Building the Market for Rural Electrification in Ethiopia

A mini-grid productive use assessment

April 2020

VERITAS

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About this document

This document is an output from the Mobilising Investment Project for Nationally Determined Contributions (NDCs) implementation, an initiative of the Climate and Development Knowledge Network (CDKN) that is contracted through and managed by SouthSouthNorth (SSN). The International Climate Initiative (IKI) of the German Federal Ministry funds the Mobilising Investment project for the Environment, Nature Conservation and Nuclear Safety (BMU), on the basis of a decision adopted by the German Bundestag. Delivery partners for the project include the National Renewable Energy Laboratory (NREL), Overseas Development Institute (ODI) and PricewaterhouseCoopers (PwC) UK.

Throughout the development of this report, a consultative approach was taken with both government and non-government stakeholders. The report was created in close cooperation with the Ethiopian Ministry of Water, Irrigation and Energy and its constituents, the Ethiopia Electric Authority and Ethiopia Electric Utility. This was to ensure the research aligned with the energy sector national goals, the national economic development agenda, and the needs and expectations of these organisations. To complement this consultative approach and for data collection, the team carried out individual stakeholder interviews. Final results from the research were presented at two multi-stakeholder workshops in Addis Ababa during the second half of 2019 and early 2020.

Veritas Consulting

Veritas Consulting was the lead consultancy for this project. Veritas is a multi-sector and Ethiopia-focused management consultancy. Its areas of support for clients organise around three platforms. In the private sector client area, Veritas' work supports private equity firms and multi-national investors in transaction services and market entry analysis. For economic development support, Veritas works with the private sector facing public institutions to develop frameworks, policies and programmes to better engage with FDI and local investors. This is typically in close coordination with development partners. In public policy, Veritas supports public institutions at all levels to develop sectoral strategies that impact broad areas of the economy.

Powerhive

Powerhive is a technology venture founded in 2011 that partners with utilities and independent power producers to provide access to productive, affordable and reliable mini-grid electricity for millions of rural homes and businesses around the globe. Their proprietary technology platform and business model enables the financing, monetisation, and management of off-grid utility solutions. Powerhive is headquartered in Berkeley, California, and has a significant presence on the ground in East Africa where it owns and manages 23 mini-grid sites.

SouthSouthNorth

SouthSouthNorth (www.southsouthnorth.org) is a twenty-year old Cape Town-based non-profit consultancy that supports national and regional responses to climate change through policy and knowledge interventions, partnerships and deep collaboration. We do this by connecting people and information, enhancing capability and mobilising resources to respond innovatively to the challenges and opportunities that climate change presents. Being positioned in the Global South affords a deeper understanding of, and connection to, the climate and development challenges facing the region. We enhance developing countries' access to climate information by brokering climate knowledge through formalised exchanges among various stakeholders. We assist decision-makers in delivering climate compatible development by informing policy formulation and implementation. We bring good governance to the management of donor funds, technical assistance and project management.

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ACRONYMS

AI	Artificial Insemination
ACC	Agriculture Commercial Clusters
ATA	Ethiopian Agricultural Transformation Agency
BOO	Build, Own, Operate model of public-private partnerships
BOOT	Build, Own, Operate, Transfer model of public-private partnerships
BOT	Build, Operate, Transfer model of public-private partnerships
BTS	Base Transceiver Station
CapEx	Capital Expenditures
CRGE	Climate Resilient Green Economy
CSA	Central Statistics Agency
DOE	Directorate of Electrification
EEA	Ethiopian Energy Authority
EEU	Ethiopian Electric Utility
FAO	Food and Agriculture Organisation
EPC	Engineering, Procurement and Construction model of public-private partnerships
FPC	Farmer Productive Cluster
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GoE	Government of Ethiopia
GTP II	Growth and Transformation Plan II
IAIPs	Integrated Agro-Industry Parks
IRR	Internal Rate of Return
kW	Kilowatt
MCCs	Milk Collection Centres
MoA	Ministry of Agriculture
MoE	Ministry of Education
MoH	Ministry of Health
MoTI	Ministry of Trade and Industry
MoWIE	Ministry of Water, Irrigation and Energy
MW	Megawatt
NDC	Nationally Determined Contribution
NEP 2.0	National Electrification Programme 2.0
OpEx	Operating Expenses
PHCU	Primary Health Care Units
PPP	Public-Private Partnership
PV	Photovoltaics
ROI	Return on Investment
SME	Small and-Medium-sized Enterprise
SNNP	Southern Nations, Nationalities and Peoples
SSN	SouthSouthNorth
SWARM	Site Wizard for Analysis, Reconnaissance, and Mapping
USAID	United States Agency for International Development
WTP	Woreda Transformation Plan

1 EXECUTIVE SUMMARY

Ethiopia's economy has grown rapidly over the past decade; it's nearly 10% growth for this period ranks it among the fastest-growing economies in the world[1]. This growth has occurred with an awareness by the government that a climate sustainable growth approach best serves the long-term benefit of the country. In addition to alignment with Nationally Determined Contribution (NDC) agreements, Ethiopia's Climate-Resilient Green Economy (CRGE) strategy plays an integral part in all development approaches it undertakes.

This rapid growth built upon a relatively low base and substantial challenges need to be overcome for Ethiopia to reach middle-income status. Access to electricity is among the principal challenges facing the country, particularly in rural areas. At an aggregate level, about 96% of urban households are connected to the grid (Addis Ababa, the capital city, scores 99.9%). In contrast, only 27% of rural households have access to electricity services, mostly through off-grid solutions[2]. It is against this backdrop that the country launched the National Electrification Plan 2.0 (NEP 2.0) in 2019. NEP 2.0 is an updated action plan to achieve universal electricity access by 2025. The plan envisions 65% of electricity access coming from grid solutions and 35% from off-grid solutions. The Ministry of Water, Irrigation, and Energy (MoWIE) is responsible for the implementation of NEP 2.0.

This report begins with the overall economic context of Ethiopia, with an emphasis on electrification. The Background in Section 2, begins with an outline of the overall scope of the engagement, which is best summarised with the objectives: To perform a market assessment of the mini-grid market in Ethiopia, with a focus on private-sector operated mini-grids; to develop a financial model for a small scale mini- or micro-grid system that can examine different scenarios (e.g. different business models, interest rates and retail tariffs) and returns to investors; and recommend to policymakers appropriate regulatory changes or options for capital market interventions that would be effective at accelerating mini-grid deployment by private-sector operators in Ethiopia.

Section 3 of the report provides an overview of key regulatory considerations for mini-grid investors. Here, the principal sector authority is MoWIE, while the Ethiopian Electric Authority (EEA) is the regulatory entity governing mini-grids, and Ethiopian Electric Utility (EEU) is the public authority that is responsible for generating and distributing practically all of the grid and off-grid power in the country. Recent political developments have resulted in substantial deregulation of sectors across the economy, with the principal thrust being a greater focus on private sector solutions; the energy sector is a part of this narrative. Most pertinent for the mini-grid sector are efforts by MoWIE and EEA to address the challenge of introducing cost-reflective

[1] World Bank. *World Bank Ethiopia Overview*, Sep 26, 2019 (https://www.worldbank.org/en/country/ethiopia/overview)
[2] MoWIE. *National Electrification Plan 2.0 (NEP 2.0),* 2019 (https://www.east-africa-summit.com/sites/default/files/clarion_www_poweringafricatanzania_com/pdfs/nep_2.0_ethiopia.pdf)

tariffs into the sector.

Power sector investors in Sub-Saharan Africa generally, and in Ethiopia specifically, are mindful of the substantially discounted tariff rates for grid service provided by the public power authority, and the subsequent difficulty for private operators to introduce cost-reflective rates for stand-alone off-grid sites. This section of the report is mainly concerned with EEA's efforts to attract private investment by allowing the adoption of the 'ABC' business model in order to meet both commercial return requirements and maintain household tariff rates at the national tariff.

The ABC model assumes the following segmentation of a rural community customer base:

- *Anchor (A) customer:* a customer that has a high demand for electricity and is creditworthy
- *Business (B) customer:* in addition to the anchor customer, a second source of revenue coming from business customers
- *Community (C) customer:* private households who use electricity for domestic needs

In the context of Ethiopia, this assumes a segmented tariff structure that would see the household customer paying tariff rates on par with grid users and the anchor customer (together potentially with business customers) cross-subsidising through higher tariffs.

With this framework in mind, Section 4 of this report identifies the productive uses of energy in Ethiopia that can potentially serve as anchor customers in a given community. Considering that 30% of Ethiopia's economy and 80% of its workforce is engaged in the agriculture sector and that these figures are significantly higher in rural communities, the research focused on off-grid electricity for productive use in three broad agriculture areas:

1. Ethiopia has the fifth largest cattle population in the world[3]; however, a lack of water is one of the principal reasons why dairy yields are at 10%-20% of those in neighbouring countries. The poultry sector suffers similar challenges because of the lack of water.
2. This section further reviews potential power uses for agriculture crops, with irrigation being the most significant use of power at this stage of the country's agriculture sector development.
3. Lastly, further downstream value chain activities, where rural communities can make use of power, are reviewed. These include storage, mechanisation, drying, small-scale processing and transportation. These power uses are likely to expand in the future.

Section 5 of this report describes the efforts undertaken to identify potential mini-grid

[3] Food and Agriculture Organization of the United Nations. *FAOSTAT* (http://www.fao.org/faostat/en/#home)

sites with sufficient productive use activities, and thus adequate numbers of anchor power users, to be viable for potential commercial investment. A two-pronged approach was deployed in this activity – a bottom-up and a top-down approach.

For the bottom-up method, a broad range of socio-economic data was collected and plotted geographically. This data was sourced from public, private and development sources. The most important data for this report's purposes were concentrations of agriculture activity and inputs for agriculture. To this end, data were collected from the Central Statistics Agency and other relevant institutions to plot agriculture activities by elements such as Base Transceiver Station (BTS) towers and power-intensive agriculture production. This data was complemented by overlaying additional geographic data from household income surveys, clinics, small-scale manufacturing, BTS towers, and population clusters. From all this data, nearly 1,500 potential sites with viable commercial investment prospects were identified.

The top-down approach that was taken is likely the most far-reaching element of this report and, if leveraged appropriately, has the potential to address both cost-reflective electrification expansion and targeted economic development gains in tandem and at scale. For the past 27 years, Ethiopia has followed a developmental state growth model. In such an environment, the state plays both a catalytic and a scaling role. The recent political transition has resulted in a substantially expanded opportunity for the private sector, leveraging the foundational work of recent government programmes.

These programmes are designed to support the aggregation of interventions in rural communities and help to mitigate several of the principal constraints to private investment in the mini-grid sector in Ethiopia. Specifically, this relates to the lack of anchor customers (those with the capacity to pay premium tariffs) in significant enough numbers within a given rural catchment area. There are four programmes identified at various levels of development: Agriculture Commercial Clusters (ACCs), Integrated Agriculture Industrial Parks (IAIPs), Milk Collection Centres (MCCs), and the Woreda Transformation Plan (WTP).

1. The ACCs refer to an initiative presently being scaled by the Ethiopian Agriculture Agency (ATA), where the ATA plays a systems integration role in focusing rural agriculture interventions on specific crops for certain commodities. Ten commodities were selected, and each woreda generally focuses on a maximum of two commodities.[4] Following a pilot year enrolment of approximately 600,000 farmers, this second year has over 1.2 million farmers enrolled. A substantial majority of these farmers do not have access to electric power.

2. IAIPs are industrial parks with a specific focus on food processing and agribusinesses. The parks are strategically located to source their inputs from smallholder farmers. There are four parks presently under development, and their potential sourcing farmers similarly lack electric power.

[4] A woreda is an administrative district; in the rural setting they typically consist of several dozen kebeles (the smallest administrative unit).

3. The MCCs are a scaled dairy sector intervention being implemented by the Ministry of Agriculture (MoA) and United States Agency for International Development's (USAID) Feed the Future programme. The programme seeks to improve the livelihoods and commercial viability of small-scale milk producers. Dairy is a highly perishable product, and the lack of power has been cited as a substantial constraint to the sector's growth.

4. The WTP is designed as a nationwide initiative which seeks to synthesise cross-sectorial plans into a woreda-level roll-out. Nationwide initiatives in health, infrastructure, agriculture and every other sector will be implemented, monitored, and evaluated at a woreda level, with the understanding that when it comes to national progress, actual implementation and change happens at the household level. This approach ensures that no woreda is left behind in the nation's development process.

Since the ACCs are the most developed to date, this report focuses its research and the development of potential investment pilots through this initiative. The key productive activity related to power in the case of ACCs is irrigation and, more specifically, irrigation for horticulture clusters that have anywhere from 60 to over 400 farmers engaged within a given mini-grid catchment area. The research for the ACC crops finds that horticulture farmers (avocado, banana, mango, onion and tomato) earn substantially more than their cereal farming (barley, maize, sesame, *teff*, wheat) counterparts; in most cases, this is at least ten-fold higher earnings. However, horticulture farmers have a much higher requirement for irrigation, and their ability to function is highly or almost entirely dependent on irrigation. This provides a mini-grid operator in a horticulture ACC area with a substantial demand for power, via irrigation, along with a user pool that has a high capacity and willingness to pay meaningful tariffs.

Importantly, ten potential ACC horticulture sites were identified for potential mini-grid pilots. These sites were selected in close consultation with MoWIE and ATA with the explicit objectives to demonstrate financial viability and a clear strategy for scaling.

