplying light to one individual household. W1 self!=6 M1 Are you absolutely sure nearly everyone has a solar home system?	SINGLE-SELECT ap_shs_owners 01 O no one 02 O 1 in 10 people (rare) 03 O 3 in 10 people (common, but not majority) 04 O 5 in 10 people (50 - 50) 05 O 7 in 10 people (most people) 06 O almost everyone
How many households and businesses own <u>diesel or petrol generators</u> that can provide light and power appliances? W1 self!=6 M1 Are you absolutely sure nearly everyone has a generator?	SINGLE-SELECT ap_genset_owners 01 O no one 02 O 1 in 10 people (rare) 03 O 3 in 10 people (common, but not majority) 04 O 5 in 10 people (50 - 50) 05 O 7 in 10 people (most people) 06 O almost everyone
What is the price of <u>diesel</u> fuel in %cover_com_name%? I Record answer in ETB W1 self< 30 M1 Are you sure that you pay more than 30ETB for diesel?	NUMERIC: INTEGER community_diesel_price _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
What is the unit of diesel corresponding to this price? E IsAnswered(community_diesel_price)	SINGLE-SELECT community_diesel_unit 01 O kilogram 02 O tonne 03 O liter 04 O pick-up truck 99 O other
Describe 'Other' unit E community_diesel_unit == 99	TEXT diesel_unit_other ....
How much money do you pay to transport this diesel from the seller to where you use it? E IsAnswered(community_diesel_price)	NUMERIC: INTEGER diesel_transport_addl _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
What is the price of <u>petrol</u> fuel in %cover_com_name% in ETB/%community_diesel_unit%? I ETB/liter, including transport costs W1 self < community_diesel_price M1 Is petrol fuel really more expensive than diesel in %cover_com_name% ? Make sure prices are recorded correctly.	NUMERIC: INTEGER community_petrol_price _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
What is the unit of petrol corresponding to this price? E !IsAnswered(community_diesel_unit) && IsAnswered(community_petrol_price)	SINGLE-SELECT community_petrol_unit 01 O kilogram 02 O tonne 03 O liter 04 O pick-up truck 99 O other
Describe 'Other' unit E community_petrol_unit == 99	TEXT petrol_unit_other ....

How much money do you pay to transport this petrol from the seller to where you use it? E `!IsAnswered(diesel_transport_addl) && IsAnswered(community_petrol_price)`	NUMERIC: INTEGER `petrol_transport_addl` ________________

B - COMMUNITY INTERVIEW

ECONOMIC ACTIVITY

`econ_activities`

Which of the following non-agricultural businesses have operated in the community in the past 12 months? I Note this question focuses on non-agricultural businesses. The following questions will ask about agric processing. Use up to three "Other" categories to capture major businesses not included in selec And 7 other symbols [1]	MULTI-SELECT `business_select` 001 ☐ Restaurants and Bars 002 ☐ Hotels 003 ☐ Video Viewing Centers 004 ☐ Computer Technology Shops 005 ☐ Small Shops and Petty Traders 006 ☐ Welders 007 ☐ Barbers and Hairdressers (Salons) 008 ☐ Tailors 009 ☐ Mechanics 010 ☐ Carpenters/ Furniture Makers/ Artisans 011 ☐ Caterers 996 ☐ Other 1 (please specify) 997 ☐ Other 2 (please specify) 998 ☐ Other 3 (please specify)
Describe 'Other' business #1 E `business_select.Contains(996)`	TEXT `business_other_1` ________________
Describe 'Other' business #2 E `business_select.Contains(997)`	TEXT `business_other_2` ________________
Describe 'Other' business #3 E `business_select.Contains(998)`	TEXT `business_other_3` ________________

B - COMMUNITY INTERVIEW / ECONOMIC ACTIVITY

Roster: NUMBER OF NON-AG BUSINESSES

generated by multi-select question `business_select`

`business_nums`

E `@rowcode.InList(1,2,3,4,5,6,7,8,9,10,996,997,998)`

How many %rostertitle% are operating in this community? V1 `self > 0` M1 There should be at least one of these operating in the community.	NUMERIC: INTEGER `num_of_business` ________________

Which of the following public organizations are located in the kebele?	MULTI-SELECT community_org_select 001 ☐ Schools 022 ☐ Pharmacies 002 ☐ Health Facility 003 ☐ Christian Churches 004 ☐ Mosques 005 ☐ Agricultural Cooperatives 006 ☐ Youth Groups 007 ☐ Community Development Association 996 ☐ Other 1 (please specify) 997 ☐ Other 2 (please specify) 998 ☐ Other 3 (please specify)
Describe 'Other' organization #1 E community_org_select.Contains(996)	TEXT org_other_1 ....
Describe 'Other' organization #2 E community_org_select.Contains(997)	TEXT org_other_2 ....
Describe 'Other' organization #3 E community_org_select.Contains(998)	TEXT org_other_3 ....

B - COMMUNITY INTERVIEW / ECONOMIC ACTIVITY

CO-OPS INFO

E community_org_select.Contains(5)

Please list the names of the agricultural cooperative, farmer groups and other groups active in the community within the past 12 months	LIST agric_coop_names ....

B - COMMUNITY INTERVIEW / ECONOMIC ACTIVITY / CO-OPS INFO

Roster: CO-OP INFO

generated by list question agric_coop_names com_coops

E IsAnswered(agric_coop_names)

Which of the following services/support does %com_coops% provide in %cover_com_name%?	MULTI-SELECT coop_services 01 ☐ Financial services including credit and thrift 02 ☐ Extension services (e.g. farming technique training) 03 ☐ Improved agricultural inputs (e.g. fertilizer, seeds) 04 ☐ Access to agri-processing equipment 05 ☐ Channels to collect and sell product at market 99 ☐ Other
If "other" service/support, please describe E coop_services.Contains(99)	TEXT coop_services_oth ....

Who is the group representative for this coorperative in the community?	TEXT	coop_contact_name
What is a good contact number for %coop_contact_name%? E IsAnswered(coop_contact_name)	TEXT	coop_contact_num
Please select which financial institutions are locally active	MULTI-SELECT 01 ☐ Commercial bank agents (e.g. Commercial Bank of Ethiopia) 02 ☐ Microfinance banks (e.g. Africa Villages Financial Services S.C) 03 ☐ Mobile money providers (eg. M-Birr) 99 ☐ Others	financial_inst
Please specify "other" financial institutions by name (maximum of 3) E financial_inst.contains(99)	LIST	financial_inst_oth

B - COMMUNITY INTERVIEW

AGRICULTURE

iv_ag

Which of the following are produced by more than 5 farmers/producers in the community?	MULTI-SELECT 0572 ☐ Avocado 0486 ☐ Bananas 0044 ☐ Barley 0656 ☐ Coffee 0004 ☐ Cows milk 0406 ☐ Garlic 0358 ☐ Head Cabbage 0056 ☐ Maize 0571 ☐ Mango 0403 ☐ Onion 0401 ☐ Red pepper 0289 ☐ Sesame 0003 ☐ Sheep or goat milk 0083 ☐ Sorghum 0102 ☐ Teff 0388 ☐ Tomato And 6 other symbols [16]	community_crops

B - COMMUNITY INTERVIEW / AGRICULTURE

Roster: B1 FARMER INVENTORY

generated by multi-select question community_crops

multi_crop_roster

Estimate the number of farmers/producers for %multi_crop_roster% in your community. V1 self > 5 M1 Crop has fewer than 5 farmers. Probe respondent's answer and remove from crop checklist if not a major crop.	NUMERIC: INTEGER -	num_farmers

List any female farmers in the community that produce %multi_crop_roster% I Make sure to confirm that the names provided are not subsistence far mers... we are interested in capturing the perspectives of farmers who sell their crops. E num_farmers >0	LIST	farmers_f

B - COMMUNITY INTERVIEW / AGRICULTURE / B1 FARMER INVENTORY

Roster: FEMALE FARMER INFO

generated by list question farmers_f — farmer_female

E IsAnswered(farmers_f)

What is a working phone number for %rostertitle%?	TEXT	farmers_f_phone
Describe any directions for where I can find %rostertitle%... I Take note of any directions if you think it would be helpful	TEXT	farmer_f_directions
Please list any other farmers that grow/produce %multi_crop_roster% in %cover_com_name% for profit? I Make sure to confirm that the names provided are not subsistence far mers... we are interested in capturing the perspectives of farmers who sell their crops.	LIST	farmer_list

B - COMMUNITY INTERVIEW / AGRICULTURE / B1 FARMER INVENTORY

Roster: FARMER INFO

generated by list question farmer_list — farmer_rest

E IsAnswered(farmer_list)

What is a working phone number for %farmer_rest%?	TEXT	farmer_phone
Describe any directions for where I can find %farmer_rest%... I Take note of any directions if you think it would be helpful	TEXT	farmer_directions
Are there any other major crops produced in %cover_com_name% outside of the crops that I mentioned earlier?	LIST	other_crops
Describe 'Other' crop #1 E community_crops.Contains(9995)	TEXT	crop_other_1
Describe 'Other' crop #2 E community_crops.Contains(9996)	TEXT	crop_other_2
Describe 'Other' crop #3 E community_crops.Contains(9997)	TEXT	crop_other_3
Describe 'Other' crop #4 E community_crops.Contains(9998)	TEXT	crop_other_4

Describe 'Other' crop #5 E community_crops.Contains(9999)	TEXT crop_other_5 ....
Do any farmers in %cover_com_name% use irrigation?	SINGLE-SELECT irrigation_status 00 ○ No 01 ○ Yes
How are fields irrigated in %cover_com_name%? E irrigation_status == 1	MULTI-SELECT irrigation_method 01 ☐ Using pumps 02 ☐ Manually (e.g. watering can) 03 ☐ Natural methods (e.g. water channeling into farm, ditches) 99 ☐ other irrigation method
How are irrigation pumps typically powered in %cover_com_name%? Select all that apply E irrigation_status == 1 && irrigation_method.Contains(1)	MULTI-SELECT irrigation_power 01 ☐ petrol 02 ☐ diesel 03 ☐ electricity from grid or minigrid 04 ☐ solar panels on the pumps 99 ☐ Other
If "other" type of irrigation is selected, please describe. E irrigation_method.Contains(99) && irrigation_status == 1	TEXT irrigation_other ....

B - COMMUNITY INTERVIEW / AGRICULTURE

AGRO-PROCESSING

STATIC TEXT

Respondent: The next questions ask about the agricultural processing activities undertaken within %cover_com_name%

Which of the following activities are undertaken in the community for commercial purposes? I These activities can be undertaken manually or with machine.	MULTI-SELECT community_activities 01 ☐ threshing/shelling 03 ☐ grating/grinding 05 ☐ grain flour milling 06 ☐ animal feed production 07 ☐ malting 08 ☐ drying 09 ☐ cold storage 10 ☐ milk chilling 11 ☐ milk churning 13 ☐ milk pasteurization 14 ☐ packaging 98 ☐ Other activity 1 99 ☐ Other activity 2
Describe 'Other' activity #2 E community_activities.Contains(99)	TEXT activity_other_2 ....
Describe 'Other' activity #1 E community_activities.Contains(98)	TEXT activity_other_1 ....

Roster: B2 PROCESSING ACTIVITIES

generated by multi-select question community_activities — multi_activity_roster

To what extent is %multi_activity_roster% mechanized in %cover_com_name%?	SINGLE-SELECT — activity_mechanized 01 O no one uses machine 02 O 1 in 10 people use machine (rare) 03 O 3 in 10 people use machine (common, but not majority) 04 O 5 in 10 people use machine (50 - 50) 05 O 7 in 10 people use machine (most people) 06 O almost everyone uses machine
Estimate the number of processors associated with %multi_activity_roster% in your community. W1 self <= 100 M1 Are you sure more than 100 people conduct this activity in %cover_com_name%? V2 self > 0 M2 If no people conduct this activity in %cover_com_name%, remove it from the list of processing activities.	NUMERIC: INTEGER — num_processors --------------------------------
List any female processors in the community that own a machine for %multi_activity_roster% I Make sure to confirm that the names provided are not subsistence processors... we are interested in capturing the perspectives of processors who are operating businesses. E num_processors >0	LIST — processors_f ....

B - COMMUNITY INTERVIEW / AGRICULTURE / AGRO-PROCESSING / B2 PROCESSING ACTIVITIES

Roster: FEMALE PROCESSOR INFO

generated by list question processors_f — processor_female

E IsAnswered(processors_f)

What is a working phone number for %rostertitle%?	TEXT — processors_f_phone ....
Describe any directions for where I can find %rostertitle%... I Take note of any directions if you think it would be helpful	TEXT — processor_f_directions ....
Where is %multi_activity_roster% most likely to occur? Rank the following in terms of likelihood (e.g. if maize milling almost always happens in %cover_com_name% but sometimes occurs at a bigger community within this kebele, choose "community" first, then "kebele")	MULTI-SELECT: ORDERED — activity_location 01 ☐ This community 02 ☐ A nearby community within this kebele 03 ☐ A community within this woreda 04 ☐ A large community outside of this woreda

Who performs this %multi_activity_roster% activity?	SINGLE-SELECT activity_gender 01 O always men 02 O often men 03 O even mixture of men and women 04 O often women 05 O always women
Please list any other processors that carry out %multi_activity_roster% in %cover_com_name%? I Make sure to confirm that the names provided are not subsistence pro cessors... we are interested in capturing the perspectives of processor s who are operating businesses.	LIST processor_list ....

B - COMMUNITY INTERVIEW / AGRICULTURE / AGRO-PROCESSING / B2 PROCESSING ACTIVITIES

Roster: PROCESSOR INFO

generated by list question processor_list processor_rest

E IsAnswered(processor_list)

What is a working phone number for %rostertitle%?	TEXT processors_phone ....
Describe any directions for where I can find %rostertitle%... I Take note of any directions if you think it would be helpful	TEXT processor_directions ....

C - AGRIC PROCESSOR INTERVIEW

form_c

E respondent_type.Contains(2)

STATIC TEXT

Enumerator: note that answering these questions may require talking to various people in the household (e.g. male head knows total quantity of product sold at market, women know how long it takes to peel cassava). Gather all the respondents needed for the conversation.

For our study, a processor is someone who makes money by owning and operating machinery that processes crops after harvest. Do you engage in this kind of processing?

V1 self == 1

M1 <big>Please exit the process interview if the respondent does not fit th e definition</big>

SINGLE-SELECT — ap_isprocessor

01 Yes
02 No

C - AGRIC PROCESSOR INTERVIEW

BASIC INFO

ap_basics

What is your relationship to the processing operation?

SINGLE-SELECT — ap_position

01 Owner
02 Employee or manager (not owner)
99 Other

Please describe "other"

E ap_position == 99

TEXT — ap_position_other

How long has this business been in operation (in years)?

V1 self > 0

M1 The business must be more than 0 years old.

NUMERIC: DECIMAL — ap_age

Is this interview being conducted at the location where you conduct processing?

I (within 50 meters of the processing equipment)

W1 self == 1

M1 Enumerator: If convenient, relocate the interview t o a location nearer to the processing site/equipment and change answ er to the previous question.

SINGLE-SELECT — ap_at_process_site

01 Yes
02 No

If this is the site where processing takes place, record GPS coordinates:

E ap_at_process_site == 1

GPS — ap_process_location

N

W

A

Is this processor connected to the minigrid?

E com_mg_connected == 1

SINGLE-SELECT — ap_mg_conn

01 Yes
02 No

Question	Response	Variable
How far is this processing site from the generation source (minutes walking)? I Ask the community leader to help estimate this walking distance if the respondent does not know E ap_mg_conn == 2	SINGLE-SELECT 01 O 1-15 minutes 02 O 15-30 minutes 03 O 30-45 minutes 04 O >45 minutes	ap_dist_mg
How many minutes would it take to walk from the processing site to the minigrid generation source? I Ask the community leader to help estimate this walking distance if the respondent does not know E ap_dist_mg == 4	NUMERIC: INTEGER ________________	ap_dist_other
(for enumerator) Please take a good quality photograph of the respondent with his/her business, machine, or equipment. If the respondent is made very nervous by the personal photo, it is ok to skip. E ap_at_process_site == 1	PICTURE	ap_bus_photo
Have you taken any loans for this business? Please list the amounts borrowed in ETB.	LIST ________________	ap_loans

C - AGRIC PROCESSOR INTERVIEW / BASIC INFO

Roster: LOANS ROSTER

ap_loans_roster

generated by list question ap_loans

E IsAnswered(ap_loans)

Question	Response	Variable
Who did you borrow %ap_loans_roster%ETB from?	SINGLE-SELECT 01 O Community Leader 02 O Microfinance Institution 03 O Commercial Bank 04 O NGO or non-profit organization 05 O Family Member 99 O Other	ap_lender
Please describe "other" lender E ap_lender == 99	TEXT ________________	ap_lender_other
What is the name of the %ap_lender%? E ap_lender.InRange(1,4)	TEXT ________________	ap_lender_name

C - AGRIC PROCESSOR INTERVIEW

PROCESSING ACTIVITIES

ap_processing_info

Which activities have been performed by your household or business within the past two years?	MULTI-SELECT ap_activity_select 01 ☐ threshing/shelling 03 ☐ grating/grinding 05 ☐ grain flour milling 06 ☐ animal feed production 07 ☐ malting 08 ☐ drying 09 ☐ cold storage 10 ☐ milk chilling 11 ☐ milk churning 13 ☐ milk pasteurization 14 ☐ packaging 98 ☐ Other activity 1 99 ☐ Other activity 2
For which of these activities do you use a machine? F ap_activity_select.Contains(@optioncode) E IsAnswered(ap_activity_select)	MULTI-SELECT ap_mech_activity 01 ☐ threshing/shelling 03 ☐ grating/grinding 05 ☐ grain flour milling 06 ☐ animal feed production 07 ☐ malting 08 ☐ drying 09 ☐ cold storage 10 ☐ milk chilling 11 ☐ milk churning 13 ☐ milk pasteurization 14 ☐ packaging 98 ☐ Other activity 1 99 ☐ Other activity 2

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES

Roster: C1 PROCESSING ACTIVITY

generated by multi-select question ap_mech_activity — ap_activity_roster

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES / C1 PROCESSING ACTIVITY

CROP AND PROCESS

activity_crop_info

Describe 'Other' activity #1 E @rowcode == 98	TEXT ap_activity_other_1 ....
Describe 'Other' activity #2 E @rowcode == 99	TEXT ap_activity_other_2 ....
Estimate the number of processors doing %ap_activity_roster% within %cover_com_name%. I Only consider processors specifically doing %ap_activity_roster%, not a ll processors for this value chain. E !IsAnswered(community_activities)	NUMERIC: INTEGER ap_num_processors -

For which crops do you perform %ap_activity_roster%? I (start typing in search bar to select) E !(@rowcode.InList(10,6))	MULTI-SELECT ap_activity_crop 0572 ☐ Avocado 0486 ☐ Bananas 0044 ☐ Barley 0656 ☐ Coffee 0004 ☐ Cows milk 0406 ☐ Garlic 0358 ☐ Head Cabbage 0056 ☐ Maize 0571 ☐ Mango 0403 ☐ Onion 0401 ☐ Red pepper 0289 ☐ Sesame 0003 ☐ Sheep or goat milk 0083 ☐ Sorghum 0102 ☐ Teff 0388 ☐ Tomato And 6 other symbols [16]
Describe 'Other' crop #1 E ap_activity_crop.Contains(9995)	TEXT ap_crop_other_1 ....
Describe 'Other' crop #2 E ap_activity_crop.Contains(9996)	TEXT ap_crop_other_2 ....
Describe 'Other' crop #3 E ap_activity_crop.Contains(9997)	TEXT ap_crop_other_3 ....
Describe 'Other' crop #4 E ap_activity_crop.Contains(9998)	TEXT ap_crop_other_4 ....
Describe 'Other' crop #5 E ap_activity_crop.Contains(9999)	TEXT ap_crop_other_5 ....