Section 6 of this report covers site validations undertaken as part of this project. A vital part of the study's understanding of the market demand for power comes from these validations. The data from the site validations served to inform understandings of tariff flexibility, alternatives to electricity being used and their commercial and climate cost, geographic layout for grid design, and overall load profile data for each site and ultimately a baseline that can develop a foundational hypothesis. Overall, 65 site validations were conducted, with three specific goals in mind:

1. There were 50 sites validated to support the government-funded mini-grid programme; these sites will ideally be tendered for Engineering, Procurement and Construction (EPC) contracts and ultimately operated by EEU.
2. Four sites were validated to ascertain the soundness of the bottom-up site selection approach and to provide more in-depth baseline data for financial modelling.

3. There were 11 sites validated from selected ACC sites to support the development of pre-feasibility reports for potential pilot investments.

Section 6 introduces a financial model which was developed in response to a request from MoWIE. The financial model is meant to be used by different stakeholders for distinct purposes. MoWIE will be able to use the model to develop an overall understanding of the mini-grid subsector it manages and to quantify the cost of mini-grids and the impact of policy decisions. EEU can use the model to price the mini-grid sites they are currently developing or planning to develop in the future. The model will provide EEU with an independent tool to assess EPC and public-private partnership (PPP) arrangements. EEA can use the model to understand the implications of policy on mini-grid projects and to evaluate the sensitivity of the project to different parameters such as energy price and tariff models. The Veritas/Powerhive project team will use the model to assess identified and validated potential mini-grid ACC sites that will form the basis of ten investment cases for pilot investments. For the pre-feasibility that will be developed for the pilots, the financial model will be used to analyse the financial feasibility of the sites and to provide capital expenditures (CapEx), operating expenses (OpEx), and tariff assessments of these sites.

To illustrate the utility of the financial model within the context of the ABC tariff structure, this report takes the data from a recent EEU tender and purposively assigns 400 of the farms as mango producers. An assessment is then presented with the calculated load profiles, CapEx/OpEX requirements, and financial returns with and without irrigation.

The Summary Section of this report focuses on what comes next. This project has strived as exhaustively as possible for an engagement of this scope, to develop viable commercial frameworks for mini-grid investment. To this end, these findings have to be tested through the ten pilot investments that are under design. The focus of these pilots will be to test the viability of these investments across various business models, geographies and anchor investment horticulture crops. Additionally, the summary reviews the broad potential of IAIPs, MCCs, and WTPs for further study and mini-grid investment.

2 BACKGROUND

2.1 The Scope of Work

SouthSouthNorth (SSN) is supporting the Government of Ethiopia (GoE) via MoWIE to establish an investment-friendly environment and attract private capital to the renewable energy sector, with a focus on rural mini-grids. Veritas Consulting and Powerhive have been engaged by SSN to undertake research and deliver discrete work outputs to support the objectives of the programme as outlined below:[5]

Objectives

- To perform a market assessment of the mini-grid opportunity in Ethiopia, with a focus on attracting private-sector investments.
- To develop a financial model for a small scale mini- or micro-grid system that can examine different scenarios (e.g. different business models, interest rates, retail tariffs, value-chains etc.) and returns to investors.
- To recommend to policymakers appropriate regulatory changes or options for capital market interventions that would be effective at accelerating mini-grid deployment by private-sector operators in Ethiopia.

Task 1: Market assessment and data collection

- Identify current mini-grid operators, their business models and customers, and key challenges.
- Identify common and bankable productive uses.
- Outline costs and variability.
- Conduct a high-level assessment of the current costs of energy services in target communities and their implications for willingness and ability to pay.
- Identify ongoing initiatives.

Task 2: Develop a financial model based on current market conditions with two scenarios of potential future pathways

- Develop a financial model that includes the various factors associated with cost, revenue, risks to mini-grid development in Ethiopia, and review other models.
- Identify key aspects of the value chain; the model should unpack the value chain into individual parameters for the CapEx, OpEx and socio-economic factors to identify the drivers behind mini-grid investment cost on the one hand and the end-user capacity and willingness to pay on the other hand.
- Examine return on investment under different scenarios.

Task 3: Recommend potential regulatory changes and options for capital market intervention

[5] The below listed tasks do not include additional request fulfilled for MOWIE via the validation of 50 sites. The report does, however, detail the additional work later in this report.

- Recommend potential bankable models, possible regulatory changes, and capital market interventions.
- Stakeholder engagement and peer-to-peer exchange to inform the recommendations on i) business model; ii) regulatory changes; and iii) capital market intervention.
- Provide insight into market opportunities.
- Provide background for a Green Climate Fund application

2.2 Developmental and Climate Change Context

Clean energy measures to ensure climate-friendly sustainable growth, reduce climate-related risks and avoid catastrophic outcomes of climate change have become a critical feature of national development plans. As a responsible member of the global community, Ethiopia has taken a constructive role in international climate negotiations, stating its ambition to become a “green economy front-runner” as an expression of its potential, for and belief in, sustainable models of growth.

This initiative’s goals are consistent with Ethiopia’s green growth ambitions and align with the country’s NDCs. Inherent in the project design is the assumption that policies that support sustainable growth will help Ethiopia achieve development targets that are aligned with the Climate-Resilient Green Economy (CRGE) strategy. The CRGE aims to protect the country from the adverse effects of climate change and support development ambitions to reach middle-income status before 2025. These policies are a critical framing instrument for Ethiopia’s broad economic planning and have proven to be particularly central in the design of Ethiopia’s power development strategy.

Mini-grids powered by renewable energy directly address two NDC components: (i) reduction of greenhouse gas (GHG) emissions and (ii) reduction of the impact of climate change on Ethiopia’s population, environment and economy. Mini-grid development also helps to deliver on key CRGE objectives viz: (i) ensuring economic development is sustainable by limiting GHG emissions, (ii) creating green job opportunities, and (iii) protecting the economy and people from the adverse effects of climate change.

2.3 Challenges and Opportunities in the Off-grid Power Sector

Ethiopia is Sub-Saharan Africa’s second-most populous country, with a population of over 100 million, but it is among the least developed. However, starting from a low base, Ethiopia has been the fastest growing economy in the world over the past decade with an average Gross Domestic Product (GDP) growth of 9.9% over that period[6]. Access to electricity services, particularly in rural areas, is a developmental challenge facing the country. At an aggregate level, about 96% of urban households are connected to the

[6] The seeming contradiction between high growth rates and continued poverty can be explained by a very nascent base.

electric grid (Addis Ababa, the capital city, scores 99.9%). In contrast, only 27% of rural households have access to electricity services, and mostly through off-grid solutions[7].

The current iteration of a series of successive five-year economic plans, and designed for 2015-2020, Ethiopia's Growth and Transformation Plan (GTP II) targets the country reaching middle-income status by 2025. The plan is to drive development with a transition to carbon-neutral energy, limiting net GHG emissions to 64% from the business-as-usual scenario by 2030 by increasing agricultural productivity, strengthening the industrial base, and fostering export growth. Since rural electrification is key to achieving these goals, renewable energy mini-grids will play a vital role.

The NEP 2.0 was launched in 2019 as an updated action plan from GTP II. The overarching goal of the plan is to achieve universal electricity access by 2025. The plan envisions 65% of access coming from grid solutions and 35% from off-grid solutions.

NEP 2.0 highlights the agriculture sector specifically for productive use possibilities through the expansion of electrification. Ethiopia's historically vulnerable agriculture sector is particularly susceptible to the impacts of changing climate conditions. Agriculture is the source of over 80% of Ethiopia's employment and approximately 30% of its GDP. Episodic droughts, with the potential for future catastrophic humanitarian and economic damage, are now more frequent due to climate change[8]. And, while the Ethiopian government's capacity to mitigate the impact has improved substantially, the livelihoods of farmers and rural communities stagnate with such shocks. Increased availability of power will allow farmers to shift from rainfed production methods to more sustainable farming and value chain management through irrigation, storage, drying, and small-scale processing, which is expected to improve productivity, and build community resilience against future climate shocks.

[7] MoWIE. *National Electrician Plan 2.0 (NEP 2.0)*, 2019

[8] United Nations News Centre. *As new drought hits Ethiopia, UN urges support for Government's 'remarkable' efforts,* January 2017. (https://refugeesmigrants.un.org/new-drought-hits-ethiopia-un-urges-support-governments-remarkable-efforts)

3 REGULATORY CONSIDERATIONS

3.1 Relevant Institutions

MoWIE is responsible for implementing NEP 2.0 and is the point of contact for the Mobilising Investment Programme. Along with the cross-sectoral National Steering Committee, MoWIE coordinates both on-grid and off-grid power supply in the country through its Directorate of Electrification (DOE). This includes policy development, programme coordination, and the monitoring of the implementation of the off-grid programme[9]. Furthermore, they have oversight over both the EEA and the EEU.

Reporting to MoWIE, the EEA was established in 2013 by the Ethiopian Government through proclamation No 810/2013 and Counsel of Ministers Regulation 308/2014, authorising it to undertake in regulatory activities in the energy sector. Within this mandate, the agency has a focus on efficiency, conservation, and safety, and has responsibility for:[10]

- Regulation and licensing across the functional value chain of generation, transmission, distribution, and sales – including private sector investment.
- Establishment of standards and regulations required for the implementation of the on- and off-grid programmes, including social, safety, and environmental safeguards and compliance.
- Defining and enforcing licensing requirements, rights and obligations of parties, amendments and certificates of competency.
- Advising the government on tariff proposals submitted by licensees for both on- and off-grid projects.
- Promotion of energy efficiency and conservation, standards for equipment, appliances, and labelling.
- Dispute settlements, mediation and arbitration.

Another principal actor under MoWIE in the power sector is the EEU. EEU is a public authority with a monopoly over distribution, retail of power and generation infrastructure. Currently there are several private power generation projects at various stages of planning with MoWIE and EEU to feed power into EEU's national grid, and there are a series more such agreements envisioned. This includes a USD $2.5 billion 520 megawatt (MW) geothermal project and two 125 MW solar photovoltaic (PV) projects. The intermediate plan is that EEU will leave the generation business and focus on the management of distribution.

However, in order to help electrify population-dense rural areas unreached by the national grid, EEU plans to develop 285 standalone mini-grids. These sites are being tendered to private EPC developers but will be operated by EEU. At the time of this writing, 12 sites are under development, 25 have been tendered for EPC development, and an additional 50 sites have been validated as part of this engagement, for future tenders.

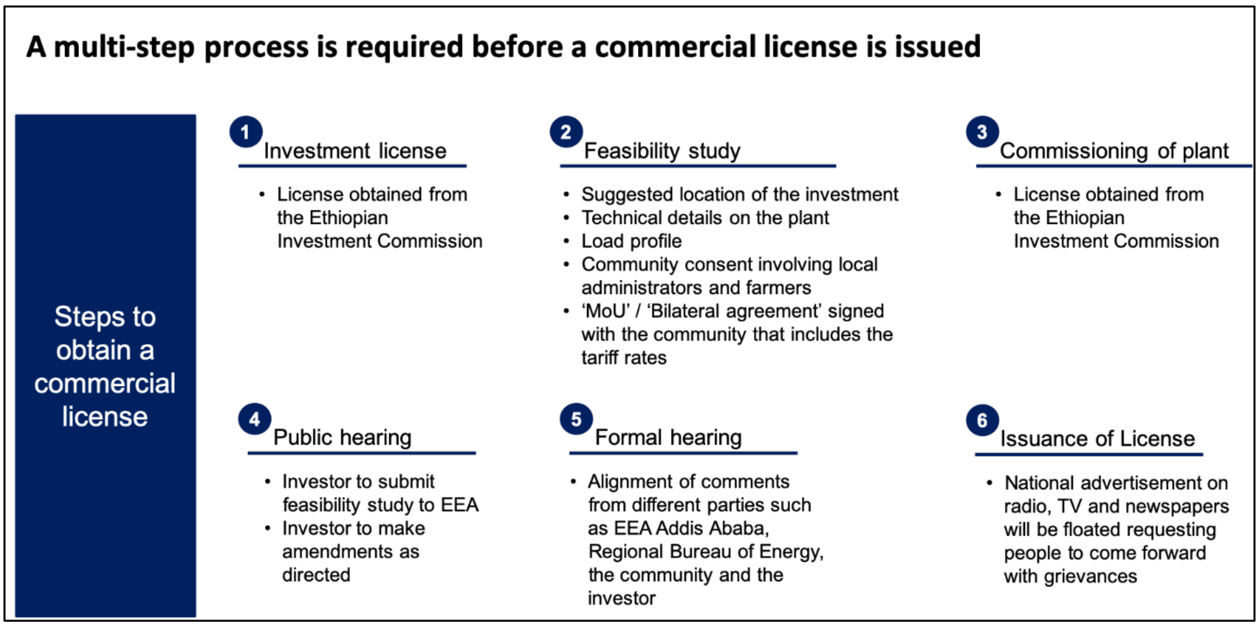
[9] MoWIE. *National Electrification Plan 2.0 (NEP 2.0),* 2019
[10] MoWIE. *National Electrification Plan 2.0 (NEP 2.0),* 2019

3.2 Relevant Regulations for Mini-grid Development

The Ethiopian Government's policy position, articulated in the NEP 2.0, is for an expanded role for private sector participants in the off-grid power sector[11]. To this end, a series of draft regulations were introduced in 2019 that are expected to define the future operating environment. It bears noting that under the previous regulatory regime, only one operator (Ethio Resource Group) received a business licence for a private standalone mini-grid.

The existing licensing process is outlined in the figure below.

Figure 1: The licensing process for privately owned mini-grids



Source: Veritas summary of EEA licensing guidelines

It is important to highlight the particular challenge in step three of the licensing process, where commissioning a plant precedes the issuance of a licence which represents a substantial risk to investors. Regardless, the process is extended and cumbersome, and attracting private capital may thus be challenging. Improving the licensing process is a key objective of some of the draft legislation.

In January 2019, Regulation No. 447/2019[12] was ratified, aiming to govern: (i) licensing and certificate of competency of companies; (ii) generation, transmission, and distribution of energy; (iii) tariff rate structures, and (iv) energy efficiency and conservation

The licensing structure of this regulation is segmented to two power generation levels: 1) up to 10MW, and 2) above 10MW. However, it does not differentiate between large-scale

[11] MoWIE. *National Electrification Plan 2.0 (NEP 2.0)*, 2019
[12] Ethiopian Power Energy Authority. *Energy Regulation No. 447 2019*, January, 2019. (http://www.eea.gov.et/index.php?option=com_content&view=article&id=192:energy-regulation-no-447-2019&catid=46&Itemid=184&lang=en)

energy producers and small-scale producers such as mini-grid operators. In order to address this gap, EEA currently has two directives at the draft stage which, when finalised, could be ratified as law.

The first directive for *licensing requirements relates to the generation, transmission, distribution and sale, import, and export of electricity*. The directive covers the type, form of application, and information requirement for the issuance of licences for commercial activities in the electricity supply industry. There are two tiers to this directive: one for licensing of on-grid systems above 50kW (kilowatts), and one for licensing off-grid systems below 50kW, both of which are pertinent to mini-grids. In this new directive, mini-grid operators would need to provide information on the following to obtain a licence:

- Scope of operation, including the source of electricity and the planned installed capacity of the facility
- Business licence registration, including commercial registration certificate, investment permit from the Ethiopian Investment Commission, and power of attorney (if required)
- Proof of financial capability, including guarantees, bank commitments, credit agreements, and forecasted financial statements
- Statement of the description of assets and technology
- Feasibility report, business plan, organisational history and existing activities, operational experience and expertise
- Environmental impact assessment and environment authorisation from the Ethiopian Environment Protection Agency
- Public health and safety plan
- Site layout and drawings, implementation agreements and agreements with the off-takers, detailed implementation schedule, plant and machinery specifications

The second directive is for *rural electrification minimum design standards* which prescribe minimum design standards for electricity supply to rural communities with populations from 3,000 to 12,000 people. This directive is meant to assist in the licensing process and prescribes a minimum standard that will provide an efficient and safe supply at the lowest cost. Under this directive, potential mini-grid operators would need to consider issues such as certifications for PV modules, charge controllers, types of cables, and the type of connection to customers' premises. As per the draft directive, during the licensing process, the mini-grid operator must submit a detailed design, adhering to regulation standards, for EEA approval.

In addition to these two draft directives, EEA has also presented a draft set of guidelines to determine off-grid tariffs, which could be incorporated into one of the draft directives once finalised. The guidelines detail the regulatory options and actions that are available in case a mini-grid is 'enveloped' or 'absorbed' by the main grid in the future. The guidelines are not particularly prescriptive and simply state that "it is important to ensure that off-grid customers who are mostly rural customers, do not pay excessive tariffs and that regulatory reporting requirements and service standards be set lower than grid-connected systems thus reducing the cost so that tariffs will be lower and more affordable." The guideline further states that the business model of the off-grid operator is a critical component to ensure its success and should consider the “ABC Model”, by which they mean that models should include:

- *Anchor (A) customer*: a customer that has a high demand for electricity and is creditworthy
- *Business (B) customer*: in addition to the anchor customer, a second source of revenue coming from business customers
- *Community (C) customer*: private households who use electricity for domestic needs

In the context of Ethiopia, and accounting for the limited experience in working with private power operators, these are relatively positive developments. In the figure below is a summary of the main policy constraints for potential mini-grid investors and operators, the possible regulatory resolutions, and potential workarounds.

Figure 2: The main policy constraints for potential mini-grid investors and operators

Identified Regulatory Challenges	Possible Resolutions	Potential Workarounds
The registration process remains complex and bureaucratic	• Streamline the consultative approach with community, EEA and regional EEU	• International best practices / regional observations (Rwanda, etc.)
Exclusivity has to be defined	• Parameters required by government articulated in licensing process	• Parameters required by government articulated in licensing process
Offering assets such as pumps for irrigation would require a separate set of investment licenses	• Regulatory solution through MoA or ATA	• Engage MFIs as ‘middlemen’
Repatriation of capital and profits could be a challenge for mini-grid investors	• Ensure that the ministry of finance guarantees repatriations on a timely basis **(NBE, MoFEC)**	• Tap into insurance programs to de-risk investment
Substantial investment is required before rate structure is approved	• Consultative approach with EEA	• Consultative approach with EEA

Source: Veritas

4 PRODUCTIVE USE CASES

4.1 Identifying Productive Uses

The concept of identifying productive uses of energy, while intuitive, is relatively new and can take on various frameworks. The two principle distinctions to consider is between productive and consumptive use. The productive use of energy manual (PRODUSE)[13], provides a broad definition:

"In simple terms, productive uses of electricity are those that increase income or productivity (that is, they add value which is taxable in the form of VAT if part of the formal economy). In rural contexts in developing countries, typical productive uses can be found in agro-processing (e.g. grain milling), various manufacturing industries such as carpentry, tailoring, welding and looming, and in the service sector, e.g. in bars and restaurants that use electricity for lighting, sound systems and refrigeration, as well as for charging mobile phones."

The World Bank's definition states that "these activities are typically in agriculture, rural enterprise, health and education sectors. Examples of such activities are pumping water and irrigation for agriculture, agro-processing, lighting, information and communications, and vaccine refrigeration."[14]

There are many examples of productive uses for electricity in Ethiopia. Included among these are schools, clinics, businesses, government institutions, BTS towers, electric vehicles and agricultural operations. These institutions and economic units require electricity for daily operations. However, considering that 30% of the GDP and over 80% of employment in Ethiopia is in agriculture, this is the primary sector under examination in this study.

In addition to the above-mentioned agricultural productive uses, a host of additional activities can be considered, such as cold storage, mechanisation and small-scale processing such as drying, milling, and milk processing. Each of these productive uses of power in farming communities can result in an increase in income and an associated increase in willingness to pay cost-reflective rates for electricity, as well as contribute positively to local economic development.

4.1.1 Water Pumping and Related Livestock Needs

Water pumping is among the most basic productive applications of power in rural farm settings. With livestock, adequate water supply helps to boost milk production, as well as improve the overall growth and wellbeing of the animals, which positively affect their usefulness and market value.

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[13] Bruderle, A; Attigah, B; Bodenbender, M. *Productive Use of Energy (PRODUSE) - A Manual for Electrification Practitioners*, 2011

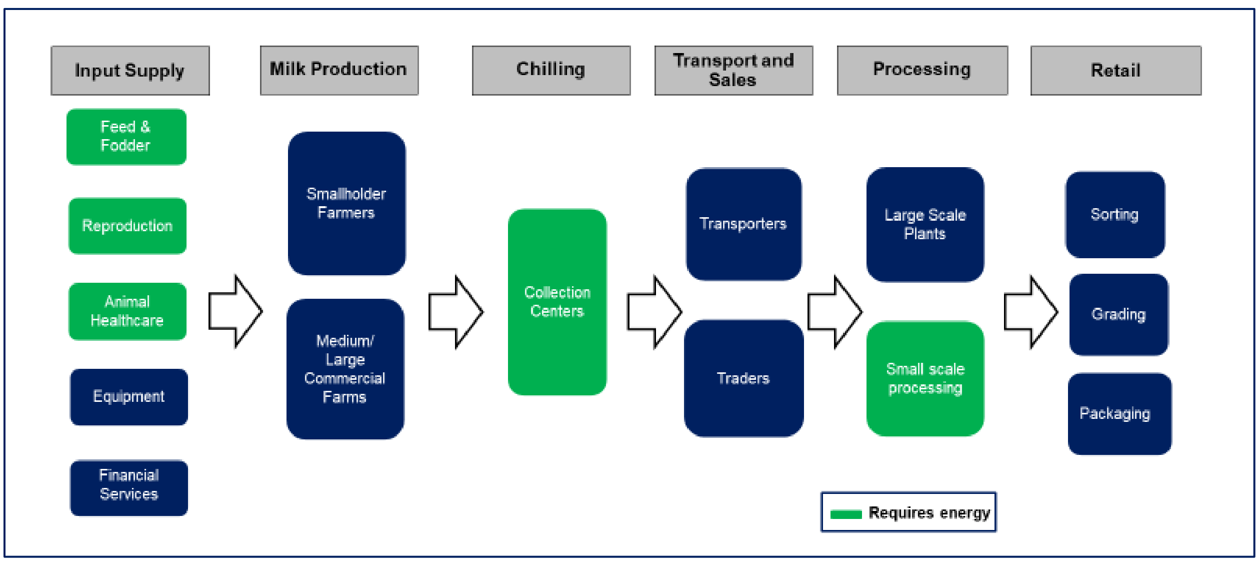
[14] World Bank. *Productive uses of Renewable Energy*, 2004

Ethiopia has the fifth-highest livestock population in the world. However, Ethiopia currently has the lowest rate of milk production per cow in Sub-Saharan Africa, at one to two litres per day. In contrast, neighbouring Kenya produces eight to ten litres per day per cow - the international norm for dairy cows is about 25-30 litres[15]. One of the principal reasons that Ethiopian milk production lags so far behind other markets is the lack of access to water; milk is comprised of over 85% water, and cows need sufficient water to increase dairy production[16]. In Ethiopia, dairy cows in rural areas only tend to get enough water to drink during the rainy season, which is less than half the year. The availability of clean water in troughs or feed/fodder would have an immediate impact on the quantity of milk produced.

Ethiopian dairy/cattle industry is dominated by indigenous breeds that produce limited volumes of milk, because of the limited water access. These breeds account for 97% of the country's total annual milk production. However, Ethiopia has a favourable climate for improved, high yielding dairy cattle breeds as well as several regions with reduced incidence of animal disease.

Access to electricity and basic water pumps would provide substantial support to Ethiopia's many dairy farmers, including other intermediate industries in the value chain. The figure below illustrates the power requirements for the dairy farming value chain.

Figure 3: Power requirements for the dairy value chain



Source: Veritas research

There are various segments along the value chain – in addition to production - where access to electricity could improve yields, improve market linkages, support agro-processing, and ultimately increase profitability, allowing farmers to address some of the critical obstacles the subsector faces in its growth and development. These include refrigeration of milk at farm level or collection centres, and the introduction of cream separators.

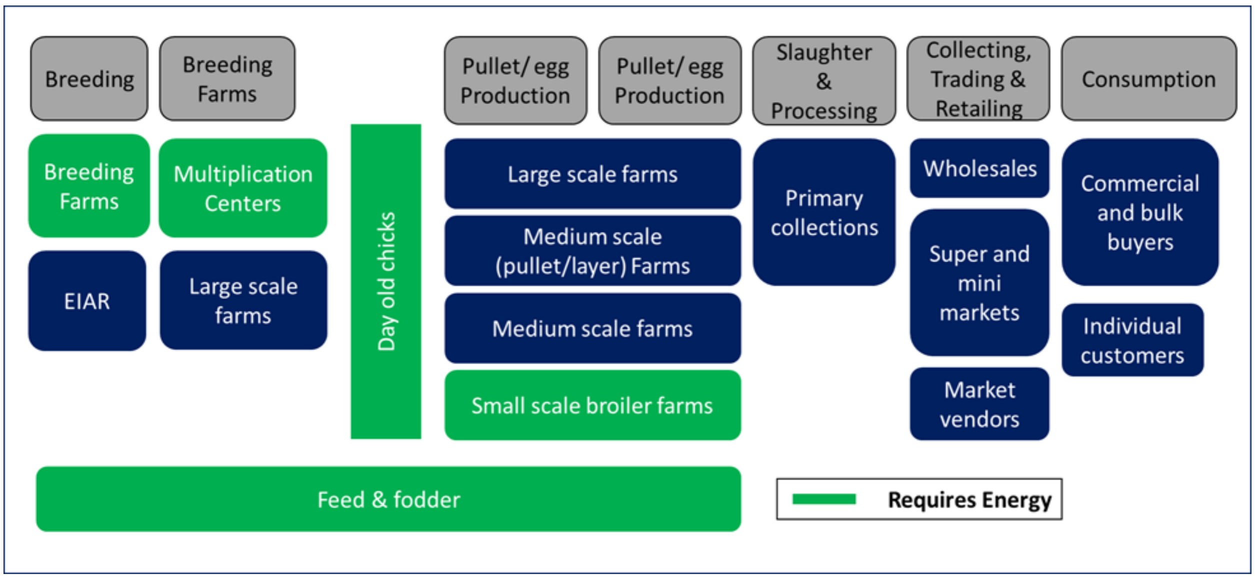
[15] FAO. *A Review of the Ethiopian Dairy Sector*, 2011
[16] Milk Facts. *Nutrient Content of Milk Varieties* (milkfacts.info/nutrition)

For example, animal healthcare, including access to antibiotics and artificial insemination, is often dependent on the availability of refrigeration. The ready availability of both would ensure that cows stay healthy, and farmers do not miss short oestrus periods, significantly impacting and increasing the production of milk. Similarly, improved access to cold storage increases farmers' income as unpasteurised milk is a highly perishable product, and for commercial logistics needs to be chilled rapidly in order to store and transport for processing. Thus, cold storage is a critical factor in ensuring that milk is preserved until it is sold or processed into butter, cheese or yogurt.

4.1.2 Water Needs for Poultry

The poultry value chain is similarly dependent on water pumping and additional electric power needs, as illustrated in the value chain map with poultry power requirements in the figure below.