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES / C1 PROCESSING ACTIVITY

BACKGROUND

activity_background

Who performs this %ap_activity_roster% activity in your business?	SINGLE-SELECT ap_activity_gender 01 ○ always men 02 ○ often men 03 ○ even mixture of men and women 04 ○ often women 05 ○ always women
To what extent is %ap_activity_roster% mechanized in your business?	SINGLE-SELECT ap_activity_mechanized 01 ○ always manually performed 02 ○ sometimes use machine 03 ○ often use machine 04 ○ always use machine

Where do you procure machinery from to carry out %ap_activity_roster%? E `ap_activity_mechanized.InList(2,3,4)`	TEXT — mechanized_source ....
How does your %ap_activity_roster% business work? (select all that apply) I If respondent processes for others for a fee and also processes own crops, then mark both boxes.	MULTI-SELECT — ap_processor_type 01 ☐ Buy raw inputs, process them, then sell final product 02 ☐ Fee for service 03 ☐ Process my own crops for home consumption or to make money 04 ☐ Process my own crops for home consumption only

STATIC TEXT

E `ap_processor_type.Length == 1 && ap_processor_type.Contains(4)`

Enumerator: If this person processes only for household consumption, end the interview here and find a processor that markets their end product

Would you be interested in operating your processing under a "fee-for-service" model? I Fee-for-service means charging customers a fee to process their crops for them. The operator would not own any of the crops being processed. E `IsAnswered(ap_processor_type) && !(ap_processor_type.Contains(2))`	SINGLE-SELECT — ap_fee_service 01 ○ Yes 02 ○ No
Do you have some %ap_product_form% nearby that I can photograph?	PICTURE — ap_product_pic
Do you want to expand or enhance %ap_activity_roster% to make more money, even if it will require your investment and time?	SINGLE-SELECT — ap_prefs 01 ○ Definitely no 02 ○ Maybe 03 ○ Definitely yes
What is limiting your ability to grow your processing capacity for the activities we've discussed? Choose the follwing in order of importance: E `ap_prefs != 1`	MULTI-SELECT: ORDERED — ap_limitations_1 01 ☐ Access to financing (loans) 02 ☐ Lack of market access (can't sell more that I already do) 03 ☐ Lack of know-how or experience (e.g. needs further education) 04 ☐ Lack of reliable electricity for machines (currently owned or not) 99 ☐ Other
Please describe the other barrier to growing processing capacity E `ap_limitations_1.Contains(99)`	TEXT — ap_limitations_1_other ....
Why are you not interested in expanding your business? (E.g. Are there alternative businesses that you are more interested in pursuing?) E `ap_prefs == 1`	TEXT — ap_not_interested ....

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES / C1 PROCESSING ACTIVITY

SEASONALITY

activity_seasonality

STATIC TEXT

E @rowcode != 10 && @rowcode != 12 && @rowcode != 6

Respondent: For the following questions, please consider the main crop for which you perform %ap_activity_roster%.

Is %ap_activity_roster% affected by the seasons? If so, how many busy seasons do you experience per year?	SINGLE-SELECT ap_seasonality 00 O This activity is not seasonal 01 O 1 harvest (busy) season per year 02 O 2 harvest (busy) seasons per year
What month does the first busy period for %ap_activity_roster% start? E ap_seasonality == 1 || ap_seasonality == 2	SINGLE-SELECT ap_season_start_1 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December
What month does the first busy period for %ap_activity_roster% end? E ap_seasonality == 1 || ap_seasonality == 2	SINGLE-SELECT ap_season_end_1 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December
What month does the second busy period for %ap_activity_roster% start? E ap_seasonality == 2	SINGLE-SELECT ap_season_start_2 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December

What month does the second busy period for %ap_activity_roster% end? E ap_seasonality == 2	SINGLE-SELECT ap_season_end_2 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December
During this busy season, how often do you reduce processing because you do not have the energy resources you need (electricity, fuel, etc) to run your machine? I If energy is a problem, please add a comment to describe in further de tail.	SINGLE-SELECT ap_energy_src_freq 01 O I always have the energy sources I need 02 O I must limit production a few days per season 03 O I must limit production once per week 04 O I must limit production every day 05 O I rarely have the energy sources I need
How many days per week do you perform %ap_activity_roster%? E ap_seasonality == 0 V1 self<=7 M1 Days per week cannot exceed 7	NUMERIC: INTEGER ap_days_per_wk_ns ________________
During the busy period (harvest season), how many days per week do you perform %ap_activity_roster%? E ap_seasonality != 0 V1 self<=7 M1 Days per week cannot exceed 7	NUMERIC: INTEGER ap_days_per_wk_busy ________________
During the slow period (off-season), how many days per week do you perform %ap_activity_roster%? E ap_seasonality != 0 V1 self<=7 M1 Days per week cannot exceed 7	NUMERIC: INTEGER ap_days_per_wk_slow ________________

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES / C1 PROCESSING ACTIVITY

MATERIAL SALES/INPUT/OUTPUT

In what <u>form</u> does raw material enter the %ap_activity_roster% process? (e.g. teff grain, maize green on the cob, raw milk)	SINGLE-SELECT: COMBO BOX ap_input_form 0561 O maize, dry on cob 0562 O maize, green on cob 0563 O maize, grain with husk 0564 O maize, grain without husk 0565 O maize, flour 0566 O maize, other product 0151 O wheat, dry on head 0152 O wheat, grain with husk 0153 O wheat, grain without husk 0154 O wheat, flour 0155 O wheat, other product 0041 O milk, cow fresh 0042 O milk, cow chilled 0043 O milk, cow dried 0044 O milk, cow sweetened condensed 0045 O milk, cow butter And 42 other symbols [17]
In what form does material <u>exit</u> the %ap_activity_roster% process? (e.g. grated cassava, maize flour, cold milk)	SINGLE-SELECT: COMBO BOX ap_output_form 0561 O maize, dry on cob 0562 O maize, green on cob 0563 O maize, grain with husk 0564 O maize, grain without husk 0565 O maize, flour 0566 O maize, other product 0151 O wheat, dry on head 0152 O wheat, grain with husk 0153 O wheat, grain without husk 0154 O wheat, flour 0155 O wheat, other product 0041 O milk, cow fresh 0042 O milk, cow chilled 0043 O milk, cow dried 0044 O milk, cow sweetened condensed 0045 O milk, cow butter And 42 other symbols [17]
During one day of processing, how many customers come in for %ap_activity_roster%? W1 `self <= ap_mass_in` M1 Please make sure that the output is not more than input.	NUMERIC: INTEGER ap_cust_num ________________________________
On average, how much crop does one customer usually want processed?	NUMERIC: INTEGER ap_cust_avg ________________________________

Record units for the %ap_cust_avg% reported in the previous question.	SINGLE-SELECT ap_cust_avg_unit 01 O kilogram 02 O bag 03 O tonne 04 O liter 05 O pick-up truck 06 O large trailer load 07 O quintal 99 O other
If "Other", please specify units in full. E ap_cust_avg_unit == 99	TEXT ap_cust_avg_unit_oth ....
Do customers typically have to wait to get service (because of the capacity of equipment)?	SINGLE-SELECT ap_cust_wait 01 O Yes- all the time 02 O Yes- sometimes 03 O Yes- not often 04 O No- never
How long do customers typically have to wait for service (in minutes)? E IsAnswered(ap_cust_wait) && (ap_cust_wait != 4)	NUMERIC: INTEGER ap_cust_wait_time --------------------------------

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES / C1 PROCESSING ACTIVITY / MATERIAL SALES/INPUT/OUTPUT

INPUT/OUTPUT QUANTITIES

STATIC TEXT

Respondent: For the following questions, please consider %ap_activity_roster% on your main crop, during a typical day during the busy season.

Enumerator: if the respondent has difficulty in estimating quantities, use the "Size Reference" section to help understanding

During one day of processing, what quantity of %ap_input_form% enters the process? (e.g. cassava root, maize grain, raw milk) I Enumerator: if the respondent has difficulty in estimating quantities, us e the "Size Reference" section to help clarify E !(@rowcode == 12)	NUMERIC: INTEGER ap_mass_in --------------------------------
Record units for the %ap_mass_in% reported in the previous question.	SINGLE-SELECT ap_mass_in_unit 01 O kilogram 02 O bag 03 O tonne 04 O liter 05 O pick-up truck 06 O large trailer load 07 O quintal 99 O other
If "Other", please specify units in full. E ap_mass_in_unit == 99	TEXT ap_mass_in_unit_oth ....

Question	Response
What size of bag are you referring to? I Select the answer that seems closest to the average bag size, or enter a number E `ap_mass_in_unit == 2`	NUMERIC: INTEGER — ap_in_bag_size ________________ SPECIAL VALUES 010 10 kg 025 25 kg 050 50 kg 100 100 kg
How much does %ap_input_form% cost per %ap_mass_in_unit%? I If the input material is from their own farm production, enter "0" E `ap_processor_type.Contains(1) || ap_processor_type.Contains(3)`	TEXT — ap_mass_in_cost ________________
Do you require special quality characteristics in %ap_input_form%? Please describe I For example, does cassava root need to be peeled and harvested within 2 days? Do maize grains need to be dried a certain amount?	TEXT — ap_input_quality ________________
During this busy season, how often do you reduce processing because you cannot source enough quality input?	SINGLE-SELECT — ap_input_quality_freq 01 O I always have enough good quality input 02 O I must limit production a few days per season 03 O I must limit production once per week 04 O I must limit production every day 05 O I rarely have enough good quality input
For fee-for-service processing, how much do you charge for one **%ap_mass_in_unit% of %ap_input_form%** for %ap_activity_roster%? I Report in ETB. E `ap_processor_type.Contains(2)`	TEXT — ap_fee_ffs ________________
During one day of processing, how much %ap_output_form% exits the process? W1 `self <= ap_mass_in` M1 Please make sure that the output is not more than input.	NUMERIC: INTEGER — ap_mass_out ________________
Record units for the %ap_mass_out% reported in the previous question.	SINGLE-SELECT — ap_mass_out_unit 01 O kilogram 02 O bag 03 O tonne 04 O liter 05 O pick-up truck 06 O large trailer load 07 O quintal 99 O other

What size of bag are you referring to? I Select the answer that seems closest to the average bag size, or enter a number E ap_mass_out_unit == 2	NUMERIC: INTEGER ap_out_bag_size ________________ SPECIAL VALUES 010 10 kg 025 25 kg 050 50 kg 100 100 kg
If "Other", please specify units in full. E ap_mass_out_unit == 99	TEXT ap_mass_out_unit_oth ________________
VARIABLE ap_mass_out/ap_mass_in	DOUBLE ap_io_mass_ratio
After %ap_activity_roster% do you sell the %ap_output_form%? I Note: if only packaging is needed before sale, mark the first option E ap_processor_type.ContainsAny(1,3)	SINGLE-SELECT ap_next_steps 00 O I sell this output directly 01 O I do more processing before I sell
In the past 12 months, what is the most common form in which you sell your final product from this activity? I E.g. cassava tuber, cassava paste, garri, or cassava flour?; fresh milk or yoghurt?; dry maize grain or maize flour? E ap_next_steps == 1	SINGLE-SELECT: COMBO BOX ap_product_text 0561 O maize, dry on cob 0562 O maize, green on cob 0563 O maize, grain with husk 0564 O maize, grain without husk 0565 O maize, flour 0566 O maize, other product 0151 O wheat, dry on head 0152 O wheat, grain with husk 0153 O wheat, grain without husk 0154 O wheat, flour 0155 O wheat, other product 0041 O milk, cow fresh 0042 O milk, cow chilled 0043 O milk, cow dried 0044 O milk, cow sweetened condensed 0045 O milk, cow butter And 42 other symbols [17]
VARIABLE IsAnswered(ap_product_text)? ap_product_text : ap_output_form	LONG ap_product_form

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES / C1 PROCESSING ACTIVITY

SCHEDULE AND PRICES

What is the sale price of the product you sell, on average? E ap_processor_type.Contains(1) || ap_processor_type.Contains(3)	NUMERIC: INTEGER ap_product_price ________________

Product price of %ap_product_price% is in terms of ETB per... E IsAnswered(ap_product_price)	SINGLE-SELECT ap_product_price_unit 01 O kilogram 02 O bag 03 O tonne 04 O liter 05 O pick-up truck 06 O large trailer load 07 O quintal 99 O other
If "ETB/Other", please specify units in full. E ap_product_price_unit == 99	TEXT ap_product_price_unit_oth ....
If ETB/bag, what size of bag are you referring to? I Select the answer that seems closest to the average bag size, or enter your own estimate E ap_product_price_unit == 2	NUMERIC: INTEGER ap_product_bag_size - SPECIAL VALUES 010 10 kg 025 25 kg 050 50 kg 100 100 kg
Do you have power to bargain with customers over the prices for processing %ap_activity_roster%?	SINGLE-SELECT ap_bargaining 01 O Yes 02 O No
How many cycles of %ap_activity_roster% do you run per day? I A cycle is a continuous period during which the processing will happen. For example if the processor usually processes during the morning, an d then again in the evening after a break-- this would coun And 16 other symbols [2] V1 self <= 5 M1 Please ensure that the number of cycles is less than or equalt to 5.	NUMERIC: INTEGER num_cycles - SPECIAL VALUES 01 First 02 Second 03 Third 04 Fourth 05 Fifth

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES / C1 PROCESSING ACTIVITY / SCHEDULE AND PRICES

Roster: PROCESSING SCHEDULES

generated by numeric question num_cycles — ap_schedule_roster

E IsAnswered(num_cycles)

What time of day do you start %ap_activity_roster% for this cycle?	SINGLE-SELECT 05 O 5 am 06 O 6 am 07 O 7 am 08 O 8 am 09 O 9 am 10 O 10 am 11 O 11 am 12 O 12 pm (Noon) 13 O 1 pm 14 O 2 pm 15 O 3 pm 16 O 4 pm 17 O 5 pm 18 O 6 pm 19 O 7 pm 20 O 8 pm And 8 other symbols [22]	ap_equip_start
What time of day do you stop %ap_activity_roster% for this cycle?	SINGLE-SELECT 05 O 5 am 06 O 6 am 07 O 7 am 08 O 8 am 09 O 9 am 10 O 10 am 11 O 11 am 12 O 12 pm (Noon) 13 O 1 pm 14 O 2 pm 15 O 3 pm 16 O 4 pm 17 O 5 pm 18 O 6 pm 19 O 7 pm 20 O 8 pm And 8 other symbols [23]	ap_equip_end
VARIABLE `Math.Abs(ap_equip_end.Value - ap_equip_start.Value)`	LONG	ap_hrs_day_calc
How much money do you make during a busy week?	NUMERIC: INTEGER ________________	ap_weekly_earnings

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES / C1 PROCESSING ACTIVITY

PRODUCT FLOW

STATIC TEXT

Respondent:The following three questions attempt to assess how much of %ap_product_form% goes to your household consumption, sale, and how much is spoiled.

Enumerator: Note that percentages must add to 100%

What percentage (%) of %ap_product_form% is consumed by your household? V1 `self >= 0 && self <= 100 && !self.InRange(0.001,1)` M1 Report as whole number between 0 and 100 (e.g. 30)	NUMERIC: INTEGER ap_pct_consumed - - - - - - - - - - - - - - - -
What percentage (%) of %ap_product_form% is lost to spoilage? V1 `self >= 0 && self <= 100 && !self.InRange(0.001,1)` M1 Report as whole number between 0 and 100 (e.g. 30)	NUMERIC: INTEGER ap_pct_spoiled - - - - - - - - - - - - - - - -
What percentage (%) of %ap_product_form% is sold? V1 `self >= 0 && self <= 100 && !self.InRange(0.001,1)` M1 Report as whole number between 0 and 100 (e.g. 30) V2 `(ap_pct_consumed + ap_pct_sold + ap_pct_spoiled == 100 | | ap_pct_consumed + ap_pct_sold + ap_pct_spoiled == 0)` M2 The sum of the percentages from the previous three questions should be equal to 100%.	NUMERIC: INTEGER ap_pct_sold - - - - - - - - - - - - - - - -
Do you know what change could reduce these losses? If so, please describe. E `ap_pct_spoiled > 15`	TEXT ap_spoilage_reason ....
What is preventing these changes from happening and reducing spoilage? E `ap_pct_spoiled > 15`	TEXT ap_spoilage_barrier ....

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES / C1 PROCESSING ACTIVITY

EQUIPMENT

Which of the following equipment do you use for this activity? I GENERATOR ONLY APPLIES TO ELECTRIC MACHINES THAT ARE PLUG GED INTO A GENERATOR. If a machine has its own lister or motor, do not check generator.	MULTI-SELECT ap_equip_select 111 ☐ diesel generator 222 ☐ petrol generator 001 ☐ thresher/sheller 002 ☐ hydraulic press 003 ☐ grater/grinder 005 ☐ flour mill 008 ☐ fryer/cooker 009 ☐ dryer 010 ☐ refrigerator 011 ☐ freezer 012 ☐ bulk milk chiller 013 ☐ water pump 014 ☐ pasteurizer 098 ☐ Other equipment 1 099 ☐ Other equipment 2

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES / C1 PROCESSING ACTIVITY / EQUIPMENT

Roster: C1.1 EQUIPMENT

generated by multi-select question ap_equip_select ap_equip_roster

Can I take a photo of %ap_equip_roster%? I Take a photo of the entire piece of equipment.	PICTURE ap_equip_photo

Is there a nameplate/information sticker on the %ap_equip_roster% that I can photograph? I Take a photo of the nameplate with device specifications. Look for the sticker with numbers marked as hp, kVA, V,"capacity", etc.	PICTURE ap_nameplate_photo
What is the power source for this equipment?	MULTI-SELECT ap_equip_psource 01 ☐ Diesel fuel 02 ☐ Petrol fuel 03 ☐ electricity from diesel generator 04 ☐ electricity from petrol generator 05 ☐ electricity from grid or minigrid 06 ☐ manual (human) power 07 ☐ simple machine (levers, water channels for irrigation, etc) 08 ☐ firewood for heat 09 ☐ other fuel for heat (please specify) 99 ☐ Other source (please specify)
What is the appliance power capacity? Report in kilowatts, kVA or Horsepower.	NUMERIC: DECIMAL ap_equip_cap --------------------------------
Select appliance capacity units. E IsAnswered(ap_equip_cap)	SINGLE-SELECT ap_equip_cap_units 01 O kilowatts 02 O kVA 03 O Horsepower 99 O Other units
Specify "other" units E ap_equip_cap_units == 99	TEXT ap_equip_cap_units_oth ....
Electricity bill (ETB/month) I Okay to use household bill as basis for electricity cost, including estimated bills E ap_equip_psource.Contains(5)	NUMERIC: INTEGER ap_equip_electricity --------------------------------
If the equipment uses different sources of energy for different functions, please explain here (e.g. a cocoa dryer may use electricity to run control systems but burn diesel for heat) E ap_equip_psource.Length>1	TEXT ap_equip_psource_multi ....