Figure 4: Power requirements for the poultry value chain



Source: Veritas research

From breeding and multiplication to the production of eggs and the raising of chickens for meat on broiler farms, the poultry value chain has many productive uses for power. Ethiopia's poultry industry, which is still in its infancy, has considerable potential for growth, especially when considering that average per capita poultry consumption of 0.5 kg is among the lowest in the world. By comparison, per capita consumption across Sub-Saharan Africa is 2.3 kg[17]. Interviews with poultry sector investors in Ethiopia inform that the improved availability of power could address some of the challenges the sector faces in the following ways:

[17] Boere, A. et al. *Business Opportunities Report Poultry #3 in the series written for the "Ethiopian Netherlands business event 5–6 November 2015, Rijswijk, The Netherlands."*, 2015

- Provision of clean water to be used in troughs or in feed/fodder would allow the chickens to grow better with higher fat content.[18]
- Meeting demand from smallholder farmers for day-old chicks. Existing breeding farms and multiplication centres have been unable to meet demands thus far[19]. This chronic shortage of day-old chicks results in many smallholder farmers abandoning poultry because their poultry houses will often be empty for months while they are waiting for new supplies from the hatcheries.[20]
- Hatcheries require power for heating, and this, in turn, allows farmers to raise broilers and earn a higher income.

4.1.3 Irrigation

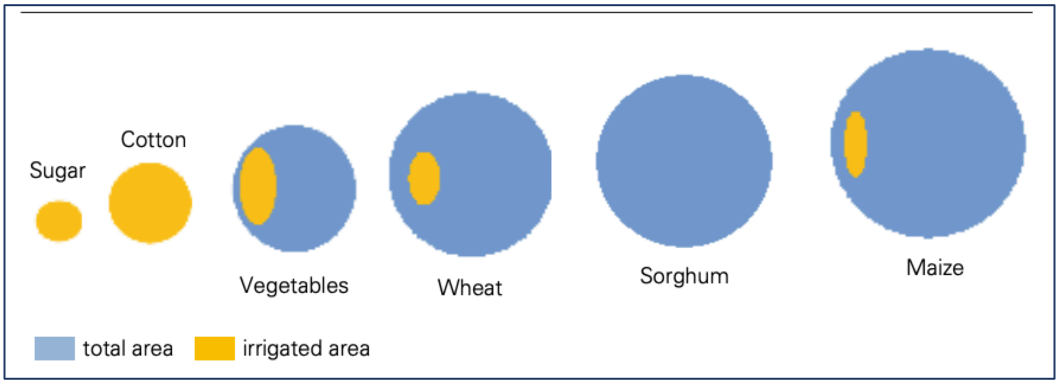
In addition to the substantial amount of water required for livestock-related produce, water pumping is crucial for the irrigation of farms. Irrigation involves both lifting the water with a pump and distributing the water for growing crops, including the use of water storage, where appropriate. The energy demand for irrigation purposes is the energy required to lift water by pumping from surface sources, such as ponds, streams, or canals; or from below-ground sources using open wells or boreholes, and then distributing across to the crops. Conservative estimates show that shallow groundwater resources distributed throughout Ethiopia have the potential to irrigate 1.16 million hectares of land at the household level with resources at a depth of less than 30 meters.[21]

Irrigation is also a viable alternative to Ethiopia's unpredictable rainfall patterns, which have been exacerbated by climate change. As a baseline, the Food and Agriculture Organization (FAO) estimates that about 37% of all vegetable production is irrigated, and this is accomplished through flood irrigation. All of the sugar and cotton production is irrigated, while only a limited portion of wheat, sorghum and maize farms benefit from irrigation.[22] The current patterns of irrigation are therefore clearly limited in scale and dependent on rainwater.

[18] National Research Council. *Nutritional Requirements of Poultry Subcommittee on Poultry Nutrition*, 1994
[19] Boere, A. et al. *Business Opportunities Report Poultry #3 in the series written for the "Ethiopian Netherlands business event 5–6 November 2015, Rijswijk, The Netherlands."*, 2015
[20] Veritas. *Interviews with poultry sector executives*

[21] Ethiopian Agricultural Transformation Agency (www.ata.gov.et)
[22] FAO. *Ethiopia Irrigation Market*, 2015

Figure 5:FAO Estimates of the relative size of irrigated area by crop in Ethiopia, 2013



Source: FAO Aquastat

Climate variability and increased frequency of droughts have made rainfed farming increasingly risky for the Ethiopian farmer. By shifting from rainfed dependency to irrigation, farmers can stabilise production, increase yields, and in the case of some crops even increase the number of harvests per year. Therefore, irrigation is a valuable climate change adaptation strategy, although careful consideration has to be undertaken in managing the volume of water abstracted. An appropriate large-scale irrigation strategy should include policies and procedures for measurement and recharging of groundwater.

4.1.4 Cold Storage

Cold storage has several productive use agriculture applications that can be introduced with the provision of power. Cold storage facilities are critical for dairy, meat, fruit, and vegetable value chains. Over 90% of Ethiopia's livestock are located in rural areas[23], where refrigeration is unavailable due to the lack of energy; thus, perishable food items such as milk and by-products cannot be brought to market. Cold storage facilities are crucial to minimising and maintaining the quality and safety of perishable items while decreasing deterioration until consumption. Much of Ethiopia's refrigeration capacity is aimed at large agriculture ventures geared towards export, with very few schemes available at the smallholder farmer level even though smallholder farmers cultivate over 95% of farmland in the country[24].

4.1.5 Mechanisation

Mechanisation[25] is another productive use of power for farming communities. Nearly all of the agriculture products grown by smallholder farmers need some amount of ground levelling, ploughing, planting, harvesting and threshing. Although the mechanisation of farming activities directly increases yield while reducing the amount of input used when

[23] *Ethiopia Livestock Master Plan – Roadmaps for Growth and Transformation*, 2015
[24] Ethiopia. *Second Growth and Transformation Plan* (GTP2), 2015
[25] FAO. *Mechanization*. The FAO defines agricultural mechanisation as "a process of improving farm labour productivity through the use of agricultural machinery, implements and tools." It involves the provision and use of all forms of power sources and mechanical assistance to agriculture, from simple hand tools, to animal draught power (DAP), and to mechanical power technologies. (http://www.fao.org/tc/exact/sustainable-agriculture-platform-pilot-website/energy-management/mechanization/en/)

compared to traditional methods, Ethiopia has one of the lowest usages of mechanical equipment in farming in the world[26]. The transition to increased mechanisation of agricultural operations presently occurs using diesel or gasoline-powered tractors and harvesters. Fuel-powered two-wheel tractors are often used for agricultural production, with different attachments for tillage, bed planting, ro1w planting, harvesting and threshing.

However, one of the challenges in making the transition is the lack of knowledge on how to operate this machinery by farmers, as well as the lack of availability of gas and service stations to maintain the equipment; a challenge that is amplified by Ethiopia's vast geography. Switching the gasoline-powered engines to a solar-charged battery immediately solves one of the major challenges of scaling up small tractors in Ethiopia, as the component that needs the most regular maintenance is the engine.[27] Furthermore, the farmer no longer has to travel vast distances for fuel. Use of battery-powered machines also causes a marked reduction in carbon dioxide emissions. This alternative may not be as financially feasible presently, but the operating expense dynamics mean that as the cost of solar alternatives improves, this option grows more appealing.

4.1.6 Drying

Drying is an essential value-adding step for farm produce. Drying aims to lower the moisture content of the grain for safe storage and further processing. Thus, drying is the phase of the post-harvest system during which the product is rapidly dried until it reaches the 'safe-moisture' level. Nearly all smallholder farmers currently use traditional drying methods, which are slow, highly dependent on the weather, carry a heightened risk of contamination, and are susceptible to loss due to birds and rodents. The process can be used for cereals such as maize, wheat, and malt barley. Meanwhile, dried horticulture crops (mango, tomato, avocado, banana and onion) can fetch particularly high prices from high-end markets. Farmers with access to power and ability to invest in artificial drying machinery which facilitates early harvest, reduce shattering in the field and dependency on increasingly unpredictable weather conditions.

4.1.7 Processing

Within the scope of productive uses of power in the agriculture sector, small-scale processing and the activities that support it have substantial value-addition potential at the farm level. This has applications for cereal such as wheat, barley, and maize, and horticulture crops, such as mango, tomato, avocado, banana, and onion.

Small-scale processing applications include grinding, milling, extracting oil, juicing, making tomato sauce, and producing other marketable by-products. By moving up the value chain through more value addition, local communities and attached industries can keep a larger portion of the value from their agriculture produce. This not only benefits

[26] MoA; ATA. *Ethiopian National Agricultural Mechanization Strategy*, December 2014
[27] F. Lambert. *John Deere unveils latest all-electric tractor prototype for zero-emission agriculture*, 2016 (https://electrek.co/2016/12/05/john-deere-electric-tractor-prototype/)

farmers and the agro-industry, but it can also have a tremendous impact on the Ethiopian economy. Rather than importing oil, juices, and processed foods, domestic agro-processing can meet local demand and lead to the export of valuable products.

4.1.8 Transportation

Beyond the agriculture sector, there are numerous examples of productive uses of energy throughout the country. One such example is in the transportation sector. In the same sense that gas-powered farming equipment introduces a number of obstacles, gas-powered vehicles for transportation are problematic due to the cost of fuel and regular maintenance of engines. The introduction of electric vehicles can alleviate many of these problems. Electric vehicles are quieter, faster, cleaner and cheaper to maintain than their gasoline- or diesel-powered counterparts. They can also provide uninterrupted service for the public transport system. Mitsui & Co Ltd, a Japanese electric auto manufacturer, recently announced its plan to assemble two- and three-wheeled electric vehicles in the country.[28] Presently, similar diesel-powered vehicles, referred to locally as *bajaj*, are the principle form of mechanised transport in rural Ethiopia.

4.2 Site Selection: Bottom-up vs Top-down

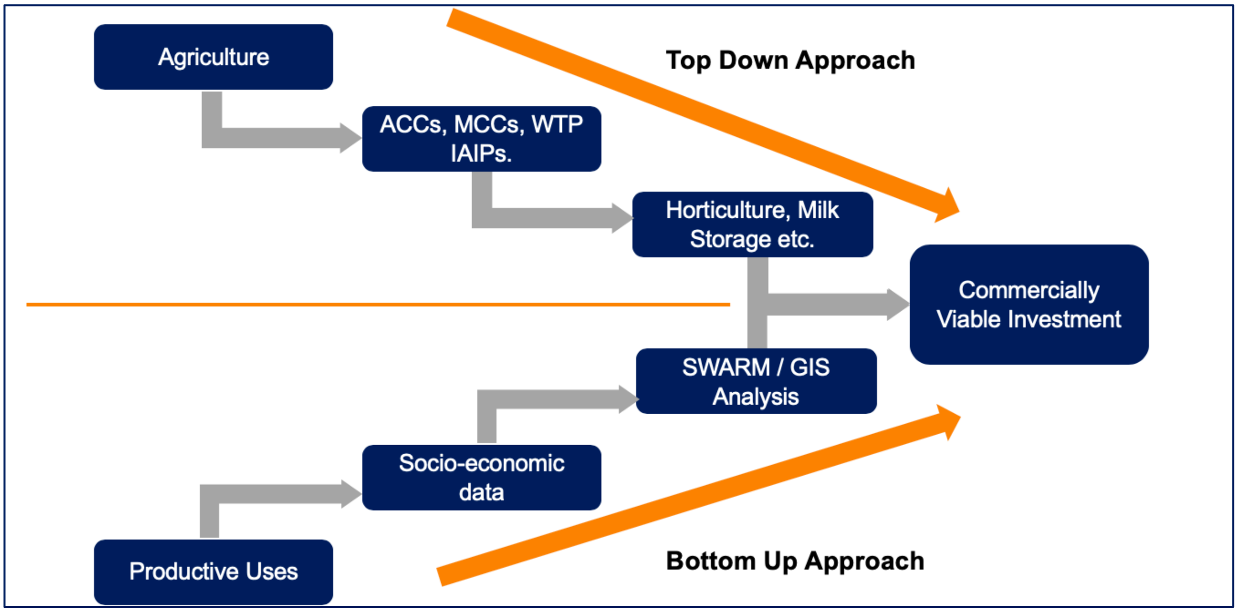
The above-mentioned productive uses are generic examples. However, the research indicates that across Ethiopia there are a substantial number of sites that present attractive opportunities for off-grid power investments with consumer bases that have identifiable and highly productive use requirements. These are sites where the provision of power can have the greatest potential impact, yielding higher levels of productivity, reduced power costs and greater product value addition within the community. In order to identify such sites, a two-pronged approach was taken.

The first method followed a top-down approach by establishing a set of criteria and considering government projects, at the macro level, that matched them. The second method followed a bottom-up approach, which began by identifying on-the-ground needs at the micro-level, and building a broader picture from there, aggregating a wide range of information from multiple sources.

Both approaches have their merits, and the below figure illustrates the principle steps that were taken for each.

[28] New Business Ethiopia. *E-Trike Launches Electric Car Assembly in Ethiopia,* 2019. (https://newbusinessethiopia.com/manufacturing/e-trike-launches-electric-car-assembly-in-ethiopia/)

Figure 6: Top-down and bottom-up approaches to identify mini-grid sites



Source: Veritas Research

4.2.1 Bottom-up

The bottom-up approach consisted of collecting data across a myriad of sectors from multiple relevant sources. Data on farming communities were collected from the MoA and the ATA. Similarly, geographic data provided by the Ministry of Education (MoE) was collected to locate schools and data from the Ministry of Health (MoH) was used to locate clinics. For large-scale development programmes, such as USAID's Feed the Future initiative, contractors were approached for data sets. In addition, the Ethiopian Central Statistics Agency (CSA) provides substantial data in its episodic surveys which are listed in Table 1 below. Various sets of geographic information systems (GIS) data were utilised (as per Table 1). Table 1 offers a list of various parameters for which data was secured from public and private sources that helped in the bottom-up site selection. While this is certainly not an exhaustive list, based on our review of previous works in the sector, this is a substantially thorough set of primary data sources.

Table 1: Summary of mapping data sources

Data	Description of Data	Source	Year (recent data)
National Kebele mapping	Kebele map for Oromia, Amhara, Tigray, Benishangul-Gumuz, and Gambella regions, as well as woreda shapefile for the entire country.	CSA	
Region, zone and woreda code and name	This is the name and code given by CSA for each region, zone, and kebele.	CSA	2007
Income and source of income proxy	Household income (along with consumption expenditure) was collected in the Household Income and Consumption Expenditure (HICE) study for the periods 1996, 2000, 2005. For the recent two surveys, however (i.e. for periods 2011	CSA Household and	2016

Data	Description of Data	Source	Year (recent data)
	and 2016), only household expenditure was collected because income data is difficult to collect for a variety of reasons. Consumption expenditure has been used as a proxy for income in other studies and poverty reports by the government.	Consumption Survey	
Commercial Activities			
Small-scale manufacturing (by sector)	CSA conducted a small-scale manufacturing industries survey for 2016/17. Small-scale manufacturing is defined as engaging less than ten people and using power-driven machinery.	CSA	2014
Trade and service	CSA collected national data for the service and trade activities.	CSA	2014
Agriculture Activities			
Small scale	CSA has collected data about the total production of agriculture products by type and location from smallholder farmers.	CSA	2016/17
Commercial farming	CSA has collected data about total production of agriculture products by type and location from large commercial farms.	CSA	2016/17
National ACC Woreda level			
ACC	ATA collected ten types of crops at woreda level incorporating one to two priority commodities.	ATA	2019
Horticulture	ATA exclusively collected horticulture crops at the woreda level incorporating one to two priority commodities.	ATA	2019
Solar insolation	Global Solar Atlas has provided the amount of electromagnetic energy incident on the surface of Ethiopia.	Solargis	2019
Medium and high voltage grid data	Data for medium/high voltage transmission lines in Ethiopia. The data were compiled for the AICD study led by the World Bank. A variety of sources were consulted, including regional power pool documents and maps from World Bank project documents.	World Bank	2017
Grid	Black Marble Satellite Imagery provides night vision of the whole country, identifying concentrations of human populations.	NASA	2019
Health facilities	Locations of public sector health facilities in the country.	MoH	2012
Dairy clusters (MCC)	Has regional and satellite office. MCCs, Milk processing supported by woreda, zone and regional level.	USAID's Feed the Future programme	2019
BTS	Entails data for BTS both on-grid and off-grid.	Historic tenders	2019
Rooftops	GIS team used Google earth and QGIS to digitise rooftops in various areas in the country.	Google Earth	2019

These large datasets from institutions such as CSA, ATA, World Bank and others provided reliable data on critical activities investors look for in off-grid site selection. From there, GIS mapping indicated where the most significant confluence of these investment variables were, thus identifying sites with the highest likelihood of sufficient power demand to make them economically viable to supply commercial power. This included the identification and mapping of medium and high voltage lines to ascertain distance from the grid and rooftops to assess potential population density (the last census for Ethiopia was conducted in 2007). The figures below illustrate how some of this data interplays at a national level for key parameters.

Figure 7 shows, at a national level, the geographic locations of BTS towers, health facilities, and solar irradiation overlaid. Figure 8 then shows where the medium and low voltage lines are in Ethiopia and overlays this data set with rooftops. Figure 9 uses the rooftop data as an initial filter (a minimum of 200 households), adds agriculture geographic data points that will likely have productive use characteristics. Figure 9 further indicates that when this data is run through Powerhive's Site Wizard for Analysis, Reconnaissance, and Mapping (SWARM) software, along with the various socioeconomic data points in Table 1, 1,471 sites are identified as being potentially viable for mini-grid development because of productive use activity.

Figure 7: National level mapping – basic socioeconomic data

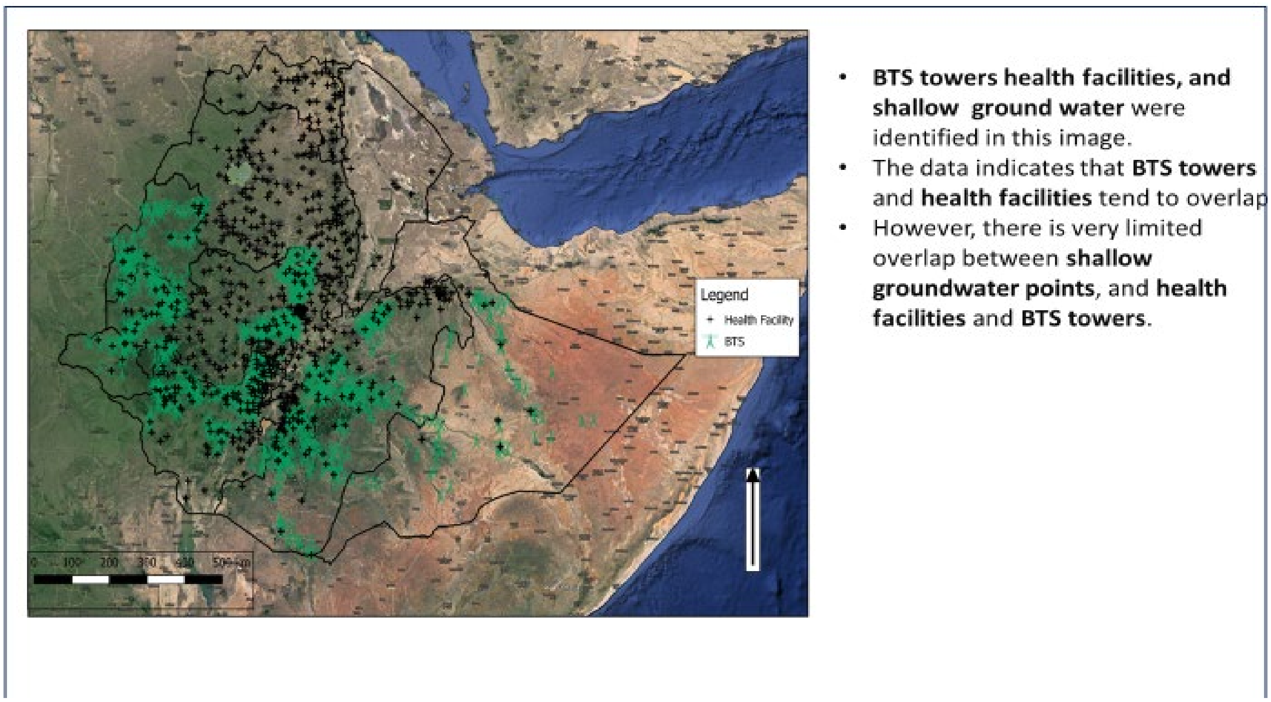


Figure 9: National level mapping – agriculture overlay and potential sites

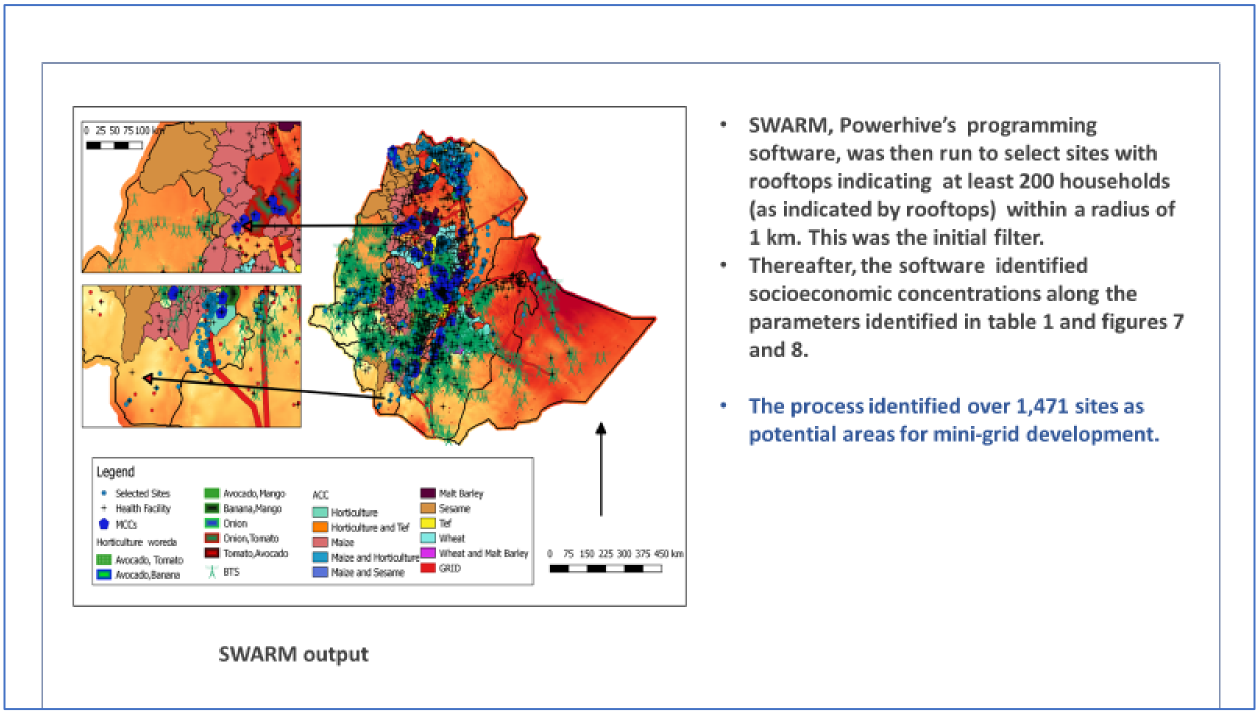
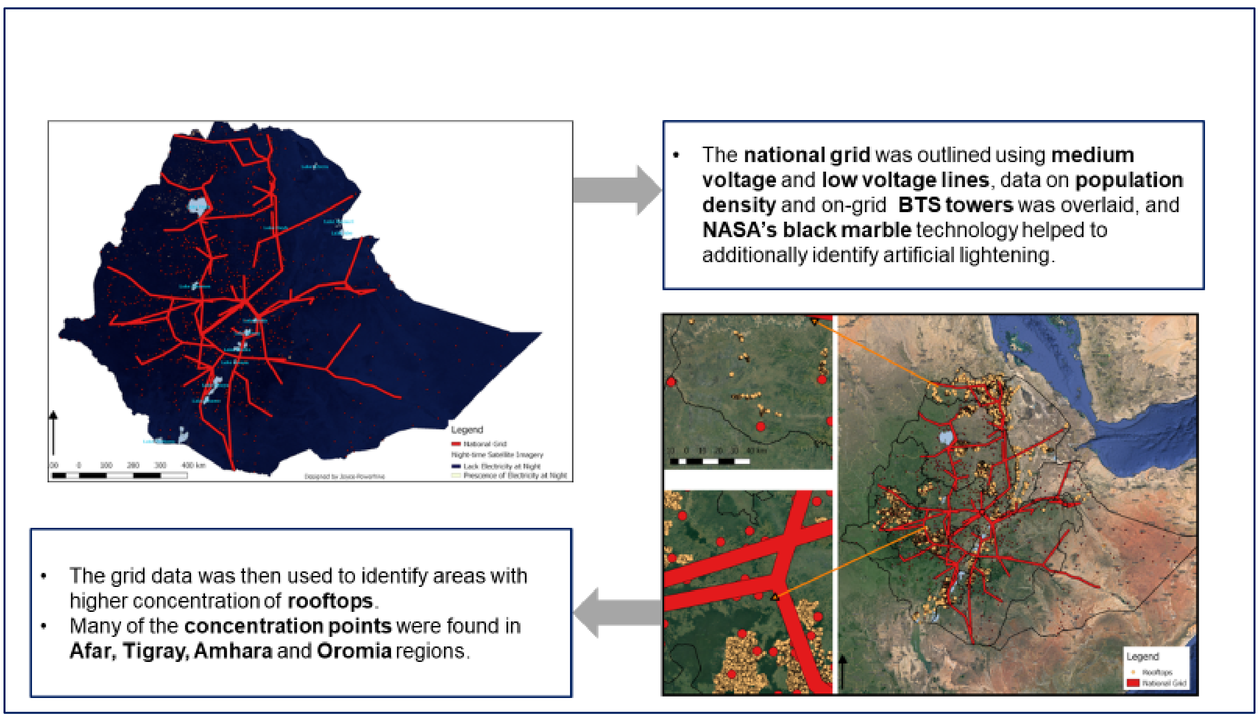


Figure 8: National level mapping – gridlines and rooftops



This approach helped to filter 1,471 high potential sites, ultimately selecting four sites for a more robust validation survey and analysis. These four sites were validated through four sample surveys, which provided baseline data from which a financial model could be developed. These sites are reviewed more closely in the validation section of this document. It is cautioned that a standalone study for this bottom-up approach is required for a more thorough filtering assessment and should be accompanied by more extensive site validations to isolate and test various selection parameters.

4.2.2 Top-down

The top-down approach involved identifying large and rurally focused government and development organisation projects that would structurally have the potential for meaningful, productive use activities developed within a given community. This is premised on the observation that although one of the principle challenges of doing business in Ethiopia is that the government has historically crowded out private sector investment[29], this public investment can also serve as a scaffolding opportunity, creating the foundation for private sector actors to build on and invest in the opportunities created by the government and development organisations.