STATIC TEXT

Respondent: In the following questions, consider how you use %ap_equip_roster% during a typical day in the busy season.

Fuel costs for %ap_equip_roster% (ETB/day) I If the appliance is powered by a separate generator, complete a separate equipment entry and do not double-count fuel accross equipment. E ap_equip_psource.Contains(1) || ap_equip_psource.Contains(2)	NUMERIC: INTEGER ap_equip_fuel --------------------------------

How often do you have to service your macine (not including the motor)?	SINGLE-SELECT ap_equip_repair 01 Daily 02 Weekly 03 Monthly 04 Every 6 months 05 Yearly 99 Other
Describe "other" time unit E ap_equip_repair == 99	TEXT ap_repairunit_other ....
How much do you typically spend to service your machine (not including the motor) when you do so %ap_equip_repair%? I Record answer in ETB E IsAnswered(ap_equip_repair)	NUMERIC: INTEGER ap_equip_maint_cost --------------------------------
How often do you have to service your motor (not including the belt and processing equipment parts)? E ap_equip_psource.Contains(1) || ap_equip_psource.Contains(2)	SINGLE-SELECT ap_motor_repair 01 Daily 02 Weekly 03 Monthly 04 Every 6 months 05 Yearly 99 Other
Describe "other" time unit E ap_motor_repair == 99	TEXT ap_motorunit_other ....
How much do you typically spend to service your motor when you do so %ap_motor_repair%? I Does not include repairs to the processing equipment itself (e.g. belt replacement) -- only the petrol/diesel engine or genset. Record answer in ETB. E IsAnswered(ap_motor_repair)	NUMERIC: INTEGER ap_motor_maint_cost --------------------------------
How often does the machine break down unexpectedly?	SINGLE-SELECT ap_breakdown 01 Daily 02 Weekly 03 Monthly 04 Every 6 months 05 Yearly 06 Never 99 Other

Question	Response
What sort of after-sale services were available to you when you purchased this equipment?	SINGLE-SELECT ap_after_sale 01 O Free repairs to the equipment (not including the motor) for a certain period after purchase 02 O Free repairs to the equipment (including the motor) for a certain period after purchase 03 O Discounted repairs to the equipment (not including the motor) for a certain period after purchase 04 O Discounted repairs to the equipment (including the motor) for a certain period after purchase 05 O Free replacement of the equipment (not including the motor) for a certain period after purchase 06 O Free replacement of the equipment (including the motor) for a certain period after purchase 07 O No After Sales Service
How long after purchasing the equipment is this after-sale service available to you? E ap_after_sale.InRange(1,6)	TEXT ap_after_sale_length ....
When the appliance is "on", describe the level/speed at which the appliance is running most often: I If there is only an on/off switch, select "75%-100%". Otherwise determi ne what % of the max speed/power/scale that the respondent usually u ses.	SINGLE-SELECT ap_equip_cap_level 01 O 0 - 25% of full power 02 O 25 - 50% 03 O 50-75% 04 O 75% - 100% (select if appliance only has an on/off switch)
How many hours per day do you run your business during the busy season? I If the business is always "open", enter "24" V1 self <= 24 M1 There are only 24 hours in a day. Please enter a valid number between 0 and 24	NUMERIC: INTEGER ap_daily_runtime --------------------------------
Do you keep the %ap_equip_roster% turned on for the entire time that the business is open during the day?	SINGLE-SELECT ap_equip_on 01 O Yes 02 O No
During these %ap_daily_runtime% hours of use, what percentage (%) of the time are you processing crops with the %ap_equip_roster%? I If the business is operating for 1 hr/day, but only the processor uses th e machine to process crop for 30 minutes during that time, then answe r "50". Record answer in whole number. V1 self >= 0 && self <= 100 && !self.InRange(0.001,1) M1 Enter a whole number between 1 and 100.	NUMERIC: INTEGER ap_equip_proc --------------------------------

Question	Response
Do you use this %ap_equip_roster% to process multiple crops? If yes, select all crops processed	MULTI-SELECT ap_equip_multi_crop 0572 ☐ Avocado 0486 ☐ Bananas 0044 ☐ Barley 0656 ☐ Coffee 0004 ☐ Cows milk 0406 ☐ Garlic 0358 ☐ Head Cabbage 0056 ☐ Maize 0571 ☐ Mango 0403 ☐ Onion 0401 ☐ Red pepper 0289 ☐ Sesame 0003 ☐ Sheep or goat milk 0083 ☐ Sorghum 0102 ☐ Teff 0388 ☐ Tomato And 6 other symbols [16]
Describe Other crop 1 E ap_equip_multi_crop.Contains(9995)	TEXT ap_equip_multi_other1 ....
Describe Other crop 2 E ap_equip_multi_crop.Contains(9996)	TEXT ap_equip_multi_other2 ....
Describe Other crop 3 E ap_equip_multi_crop.Contains(9997)	TEXT ap_equip_multi_other3 ....
Describe Other crop 4 E ap_equip_multi_crop.Contains(9998)	TEXT ap_equip_multi_other4 ....
Describe Other crop 5 E ap_equip_multi_crop.Contains(9999)	TEXT ap_equip_multi_other5 ....
Do you use any of your equipment simultaneously with other equipment? If so please list those machines that are running at the same time. E IsAnswered(ap_equip_select)	LIST ap_equip_simul ....
Why don't you currently own any equipment for %ap_activity_roster%? E !IsAnswered(ap_equip_select)	MULTI-SELECT ap_non_equip 01 ☐ Unable to afford equipment 02 ☐ Don't know what equipment could be used for processing 03 ☐ No suppliers nearby 04 ☐ Don't want to purchase equipment 99 ☐ Other
Describe Other barrier E ap_non_equip.Contains(99)	TEXT ap_nonequip_other ....

Why don't you want to purchase equipment? E ap_non_equip.Contains(4)	TEXT ap_non_equip_nonint ....
Please select any other inputs you need to buy to conduct %ap_activity_roster%. This does not include equipment-specific costs like fuel and maintenance or raw material discussed above (e.g. purchase of maize cob for maize grinding).	MULTI-SELECT ap_process_inputs 01 ☐ Labor (employees) 02 ☐ Transportation 03 ☐ Land or rent 98 ☐ Other supplies

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES / C1 PROCESSING ACTIVITY / EQUIPMENT

Roster: C1.2 INPUT COSTS

generated by multi-select question ap_process_inputs

ap_input_roster

What other supplies does this include? I Enter each followed by a comma (e.g. water, salt). REMEMBER FUEL PRICES ARE NOT INCLUDED IN THIS CATEGORY E @rowcode == 98	LIST ap_supplies_oth ....
How much do you spend per day on %ap_input_roster%	NUMERIC: INTEGER ap_input_day -

C - AGRIC PROCESSOR INTERVIEW / PROCESSING ACTIVITIES

AIR DRYING

air_dry

Do you use sun or open-air drying for any of your processed products?	SINGLE-SELECT ap_air_dry_yn 01 O Yes 02 O No
How frequently do you experience drying problems during the busy season? E ap_air_dry_yn == 1	SINGLE-SELECT ap_air_dry_freq 01 O never 02 O one or two days per season 03 O three to ten days per season 04 O ten to twenty days per season 05 O I am not able to sufficiently air-dry my crops during the busy season

What are the crops you have most difficulty drying? E ap_air_dry_yn == 1	MULTI-SELECT ap_air_dry_crops 0572 ☐ Avocado 0486 ☐ Bananas 0044 ☐ Barley 0656 ☐ Coffee 0004 ☐ Cows milk 0406 ☐ Garlic 0358 ☐ Head Cabbage 0056 ☐ Maize 0571 ☐ Mango 0403 ☐ Onion 0401 ☐ Red pepper 0289 ☐ Sesame 0003 ☐ Sheep or goat milk 0083 ☐ Sorghum 0102 ☐ Teff 0388 ☐ Tomato And 6 other symbols [16]
Describe Other crop 1 E ap_air_dry_crops.Contains(9995)	TEXT ap_airdry_other1 ....
Describe Other crop 2 E ap_air_dry_crops.Contains(9996)	TEXT ap_airdry_other2 ....
Describe Other crop 3 E ap_air_dry_crops.Contains(9997)	TEXT ap_airdry_other3 ....
Describe Other crop 4 E ap_air_dry_crops.Contains(9998)	TEXT ap_airdry_other4 ....
Describe Other crop 5 E ap_air_dry_crops.Contains(9999)	TEXT ap_airdry_other5 ....

C - AGRIC PROCESSOR INTERVIEW

BARRIERS TO GROWTH

List all the nearest equipment manufacturers or suppliers operating in or around this community? I Please ensure that the respondent names all manufacturers and suppliers both inside and outside the community.	LIST ap_equip_sup ....

C - AGRIC PROCESSOR INTERVIEW / BARRIERS TO GROWTH

Roster: SUPPLIER QUESTION ROSTER

generated by list question ap_equip_sup ap_supplier_roster

E IsAnswered(ap_equip_sup)

Is %ap_supplier_roster% located in %cover_com_name%?	SINGLE-SELECT ap_supplier_comm 01 ○ Yes 02 ○ No

Question	Response
How far away from the town center is %ap_supplier_roster% (in km)? E ap_supplier_comm == 2	NUMERIC: DECIMAL ap_equipment_supplier_distance ________________
Do you have a contact number for %ap_supplier_roster%?	TEXT ap_supplier_contact ....
Are there other opportunities to increase your earnings that you are not currently able to do? These can be expansion of the activities we discussed or new business ideas. If so, please list up to 3 that you would seriously consider. I If the respondent has many ideas, use your judgment to select the top 3 ideas	LIST ap_latent ....
What is limiting your ability to do these other activities that you aren't already doing? Choose the following in order of importance: E ap_latent.Length >= 1	MULTI-SELECT: ORDERED ap_limitations_2 01 ☐ Access to financing (loans) 02 ☐ Lack of market access (can't sell more than I already do OR can't reach the customers I would sell to) 03 ☐ Lack of know-how or experience (e.g. need further education) 04 ☐ Lack of reliable electricity for machines (currently owned or not) 05 ☐ I have personal activities at home or for my family that I must attend to during the day 99 ☐ Other
Please describe the other barrier to pursuing these other activities E ap_limitations_2.Contains(99)	TEXT ap_limitations_2_other ....
Would you be willing to join forces with other processors in this community to form a larger joint processing business?	SINGLE-SELECT ap_joint_interest 01 O Yes 02 O No
Why are you not interested in starting a joint business with other processors? E ap_joint_interest == 0	TEXT ap_joint_non_why ....

D - FARMER INTERVIEW

form_d

E respondent_type.Contains(3)

STATIC TEXT

Enumerator: note that answering these questions may require talking to various people in the household (e.g. male head knows total quantity of maize sold at market, women know amount of milk produced per day)

D - FARMER INTERVIEW

BACKGROUND

(for enumerator) Which of the following describe the respondent's relationship to the farming operation?	SINGLE-SELECT f_position 01 O Owner 02 O Employee or manager (not owner) 03 O Relative of owner or employee 04 O Other
Is this interview being conducted where crops are grown? I (within 100 meters of the farm fields or fish pond) W1 self == 1 M1 Enumerator: If convenient, relocate the interview to a location nearer to the field/pond and change answer to the previous question.	SINGLE-SELECT f_at_farm_site 01 O Yes 02 O No
(for enumerator) If this is close to the farm field, record GPS coordinates: E f_at_farm_site == 1	GPS f_farm_location --------------------------------- N --------------------------------- W --------------------------------- A
(for enumerator) If this interview is not conducted near the farm fields, how many minutes would it take to walk there from the city center? E f_at_farm_site == 2	SINGLE-SELECT f_farm_min_walk 01 O 1-15 minutes 02 O 15-30 minutes 03 O 30-45 minutes 04 O >45 minutes
Please describe the type of farm you are running V1 self!=1 M1 <big> This interview must be carried out with a farmer who is earning an income from selling crops/products. If this is not the case, please leave this interview and seek out another farmer that is not a subsistence farmer. </big>	SINGLE-SELECT f_type 01 O Subsistence-- grow crops mainly for consumption within the household 02 O Grow crops to sell to market or others within and outside the community 03 O Sell the majority of crops grown and consume a small fraction of crops in the household

What is the overall size of your farm (in hectares)? V1 `self> 0` M1 This value must be greater than 0. W2 `self<50` M2 Please confirm the area. If area >150ha, this is a largescale farmer. We would like to target small scale farmers (area=0.5-5ha). If there are no more smallscale farmers available, proceed with this interview. Otherwise, stop the interview here.	NUMERIC: DECIMAL f_size ________________
Could you specify how far away the farm is from the community center? E `f_farm_min_walk == 4` V1 `self <= 120` M1 If the farming area is more than 2 hours away, is it in a different community? If so, interview a farmer from the community associated with this interview.	NUMERIC: DECIMAL f_farm_min_walk_other ________________

D - FARMER INTERVIEW

CROPS AND PRODUCTION

Which of the following are major crops that you produce and sell to make money? I If the farmer has more than 3 crops, please ask him/her to prioritize the top 3 crops by value V1 `!f_crops.ContainsAny(9998,9999)` M1 Use "Other Crop 1,2,3"	MULTI-SELECT f_crops 0572 ☐ Avocado 0486 ☐ Bananas 0044 ☐ Barley 0656 ☐ Coffee 0004 ☐ Cows milk 0406 ☐ Garlic 0358 ☐ Head Cabbage 0056 ☐ Maize 0571 ☐ Mango 0403 ☐ Onion 0401 ☐ Red pepper 0289 ☐ Sesame 0003 ☐ Sheep or goat milk 0083 ☐ Sorghum 0102 ☐ Teff 0388 ☐ Tomato And 6 other symbols [16]
Describe 'Other' crop #1 E `f_crops_oth.Contains(9995)`	TEXT f_crop_1 ....
Describe 'Other' crop #2 E `f_crops_oth.Contains(9996)`	TEXT f_crop_2 ....
Describe 'Other' crop #3 E `f_crops_oth.Contains(9997)`	TEXT f_crop_3 ....

Are there any other major crops that you produce and sell that I've missed?	MULTI-SELECT f_crops_oth 0572 ☐ Avocado 0486 ☐ Bananas 0044 ☐ Barley 0656 ☐ Coffee 0004 ☐ Cows milk 0406 ☐ Garlic 0358 ☐ Head Cabbage 0056 ☐ Maize 0571 ☐ Mango 0403 ☐ Onion 0401 ☐ Red pepper 0289 ☐ Sesame 0003 ☐ Sheep or goat milk 0083 ☐ Sorghum 0102 ☐ Teff 0388 ☐ Tomato And 6 other symbols [16]
Describe 'Other' crop #1 E f_crops_oth.Contains(9998)	TEXT f_crop_other_1 ....
Describe 'Other' crop #2 E f_crops_oth.Contains(9996)	TEXT f_crop_other_2 ....
Describe 'Other' crop #3 E f_crops_oth.Contains(9997)	TEXT f_crop_other_3 ....
Describe 'Other' crop #4 E f_crops_oth.Contains(9998)	TEXT f_crop_other_4 ....
Describe 'Other' crop #5 E f_crops_oth.Contains(9999)	TEXT f_crop_other_5 ....

D - FARMER INTERVIEW / CROPS AND PRODUCTION

Roster: D1 FARMED CROPS

generated by multi-select question f_crops — f_crop_roster

D - FARMER INTERVIEW / CROPS AND PRODUCTION / D1 FARMED CROPS

PLOT SIZE

About how many hectares of land do you use for %f_crop_roster% on this farm? W1 self < 100 M1 If over 100 hectares are farmed, this person is a very large scale farmer. Please comment to clarify the scale and type of operation. V2 self >0 M2 This value must be greater than 0.	NUMERIC: DECIMAL f_hectares_farm -

D - FARMER INTERVIEW / CROPS AND PRODUCTION / D1 FARMED CROPS

SEASONALITY

Is %f_crop_roster% affected by the seasons? If so, how many harvest seasons do you experience per year?	SINGLE-SELECT f_seasonality 00 O This activity is not seasonal 01 O 1 harvest (busy) season per year 02 O 2 harvest (busy) seasons per year
What month do you plant for the first season? E f_seasonality == 1 || f_seasonality == 2	SINGLE-SELECT f_season_plant_1 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December
What month do you harvest for the first season? E f_seasonality == 1 || f_seasonality == 2	SINGLE-SELECT f_season_harvest_1 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December
What month do you plant for the second season? E f_seasonality == 2	SINGLE-SELECT f_season_plant_2 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December

What month do you harvest for the second season? E f_seasonality == 2	SINGLE-SELECT f_season_harvest_2 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December

D - FARMER INTERVIEW / CROPS AND PRODUCTION / D1 FARMED CROPS

HARVEST QUANTITY

What is the typical quantity you harvest in a year? I Enumerator: if the respondent has difficulty in estimating quantities, us e the "Size Reference" section to help clarify E f_seasonality == 0	NUMERIC: INTEGER f_season_qty_ns --------------------------------
What is the typical quantity you harvest in this first season? I Enumerator: if the respondent has difficulty in estimating quantities, us e the "Size Reference" section to help clarify E f_seasonality == 1 || f_seasonality == 2	NUMERIC: INTEGER f_season_qty_1 --------------------------------
What is the typical quantity you harvest in this second season? I Record answer in same units as for season 1 E f_seasonality == 2	NUMERIC: INTEGER f_season_qty_2 --------------------------------
Record units for the quantity reported in the previous question.	SINGLE-SELECT f_harvest_unit 01 O kilogram 02 O bag 03 O tonne 04 O liter 05 O pick-up truck 06 O large trailer load 07 O quintal 99 O other
What size of bag are you referring to? I Select the answer that seems closest to the average bag size, or enter your own estimate E f_harvest_unit == 2	NUMERIC: INTEGER f_harvest_bag_size -------------------------------- SPECIAL VALUES 010 10 kg 025 25 kg 050 50 kg 100 100 kg
If "Other", please specify units in full. E f_harvest_unit == 99	TEXT f_harvest_unit_oth ....