To this end, four national programmes were identified which have sufficient productive use potential to support commercial mini-grid investments. These four programmes reflect the general thrust of public investment in Ethiopia – the agriculture sector is substantially represented in these programmes, heavy industry and the potential for the light industry is among the productive use cases, and the potential for overall societal development is an underpinning of all four.

The four programmes, though not exhaustive of large-scale programmes that could be applicable are: 1) the ACCs run by ATA, 2) MCCs run by USAID and MoA, 3) IAIPs run by the Ministry of Trade and Industry (MoTI), and 4) the WTP which is designed to be run in a cross-sectoral manner.

4.2.2.1 Agricultural Commercialisation Clusters (ACCs)

The ACC concept was developed by the ATA and is organised as a mechanism to integrate their many interventions in the agriculture sector[30] and to prioritise them within specific geographies and limit the support to a number of high-value commodities. The priority crop commodities are: cereals (wheat, maize, sesame, and malt barley) and horticulture (tomato, onion, banana, mango and avocado). In the pilot year, 2018-2019[31], approximately 600,000 farmers were engaged in the ACC clusters; in the subsequent year, over 1.2 million farmers were organised into ACCs.[32] In November 2019, the ACC programme was formally launched by Her Excellency Sahle-Work Zewde, President of the Federal Democratic Republic of Ethiopia.

An ACC allows smallholders to benefit from access to various interventions through economies of scale. Examples are infrastructures such as irrigation, high quality and cost-

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[29] International Monetary Fund. *Article IV 2018 and 2019 Consultation.* IMF Article IV 2018 and 2019 Consultations evolve from language that resources should be freed up for the private sector, to potential strategies to crowd-in the private sector. A thorough reading of the Consultations over the past decade illustrate the recurring crowding-out theme.

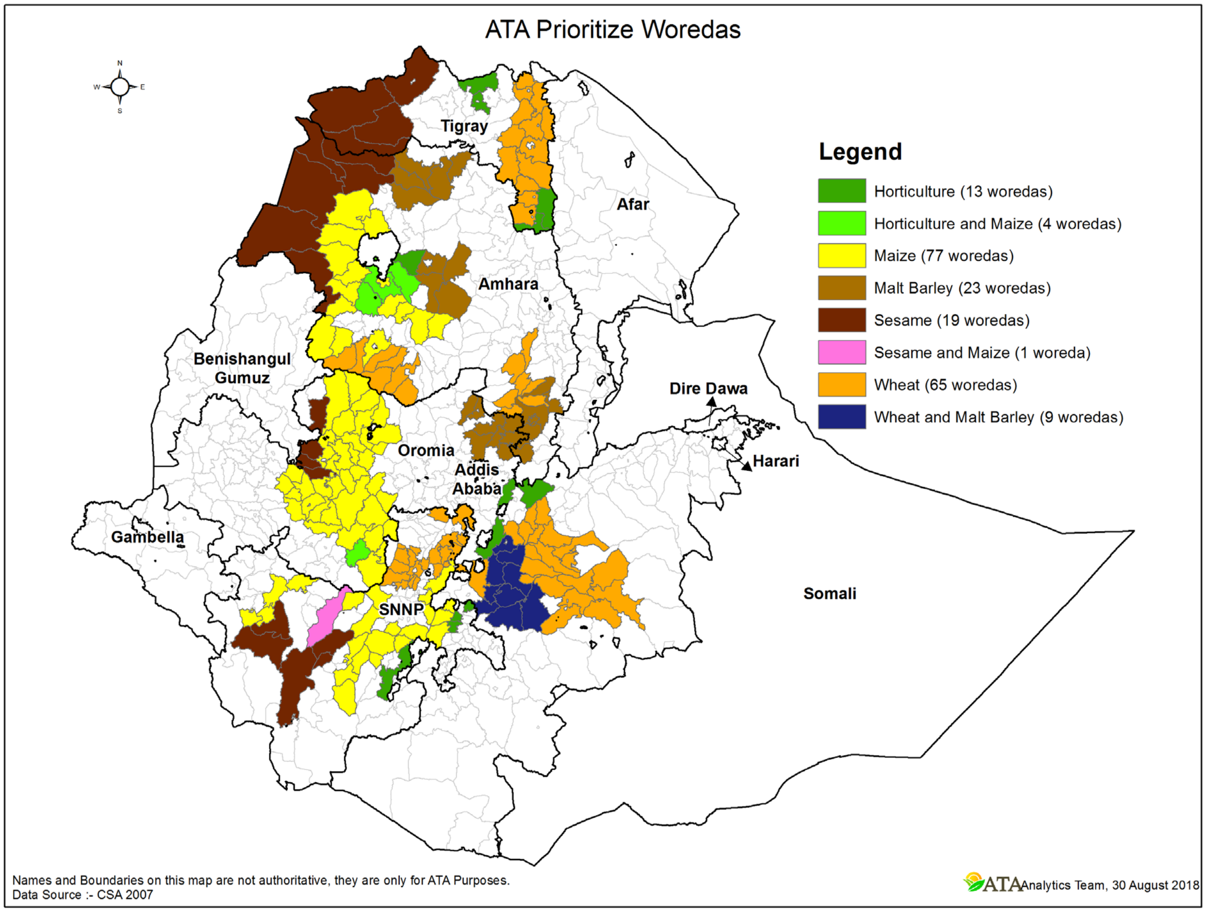
[30] Ethiopian Agricultural Transformation Agency. *Annual Report 2010, 2019* (http://www.ata.gov.et/wp-content/uploads/2019/01/ATA_AnnualReport_2010.pdf)

[31] The Ethiopian Government calendar ends July 7

[32] Veritas. *Interview with ACC Senior Director*

effective inputs, processing and storage facilities, finance, and markets. The map below shows where 213 of the 284 ACC woredas are located, as well as the primary crops that are grown in each.

Figure 10: ACC woreda map



Source: Central Statistics Agency

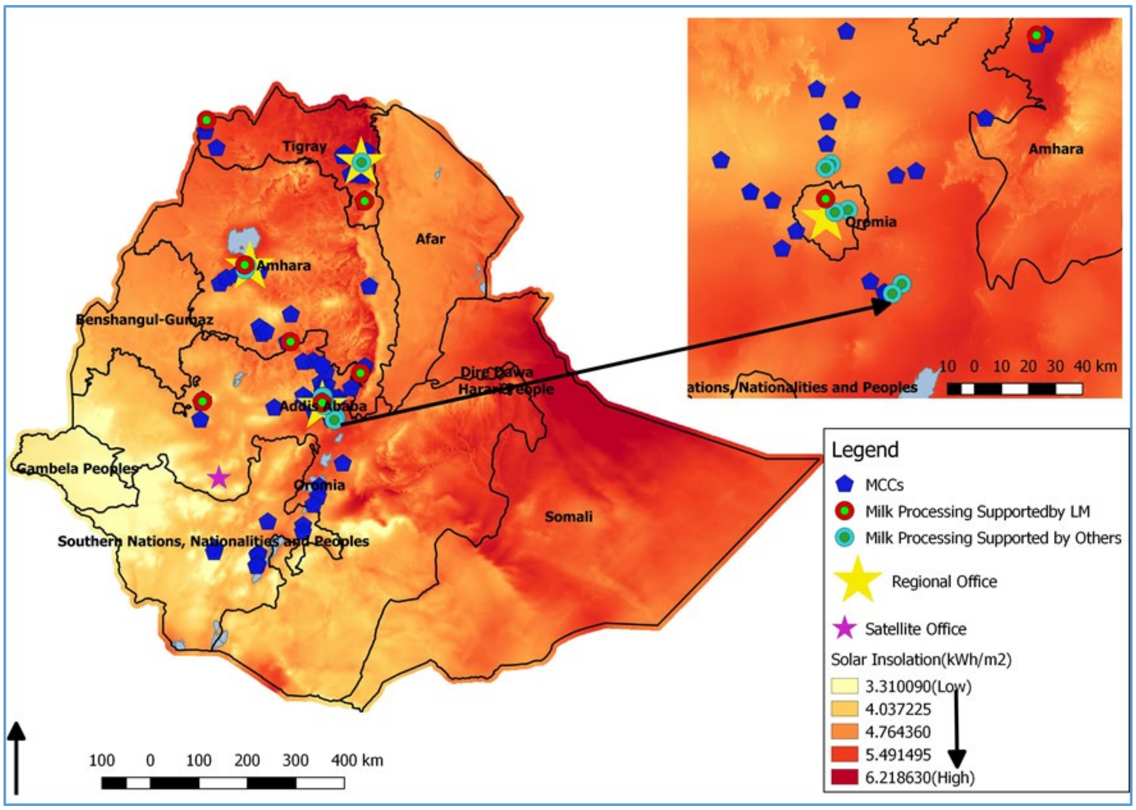
4.2.2.2 Milk Collection Centres (MCCs)

Milk Collection Centres (MCCs) are collection points where milk can be brought from nearby milk producers and then transported *en masse* to processing plants. FINTRAC, one of the implementing partners of USAID's Feed the Future programme, has identified and is supporting 100 MCCs in Ethiopia. These centres all require power; however, only 30 locations are currently on-grid, and the other 70 require continuous off-grid solutions. By providing power to these collection centres, refrigeration (important for storage of milk, medications, and artificial insemination) and processing can be supported.

Unpasteurised milk is a perishable food item and needs to be chilled rapidly in order to store and transport it for processing. Small-scale processing allows farmers to benefit from a value addition close to their farm, and increases the shelf life, negating the need to find a buyer for the aggregated milk. With the application of these productive uses, farmers are able to maintain the quality of milk, thus fetching higher prices in the market. They are then able to receive a higher income from the sale of processed products such as butter, cheese, and yogurt. Furthermore, as mentioned earlier in the overview of productive uses, pumping water is a critical step towards increasing Ethiopia's milk productivity. This is further evidenced by the fact that, although Ethiopia has the fifth largest cattle population in the world, it still imports milk. All of these factors make MCCs ideal candidates for mini-grid development, and as such, they have been prioritised in the mapping process.

The map below illustrates the location of the MCCs within the four regions: Amhara, Oromia, Southern Nations, Nationalities and Peoples (SNNP) and Tigray. Approximately 60 of the centres are located within Oromia or Amhara region with the remaining 40 within SNNP and Tigray.

Figure 11: Map of the MCCs



4.2.2.3 Integrated Agro-Industry Parks (IAIPs)

The third area of consideration on a national level is the farmers connected to IAIPs. IAIPs are industrial parks that are focused entirely on agro/food processing. A single industrial park can be connected to up to 100,000 or more farmers. The vast majority of these smallholder farmers do not have access to electricity. This limits the IAIPs' overall capacity, and therefore Ethiopia's overall industrial strategy.

Below is a map of these sites across the country.

Figure 12: Map of IAIPs.

Source: UNIDO

4.2.2.4 Woreda Transformation Plan (WTP)

The fourth initiative, which presents a context for productive use of power in the country is the WTP. The WTP is designed as a nationwide initiative which seeks to synthesise cross-sectorial plans into a woreda-level roll-out. Nationwide initiatives in health, infrastructure, agriculture and every other sector, will be implemented, monitored, and evaluated at a woreda level, with the understanding that when it comes to national progress, actual implementation and change happens at the household level. This approach ensures that no woreda is left behind in the nation's development process. Therefore, this plan provides an avenue by which investors and government actors can offer services to households and developing geographies across many woredas at once. For example, the MoH plans to narrow the gap between the high and low performing woredas through creating model kebeles, to develop financial protection through community-based health insurance, and to create a network of high performing Primary Health Care Units (PHCUs). These PHCUs require a constant supply of power and could serve as an anchor client to a mini-grid.

4.3 Narrowing in on ACCs

Of all the current national programmes evaluated, ACCs present the most persuasive case for the productive use of power and provide ideal sites for mini-grid investments. ACCs are a priority project of the government due to the crucial role agriculture is intended to play in the continued growth of the economy, and their utility for productive use is recognised in NEP 2.0. Regulations for the mini-grid sector relating to the ABC tariff are also particularly well suited to the ACCs because of the concentration of potential productive uses within a single community. Additionally, they present a context in which 1.2 million farmers are already organised, demonstrating substantial productivity gains, and are closely tied to the overall economic activity of their surrounding communities.

Furthermore, the other three initiatives, although each showing promise, are not yet ready for full-scale investment. WTP is still in the early stages with a pilot site and, while MCCs are attractive, they do not yet have the scale and concentration of activities within a given geography. Equally, IAIPs are not yet fully up and running. These will all be attractive for investment at some juncture and they should be closely monitored but for the purpose of this study, the focus will now be on the ACCs.

4.3.1 A Deep Dive - What is an ACC, and Why Was it Created?

ACCs were set up to create a scalable model for agricultural production, with the goal of increasing the potential for commercialisation and industrialisation of the sector. In Ethiopia, Agriculture has traditionally been subsistence-based, with smallholder farmers working small plots of land, using basic hand tools, and only growing what they can eat or sell locally. Despite efforts to introduce more modern agricultural practices, limited progress has been made; mechanisation and the use of improved input are not widespread and productivity remains much lower than its potential. ACCs were designed to address these shortfalls. Prioritised in GTP II as a key driver of agricultural transformation, the ACC strategy is to integrate efforts in targeted geographies that benefit smallholder farmers and other value chain actors.

ACCs function at a woreda level, where ATA focuses its interventions on one or two of the primary commodities. The ACC initiative prioritises the ten aforementioned commodities (wheat, maize, sesame, malt, barley, tomato, onion, banana, mango and avocado) across 284 woredas within four regions: Amhara, Oromia, SNNP and Tigray. Maize has the widest coverage in hectares and can be found in 91 woredas across three of the regions (the exception is Tigray)[33]. Following maize, wheat is the most prevalent priority crop; it is the primary crop in 79 woredas[34] and present in all four regions.

At sub-kebele level, ATA organises farmers into Farmer Productive Clusters (FPCs). These FPC's have anywhere up to 400 farmers producing the same agricultural product in one contiguous area, and will collectively purchase inputs, aggregate harvest, and go to market. At the farming level, this means investments in productivity stand to benefit from economies of scale not available to an individual or even several farmers. Such economies of scale are particularly critical for power needs that can have a substantial impact on yield and total production. Additionally, these clusters would now have the scale to command stronger market terms and over time, develop the coordinative capacity to invest in power-driven agro-processing.

ACCs have been set-up specifically with an investment project, such as mini-grids, in mind. The Ethiopian Government and the ATA have recognised that without organising

[33] Ethiopian Agricultural Transformation Agency. (www.ata.gov.et)
[34] A woreda is an administrative district; in the rural setting they typically consist of several dozen kebeles (the smallest administrative unit).

for commercialisation, farming will remain at a subsistence level and struggle to develop as an engine for growth and industrialisation.

Additionally, modern technologies in irrigation and post-harvest storage constitute a paradigm shift for the smallholder farmer. Traditional farmers using rainfed agriculture practices typically enjoy only one harvest a year in Ethiopia. Irrigated farms can have multiple harvests, increased yield per harvest, improved produce quality, reduction in waste, and better positioning for additional value-addition activities. Irrigation can also mitigate the negative effect of episodic droughts, increasingly exacerbated by climate change, that have devastated Ethiopian farmers. These benefits mean the farmers in an ACC are much more likely to be able and willing to pay for cost-reflective electricity.

4.3.2 Why Have Horticulture Clusters Been Chosen Over Cereals?

This study has selected the five horticulture crops (avocado, mango, onion, tomato, and banana) and their respective clusters as the areas of focus in the development of mini-grid use cases rather than cereals due to their income potential, infrastructure, and sustainability:

- *Income potential*: Across all crops, horticulture has a much higher revenue potential than cereals. Interviews with agriculture experts indicate that a horticulture farmer can earn up to ten times more than cereal farmers on the same amount of land. For example, a commercial avocado farmer can earn well above USD $30,000 per hectare (ha) or more per year, while a commercial maize farmer can typically earn approximately USD $2,400 per ha per year[35].
- *Irrigation as an income driver*: water is particularly important for horticulture crops. With irrigation, interviews with agriculture experts indicate that farmers typically experience up to a 30% increase in yield per harvest and, for certain crops, can have up to multiple harvests per year[36]. Without irrigation, some horticulture crops, such as tomatoes and onions and mango, are simply not feasible, and those that are possible remain limited to the single annual harvest. These benefits are not as pronounced for cereals, which have a longer growth period and thus are limited in the number of harvests, regardless.
- *Infrastructure*: Energy requirements for horticulture are much higher than for cereals. The need for seedling production, irrigation, and cold storage means that energy requirements per hectare can be more than 50 times those of cereal crops. This creates ample opportunity for mini-grid supply at different stages of the value chain.

The figure below demonstrates the impact irrigation can have on crops when compared to strictly rainfed farms. Notice the comparatively high impact irrigation has on horticulture versus cereal crops. Income from rainfed horticulture production is on average three times that of cereals without irrigation, but with irrigation that rises to 4.3 times more.[37]

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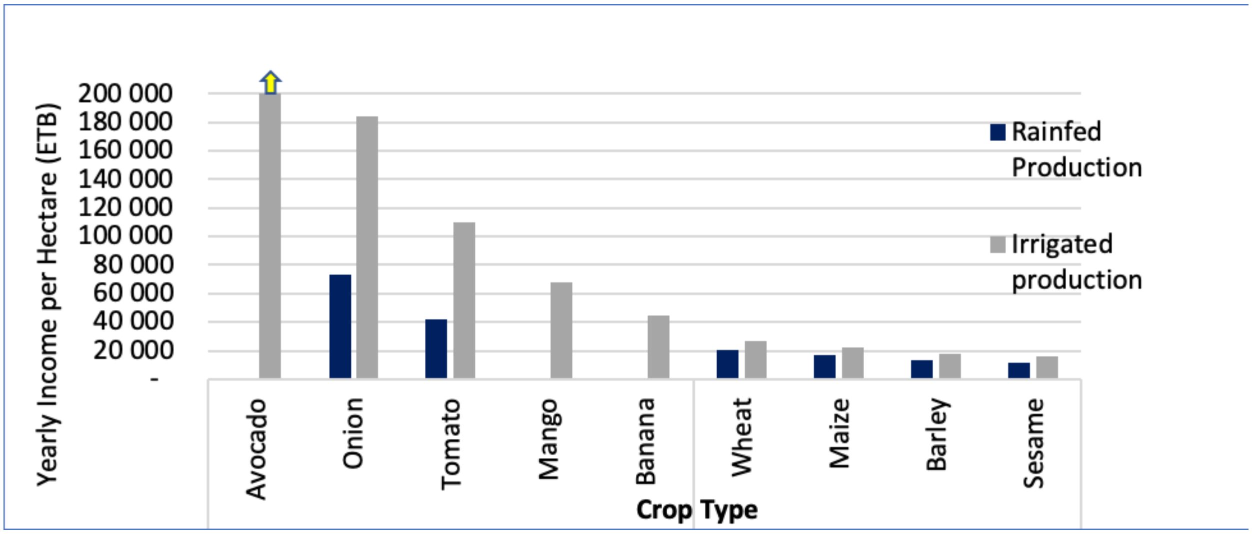
[35] Veritas. *Information from interviews with avocado farmers in a cluster south of Addis Ababa*

[36] Veritas. *Interviews with industry experts*

[37] This data was derived from interviews with numerous agriculture experts in Ethiopia. There is some geographic and seasonal variability in price and yield, and no two sets of numbers were identical. However, the overall scale is consistent across the various interviews.

Figure 13: Increased income potential for irrigated horticulture crops.



Source: Veritas interviews with agriculture experts.

4.3.3 Investment Cases

In consultation with MoWIE, MoA and ATA, ten sites have been selected for private sector investment for commercial rate tariff mini-grid development across four key regions in Ethiopia. This includes deep-dive site validation, tariff design, and infrastructure development assessment. Once finalised, these ten specific investment sites will be published in the form of detailed pre-feasibility studies and will be made available to mini-grid investors. The structure of these pilots is under discussions with MoWIE, SSN and other relevant stakeholders. It is expected that these pilots will undertake various private and public/private formulations to assess both the utility for various developer types and the most scalable models.

At present, the three business structures under consideration are: a) private ownership and operations; b) a joint venture with a private operator and EEU; and c) private investment with EEU building the distribution lines and charging wheeling fees. The table below further details the load profile of each of these potential sites. These are decidedly farming communities. The implication is that there are very few shops or other business activities. Typically, the farmers will walk up to five to seven kilometres to the nearest kebele centre to access souks and other basic small business needs. The load profile, in this case, will then be unique from the usual mini-grid community seen in the broader region, as the load is made up of almost all smallholder farming needs.[38]

[38] Veritas. *Site validations*

Table 2: The characteristics of ten sites selected for the mini-grid pilot programme

Name of Region/ kebele / village	*Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10
Village level										
Total Number of HH in the village	775	218	220	234	300	395	300	451	420	312
Premium or High Income HH	245	46	150	206	17	56	60	40	9	150
Regular/ basic Income HH	407	132	70	28	211	302	240	411	411	162
Irrigated Farms (ACC Farms)	685	100	200	189	225	378	300	165	165	215
Principal Crop	Banana And Avocado	Onion, tomato	Onion, tomato	Onion, Tomato, Avocado	Onion and tomato	Onion and tomato	Onion and tomato	Onion and Tomato	Banana	Avocado
Business /Enterprises/other										
Non -irrigated farms (Non- ACC Farms)	90	118	20	45	7	17	0	296	255	97
Number of Schools	1	0	1	1	1	1	1	1	1	1
Number of Health facilities	1	0	0	0	0	0	0	0	0	1
Religious centers	8	4	2	1	0	1	1	1	2	5
Number of Gov't office	10	1	3	0	0	0	0	0	0	0
SMEs	1	0	0	1	0	0	0	0	0	6
Souk	16	2	0	4	7	11	6	30	5	4
BTS within the village (Y/N)	No	No	No	No	No	No	No	No	No	No
Nearby BTS in KM	7	10	1	4	6	5	4	10	22	6
Deep Dive into ACC										
Number of ACC farms	685	100	200	189	225	378	300	165	165	215
Average farm size	0.1	0.5	0.3	0.6	0.2	1.3	1.5	1.4	1.2	1.6
Number of Wells	52	42	32	45	4	205	0	33	0	0
Number of Diesel Generators	112	2	45	150	200	138	250	33	5	12
Source of water for irrigation/farming	Rain/River	Ground water /well	Ground water /well	Ground water /well	River	River	River	Well	River	River
Over View of kebele Level										
Number of HH within the kebele	775	999	621	937	1511	1475	2800	1769	1108	1015
Number of Farms within the Kebele	90	875	400	487	1286	1097	2500	1604	943	800
Do they irrigate ? (Y/N)	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Number of irrigation farms	0	0	0	0	1	1097	2500	250	688	455
Business /Enterprises										
Number of Schools	1	2	1	4	2	4	5	4	1	3
Number of Health facilities	1	1	1	2	1	1	2	2	1	3
Number of Gov't and public enterprises	29	8	3	25	0	6	10	19	2	24
Number of SMEs and shops	16	2	3	4	7	31		150	5	52
Nearest power line (Grid)	Serbo	Obolecho	Liben Gadula	Ude	Wanza	Kuhar	Kidest Hanna	Bala	Shelle	Telamo
Road Condition	All season	Non-rain	All season	All season	All season	All season	All season	All season	Non-rain	All season
***Entire kebele**	**Entire kebele**									

5 VALIDATIONS

5.1 Sampling Methodology

Ground truthing, or site validation, is a vital component of off-grid development, given that best efforts at GIS mapping and geographic data collection are invariably subject to some level of inaccuracy. As part of this study, 65 sites have been validated. The extent of validation at each site depended on the reason behind each particular effort; there were three primary motivators for the 65 validations, each of which required a slightly different approach:

1. Fifty sites were validated to support the government-funded mini-grid EPC programme; these sites will ideally be tendered for EPC contracts and ultimately operated by EEU.
2. Four sites were validated to ascertain the validity of the bottom-up site selection approach, and to provide more in-depth baseline data for financial modelling.
3. Eleven sites were validated to assess top-down selected ACC sites for potential pilot investments.

All three approaches required well-designed surveys (including questionnaires), followed by research-standard sampling methodologies, to gain an accurate picture of these communities and sites.

The steps taken in the **validation process** were:

1. Design survey and questionnaire
2. Conduct random sampling for the sites being validated
3. Visit woreda and kebele offices to collect macro-level data and prepare the way for surveyors (number of houses, business, farms, etc.)
4. Geotag specific locations to be validated; principally these are irrigated farms
5. Conduct field cross-sectional surveys of households, businesses and farms
6. Data quality assurance and analysis

5.2 Validations Conducted for EEU

On behalf of MoWIE and EEU, 50 sites were validated which EEU intends to put out to tender to private EPC contractors but will be operated by EEU in order to electrify rural settlements unreached by the national grid. They were selected preliminarily through population density assessments and their distance from the grid. A site-by-site validation was then conducted, which included geotagging the key business and government locations, and collecting data on consumer and commercial user loads. These validations consisted of one field day per site.

The findings of this analysis have been submitted to EEU. Since these are subject to a potential public tender, this report takes caution not to provide data associated with these validations at this stage.

5.3 Four Bottom-up Sites

Four sites were validated to collect data necessary for developing a financial model and productive use cases generated by the bottom-up socio-economic analysis. In comparison to the 50-site survey, more substantial interviews were conducted to ascertain willingness to pay, and social and economic activity. These validations were conducted over three to four days at each site. These validations provided a picture of an average off-grid community in Ethiopia and guided the implementation of other ongoing validations. The validation included four field survey instruments deployed in each kebele to assess their infrastructure, the current power availability, the power needs, and the willingness and the ability of individuals and businesses to pay for power. The four types of surveys administered are community, household, business and taxi transportation surveys.

- The community survey collected information on the specific characteristics of each site concerning location, infrastructure, and segmentation of business entities and public institutions. The data was gathered from kebele officials.
- The household survey collected three data components: the first was general information about households, household size, and income; the second about farming activities; and the third focused on power consumption and demand for power. A total of 38 households were surveyed in the four kebeles.
- The business survey contains general information about businesses in the kebeles and their power consumption practices and demands. A sample of 32 businesses were surveyed.
- The taxi transportation survey addressed questions about daily revenue, fuel usage, and cost of fuel for main transportation providers in the area. This included three *bejaj* drivers (three-wheeled motor vehicles) and 11 motorcyclists.

On the whole, the data reveals that there is a high need and willingness to pay for power in the off-grid areas surveyed. Most of the households sampled want to be connected to the grid and expressed willingness to spend more on power than they currently spend. They also want to use many appliances that require power to function.

However, low-income levels limit the ability to pay, as evidenced by the fact that 60% of the households still use traditional lamps for lighting despite the availability of stand-alone home solar systems.

Annex 1 provides more detailed data, and we caution that broader surveys and actual use cases with power will be required before drawing firm conclusions.