VARIABLE IsAnswered(f_season_qty_ns) ? f_season_qty_ns : IsAnswered(f_season_qty_1) ? f_season_qty_1 : f_season_qty_2	DOUBLE	f_harvest_qty

D - FARMER INTERVIEW / CROPS AND PRODUCTION / D1 FARMED CROPS

STORAGE AND LOSSES

Of the %f_harvest_qty% %f_harvest_unit%s of %f_crop_roster% you harvest, how many %f_harvest_unit%s are spoiled before it can be consumed, processed or sold? V1 f_hh_spoil < f_harvest_qty M1 this quantity cannot be more than the total quantity harvested	NUMERIC: DECIMAL ________________	f_hh_spoil
VARIABLE f_hh_spoil/f_harvest_qty*100	DOUBLE	f_pct_spoil
Of the %f_harvest_qty% %f_harvest_unit%s of %f_crop_roster% you harvest, how many %f_harvest_unit%s are consumed within your household? V1 f_hh_consum < f_harvest_qty M1 this quantity cannot be more than the total quantity harvested	NUMERIC: DECIMAL ________________	f_hh_consum
VARIABLE f_hh_consum/f_harvest_qty*100	DOUBLE	f_pct_consum
How is this crop stored post-harvest? E f_pct_spoil > 10	TEXT ________________	f_ph_storage
Do you know what causes this %f_pct_spoil%% of the crop to spoil? I If the respondent does not know, leave this question blank E f_pct_spoil > 10	TEXT ________________	f_ph_cause
What change do you think could reduce these losses? E f_hh_spoil > 10 && IsAnswered(f_ph_cause)	TEXT ________________	f_ph_change

D - FARMER INTERVIEW / CROPS AND PRODUCTION / D1 FARMED CROPS

THRESHING

f_threshing

E @rowcode.InList(56,102,446,15)

How do you typically thresh %f_crop_roster%?	SINGLE-SELECT 00 O Mechanically thresh for a fee 01 O Hire labor to manually thresh 02 O Manually thresh with friends/family at no charge 03 O Other	f_thresh_method
About how much money do you spend per %f_crop_roster% harvest on this labor? I ETB per harvest E f_thresh_method == 1	NUMERIC: INTEGER ________________	f_thresh_labor

About how much money do you spend on mechanical threshing services per harvest? E f_thresh_method == 0	NUMERIC: INTEGER f_thresh_mech_spend ________________
Which of the following problems do you encounter during the %f_crop_roster% **threshing** process?	MULTI-SELECT f_thresh_problems 01 ☐ It is expensive 03 ☐ Broken grains lower price 04 ☐ Hired labor steals some of the crop during threshing 99 ☐ Other
Please describe the other problems you face with threshing E f_thresh_problems.contains(99)	TEXT F_thr_prob_oth ....
Please rate your agreement with the following: If the thresher were fixed in place in the community center, I would be willing to transport my harvested %f_crop_roster% from the field to be threshed.	SINGLE-SELECT f_thresher_location 01 ○ strongly disagree 03 ○ neutral, depends on price 05 ○ strongly agree

D - FARMER INTERVIEW / CROPS AND PRODUCTION / D1 FARMED CROPS

SALES

In what form do you sell this crop most often? E f_pct_spoil + f_pct_consum < 100	SINGLE-SELECT: COMBO BOX f_sale_product 0561 ○ maize, dry on cob 0562 ○ maize, green on cob 0563 ○ maize, grain with husk 0564 ○ maize, grain without husk 0565 ○ maize, flour 0566 ○ maize, other product 0151 ○ wheat, dry on head 0152 ○ wheat, grain with husk 0153 ○ wheat, grain without husk 0154 ○ wheat, flour 0155 ○ wheat, other product 0041 ○ milk, cow fresh 0042 ○ milk, cow chilled 0043 ○ milk, cow dried 0044 ○ milk, cow sweetened condensed 0045 ○ milk, cow butter And 42 other symbols [17]
Would you pay to have your crop processed before you sell to a trader?	SINGLE-SELECT f_processing_interest 01 ○ Yes 02 ○ No
Why wouldn't you pay to process crops before selling to traders? E f_processing_interest== 2	TEXT f_procesing_reason ....

How often do traders want more %f_crop_roster% than you have available to sell?	SINGLE-SELECT f_sell_outsell 01 O All the time 02 O Often 03 O Sometimes 04 O Rarely 05 O Never
Would you like to grow more %f_crop_roster% to sell more %f_sale_product% to make more money?	SINGLE-SELECT f_preference 01 O Definitely no 02 O Unsure 03 O Definitely yes
What is limiting your capacity to grow and sell %f_crop_roster% as we've discussed? Choose the following in order of importance: E f_preference != 1	MULTI-SELECT: ORDERED f_ph_limitations 01 ☐ Access to financing (loans) 02 ☐ Lack of market access (can't sell more than I already do OR can't reach the customers I would sell to) 03 ☐ Lack of know-how or experience (e.g. need further education) 04 ☐ Lack of reliable electricity for machines (currently owned or not) 05 ☐ I have personal activities at home or for my family that I must attend to during the day 99 ☐ Other
Please describe the other problems you face with threshing E f_ph_limitations.contains(99)	TEXT f_ph_lim_oth ....
Why aren't you able to sell all your %f_sale_product%? E f_ph_limitations.contains(2)	MULTI-SELECT f_market_challenge 01 ☐ Cannot transport to market to sell 02 ☐ Cannot find a good price 03 ☐ Cannot process my crop into the sale product 04 ☐ Cannot find an offtaker in my community
Do you have some of this product that I can photograph?	PICTURE f_product_photo
Who do you sell to? I Rank by quantity they sell. E f_hh_consum < 100	MULTI-SELECT: ORDERED f_sell_to 01 ☐ local trader or processor 02 ☐ market in my community 03 ☐ market in a different community 04 ☐ Co-op in my community

D - FARMER INTERVIEW / CROPS AND PRODUCTION / D1 FARMED CROPS / SALES

Roster: TRADER INFO

generated by multi-select question f_sell_to trader_info

E IsAnswered(f_sell_to)

What is the trader's name?	TEXT	trader_name
Do you have a contact phone number for %trader_name%? E IsAnswered(trader_name)	TEXT	trader_num

STATIC TEXT

Respondent: What is the range of common sale prices for %f_sale_product%?

low end of sale price range:	TEXT	f_sale_price_low
high end of sale price range:	TEXT	f_sale_price_high
Price of %f_sale_price_high% is in terms of ETB per...	SINGLE-SELECT 01 O kilogram 02 O bag 03 O tonne 04 O liter 05 O pick-up truck 06 O large trailer load 07 O quintal 99 O other	f_sale_price_unit
If "ETB/Other", please specify units in full. E f_sale_price_unit == 99	TEXT	f_sale_price_unit_oth
If ETB/bag, what size of bag are you referring to? I Select the answer that seems closest to the average bag size, if none a pply, enter your own estimate E f_sale_price_unit == 2	NUMERIC: DECIMAL - - - - - - - - - - - - - - - - SPECIAL VALUES 010 10 kg 025 25 kg 050 50 kg 100 100 kg	f_sale_bag_size
Are parts of your %f_crop_roster% fed to animals?	SINGLE-SELECT 01 O Yes 02 O No	f_feed
Do you make money from parts of %f_crop_roster% fed to animals? E f_feed == 1 && IsAnswered(f_feed)	SINGLE-SELECT 01 O I do not make any money 02 O I do not charge to take it, but people give me small tips 03 O I package and sell this feed for profit	f_feed_monetized
What part of %f_crop_roster% do you sell for animal feed? I If multiple, report the form that makes the most profit. E f_feed_monetized == 3	TEXT	f_feed_form

How much do you sell this %f_feed_form% for? E f_feed_monetized == 3	NUMERIC: INTEGER f_feed_price ________________
Price of %f_feed_price% is in terms of ETB per... E IsAnswered(f_feed_price)	SINGLE-SELECT f_feed_price_unit 01 O kilogram 02 O bag 03 O tonne 04 O liter 05 O pick-up truck 06 O large trailer load 07 O quintal 99 O other
If ETB/bag, what size of bag are you referring to? I Select the answer that seems closest to the average bag size, if none a pply, enter your own estimate E f_feed_price_unit == 2	NUMERIC: DECIMAL f_feed_bag_size ________________ SPECIAL VALUES 010 10 kg 025 25 kg 050 50 kg 100 100 kg
If "ETB/Other", please specify units in full. E f_feed_price_unit == 99	TEXT f_feed_price_unit_oth ....

D - FARMER INTERVIEW
CROP DRYING

Do you use sun or open-air drying? E !IsAnswered(ap_air_dry_yn)	SINGLE-SELECT f_air_dry_yn 01 O Yes 02 O No
How frequently do you experience drying problems during the busy season? E !IsAnswered(ap_air_dry_freq)	SINGLE-SELECT f_air_dry_freq 01 O never 02 O one or two days per season 03 O three to ten days per season 04 O ten to twenty days per season 05 O I am not able to sufficiently air-dry my crops during the busy season

D - FARMER INTERVIEW
IRRIGATION

Do you use irrigation on <u>your fields</u>?	SINGLE-SELECT f_irrigation_status 01 O Yes 02 O No
Can I take a photo of your irrigated field? I Please take a picture of the irrigation setup to show the crops being fe d with water and field landscape. E f_irrigation_status ==1	PICTURE f_irrigation_pic

Question	Response
On your farm, how are fields irrigated? E f_irrigation_status == 1	MULTI-SELECT f_irrigation_method 01 ☐ Using pumps 02 ☐ Manually (e.g. watering can) 03 ☐ Natural methods (e.g. water channeling into farm, ditches) 99 ☐ other irrigation method
If "other" type of irrigation is selected, please describe. E f_irrigation_method.Contains(99)	TEXT f_irrigation_other ....
On your farm, how are irrigation pumps powered? I Select all that apply. E f_irrigation_method.Contains(1)	MULTI-SELECT f_irrigation_power 01 ☐ petrol 02 ☐ diesel 03 ☐ electricity from grid or minigrid 04 ☐ solar panels on the pumps 99 ☐ Other
Can I take a picture of your irrigation pump? I Please take a picture of the irrigation pump nameplate which should h ave printed values of the pump power rating (in W) and voltage (in V) E IsAnswered(f_irrigation_power)	PICTURE f_irr_pump_pic

D - FARMER INTERVIEW

COMMUNITY/EXTENSION SERVICES

Question	Response
How easy or difficult is it for you to access extension services, or business development services, if you need help improving your farm operations or expanding to new business?	SINGLE-SELECT f_extension_services 001 ○ Very difficult 002 ○ Difficult 003 ○ Neither easy nor difficult 004 ○ Easy 005 ○ Very easy 999 ○ I don't know
Who provides these extension or support services? Name specific organizations if you know them.	LIST f_extension_orgs ....

D - FARMER INTERVIEW / COMMUNITY/EXTENSION SERVICES

Roster: EXTENSION SERVICES ROSTER

ext_details

generated by list question f_extension_orgs

E IsAnswered(f_extension_orgs)

Question	Response
What is the name of the community representative that you regularly deal with from %ext_details%?	TEXT ext_details_name ....
What is the contact number for %ext_details_name% from %ext_details%? E IsAnswered(ext_details_name)	TEXT ext_details_num ....
Are you a member of a farmer's group or a cooperative (co-op)?	SINGLE-SELECT f_coop 01 ○ Yes 02 ○ No

Please name the co-ops or associations of which you are a member. I If one association is an informal group of farmers that share knowledg e and support, then enter "informal" E f_coop == 1	LIST f_coop_name ....
Which of the following do these coops or associations provide you? E f_coop == 1	MULTI-SELECT f_coop_services 01 ☐ Financial services including credit and thrift 02 ☐ Extension services 03 ☐ Improved inputs 04 ☐ Others
If "other", please describe E f_coop_services.Contains(4)	TEXT f_coop_services_oth ....

E - AGRIC TRADER INTERVIEW

form_e

E respondent_type.Contains(4)

For our study, a trader is someone who buys agricultural products from one entity, and then sells to another at a higher price, without conducting any value-added processes in-between . Do you engage in this kind of trading? V1 self == 1 M1 <big>Please exit the trader interview if the respondent does not fit the trader definition</big>	SINGLE-SELECT t_istrader 01 ○ Yes 02 ○ No

E - AGRIC TRADER INTERVIEW

LOCATION

Where do you conduct your trading?	MULTI-SELECT t_trade_location 02 ☐ In the market in this community 03 ☐ In the market in another community 04 ☐ With middlemen who visit this community 05 ☐ I conduct my trading outside of this community
Is this interview being conducted where trading occurs? I (within 50 meteres)	SINGLE-SELECT t_at_trade_site 01 ○ Yes 02 ○ No
(for enumerator) If this is the site where trading takes place, record GPS coordinates: E t_at_trade_site == 1	GPS t_trade_coords ________ N ________ W ________ A
(for enumerator) If this interview is not conducted where trading takes place, how many minutes would it take to walk there from the city center? E !t_trade_location.Contains(5) && !IsAnswered(t_trade_coords)	SINGLE-SELECT t_farm_min_walk 01 ○ 1-15 minutes 02 ○ 15-30 minutes 03 ○ 30-45 minutes 04 ○ >45 minutes
Could you specify how many minutes it would take to walk to the trading center from the city center? E t_farm_min_walk == 4 V1 self <= 120 M1 If the trading area is more than 2 hours away, is it in a different community? If so, interview a farmer from the community associated with this interview.	NUMERIC: DECIMAL t_farm_min_walk_other ________

E - AGRIC TRADER INTERVIEW

CROPS TRADED

Which of the following are major crops that you trade? Choose a maximum of 3. I If the farmer has more than 3 crops, please ask him/her to prioritize th e top 3 crops by value	MULTI-SELECT t_crops 0572 ☐ Avocado 0486 ☐ Bananas 0044 ☐ Barley 0656 ☐ Coffee 0004 ☐ Cows milk 0406 ☐ Garlic 0358 ☐ Head Cabbage 0056 ☐ Maize 0571 ☐ Mango 0403 ☐ Onion 0401 ☐ Red pepper 0289 ☐ Sesame 0003 ☐ Sheep or goat milk 0083 ☐ Sorghum 0102 ☐ Teff 0388 ☐ Tomato And 6 other symbols [16]
Describe 'Other' crop #1 E t_crops.Contains(9995)	TEXT t_crop_other_1 ....
Describe 'Other' crop #2 E t_crops.Contains(9996)	TEXT t_crop_other_2 ....
Describe 'Other' crop #3 E t_crops.Contains(9997)	TEXT t_crop_other_3 ....

E - AGRIC TRADER INTERVIEW / CROPS TRADED

Roster: TRADED CROPS

generated by multi-select question t_crops t_crop_roster

E - AGRIC TRADER INTERVIEW / CROPS TRADED / TRADED CROPS

SEASONALITY

Is trading of %t_crop_roster% affected by the seasons? If so, how many harvest seasons do you experience per year?	SINGLE-SELECT t_seasonality 00 ○ This activity is not seasonal 01 ○ 1 harvest (busy) season per year 02 ○ 2 harvest (busy) seasons per year

What month does the first busy trading season start? E t_seasonality == 1 || t_seasonality == 2	SINGLE-SELECT t_season_start_1 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December
What month does the first busy trading season end? E t_seasonality == 1 || t_seasonality == 2	SINGLE-SELECT t_season_end_1 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December
What month does the second busy trading season start? E t_seasonality == 2	SINGLE-SELECT t_season_start_2 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December

What month does the second busy trading season end? E t_seasonality == 2	SINGLE-SELECT t_season_end_2 01 O January 02 O February 03 O March 04 O April 05 O May 06 O June 07 O July 08 O August 09 O September 10 O October 11 O November 12 O December

E - AGRIC TRADER INTERVIEW / CROPS TRADED / TRADED CROPS

VOLUMES

Throughout the year, how much %t_crop_roster% do you trade per week? E t_seasonality == 0	NUMERIC: INTEGER t_tradevol_wk_ns ----------------------------------
During the busy season, how much %t_crop_roster% do you trade per week? I Enumerator: if the respondent has difficulty in estimating quantities, use the "Size Reference" section to help clarify E t_seasonality == 1 || t_seasonality == 2	NUMERIC: INTEGER t_tradevol_wk_s1 ----------------------------------
During the second busy season, how much %t_crop_roster% do you trade per week? E t_seasonality == 2	NUMERIC: INTEGER t_tradevol_wk_s2 ----------------------------------
Record units for the trade volumes reported	SINGLE-SELECT t_buy_units 01 O kilogram 02 O bag 03 O tonne 04 O liter 05 O pick-up truck 06 O large trailer load 07 O quintal 99 O other
If "Other", please specify units in full. E t_buy_units == 99	TEXT t_buy_units_oth ....
What size of bag are you referring to? I Enumerator: if the respondent has difficulty in estimating quantities, use the "Size Reference" section to help clarify E t_buy_units == 2	NUMERIC: DECIMAL t_buy_bag_size ---------------------------------- SPECIAL VALUES 010 10 kg 025 25 kg 050 50 kg 100 100 kg

VARIABLE	DOUBLE	t_tradevol
IsAnswered(t_tradevol_wk_ns) ? t_tradevol_wk_ns : IsAnswered(t_tradevol_wk_s1) ? t_tradevol_wk_s1 : t_tradevol_wk_s2		

E - AGRIC TRADER INTERVIEW / CROPS TRADED / TRADED CROPS

STORAGE AND LOSSES

How many days do you typically need to store %t_crop_roster% before sale? I If less than a whole day, use fractions like 0.25 or 0.5 to report quarter or half days of storage.	NUMERIC: DECIMAL	t_store_time
Of the %t_tradevol% %t_buy_units%s of %t_crop_roster% you trade per week, how many %t_buy_units%s is spoiled <u>in your possession</u> before it can be sold to the next buyer? V1 t_spoil < t_tradevol M1 Amount reported spoiled during a week is more than the total amount traded.	NUMERIC: INTEGER	t_spoil
VARIABLE t_spoil/t_tradevol*100	DOUBLE	t_pct_spoil
How do you store the purchased %t_crop_roster% before sale? E t_pct_spoil > 5	TEXT	t_ph_storage
What change could reduce these losses to spoilage? E t_pct_spoil > 5	TEXT	t_ph_change

E - AGRIC TRADER INTERVIEW / CROPS TRADED / TRADED CROPS

SALES

Would you buy this crop in its raw form and pay to process itbefore selling at market?	SINGLE-SELECT 01 O Yes 02 O No	t_proc_interest
Why wouldn't buy this crop in raw form and pay to proces it before going to market?? E t_proc_interest == 2	TEXT	t_proc_reason

What are the main forms in which you sell %t_crop_roster%? Maximum of three (3) answers I e.g. wheat flour, dried maize grain	MULTI-SELECT t_sale_product 0561 ☐ maize, dry on cob 0562 ☐ maize, green on cob 0563 ☐ maize, grain with husk 0564 ☐ maize, grain without husk 0565 ☐ maize, flour 0566 ☐ maize, other product 0151 ☐ wheat, dry on head 0152 ☐ wheat, grain with husk 0153 ☐ wheat, grain without husk 0154 ☐ wheat, flour 0155 ☐ wheat, other product 0041 ☐ milk, cow fresh 0042 ☐ milk, cow chilled 0043 ☐ milk, cow dried 0044 ☐ milk, cow sweetened condensed 0045 ☐ milk, cow butter And 42 other symbols [17]

E - AGRIC TRADER INTERVIEW / CROPS TRADED / TRADED CROPS / SALES

Roster: PRODUCT SALE PRICE ROSTER

generated by multi-select question t_sale_product — t_product_roster

From whom do you buy %t_product_roster% ?	MULTI-SELECT t_buy_from 01 ☐ smallholder farmers (<2 ha land) 02 ☐ medium to large farmers (>2 ha land) 03 ☐ small agric processors 04 ☐ cottage industry processors 05 ☐ other traders/middlemen
low end of purchase price for %t_product_roster%	NUMERIC: INTEGER t_purchase_price_low ________________
high end of purchase price for %t_product_roster%	NUMERIC: INTEGER t_purchase_price_high ________________
Record units for the %t_purchase_price_high% reported in the previous question. ETB per...	SINGLE-SELECT t_trade_units 01 ○ kilogram 02 ○ bag 03 ○ tonne 04 ○ liter 05 ○ pick-up truck 06 ○ large trailer load 07 ○ quintal 99 ○ other
If "Other", please specify units in full. E t_trade_units == 99	TEXT t_trade_units_oth ________________

If ETB/bag, what size of bag are you referring to? I Select the answer that seems closest to the average bag size, or enter your own number E `t_trade_units == 2`	NUMERIC: INTEGER `t_sale_bag_size` SPECIAL VALUES 010 10 kg 025 25 kg 050 50 kg 100 100 kg
What percentage of your purchased %t_product_roster% is bought from community members V1 `self >= 0 && self <= 100 && !self.InRange(0.001,1)` M1 Please answer as whole number between 0 and 100 (e.g. for 30% ente r "30")	NUMERIC: INTEGER `t_buy_community`
Who do you sell %t_product_roster% to?	MULTI-SELECT `t_sell_to` 03 ☐ small agric processors 04 ☐ cottage industry processors 05 ☐ other traders/middlemen 02 ☐ consumers/households
low end of sale price range:	TEXT `t_sale_price_low`
high end of sale price range:	TEXT `t_sale_price_high`
What percentage (%) of your purchased %t_product_roster% is sold to members of %cover_com_name% V1 `self >= 0 && self <= 100` M1 Please list percentage as whole number between 0 and 100	NUMERIC: INTEGER `t_sell_community`
Will customers pay more for %rostertitle% if it is produced by an electric machine instead of manually or with diesel-powered machines?	SINGLE-SELECT `t_sell_electrified` 01 ○ Yes 02 ○ No
What percentage (%) increase would customers pay? E `t_sell_electrified== 1` V1 `self >= 0 && self <= 100` M1 Please list percentage as whole number between 0 and 100	NUMERIC: INTEGER `t_sell_elect_amt`
Over the past few years, what has been the trend of demand for %rostertitle%?	SINGLE-SELECT `t_sell_trends` 01 ○ Steadily decreasing 02 ○ Mostly the same 03 ○ Steadily increasing
How often do buyers want more %rostertitle% than you have available to sell?	SINGLE-SELECT `t_sell_outsell` 01 ○ All the time 02 ○ Often 03 ○ Sometimes 04 ○ Rarely 05 ○ Never

If the agricultural processors had an increased supply of %t_crop_roster%, would you	SINGLE-SELECT t_sell_more 01 O purchase more of the product from the processor to sell 02 O purchase the same amount of the product from the processor
Would you be willing to join forces with other traders in this community to form a larger joint trading business?	SINGLE-SELECT t_joint_interest 01 O Yes 02 O No
Why are you not interested in starting a joint business with other traders? E t_joint_interest == 0	TEXT t_joint_non_why ....

SIZE REFERENCE

size_reference

STATIC TEXT

100 kg bag size

STATIC TEXT

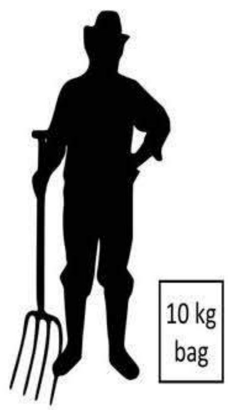
50 kg bag size

STATIC TEXT

25 kg bag size

STATIC TEXT

10 kg bag size



STATIC TEXT

1 kg bag size

STATIC TEXT

pick-up load

STATIC TEXT

large trailer load


MAN
IGWE

Z - CROP APPENDICES

crop_appendices

ENUMERATOR: select a maximum of one (1) crop-specific appendix to ask the respondent, based on his/her main activity. E respondent_type.ContainsAny(2,3,4) V1 appendix_select.InList(3,4,15,56,44,102) M1 There are only appendices for teff, maize, wheat, barley, and ruminant milk. Please select one of those crops/products.	SINGLE-SELECT 0572 O Avocado 0486 O Bananas 0044 O Barley 0656 O Coffee 0004 O Cows milk 0406 O Garlic 0358 O Head Cabbage 0056 O Maize 0571 O Mango 0403 O Onion 0401 O Red pepper 0289 O Sesame 0003 O Sheep or goat milk 0083 O Sorghum 0102 O Teff 0388 O Tomato And 6 other symbols [16]	appendix_select

Z - CROP APPENDICES

MAIZE APPENDIX

form_z2

E appendix_select ==56

VARIABLE "maize"	STRING	z2_crop

STATIC TEXT

This brief supplemental section asks some specific questions for %z2_crop%.

Are there any large %z2_crop% storage facilities in town, or accessible in a nearby community?	SINGLE-SELECT 01 O Yes 02 O No	z2_storage
Do local bakeries or food sellers use %z2_crop% flour?	SINGLE-SELECT 01 O Yes 02 O No	z2_maizeflour

Z - CROP APPENDICES

TEFF APPENDIX

form_z3

E appendix_select ==102

VARIABLE "teff"	STRING	z3_crop

STATIC TEXT

This brief supplemental section asks some specific questions for %z3_crop%.

Are there any large %z3_crop% storage facilities in town, or accessible in a nearby community?	SINGLE-SELECT 01 Yes 02 No	z3_storage
Do local bakeries or food sellers use %z3_crop% flour?	SINGLE-SELECT 01 Yes 02 No	z3_teffflour

Z - CROP APPENDICES

BARLEY APPENDIX

form_z5

E appendix_select ==44

VARIABLE "barley"	STRING	z5_crop

STATIC TEXT

This brief supplemental section asks some specific questions for %z5_crop%.

Are there any large %z5_crop% storage facilities in town, or accessible in a nearby community?	SINGLE-SELECT 01 Yes 02 No	z5_storage
Are there any large %z5_crop% malting facilities in town, or accessible in a nearby community?	SINGLE-SELECT 01 Yes 02 No	z5_malt
Do local bakeries or food sellers use %z5_crop% flour?	SINGLE-SELECT 01 Yes 02 No	z5_barleyfflour

Z - CROP APPENDICES

WHEAT APPENDIX

form_z4

E appendix_select ==15

VARIABLE "wheat"	STRING	z4_crop

STATIC TEXT

This brief supplemental section asks some specific questions for %z4_crop%.

Are there any large %z4_crop% storage facilities in town, or accessible in a nearby community?	SINGLE-SELECT 01 Yes 02 No	z4_storage
Do local bakeries or food sellers use %z4_crop% flour?	SINGLE-SELECT 01 Yes 02 No	z4_wheatflour

Z - CROP APPENDICES

RUMINANT MILK APPENDIX

form_z9

E appendix_select.InList(4,3)

Question	Response	Variable
What crops do you use for feed?	MULTI-SELECT 0572 ☐ Avocado 0486 ☐ Bananas 0044 ☐ Barley 0656 ☐ Coffee 0004 ☐ Cows milk 0406 ☐ Garlic 0358 ☐ Head Cabbage 0056 ☐ Maize 0571 ☐ Mango 0403 ☐ Onion 0401 ☐ Red pepper 0289 ☐ Sesame 0003 ☐ Sheep or goat milk 0083 ☐ Sorghum 0102 ☐ Teff 0388 ☐ Tomato And 6 other symbols [16]	z9_feed_crop
Do you give all the animals the same type of feed?	SINGLE-SELECT 01 ○ Yes 02 ○ No	z9_feed_var

Z - CROP APPENDICES / RUMINANT MILK APPENDIX

Roster: FEED PRICE

generated by multi-select question z9_feed_crop — crop_roster

E IsAnswered(z9_feed_crop)

Question	Response	Variable
Do you pay for feed using %crop_roster%?	SINGLE-SELECT 01 ○ Yes 02 ○ No	feed_pay
How much do you pay for feed using %crop_roster%? E feed_pay == 1	NUMERIC: INTEGER ________________	z9_feed_cost
Price of %z9_feed_cost% is in terms of ETB per... E IsAnswered(z9_feed_cost)	SINGLE-SELECT 01 ○ kilogram 02 ○ bag 03 ○ tonne 04 ○ liter 05 ○ pick-up truck 06 ○ large trailer load 07 ○ quintal 99 ○ other	z9_feed_price_unit
If "ETB/Other", please specify units in full. E z9_feed_price_unit == 99	TEXT	z9_feed_price_unit_oth

If ETB/bag, what size of bag are you referring to? I Select the answer that seems closest to the average bag size, if none a pply, enter your own estimate E `z9_feed_price_unit == 2`	NUMERIC: DECIMAL ________ SPECIAL VALUES 010 10 kg 025 25 kg 050 50 kg 100 100 kg	`feed_price_size`
Which of the following animals do you milk?	MULTI-SELECT 01 ☐ Cows 02 ☐ Sheep 03 ☐ Goats	`z9_milk_species`

Z - CROP APPENDICES / RUMINANT MILK APPENDIX

Roster: MILK SPECIES ROSTER

generated by multi-select question `z9_milk_species` — `z9_milk_roster`

How many %z9_milk_roster% do you milk?	NUMERIC: INTEGER ________	`z9_number_species`
Are these %z9_milk_roster% milked consistently all year?	SINGLE-SELECT 01 O Yes 02 O No	`z9_seasonality`
Approximately what date do you start milking daily? E `z9_seasonality == 1`	DATE ________	`z9_milk_start`
Approximately what do you end milking daily? E `z9_seasonality == 1`	DATE ________	`z9_milk_end`
How many days per week do you milk during this period? V1 `self.InRange(0,7)` M1 Cannot have more than 7 days in a week	NUMERIC: INTEGER ________	`z9_days_per_wk`
How much milk do you get from these %z9_milk_roster%? Answer in liters per day?	NUMERIC: DECIMAL ________	`z9_milk_per_day`

Question	Response	Variable
What crops do you use for feeding %z9_milk_roster%? E z9_feed_var == 2	MULTI-SELECT 0572 ☐ Avocado 0486 ☐ Bananas 0044 ☐ Barley 0656 ☐ Coffee 0004 ☐ Cows milk 0406 ☐ Garlic 0358 ☐ Head Cabbage 0056 ☐ Maize 0571 ☐ Mango 0403 ☐ Onion 0401 ☐ Red pepper 0289 ☐ Sesame 0003 ☐ Sheep or goat milk 0083 ☐ Sorghum 0102 ☐ Teff 0388 ☐ Tomato And 6 other symbols [16]	z9_animal_feedtype
How much feed does one of these %z9_milk_roster% consume per day?	NUMERIC: DECIMAL ---------------------------------	z9_feed_per_day
What is the unit of this amount of feed? E IsAnswered(z9_feed_per_day)	SINGLE-SELECT 01 ○ kilogram 02 ○ bag 03 ○ tonne 04 ○ liter 05 ○ pick-up truck 06 ○ large trailer load 07 ○ quintal 99 ○ other	z9_feed_unit
If "Other", please specify units in full. E z9_feed_unit == 99	TEXT	z9_feed_unit_other
If "bag", what size of bag are you referring to? I Select the answer that seems closest to the average bag size, if none a pply, enter your own estimate E z9_feed_unit == 2	NUMERIC: DECIMAL --------------------------------- SPECIAL VALUES 010 10 kg 025 25 kg 050 50 kg 100 100 kg	z9_feed_bag_size
Do you store milk at home before consumption or sale?	SINGLE-SELECT 01 ○ Yes 02 ○ No	z9_do_store
How do you store it at home? E z9_do_store == 1	TEXT	z9_storage_method

Are there milk chilling or storage facilities available in %cover_com_name%?	SINGLE-SELECT z9_comm_storage 00 O No 01 O Yes 99 O I'm not sure
Are there milk chilling or storage facilities available in a nearby community that you or other community members use?	SINGLE-SELECT z9_other_storage 00 O No 01 O Yes 99 O I'm not sure
If you are a member of a dairy cooperative? If so please tell me the name.	TEXT z9_dairy_coop_name ....
What is your preference for fresh vs powdered milk?	SINGLE-SELECT z9_milk_preference 01 O Strongly prefer powdered milk 02 O Prefer powdered milk 03 O Do not have a preference for one over the other 04 O Prefer fresh milk 05 O Strongly prefer fresh milk

Y- FEMALE RESPONDENT

E `respondent_gender == 1 && respondent_type.Contains(5)`

What agricultural business activities would you be interested in? I If respondent is interested in more than two activities, please ask her t o identify the top two activities.	MULTI-SELECT: ORDERED F_actor_prefs 01 ☐ Processing 02 ☐ Farming 03 ☐ Trading 99 ☐ Other activity
Please describe the other business activity you would be interested in. E `F_actor_prefs.Contains(99)`	TEXT F_actor_prefs_other ....
What processing business activity would you be most interested in pursuing? I Ask the interviewer to pick the two activities she is most interested in. E `F_actor_prefs.Contains(1)`	MULTI-SELECT: ORDERED F_actor_processing 01 ☐ threshing/shelling 03 ☐ grating/grinding 05 ☐ grain flour milling 06 ☐ animal feed production 07 ☐ malting 08 ☐ drying 09 ☐ cold storage 10 ☐ milk chilling 11 ☐ milk churning 13 ☐ milk pasteurization 14 ☐ packaging 98 ☐ Other activity 1 99 ☐ Other activity 2
Why are you not interested in any processing activities? E `!(F_actor_prefs.Contains(1))`	TEXT F_actor_nonprocess ....

APPENDIX A — INSTRUCTIONS

[1] business_select: Which of the following non-agricultural businesses have operated in the community in the past 12 months?
Note this question focuses on non-agricultural businesses. The following questions will ask about agric processing. Use up to three "Other" categories to capture major businesses not included in select menu.

[2] num_cycles: How many cycles of %ap_activity_roster% do you run per day?
A cycle is a continuous period during which the processing will happen. For example if the processor usually processes during the morning, and then again in the evening after a break-- this would count as two cycles.

APPENDIX B — CATEGORIES

[1] Eth_List_of_Regions
Categories: 1:Tigray, 2:Afar, 3:Amhara, 4:Oromiya, 5:Somali, 6:Benishangul, 7:SNNP, 8:Gambela, 9:Harari, 10:Addis Ababa, 11:Dire Daw
a

[2] Eth_List_of_Woredas
Categories: 1:ABERGELE, 2:ADWA, 3:ENTICHO, 4:KOLA TEMBIEN, 5:LA'ILAY MAYCHEW, 6:MEREB LEHE, 7:NAEDER ADET, 8:TAHTAY MAYC
HEW, 9:WERIE LEHE, 10:ATSBI WENBERTA, 11:GANTA AFESHUM, 12:GULOMAHDA, 13:HAWZEN, 14:IROB, 15:SAESI TSAEDAEMBA, 16:KIL
TE AWULAELO, 17:ASGEDE TSIMBELA, 18:LA'ILAY ADIYABO, 19:MEDEBAY ZANA, 20:TAHTAY ADIYABO, 21:TAHTAY KORARO, 22:TSELEMTI,
23:ALAJE, 24:ALAMATA, 25:ENDAMEHONI, 26:OFLA, 27:MAICHEW, 28:RAYA AZEBO, 29:ENDERTA, 30:HINTALO WAJIRAT, 31:SAMRE, 32:D
EGUA TEMBIEN, 33:KAFTA HUMERA, 34:TSEGEDE, 35:WELKAIT, 36:MEK'ELE, 37:AFAMBO, 38:ASAYITA, 39:CHIFRA, 40:DUBTI, 41:ELIDAR,
42:KORI, 43:MILLE, 44:ADA'AR, 45:GARANI, 46:SEMERA LOGIA, 47:ABALA, 48:AFDERA, 49:BERHALE, 50:DALLOL, 51:EREBTI, 52:KONEBA,
53:MEGALE, 54:BIDU, 55:AMIBARA, 56:AWASH FENTALE, 57:BURE MUDAYTU, 58:DULECHA, 59:GEWANE, 60:ARGOBA, 61:AWASH TOWN
, 62:CANRUKA, 63:AURA, 64:EWA, 65:GULINA, 66:TERU, 67:YALO, 68:DALIFAGE�(FORMERLY KNOWN AS�ARTUMA), 69:DEWE, 70:HADE
LE ELE�(FORMERLY KNOWN AS�FURSI), 71:SIMUROBI GELE'ALO, 72:TELALAK, 73:ARGOBBA SPECIAL WOREDA, 74:DANGILA, 75:BANJA SH
EKUDAD, 76:ANKASHA GUAGUSA, 77:GUANGUA, 78:FAGGETA LEKOMA, 79:JAWI, 80:GUAGUSA SHEKUDAD, 81:BIBUGN, 82:HULET EJ ENE
SE, 83:GONCHA SISO ENESE, 84:ENBISE SAR MIDIR, 85:ENARJ ENAWGA, 86:ENEMAY, 87:DEBAY TELATGEN, 88:DEBRE ELIAS, 89:MACHAK
EL, 90:GOZAMIN, 91:BASO LIBEN, 92:AWABEL, 93:DEJEN, 94:SHEBEL BERENTA, 95:DEBRE MARKOS�(TOWN), 96:SINAN, 97:ANEDED, 98:
ADDI ARKAY, 99:BEYEDA, 100:JAN AMORA, 101:DEBARQ, 102:DABAT, 103:MIRAB ARMACHIHO, 104:TEGEDA, 105:LAY ARMACHIHO, 106:
WEGERA, 107:GONDAR ZURIA, 108:DEMBIYA, 109:CHILGA, 110:METEMA, 111:QWARA, 112:ALEFA, 113:MIRAB BELESSA, 114:MISRAQ BEL
ESSA, 115:GONDAR�(TOWN), 116:TSELEMT, 117:TACH ARMACHIHO, 118:TAKUSA, 119:ZIKUALA, 120:SOQOTA ZURIA, 121:DEHANA, 122
:GAZBIBLA, 123:ABEREGELLE, 124:SEHALA, 125:SEKOTA�(TOWN), 126:SEMIEN ACHEFER, 127:BAHIR DAR ZURIA, 128:YILMANA DENSA, 1
29:MECHA, 130:SEKELA, 131:KUARIT, 132:DEGA DAMOT, 133:DEMBECHA, 134:JABI TEHNAN, 135:BURE, 136:WEMBERMA, 137:GONCHA,
138:DEBUB ACHEFER, 139:FINOTE SELAM�(TOWN), 140:BAHIR DAR (TOWN), 141:MIDA WOREMO, 142:MERHABETE, 143:ENSARO, 144:M
ORETNA JIRU, 145:MENZ GERA MIDIR, 146:GESHE, 147:ANTSOKIYANA GEMZA, 148:EFRATANA GIDIM, 149:MENZ MAM MIDIR, 150:TERMA
BER, 151:MOJANA WADERA, 152:KEWET, 153:ANGOLALLA TERA, 154:ASAGIRT, 155:ANKOBER, 156:HAGERE MARIAMNA KESEM, 157:BERE
HET, 158:MENJARNA SHENKORA, 159:BASONA WERANA, 160:DEBRE BERHAN�(TOWN), 161:MENZ KEYA GEBREAL, 162:MENZ LALO MIDIR,
163:SIYADEBRINA WAYU, 164:EBENAT, 165:KEMEKEM, 166:FOGERA, 167:FARTA, 168:LAY GAYINT, 169:TACH GAYINT, 170:SIMADA, 171:
MISRAQ ESTE, 172:DERA, 173:DEBRE TABOR�(TOWN), 174:MIRAB ESTE, 175:BUGNA, 176:KOBO, 177:GIDAN, 178:MEKET, 179:WADLA, 1
80:DELANTA, 181:GUBA LAFTO, 182:HABRU, 183:WOLDIYA�(TOWN), 184:LASTA, 185:DAWUNT, 186:MAGDALA, 187:TENTA, 188:KUTAB
ER, 189:AMBASSEL, 190:TEHULEDERE, 191:WERE BABU, 192:KALU, 193:ALBUKO, 194:DESSIE ZURIA, 195:LEGAMBO, 196:SAYINT, 197:DE
BRE SINA, 198:KELALA, 199:JAMA, 200:WERE ILU, 201:WEGDE, 202:KOMBOLCHA�(TOWN), 203:DESSIE�(TOWN), 204:MEHAL SAYINT, 20
5:LEGAHIDA, 206:DAWA CHEFE, 207:BATI, 208:JILE TIMUGA, 209:ARTUMA FURSI, 210:DAWA HAREWA, 211:KEMISE�(TOWN), 212:AMIG
NA, 213:ASEKO, 214:ASELLA (TOWN), 215:BALE GASGAR, 216:CHOLE, 217:DIGELUNA TIJO, 218:SHANAN KOLU, 219:DIKSIS, 220:DODOTA,
221:ENKELO WABE, 222:GOLOLCHA, 223:GUNA (WOREDA), 224:HITOSA, 225:JEJU (WOREDA), 226:LIMUNA BILBILO, 227:LUDE HITOSA, 22
8:MERTI, 229:MUNESA, 230:ROBE (WOREDA), 231:SERU (WOREDA), 232:SIRE, 233:SHERKA, 234:SUDE, 235:TENA (WOREDA), 236:TIYO (W
OREDA), 237:ZIWAY DUGDA, 238:AGARFA (WOREDA), 239:BERBERE (WOREDA), 240:DAWE KACHEN, 241:DAWE SERARA, 242:DELO MENNA
, 243:DINSHO (WOREDA), 244:GASERA, 245:GINIR (WOREDA), 246:GOBA (WOREDA), 247:GOBA�(TOWN), 248:GOLOLCHA, 249:GORO, 250
:GURADAMOLE, 251:HARENA BULUK, 252:LEGEHIDA, 253:MEDA WELABU, 254:RAYTU, 255:ROBE�(TOWN), 256:SEWEYNA, 257:SINANA
GINDHIR (TOWN), 258:ARERO, 259:DIRE (WOREDA), 260:MIYU (WOREDA), 261:MOYALE, 262:TELTELE (WOREDA), 263:YABELO (WOREDA), 2
64:DEHAS (WOREDA), 265:YABALO(TOWN), 266:DILLO (WOREDA), 267:GUCHI, 268:DUBULUK WOREDA, 269:GOMOLE (WOREDA), 270:WA
CILE (WOREDA), 271:ELOWAYE, 272:BULE HORA, 273:BIRBISA KOJAWA, 274:GALANA, 275:ABAYA, 276:DUGDA DAWA, 277:QARCA, 278:S
URO BALGOLA, 279:MALKA SODA, 280:HAMBALA WAMANA, 281:BULEHORA(TOWN), 282:QARCA(TOWN), 283:BABILLE (TOWN), 284:BEDE
NO, 285:CHINAKSEN, 286:DEDER (TOWN), 287:FEDIS, 288:GIRAWA, 289:GOLA ODA, 290:GORO GUTU, 291:GURSUM WOREDA, 292:GURS
UM (FUGNAN BIRA) TOWN, 293:HAROMAYA, 294:JARSO, 295:KERSA, 296:KOMBOLCHA, 297:KURFA CHELE, 298:MALKA BALO, 299:META, 3
00:MEYUMULUKE, 301:MIDHEGA TOLA, 302:DEDER, 303:BABILLE, 304:AWADAY(TOWN), 305:HARAMAYA (TOWN), 306:GORO MUTI, 307:
QUMBII, 308:DIRE XIYARA, 309:ADA'A, 310:ADAMA NAANNOO, 311:ADAMI TULLU AND JIDO KOMBOLCHA, 312:BISHOFTU�(TOWN), 313:
BORA (WOREDA), 314:DUGDA (WOREDA), 315:BOSET, 316:FENTALE, 317:GIMBICHU, 318:LIBEN, 319:LOME (WOREDA), 320:ZIWAY/BATU
�(TOWN), 321:HARO LIMMU, 322:LEKA DULECHA, 323:IBANTU, 324:JIMMA ARJO, 325:LIMMU (WOREDA), 326:NEKEMTE (TOWN), 327:NU
NU KUMBA, 328:SASIGA, 329:SIBU SIRE, 330:WAMA HAGALO, 331:WAYU TUKA, 332:KIRAMU, 333:GIDA AYANA, 334:GOBU SAYO, 335:G
UDAYA BILA, 336:GUDAYA JARE, 337:GUTO GIDA, 338:GIDA KIRAMU, 339:GUTO WAYU, 340:LIMMU, 341:ADOLA�REDE, 342:ANA SORA, 3
43:BORE (WOREDA), 344:DAMA (WOREDA), 345:GIRJA, 346:HARO WALABU, 347:ODO SHAKISO(TOWN), 348:ADOLA�(TOWN), 349:SABA B
ORU, 350:AGA WAYU (WOREDA), 351:GUMI ELDALO (WOREDA), 352:GORO DOLA (WOREDA), 353:LIBEN(WOREDA) NEGELE (TOWN), 354:O
DO SHAKISO, 355:URAGA (WOREDA), 356:WADERA (WOREDA), 357:ABAY CHOMEN, 358:ABE DONGORO, 359:AMURU, 360:GUDURU, 361:
HABABO GUDURU, 362:HORO, 363:JARDEGA JARTE, 364:JIMMA GENETE, 365:JIMMA RARE, 366:SHAMBU (TOWN), 367:COMAN GUDURU, 3
68:HORO BULUQ, 369:YAYO, 370:NONO SALE, 371:ALE, 372:ALGE SACHI, 373:BACHO(ILUBABOR), 374:BILONOPHA, 375:DARIMMU, 376:
DORANI, 377:HALU, 378:HURUMU, 379:MATU, 380:MATU(TOWN), 381:BURE, 382:BADELE, 383:DABOHANA, 384:DEGA, 385:CAWAQA, 3
86:GACHI, 387:DHEDHESA, 388:CORA, 389:BORECHA, 390:MAKO, 391:BEDELE(TOWN), 392:AGARO�(TOWN), 393:CHORA BOTOR, 394:D
EDO, 395:GERA (AANAA), 396:GOMMA (AANAA), 397:GUMA (AANAA), 398:KERSA, 399:LIMMU KOSA, 400:LIMMU SAKKA, 401:MANA (AAN
AA), 402:OMO NADA, 403:SEKA CHEKORSA (AANAA), 404:SETEMA, 405:SHEBE SENBO, 406:SIGMO (AANAA), 407:SOKORU (AANAA), 408:T
IRO AFETA, 409:BOTOR XOLAY WOREDA, 410:MANCHO WOREDA, 411:OMO BEYAN WOREDA, 412:BACHO WOREDA(JIMMA), 413:ANFILLO (
AANAA), 414:DALE SEDI, 415:DALE WABERA, 416:DEMBIDOLO�(TOWN), 417:GAWO KEBE, 418:GIDAMI, 419:HAWA GELAN, 420:JIMMA H
ORO�(KELEM WELEGA), 421:LALO KILE, 422:SAYO, 423:YEMALOGI WELELE, 424:SADI CHANKA, 425:ABICHUNA GNE'A, 426:ALELTU, 427:S
HARARO (AANAA), 428:DEGEM, 429:DERA, 430:FICHE�(TOWN), 431:GERAR JARSO, 432:HIDABU ABOTE, 433:JIDA, 434:KEMBIBIT, 435:KU
YU, 436:WARA JARSO, 437:WUCHALE, 438:YAYA GULELE, 439:DEBRA LIBANOS, 440:AMAYA (WOREDA), 441:BECHO, 442:DAWO, 443:ILU (
WOREDA), 444:GORO, 445:KERSA MALIMA, 446:SEDEN SODO, 447:SODO DACHA, 448:TOLE, 449:WALISO (AANAA), 450:WALISO�(TOWN),
451:WONCHI, 452:ADABA (WOREDA), 453:NEGELE ARSI (WOREDA), 454:DODOLA (WOREDA), 455:GEDEB ASASA, 456:HEBAN ARSI, 457:K
OFELE (WOREDA), 458:KOKOSA (WOREDA), 459:WANDO, 460:KORE (WOREDA), 461:NENSEBO (WOREDA), 462:SERARO, 463:SHALA (WORED
A), 464:SHASHAMENE�(TOWN), 465:SHASHAMENE ZURIA, 466:ANCHAR, 467:BADESSA�(TOWN), 468:BOKE (WOREDA), 469:CHIRO�(TO
WN), 470:CHIRO ZURIA, 471:GEMECHIS, 472:DAROLEBU, 473:DOBA (WOREDA), 474:GUBA KORICHA, 475:HABRO, 476:ODAA BULTUM PRE
VIOUSLY KNOWN AS KUNI (WOREDA)HTTPS://WWW.FACEBOOK.COM/AANAA.ODAABULTUM/, 477:SHANAN DHUUGGOO(WOREDA), 478:MIE
SO, 479:TULO, 480:HAWI GUDINA, 481:BURKA DIMTU, 482:GUMBII BORDODE(WOREDA), 483:ABUNA GINDE BERET, 484:ADA'AA BARGAA
, 485:AMBO(TOWN), 486:AMBO (WOREDA), 487:BAKO TIBE, 488:CHELIYA, 489:DANO, 490:DENDI, 491:EJERIE, 492:ELFATA, 493:GINDE B
ERET, 494:JELDU, 495:JIBAT, 496:META ROBI, 497:MIDAKEGN, 498:NONO, 499:DIRE ENCHINI, 500:TOKE KUTAYE]], 501:COBII (WOREDA),

502 : META WALQIXE, 503 : LIBAN JAWWI, 504 : EJERSA LAFOO, 505 : ILU GALAN, 506 : AYRA (WOREDA), 507 : BABO GAMBELA, 508 : BEGI, 509 : BOJI CHOKORSA, 510 : LATA SIBU, 511 : BOJI DIRMAJI, 512 : GENJI (WOREDA), 513 : GIMBI (WOREDA), 514 : GIMBI�(TOWN), 515 : GULISO, 516 : HARU (WOREDA), 517 : HOMA (WOREDA), 518 : JARSO (WELEGA), 519 : KONDALA, 520 : KILTU KARA (WOREDA), 521 : LALO ASABI, 522 : MANA SIBU, 523 : NEJO (WOREDA), 524 : NOLE KABA, 525 : SAYO NOLE, 526 : YUBDO (WOREDA), 527 : NAJO(TOWN), 528 : ADAMA, 529 : JIMMA, 530 : AKAKI, 531 : BEREH, 532 : LAGA XAFO LAGA DADHI(TOWN), 533 : BURAYU�(TOWN), 534 : DUKAM (TOWN), 535 : HOLETA GENET�(TOWN), 536 : MULO (WOREDA), 537 : CANCO (TOWN), 538 : SEBETA HAWAS, 539 : SEBETA�(TOWN), 540 : SENDAFA�(TOWN), 541 : WALMARA, 542 : SULULTA�(TOWN), 543 : SULULTA (WOREDA), 544 : GALAN (TOWN), 545 : FILTU, 546 : DOLLO ADO, 547 : QARSADULA, 548 : GURA DAMOLE, 549 : GURA BAQASA, 550 : BOQOLMAYO, 551 : HARGELLE, 552 : BAAREY, 553 : CHERATI, 554 : CEELGARI, 555 : DOLOBAY, 556 : IIMEY GALBEED, 557 : RAASO, 558 : GODGOD, 559 : QOOXLE, 560 : ILIG DHEERE, 561 : DAROOR, 562 : AWARE, 563 : DHAGAX-BUUR, 564 : DHAGAX-MADOW, 565 : GUNAGADO, 566 : GASHAMO, 567 : BIRQOD, 568 : DIG, 569 : BILCIL BUUR, 570 : ARAARSO, 571 : YOOCAALE, 572 : ELWEYN (TOWN), 573 : DHUXUN, 574 : GERBO, 575 : XARAAREY, 576 : AYUN, 577 : HOR-SHAGAH, 578 : SEGEG, 579 : FIK, 580 : XAMARO, 581 : LAGAHIDA, 582 : SALAXAAD, 583 : MAYU-MUUQDHEER, 584 : QUBI, 585 : YAXOOB, 586 : WAANGAY, 587 : CADAADLE, 588 : DANAN, 589 : FERFER, 590 : BEER CAANO, 591 : GODE, 592 : IIMEY BARI, 593 : KELAFO, 594 : MUSTAHIL, 595 : ELALE, 596 : ABAQOROW, 597 : AWBARE, 598 : JIJIGA, 599 : BABILLE, 600 : GURSUM, 601 : HARSHIN, 602 : KEBRI BEYAH, 603 : SHABEELEY, 604 : HARAWO, 605 : QOORAAN/MULLA, 606 : TULI GULED, 607 : HARORAYS, 608 : GOLJANO, 609 : WAJAALE, 610 : DHOOBOWEYN, 611 : KEBRI DAHAR, 612 : SHEYGOOSH, 613 : SHILAABO, 614 : MARSIN, 615 : HIGLOLEY, 616 : LAS DHARKAYNLE, 617 : KUDUNBUUR, 618 : BODALAY, 619 : CEEL-OGADEEN, 620 : AFDEM, 621 : AYESHA, 622 : DEMBEL, 623 : ERER, 624 : MIESO, 625 : SHINILE, 626 : HADHAGAALE, 627 : GEBLALU, 628 : BIKI, 629 : BOKH, 630 : DANOT, 631 : GALADI, 632 : WARDER, 633 : DARATOLE, 634 : GALXAMUR, 635 : LEHEL-YUCUB, 636 : HARAWO (SPECIAL ZONE), 637 : TOG WAJALE (SPECIAL ZONE), 638 : GODE (SPECIAL ZONE), 639 : KEBRI BEYAH (SPECIAL ZONE), 640 : DEGEHABUR (SPECIAL ZONE), 641 : QADHAADHUMO, 642 : HUDET, 643 : MOYALE, 644 : MUBAREK, 645 : MAO-KOMO�SPECIAL WOREDA, 646 : PAWE�SPECIAL WOREDA, 647 : ASOSA, 648 : BAMBASI, 649 : KOMESHA, 650 : HORAZAB, 651 : MENGE, 652 : ODA BILDIGILU, 653 : SHERKOLE, 654 : AGALO MITE, 655 : BELO JEGONFOY, 656 : KAMASHI, 657 : SADAL (WOREDA) / DIZA, 658 : YASO, 659 : MANDURA, 660 : DANGUR, 661 : GUBA, 662 : DIBATE, 663 : BULEN, 664 : WENBERA, 665 : KULITO (TOWN), 666 : WERA WOREDA, 667 : WERA DIJO WOREDA, 668 : ATOTI ULO WOREDA, 669 : ALE SPECIAL WOREDA, 670 : DIRASHE�(SPECIAL WOREDA), 671 : KANA WOREDA, 672 : SAGAN ZURIA, 673 : KARAT ZURIA, 674 : KARAT (TOWN), 675 : AMARO�(SPECIAL WOREDA), 676 : BASKETO�(SPECIAL WOREDA, FORMERLY PART OF NORTH OMO), 677 : BURJI�(SPECIAL WOREDA), 678 : KONTA�(SPECIAL WOREDA, FORMERLY PART OF NORTH OMO), 679 : YEM�(SPECIAL WOREDA), 680 : DEBUB BENCH, 681 : MIZAN AMAN�(TOWN), 682 : SEMIEN BENCH, 683 : SHE BENCH, 684 : SHEKO (WOREDA), 685 : GURAFARDA, 686 : MAJI, 687 : BERO, 688 : SURMA, 689 : MEINIT SHASHA, 690 : MEINIT GOLDIA, 691 : GENA, 692 : ISARA (WOREDA), 693 : LOMA (WOREDA), 694 : MAREKA, 695 : TARCHA ZURIA, 696 : KECHI, 697 : MARI MANSA, 698 : TOCHA, 699 : DISA, 700 : ZABA GARADA, 701 : ARBA MINCH�(TOWN), 702 : ARBA MINCH ZURIA, 703 : BONKE, 704 : BOREDA, 705 : CHENCHA (WOREDA), 706 : DITA (WOREDA), 707 : MIRAB ABAYA, 708 : DERAMALO, 709 : KUCHA, 710 : GARDA MARTA, 711 : DEMBA GOFA, 712 : GEZE GOFA, 713 : MALAGADO (WOREDA), 714 : MELOKOZA, 715 : OYDA, 716 : SAWLA�(TOWN), 717 : UBA DEBRETSEHAY, 718 : ZALA (WOREDA), 719 : BULE, 720 : DILA�(TOWN), 721 : DILA ZURIA, 722 : GEDEB, 723 : KOCHERE, 724 : WENAGO (WOREDA), 725 : YIRGACHEFE (WOREDA), 726 : ABESHGE, 727 : BUTAJIRA�(TOWN), 728 : CHEHA, 729 : ENDEGAGN, 730 : ENEMORINA EANER, 731 : EZHA, 732 : GETA (WOREDA), 733 : GUMER, 734 : KEBENA, 735 : GEDEBANO GUTAZER WELENE, 736 : MAREKO (WOREDA), 737 : MESKANE, 738 : MUHOR NA AKLIL, 739 : SODDO (WOREDA), 740 : WELKITE�(TOWN), 741 : ANA LEMO, 742 : DUNA (WOREDA), 743 : GIBE (WOREDA), 744 : GOMIBORA, 745 : HOSAENA�(TOWN), 746 : LEMO (WOREDA), 747 : MIRAB BADAWACHO, 748 : MISHA (WOREDA), 749 : MIRAB SORO, 750 : SIRARO BADAWACHO, 751 : MISRAQ BADAWACHO, 752 : SHASHOGO, 753 : SORO (WOREDA), 754 : BITA, 755 : BONGA�(TOWN), 756 : CHENA (WOREDA), 757 : CHETA (WOREDA), 758 : DECHA, 759 : GESHA, 760 : GEWATA, 761 : GINBO, 762 : MENJIWO, 763 : SAYILEM, 764 : TELO, 765 : ANGACHA (WOREDA), 766 : DAMBOYA (WOREDA), 767 : DOYOGENA (WOREDA), 768 : DURAME�(TOWN), 769 : HADERO TUNTO, 770 : KACHA BIRA, 771 : KEDIDA GAMELA, 772 : TEMBARO, 773 : ADILO ZURIA, 774 : ANDERACHA (WOREDA), 775 : MASHA (WOREDA), 776 : YEKI, 777 : ALETA WENDO, 778 : ARBEGONA, 779 : ARORESA, 780 : AWASA ZURIA, 781 : BENSA, 782 : BONA ZURIA, 783 : BORICHA, 784 : BURSA, 785 : CHERE, 786 : CHUKO, 787 : DALE, 788 : DARA, 789 : GORCHE, 790 : HULA, 791 : LOKO ABAYA, 792 : MALGA, 793 : SHEBEDINO, 794 : WENSHO, 795 : WONDO GENET, 796 : DARARA, 797 : BALELA, 798 : CABE, 799 : CIRONE, 800 : DAELA, 801 : BURA, 802 : GIRJA, 803 : HAWELA CAFE, 804 : TAFARI KELA, 805 : XAXICHA, 806 : SHAFAMO, 807 : ALICHO WERERO, 808 : DALOCHA, 809 : LANFRO, 810 : MIRAB AZERNET BERBERE, 811 : MISRAQ AZERNET BERBERE, 812 : SANKURRA, 813 : SILTE, 814 : WULBAREG, 815 : MITO, 816 : MISRAQ SILTI, 817 : KUTARE WOREDA, 818 : DEBUB ARI (WOREDA), 819 : BENA TSEMAY (WOREDA), 820 : HAMER (WOREDA), 821 : SEMEN ARI (WOREDA), 822 : MALE (WOREDA), 823 : NYANGATOM (WOREDA), 824 : SELAMAGO (WOREDA), 825 : DASENECH (WOREDA), 826 : BOLOSO BOMBE, 827 : BOLOSO SORE, 828 : DAMOT GALE, 829 : DAMOT PULASA, 830 : DAMOT SORE, 831 : DAMOT WEYDE, 832 : DIGUNA FANGO, 833 : HUMBO, 834 : KINDO DIDAYE, 835 : KINDO KOYSHA, 836 : OFFA (WOREDA), 837 : SODO�(TOWN), 838 : SODO ZURIA, 839 : ABELA FARACHO, 840 : HOBICHA, 841 : FANGGO BILATE, 842 : AWASA, 843 : KEFICHO SHEKICHO, 845 : ITANG (WOREDA), 846 : ABOBO, 847 : DIMMA, 848 : GAMBELA WOREDA, 849 : GOG, 850 : JOR, 851 : JIKAWO, 852 : LARE, 853 : AKOBO, 854 : MATAR WOREDA, 855 : MAKUEY WOREDA, 856 : GODERE, 857 : MENGESH, 858 : HARARI, 859 : ADDIS ABABA, 860 : DIRE DAWA, 861 : ARGOBBA

[3] Eth_Y_N
Categories: 1 : Yes, 2 : No

[4] Eth_bldg_mat_codes
Categories: 1 : WOOD AND MUD, 2 : WOOD AND THATCH, 3 : WOOD ONLY, 4 : STONE ONLY, 5 : STONE AND MUD, 6 : STONE AND CEMENT, 7 : BLOCKS, PLASTERED WITH CEMENT , 8 : BLOCKS, UNPLASTERED , 9 : BRICKS, 10 : MUD BRICKS (TRADITIONAL), 11 : STEEL ("LAMERA") , 12 : CARGO CONTAINER, 13 : PARQUET OR POLISHED WOOD, 14 : CHIP WOOD, 15 : CORRUGATED IRON SHEET, 16 : ASBESTOS, 17 : REED/BAMBOO, 18 : OTHER, SPECIFY

[5] Eth_roof_mat_codes
Categories: 1 : CORRUGATED IRON SHEET, 2 : CONCRETE/CEMENT, 3 : THATCH, 4 : WOOD AND MUD, 5 : BAMBOO/REED, 6 : PLASTIC CANVAS, 7 : ASBESTOS, 8 : BRICKS, 9 : OTHERS(SPECIFY)

[6] Eth_road_mat
Categories: 1 : TAR/ASPHALT, 2 : GRADED GRAVELED, 3 : DIRT ROAD (MAINTAINED), 4 : DIRT TRACK

[7] Eth_walking_times
Categories: 1 : 1-15 minutes, 2 : 15-30 minutes, 3 : 30-45 minutes, 4 : >45 minutes

[8] Eth_seasonality
Categories: 0 : This activity is not seasonal, 1 : 1 harvest (busy) season per year, 2 : 2 harvest (busy) seasons per year

[9] Eth_months
Categories: 1 : January, 2 : February, 3 : March, 4 : April, 5 : May, 6 : June, 7 : July, 8 : August, 9 : September, 10 : October, 11 : November, 12 : December

[10] Eth_List_of_Zones

Categories: 1 : Central Tigray, 2 : East Tigray, 3 : North West Tigray, 4 : South Tigray, 5 : South East Tigray, 6 : West Tigray, 7 : Mekele (special zone), 8 : Zone 1 - Awsi Rasu, 9 : Zone 2 - Kilbet Rasu, 10 : Zone 3 - Gabi Rasu, 11 : Zone 4 - Fantena Rasu, 12 : Zone 5 - Hari Rasu, 13 : Argobba, 14 : Agew Awi, 15 : East Gojjam, 16 : North Gondar, 17 : Wag Hemra, 18 : West Gojjam, 19 : Bahir Dar (special zone), 20 : North Shewa Amhara, 21 : South Gondar, 22 : North Wollo, 23 : South Wollo, 24 : Oromia Zone, 25 : Arsi, 26 : Bale, 27 : Borana, 28 : East Hararghe, 29 : East Shewa, 30 : East Welega, 31 : Guji, 33 : Horo Guduru Welega, 34 : Ilu Aba Bora, 35 : Buno Bedele, 36 : Jimma, 37 : Kelam Welega, 38 : North Shewa Oromia, 39 : Southwest Shewa, 40 : West Arsi, 41 : West Haraghe, 42 : West Shewa, 43 : West Welega, 44 : Adama (special zone), 45 : Jimma (special zone), 46 : Finfinne (special zone), 47 : Afder, 48 : Jarar (formerly Degehabur), 49 : Nogob (formerly Fiq or Fik), 50 : Shabelle, 51 : Fafan (formerly Jijiga), 52 : Korahe, 53 : Liben, 54 : Sitti (formerly Shinine), 55 : Dollo (formerly Werder), 56 : Asosa, 57 : Kamashi, 58 : Metekel, 59 : Bench Maji, 60 : Dawro (formerly part of North Omo Zone), 61 : Gamo (formerly part of North Omo Zone Gamo Gofa), 62 : Gedeo, 63 : Gurage, 64 : Hadiya, 65 : Keffa (formerly part of Keficho Shekicho), 66 : Kembata Tembaro, 67 : Sheka (formerly part of Keficho Shekicho), 68 : Sidama, 69 : Silti, 70 : South Omo, 71 : Wolayita (formerly part of North Omo), 72 : Alaba (special woreda), 73 : Amaro (special woreda), 74 : Basketo (special woreda formerly part of North Omo), 75 : Burji (special woreda), 76 : Dirashe (special woreda), 77 : Konso (special woreda), 78 : Konta (special woreda formerly part of North Omo), 79 : Yem (special woreda), 80 : Anuak, 81 : Mezhenger, 82 : Nuer, 83 : Harari, 84 : Addis Ababa, 85 : Dire Dawa, 86 : Erer, 87 : Harawo (special zone), 88 : Tog Wajale (special zone), 89 : Gode (special zone), 90 : Kebri Beyah (special zone), 91 : Degehabur (special zone), 92 : Dhawa (special zone), 93 : Mao Komo (Special Woreda), 94 : Gofa (formerly part of North Omo Zone Gamo Gofa), 95 : Keficho Shekicho, 97 : Awasa Special Zone, 98 : Itang, 99 : Argobba (special zone), 100 : Pawe (Special Woreda), 101 : West Guji

[11] Eth_non_ag_businesses

Categories: 1 : Restaurants and Bars, 2 : Hotels, 3 : Video Viewing Centers, 4 : Computer Technology Shops, 5 : Small Shops and Petty Traders, 6 : Welders, 7 : Barbers and Hairdressers (Salons), 8 : Tailors, 9 : Mechanics, 10 : Carpenters/ Furniture Makers/ Artisans, 11 : Caterers, 996 : Other 1 (please specify), 997 : Other 2 (please specify), 998 : Other 3 (please specify)

[12] Eth_growth_barriers

Categories: 1 : Access to financing (loans), 2 : Lack of market access (can't sell more than I already do OR can't reach the customers I would sell to), 3 : Lack of know-how or experience (e.g. need further education), 4 : Lack of reliable electricity for machines (currently owned or not), 5 : I have personal activities at home or for my family that I must attend to during the day, 99 : Other

[13] Eth_mass_units

Categories: 1 : kilogram, 2 : bag, 3 : tonne, 4 : liter, 5 : pick-up truck, 6 : large trailer load, 7 : quintal, 99 : other

[14] Eth_coop_services

Categories: 1 : Financial services including credit and thrift, 2 : Extension services (e.g. farming technique training), 3 : Improved agricultural inputs (e.g. fertilizer, seeds), 4 : Access to agri-processing equipment, 5 : Channels to collect and sell product at market, 99 : Other

[15] Eth_fuel_units

Categories: 1 : kilogram, 2 : tonne, 3 : liter, 4 : pick-up truck, 99 : other

[16] Eth_crops

Categories: 572 : Avocado, 486 : Bananas, 44 : Barley, 656 : Coffee, 4 : Cows milk, 406 : Garlic, 358 : Head Cabbage, 56 : Maize, 571 : Mango, 403 : Onion, 401 : Red pepper, 289 : Sesame, 3 : Sheep or goat milk, 83 : Sorghum, 102 : Teff, 388 : Tomato, 15 : Wheat, 9995 : Other 1, 9996 : Other 2, 9997 : Other 3, 9998 : Other 4, 9999 : Other 5

[17] Eth_product_forms

Categories: 561 : maize, dry on cob, 562 : maize, green on cob, 563 : maize, grain with husk, 564 : maize, grain without husk, 565 : maize, flour, 566 : maize, other product, 151 : wheat, dry on head, 152 : wheat, grain with husk, 153 : wheat, grain without husk, 154 : wheat, flour, 155 : wheat, other product, 41 : milk, cow fresh, 42 : milk, cow chilled, 43 : milk, cow dried, 44 : milk, cow sweetened condensed, 45 : milk, cow butter, 46 : milk, cow buttermilk, 47 : milk, cow evaporated, 48 : milk, cow yoghurt, 49 : milk, cow cheese, 50 : milk, cow other product, 31 : milk, sheep/goat fresh, 32 : milk, sheep/goat chilled, 33 : milk, sheep/goat dried, 34 : milk, sheep/goat sweetened condensed, 35 : milk, sheep/goat butter, 36 : milk, sheep/goat buttermilk, 37 : milk, sheep/goat evaporated, 38 : milk, sheep/goat yoghurt, 39 : milk, sheep/goat cheese, 40 : milk, sheep/goat other product, 441 : barley, dry on head, 442 : barley, (hulled) grain with husk, 443 : barley (pearled) grain without husk, 444 : barley, flour, 445 : barley, other product, 1021 : teff, dry on head, 1022 : teff, grain with husk, 1023 : teff, grain without husk, 1024 : teff, flour, 1025 : teff, other product, 388 : tomato, fresh, 572 : avocado, fresh, 486 : banana, fresh, 4061 : garlic, fresh, 4062 : garlic, dried, 4063 : garlic, minced, 571 : mango, 6561 : Coffee not roasted not decaffeinated, 6562 : Coffee not roasted decaffeinated, 6563 : Coffee roasted not decaffeinated, 6564 : Coffee roasted decaffeinated, 6565 : Coffee husks and skins, 831 : sorghum, dry on head, 832 : sorghum, (hulled) grain with husk, 833 : sorghum (pearled) grain without husk, 834 : sorghum, flour, 835 : sorghum, other product

[18] Eth_bag_sizes

Categories: 10 : 10kg, 25 : 25kg, 50 : 50kg, 100 : 100kg

[19] Eth_connectivity_profs

Categories: 1 : Not Connected: Minigrid Priority, 2 : Not Connected: Grid Extension Priority, 3 : Not Connected: Electrification Low Priority, 4 : Grid Connected, 5 : Minigrid Connected

[20] Eth_process_activities

Categories: 1 : threshing/shelling, 3 : grating/grinding, 5 : grain flour milling, 6 : animal feed production, 7 : malting, 8 : drying, 9 : cold storage, 10 : milk chilling, 11 : milk churning, 13 : milk pasteurization, 14 : packaging, 98 : Other activity 1, 99 : Other activity 2

[21] Eth_actor_prefs

Categories: 1 : Processing, 2 : Farming, 3 : Trading, 99 : Other activity

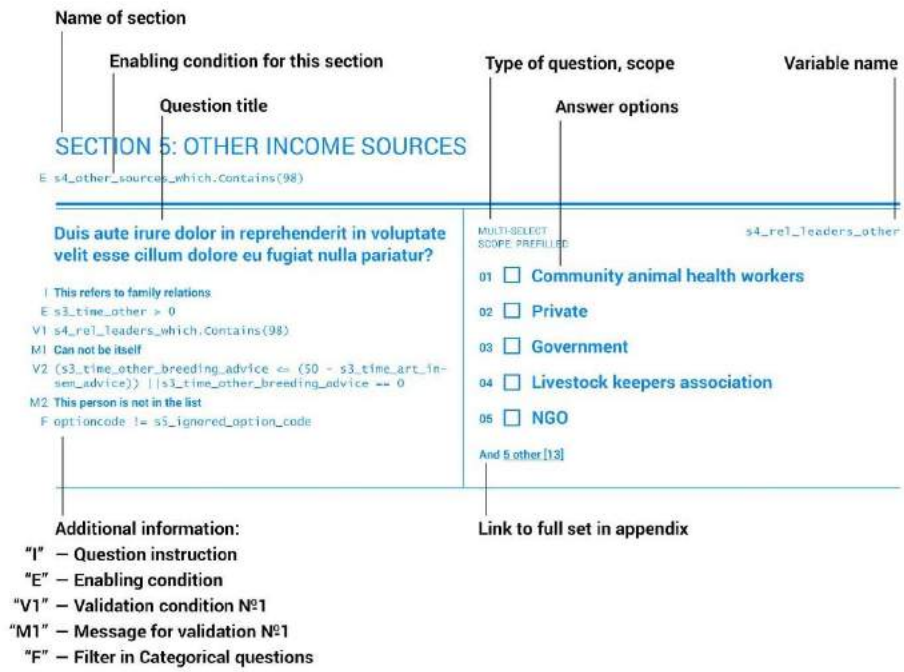
[22] ap_equip_start: What time of day do you start %ap_activity_roster% for this cycle?

Categories: 5 : 5 am, 6 : 6 am, 7 : 7 am, 8 : 8 am, 9 : 9 am, 10 : 10 am, 11 : 11 am, 12 : 12 pm (Noon), 13 : 1 pm, 14 : 2 pm, 15 : 3 pm, 16 : 4 pm, 17 : 5 pm, 18 : 6 pm, 19 : 7 pm, 20 : 8 pm, 21 : 9 pm, 22 : 10 pm, 23 : 11 pm, 0 : 12 am (Midnight), 1 : 1 am, 2 : 2 am, 3 : 3 am, 4 : 4 am

[23] ap_equip_end: What time of day do you stop %ap_activity_roster% for this cycle?
Categories: 5:5 am, 6:6 am, 7:7 am, 8:8 am, 9:9 am, 10:10 am, 11:11 am, 12:12 pm (Noon), 13:1 pm, 14:2 pm, 15:3 pm, 16:4 pm, 17:5 pm, 18:6 pm, 19:7 pm, 20:8 pm, 21:9 pm, 22:10 pm, 23:11 pm, 0:12 am (Midnight), 1:1 am, 2:2 am, 3:3 am, 4:4 am

LEGEND

Legend and structure of information in this file



Endnotes

---

[1] *Ethiopia Offgrid Solar Market Assessment*, USAID, 2019, https://www.usaid.gov/sites/default/files/documents/1860/PAOP-Ethiopia-MarketAssessment-Final_508.pdf.

[2] Ibid.

[3] Elisha, F. and Bukirwa, P., Productive Use Supply Chain Mapping in Ethiopia, 2020.

[4] *Ethiopia Offgrid solar Market Assessment.*

[5]*Agro-Business Induced Growth Programme in the Amhara National Regional State: Programme Phase 1 Completion Report*, AgroBIG, 2017.

[6] *The Opportunity at the Nexus of Energy and Agriculture*, Factor[e] Ventures, 2020, https://www.factore.com/ag-energy-nexus-report.

[7] Ibid.

[8] Livestock Primary, FAO, http://www.fao.org/faostat/en/#data/QL.

[9] *The Opportunity at the Nexus of Energy and Agriculture,* Factor[e] Ventures.

[10] From expert interview with Mr. Yonas Geleta, CEO of Oromia Capital Goods Finance Business S.C.

[11] From expert interview with Samuel Alemu, deputy general manager at Rensys Engineering.

[12] *The Opportunity at the Nexus of Energy and Agriculture,* Factor[e] Ventures.

[13] Oromia Credits and Savings Share Company, https://www.oromiamfi.com/index.php.

[14] Expert interview with DBE

[15] *The Opportunity at the Nexus of Energy and Agriculture*, Factor[e] Ventures.

[16] From expert interviews with leading MFIs.

[17] From expert interview with Mr. Yonas Geleta, CEO of Oromia Capital Goods Finance Business S.C.

[18] Asfaw Olana. "Lease Financing in Ethiopia: An Assessment of Five Regulated Lease Financing Companies," 2016.

[19] The Opportunity at the Nexus of Energy and Agriculture, Factor[e] Ventures.

[20] Ibid.

[21]Manzini, E. (2015). Design, when everybody designs: an introduction to design for social innovation. Cambridge, MA: The MIT Press.

[22] *Agricultural Sample Survey 2019/20 Volume 1: Report on Area and Production of Major Crops*, Ethiopian Central Statistical Agency, 137, 2020.

[23] Abate, G. et al., *Maize Value Chain in Ethiopia: Structure, Conduct, and Performance*, 2015, http://doi:10.13140/RG.2.1.2229.0804.

[24] *Agricultural Sample Survey 2018/19 Volume 1: Report on Area and Production of major crops,* Central Statistical Agency, 58, 2019.

[25] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[26] *Agricultural Sample Survey 2018/19 Volume 1,* Central Statistical Agency.

[27] Reynolds, C., "South Africa's 2017/18 Corn Yields Reach Second Highest on Record," 2018.

[28] Abate, G. et al., *Maize Value Chain in Ethiopia*; and *Maize Value Chain Analysis for Mecha District*, AgroBIG, 2016, https://agrobig.org/documents/1.3_Value_Chain_Analysis_MAIZE_Update_Nov_2016.pdf.

[29] Reynolds, C., "South Africa's 2017/18 Corn Yields."

[30] *Agricultural Sample Survey 2018/19 Volume 1,* Central Statistical Agency.

[31] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[32] Ibid.

[33] Reynolds, C., "South Africa's 2017/18 Corn Yields."

[34] Yetneberk, S., Teamir, M. & Teklewold, A., *Maize Based Food Products in Ethiopia: A Review of Traditional Practices and Research Outputs*, 2019.

[35] Reynolds, C., "South Africa's 2017/18 Corn Yields."

[36] Ibid.

[37] Ibid.

[38] Case study on the maize value chain in the Federal Democratic Republic of Ethiopia: Food loss analysis: causes and solutions, FAO, 2018.

[39] GIEWS Country Brief on Ethiopia, FAO, 2020, http://www.fao.org/giews/countrybrief/country.jsp?code=ETH.

[40] Ibid.

[41] Rashid, S., Getnet, K. & Lemma, S., *Maize value chain potential in Ethiopia: constraints and opportunities for enhancing the system*, Gates Open Res, 2010.

[42] Wolde, M., "Effects of aflatoxin contamination of grains in Ethiopia," 2016.

[43] Reynolds, C., "South Africa's 2017/18 Corn Yields."

[44] Rashid, S., Getnet, K. & Lemma, S., *Maize value chain potential in Ethiopia*, Gates Open Res, 2010.

[45] Román, F., Garbaba, C. A., Schellert, C. & Hensel, O., "A modification of a traditional Ethiopian maize store for solar powered ambient drying to reduce post-harvest losses," *Sci Rep 10*, 2020.

[46] *Crop and Livestock Product Utilization-Private Peasant Holdings Meher Season 2019-20*, Ethiopian Central Statistical Agency, 2020, https://www.statsethiopia.gov.et/wp-content/uploads/2020/12/Crop-and-Livestock-Product-Utilization-Private-Peasant-Holdings-Meher-Season-2019-20-2012-E.C.pdf.

[47] Gebreselassie, S., Haile, M. G. & Kalkuhl, M., *The Wheat Sector in Ethiopia: Current Status and Key Challenges for Future Value Chain Development*, 2017, https://ageconsearch.umn.edu/record/261290.

[48] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[49] Ibid.

[50] Ibid.

[51] Dorosh, P., Taffesse, A. S., Asrat, S., Asrat, S. & Gemessa, S. A. Crop Production in Ethiopia: Regional Patterns and Trends, 2011, https://www.degruyter.com/doi/10.9783/9780812208610.53.

[52] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[53] Abate, G. et al., *Maize Value Chain in Ethiopia*; and *Maize Value Chain Analysis for Mecha District*, AgroBIG, 2016.

[54] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[55] Minot, N. et al., *The Wheat Supply Chain in Ethiopia: Patterns, Trends, and Policy Options*, 2015, http://dx.doi.org/10.13140/RG.2.1.3408.7285; and Brasesco, F., Asgedom, D., Sommacal, V. & Casari, G., *Strategic analysis and intervention plan for wheat and wheat products in the Agro-Commodities Procurement Zone of the pilot Integrated Agro-Industrial Park in Central-Eastern Oromia, Ethiopia*, 104, 2019 http://www.fao.org/3/ca4202en/ca4202en.pdf.

[56] *Agricultural Sample Survey 2018/19 Volume 1,* Central Statistical Agency.

[57] Amentae, T. K., Hamo, T. K., Gebresenbet, G. & Ljungberg, D., "Exploring Wheat Value Chain Focusing on Market Performance, Post-Harvest loss, and Supply Chain Management in Ethiopia: The Case of Arsi to Finfinnee Market Chain," JAS 9, 22, 2017.

[58] Amentae, T. K., et al., "Exploring Wheat Value Chain," JAS 9, 22.

[59] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[60] Selinus, R., "The Traditional Foods of the Central Ethiopian Highlands," Ethnomed, 1971, https://ethnomed.org/resource/the-traditional-foods-of-the-central-ethiopian-highlands/.

[61] Amentae, T. K. et al., "Exploring Wheat Value Chain," JAS 9, 22.

[62] "How to Grow & Harvest Wheat on a Small Scale," The Art of Doing Stuff, 2020, https://www.theartofdoingstuff.com/im-growing-wheat-this-year-and-you-can-too/.

[63] Selinus, R., "The Traditional Foods of the Central Ethiopian Highlands," Ethnomed, 1971.

[64] Bunker, M., "Harvesting Wheat by Hand," 2015, https://michaelbunker.com/2015/06/29/harvesting-wheat-by-hand/.

[65] Ibid.

[66] Berhane, G., Paulos, Z., Tafere, K. & Tamru, S., *Foodgrain Consumption and Calorie Intake Patterns in Ethiopia*.

[67] Dorosh, P., et al., S. A. Crop Production in Ethiopia: Regional Patterns and Trends, 2011.

[68] *Maize Value Chain Analysis for Mecha District*, AgroBIG, 2016, https://agrobig.org/documents/1.3_Value_Chain_Analysis_MAIZE_Update_Nov_2016.pdf.

[69] "How to Grow & Harvest Wheat on a Small Scale," The Art of Doing Stuff, 2020; and Fortune, A., Institute Designs Own Crop Threshing Machine.

[70] "How to Grow & Harvest Wheat on a Small Scale," The Art of Doing Stuff, 2020.

[71] Amentae, T. K., et al., "Exploring Wheat Value Chain," JAS 9, 22.

[72] Minot, N. et al., *The Wheat Supply Chain in Ethiopia,* 2015.

[73] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[74] Ibid.

[75] Amentae, T. K. et al., "Exploring Wheat Value Chain," JAS 9, 22.

[76] Selinus, R., "The Traditional Foods of the Central Ethiopian Highlands," Ethnomed, 1971.

[77] Amentae, T. K. et al., "Exploring Wheat Value Chain," JAS 9, 22; and Selinus, R., "The Traditional Foods of the Central Ethiopian Highlands," Ethnomed, 1971.

[78] Selinus, R., "The Traditional Foods of the Central Ethiopian Highlands," Ethnomed, 1971.

[79] Amentae, T. K. et al., "Exploring Wheat Value Chain," JAS 9, 22.

[80] Ibid.

[81] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[82] Amentae, T. K. et al., "Exploring Wheat Value Chain," JAS 9, 22.

[83] Rashid, S. et al., *The Barley Value Chain in Ethiopia*, 2015, http://dx.doi.org/10.13140/RG.2.1.3670.8724.

[84] Amentae, T. K. et al., "Exploring Wheat Value Chain," JAS 9, 22.

[85] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[86] *Agricultural Sample Survey 2018/19 Volume 1,* Central Statistical Agency.

[87] Kifle, S. W., "Review on Barley Production and Marketing in Ethiopia," 2016.

[88] Coefficient of variation, Wikipedia, accessed 2020.

[89] Tadesse, D. & Derso, B., "The status and constraints of food barley production in the North Gondar highlands, North Western Ethiopia," *Agriculture & Food Security 8*, 2019.

[90] Kifle, S. W., "Review on Barley Production and Marketing in Ethiopia," 2016.

[91] Ibid.

[92] Kaso, T. & Guben, G., "Review of Barley Value Chain Management in Ethiopia," *Journal of Biology 15*, 2015.

[93] Kifle, S. W., "Review on Barley Production and Marketing in Ethiopia," 2016.

[94] Ibid.

[95] Ibid.

[96] Karuga, J., "Backgrounder: Malt barley production in Ethiopia," Farm Radio Scripts, http://scripts.farmradio.fm/radio-resource-packs/110-farm-radio-resource-pack/backgrounder-malt-barley-production-ethiopia/.

[97] Coefficient of variation, Wikipedia, accessed 2020.

[98] Wilcke, W. & Hellevang, K., "Drying wheat and barley," 2018, https://extension.umn.edu/small-grains-harvest-and-storage/drying-wheat-and-barley.

[99] Wolde, M., "Effects of aflatoxin contamination of grains in Ethiopia," 11, 2016.

[100] Kifle, S. W., "Review on Barley Production and Marketing in Ethiopia," 2016.

[101] Fortune, A., Institute Designs Own Crop Threshing Machine, https://addisfortune.news/institute-designs-own-crop-threshing-machine/.

[102] Diesel Grain Dryer, Opico, https://products.opico.co.uk/opico-products/grain-dryers/diesel-grain-dryers/.

[103] Kifle, S. W., "Review on Barley Production and Marketing in Ethiopia," 2016.

[104] Ibid.

[105] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[106] Karuga, J., "Backgrounder," Farm Radio Scripts.

[107] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[108] Kifle, S. W., "Review on Barley Production and Marketing in Ethiopia," 2016.

[109] Ibid.

[110] Rashid, S. et al., *The Barley Value Chain in Ethiopia*, 2015.

[111] Kifle, S. W., "Review on Barley Production and Marketing in Ethiopia," 2016.

[112] Karuga, J., "Backgrounder," Farm Radio Scripts.

[113] O'Connor, A., "Is Teff the New Super Grain?" *Well,* 2016 https://well.blogs.nytimes.com/2016/08/16/is-teff-the-new-super-grain/.

[114] Ibid.; and Why is the Ethiopian diaspora so influential? *BBC News*, 2016.

[115] *Working Strategy for Strengthening Ethiopia's Tef Value Chain*, Ethiopian Agricultural Transformation Agency, Federal Democratic Republic of Ethiopia Ministry of Agriculture, and Ethiopian Institute of Agricultural Research, 2013, http://www.ata.gov.et/download/working-strategy-for-strengthening-ethiopias-tef-value-chain/; and Minten, B., Tamru, S., Engida, E. & Kuma, T., *Ethiopia's Value Chains on the Move: The Case of Teff*, 2013.

[116] "Frequent tillage and its impact on soil quality," Iowa State University, https://crops.extension.iastate.edu/encyclopedia/frequent-tillage-and-its-impact-soil-quality.

[117] Brasesco, F., et al., *Strategic analysis and intervention plan*.

[118] *Agricultural Sample Survey 2018/19 Volume 1,* Central Statistical Agency.

[119] Amentae, T. K. et al., "Exploring Wheat Value Chain," JAS 9, 22.

[120] Ibid.

[121] Ibid.; and Mottaleb, K. A. & Rahut, D. B., "Household production and consumption patterns of Teff in Ethiopia," *Agribusiness*, 34, 668–684, 2018.

[122] Mottaleb, K.A., "Household production and consumption," Agribusiness, 2018.

[123] "Ethiopian Seasons," Ethiopian Info, accessed 2020, https://www.ethiopianinfo.com/ethiopian-seasons/.

[124] *Agricultural Sample Survey 2018/19 Volume 1,* Central Statistical Agency.

[125] *Food Loss Analysis: Causes and Solutions—Case study on the teff value chain in the Federal Democratic Republic of Ethiopia*, FAO, 2018, http://www.fao.org/3/I9972EN/i9972en.pdf.

[126] "Frequent tillage," Iowa State University; and Bunker, M., "Harvesting Wheat by Hand."

[127] *Agricultural Sample Survey 2018/19 Volume 1,* Ethiopian Central Statistical Agency.

[128] Nurse, Earle, "Teff, the Ethiopian superfood that used to be banned," CNN, 2015, https://www.cnn.com/2015/12/18/africa/ethiopian-superfood-teff/index.html.

[129] Mottaleb, K.A., "Household production and consumption," Agribusiness, 2018.

[130] Fortune, A., Institute Designs Own Crop Threshing Machine.

[131] Nurse, Earle, "Teff," CNN, 2015.

[132] "Ethiopia: Government to Resume Teff Exports," Geeska Afrika Online, 2015, https://www.geeskaafrika.com/ethiopia-government-to-resume-teff-exports/.

[133] *Analysis of price incentives for teff in Ethiopia for the time period 2005–2012*, FAO, 2015, http://www.fao.org/3/i4523e/i4523e.pdf.

[134] Ibid.

[135] "Frequent Tillage," Iowa State University; and Bachewe, F. et al., "The transforming value chain of Ethiopia's "orphan" tef crop," International Food Policy Research Institute, 250, 769–781, 2019, https://doi.org/10.1007/s00425-019-03224-0.

[136] Minten, B., Assefa, T., Adebe, G., Engida, E. & Tamru, S., *Food processing, transformation, and job creation: The case of Ethiopia's enjera markets*, International Food Policy Research Institute, 2016, https://www.ifpri.org/publication/food-processing-transformation-and-job-creation-case-ethiopias-enjera-markets.

[137] "Frequent Tillage," Iowa State University.

[138] Vandercasteelen, J., Minten, B. & Tamru, S., *Cities, value chains, and dairy production in Ethiopia*, International Food Policy Research Institute, 2019, https://doi.org/10.2499/p15738coll2.133437.

[139] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[140] Ibid.

[141] *Agricultural Sample Survey 2018-19 Volume 2: Report on Livestock and Livestock Characteristics*, Ethiopian Central Statistical Agency, 2019.

[142] Ibid.

[143] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[144] Minten, B., Habte, Y., Tamru, S. & Tesfaye, A., *Transforming agri-food systems in Ethiopia: Evidence from the dairy sector*, International Food Policy Research Institute, 2018, https://www.ifpri.org/publication/transforming-agri-food-systems-ethiopia-evidence-dairy-sector.

[145] Abate, G. et al., *Maize Value Chain in Ethiopia*.

[146] *Agricultural Sample Survey 2018-19 Volume 2: Report on Livestock and Livestock Characteristics*, Ethiopian Central Statistical Agency, 2019.

[147] The technology of traditional milk products in developing countries, FAO; and "Making an Impact with Milk in Africa," Paul Mueller Company.

[148] *Agricultural Sample Survey 2018-19 Volume 2*, Ethiopian Central Statistical Agency, 2019.

[149] Ibid.

[150] Minten, B., *Transforming agri-food systems in Ethiopia*; and Tessema, A. & Tibbo, M., *Hygienic Milk Processing: Clean Environment, Clean Utensils*, UC Davis, 2009, https://afghanag.ucdavis.edu/livestock/files/live-hygenic-milk.pdf.

[151] Tessema, A., *Hygienic Milk Processing*, UC Davis, 2009.

[152] Crichton, G., "Everything You Need to Know About Shelf-Stable (Aseptic) Milk," Dairy Discovery Zone, 2020, https://www.dairydiscoveryzone.com/blog/everything-you-need-know-about-shelf-stable-aseptic-milk.

[153] Shapiro, B. I. et al., *Ethiopia Livestock Sector Analysis*, 2017.

[154] Religions in Ethiopia, Pew-Templeton Global Religious Futures Project, Pew Research Center, http://globalreligiousfutures.org/countries/ethiopia#/?affiliations_religion_id=0&affiliations_year=2020&region_name=All%20Countries&restrictions_year=2016.

[155] Shapiro, B. I. et al., *Ethiopia Livestock Sector Analysis*, 2017.

[156] Minten, B., *Transforming agri-food systems in Ethiopia*.

[157] Ibid.

[158] Minten, B., Habte, Y., Baye, K. & Tamru, S., *Food safety, modernization, and food prices: Evidence from milk in Ethiopia*, International Food Policy Research Institute, 2020, https://ebrary.ifpri.org/digital/collection/p15738coll2/id/133795.

[159] Dijkink, B., Esveld, E., Broeze, J., Axmann, H. & Vollebregt, M., *Effects of milk cooling: A case study on milk supply chain for a factory in Ethiopia*, https://cgspace.cgiar.org/bitstream/handle/10568/106246/WP288.pdf.

[160] Fleming, Peyton, "The cold truth about Ethiopia's nutrition gap," *The Beam magazine*, 2019, https://medium.com/thebeammagazine/the-cold-truth-about-ethiopias-nutrition-gap-8401b6260f70.

[161] "Improving the efficiency of butter-making in Ethiopia," FAO, http://www.fao.org/3/V1650T/v1650T0m.htm#recommendation.

[162] Tessema, A., *Hygienic Milk Processing*, UC Davis, 2009.

[163] "Making an Impact with Milk in Africa," Paul Mueller Company, https://www.paulmueller.com/case-studies/dairy-farm/making-an-impact-with-milk-in-africa.

[164] "Improving the efficiency of butter-making in Ethiopia," FAO.

[165] Ibid.

[166] *Agricultural Sample Survey 2018-19 Volume 2*, Ethiopian Central Statistical Agency, 2019.

[167] "Making an Impact with Milk in Africa," Paul Mueller Company, https://www.paulmueller.com/case-studies/dairy-farm/making-an-impact-with-milk-in-africa.

[168] *Improving the efficiency of butter-making in Ethiopia,* FAO. http://www.fao.org/3/V1650T/v1650T0m.htm#recommendation.

[169] "Improving the efficiency of butter-making in Ethiopia," FAO.

[170] *Agricultural Sample Survey 2018-19 Volume 2*, Ethiopian Central Statistical Agency, 2019; *Birmingham Energy Institute Blog: The cold truth about Ethiopia's nutrition gap*, Birmingham Energy Institute, 2019. https://birminghamenergyinstitute.org/2019/03/06/the-cold-truth-about-ethiopias-nutrition-gap/.

[171] Tessema, A., *Hygienic Milk Processing*, UC Davis, 2009.

[172] *Agricultural Sample Survey 2019/20 Volume 1*, Ethiopian Central Statistical Agency, 2020.

[173] "Electrifying Economies," RMI, Rockefeller Foundation, Sustainable Energy for All, https://www.electrifyingeconomies.org/

[174] "Central Bank of Ethiopia Adjusts Loan Interest Rates," Capital Ethiopia, https://www.capitalethiopia.com/featured/cbe-adjusts-loan-interest-rate/.

[175] *Raya Wakena- cooperative union in Ethiopia,* AGRI TERRA. https://www.agriterra.org/raya-wakena-cooperative-union-in-ethiopia/; and from expert interview with Self Help Africa Ethiopia team.