5.4 Ten Top-down Sites: ACCs

From the four top-down initiatives discussed previously, the ACCs were selected as the most mature productive use examples**.** The ATA provided ten sites across various regions, with a focus on horticulture crops to be validated and considered as potential pilot investment sites. The ten site validations were considerably more intensive than the previous 55 validations because these sites will be used to build investment cases. A detailed outline of our three-step methodology for validating these sites is provided below:

Table 3: Detailed outline of the three-step methodology for validating sites

	Process	Description
Pre-survey	Supervisors visit kebele leaders	The kebele is the local government closest to the farming clusters, and it was, therefore, essential to gain the cooperation of kebele leaders before sending out the survey teams.
Step 1	Geotagging Survey Sites	Supervisors travelled with kebele leaders to identify key site parameters. The sites were then geo-tagged (irrigation farms and businesses) the enumerators during the survey process, to ensure accuracy. When possible, pictures were also taken of the sites.
Step 2	Household Surveys	
	Section 1: Households without farms	This helped to return data on household-level income, willingness to pay, etc.
	Section 2: Farmers outside ACCs & FPCs	Farmers outside the clusters are independent and therefore needed to be profiled separately since their potential power requirements are nominal, limited data were collected from them.
	Section 3: Farmers within ACCs	All of these farms were geo-tagged.
Step 3	Business Survey	
	Section 1: Institutions	This included health centres, schools, religious institutions, farmer training centres, and other institutions which are not privately owned and operated.
	Section 2: Businesses	This included shops, garages, restaurants and bakeries, and other privately owned and operated businesses.

Table 4: Survey team roles

Role	Criteria
Supervisors	• One Supervisor per four surveyors • Must have significant experience in power and agriculture assessments
Surveyors	• Must speak the local language of the region where they are conducting interviews • Prior power and agriculture survey
Communication Engagement Officer	• Specific for each region • Helps facilitate with local government leaders

The principal requirement for these teams was to prepare foundational geographic and customer segment data for the development of discrete investment cases for each of these sites. This required the geo-tagging of all horticulture farms in the area, identification of the types and number of businesses, the number and dispersion of households, and the prevalence of other key variables such as the presence of BTS.

6 MINI-GRID FINANCIAL MODEL

The 50-site survey on behalf of MoWIE/EEU, the four sites surveyed for research purposes, and the ten sites assessed for investments, collectively provided necessary parameter framing and load profile data from which a customised financial model was developed. Having defined the typical community, the unique needs and potential of farmers, and the constant power demand of businesses, these profiles can now be used as inputs to set the parameters of a financial model.

The main objective of the financial model is to provide an overall assessment of the financial feasibility of a single or basket of potential mini-grid projects. It is designed as a tool to analyse financial outcomes for a particular set of inputs and assumptions. It should be noted that the model is not a technical design tool but can approximate system capacities and associated CapEx requirements. The financial model is purposed to be used by different stakeholders for distinct purposes. The specific audiences and uses for the model are described below:

1. MoWIE can use the model to develop an overall understanding of the mini-grid subsector it manages and to quantify the cost of mini-grids and the impact of policy decisions.

2. EEU can use the model to price the mini-grid sites they are currently developing or planning to develop in the future. The model will also help EEU to have an independent tool to assess EPC and PPP arrangements that it may enter into.

3. EEA can use the model to understand the implications of policy on mini-grid projects and to have a sense of the sensitivity of project cost to different parameters such as energy price and tariff models.

4. The Veritas/Powerhive project team will use the model to assess identified and validated potential mini-grid sites. For the ten ACC sites that will form the basis of investment cases for pilot investments, the financial model will be used to analyse financial feasibility of the sites and to provide CapEx, OpEx, and tariff assessments of these sites.

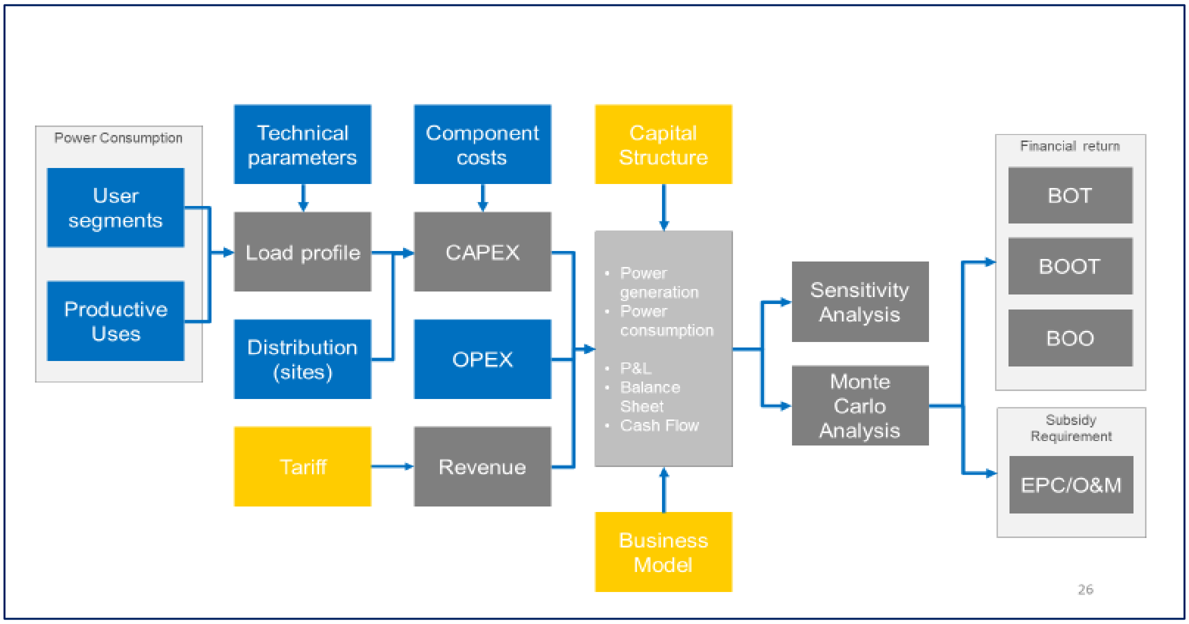
Any mini-grid developer will, and should, have a similar tool to perform their due diligence. The capacity to develop such a financial model should be a pre-requisite for a developer.

6.1 Model Structure

To help explain the model, a pictorial representation is provided below. The **blue boxes** represent inputs to the model set by the user. The values of the **light grey boxes** are automatically calculated by the model. The **yellow boxes** are financial variables that highly influence the overall financial return of a project. The **dark grey boxes** are analysis methods implemented in the model to evaluate the resilience of project cost to uncertainties and variations in different input parameters. The **dark grey boxes** also indicate output financial returns for different types of business models.

The model builds the load profile for a particular site based on the power consumption of different user segments and productive uses. Load profile and geographical information ascertained from physical site validations are used to determine technical specifications for system components such as PV, battery, and distribution line types and lengths. The CapEx for the mini-grid project is then calculated by the model based on the technical specifications and installation costs. Finally, financial metrics are computed from CapEx, OpEx and revenues for different types of business models and capital structure. These financial metrics are assessed further using sensitivity and Monte Carlo simulation analyses to evaluate the robustness of the project against uncertainties and variations in various parameters. Outputs of these analyses are used to estimate risks associated with the uncertainties and variations. The key financial metrics of the mini-grid are then presented as an output for the different type of business models considered.

Figure 14: Financial model parameters. Model was designed to provide an overall assessment of the financial feasibility of a single project or basket of potential mini-grid projects.



6.2 Model Parameters

In general, the parameters in the model can be grouped into three parts – **givens, assumptions, and outputs.** Givens and assumptions are both inputs, but givens are known variables, while assumptions are unknown variables that need to be carefully estimated. Outputs are the financial metrics of the investment project.

Figure 15: Financial model parameters

PARAMETERS	**Givens:** Important to map precisely, but cannot be influenced by developer **Assumptions:** These can be varied and it is important to develop an understanding of likely value (base case) and potential range **Outputs:** The key outputs are financial metrics: IRR, NPV, payback period.

The first group of parameters are the 'givens' or known variables. They are inputs which cannot be changed by the developer, but they are important to define. Given input parameters include:

- **Component costs** – cables, batteries and other fixed elements whose costs are market-driven.
- **Tariff** – if energy rates are tightly regulated and are fixed, e.g. in EEU owned sites.
- **Solar irradiation** – varies over the course of the year and determines the amount of energy available at a given time. To make sure that the PV plant has enough generation capacity all year round, solar irradiation of months with a high likelihood of overcast (e.g. June, July and August in Ethiopia) should be used.
- **Tax** – tax regime is an important determinant in financial outcomes and is also outside the influence of the developer.

The second group of parameters is the assumptions. These are inputs that are subject to variability.

- **Demand** – actual daily energy demand of the different customer segments and productive uses are usually not known and need to be estimated through site validations.
- **Tariff** – in cases where tariffs are not strictly regulated, the design of tariffs can be contextualised to the client. Tariff design is a key aspect, influencing both usage patterns and financial returns.
- **Capital structure** – cost of equity and debt are negotiable and are important to understanding the outcomes for a given project. Debt and tariff parameters, in particular, can have a significant impact on the Internal Rate of Return (IRR) and sustainability of a project.
- **Productive Uses** – greatly increases the utilisation of energy and economic impact of the project.

Once the invariable and variable inputs are defined, there will be a clear picture of OpEx, CapEx and revenue of the project. At this point, the user has the inputs needed to determine the key **outputs** which are our financial metrics: IRR, Net Present Value (NPV) and the payback period. Furthermore, the model determines the required PV and battery sizes based on the usage parameters, irradiation, and load profile assumptions, which in turn determines the total project CapEx. It should be noted that the level of subsidy required is either an input or an output, depending on the perspective of the user and the kind of business model that is under consideration.

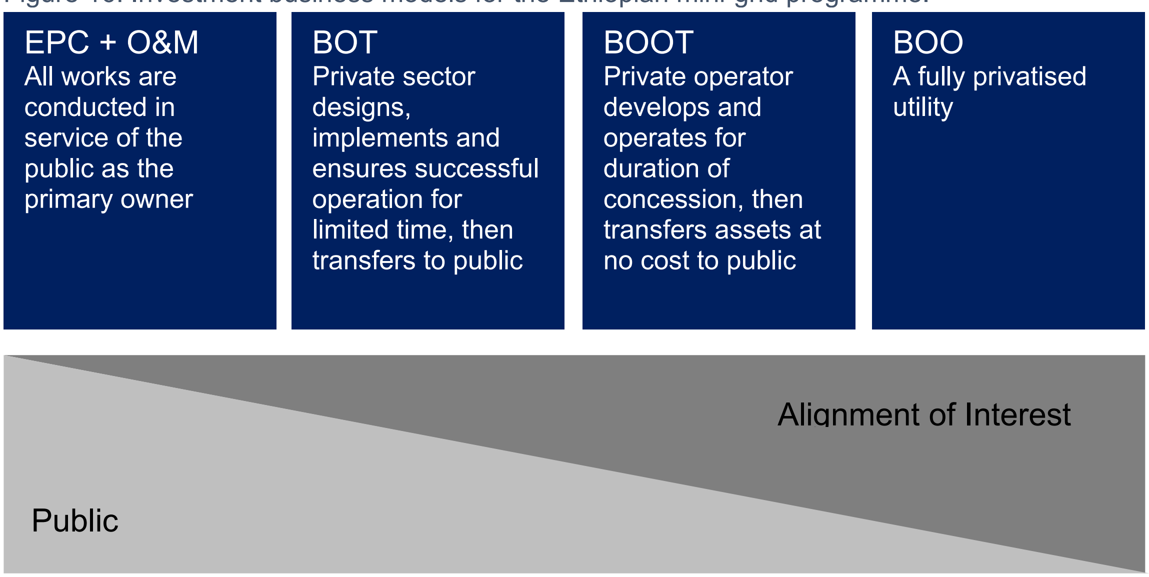
The model outputs the financial return of the project considering several factors. The effects of input uncertainty and variation on the outputs are determined using two analysis methods:

1. **Sensitivity Analysis** – it is critical to understand which inputs have the largest influence on the outputs.
2. **Monte Carlo Analysis** – many inputs are not known precisely or may change over time. Modelling the possible range of outcomes is critical to understanding risk.

6.3 Business Models

The public sector takes great interest in the social welfare effects of electrification. Therefore, investments tend to assume a wide range of business models. The financial model considers that, and allows for, variable results analysis around several PPP platforms and a standalone private framework.

Figure 16: Investment business models for the Ethiopian mini-grid programme.



The PPP models presented above operate on a sliding scale between public and private interests.

- On one end of the scale is an EPC/Operations and Maintenance (O&M) model. In this business model, the private sector is a service provider that constructs, operates and maintains the project. At the same time, the government holds ownership and carries all risks associated with the project.
- The Build, Operate, Transfer (BOT) model contracts private entities to build and operate a facility, making sure it runs smoothly, but then transfers it to public management within a short amount of time. In this model, the public sector is still the ultimate beneficial owner of the work and can keep tight regulatory control over it. Still, there is more room for knowledge and skills transfer from private experts to public operators.

- Build, Own, Operate, Transfer (BOOT), however, allows the private entity to not only build and operate but also own the facility during a concession period. The government sets a concession period as a timeframe in which incentives are provided, and private ownership is allowed before it is transferred to public ownership. The private entity usually finances the work and is allowed to operate it with relative autonomy in order to recoup its investment.
- On the other end of the scale is the Build-Own-Operate (BOO) model, where the private sector is the primary owner. Projects operated under the BOO model are entirely financed, constructed, owned and operated by the private sector. In this model, the private sector is a long-term partner in the work and carries the most risks associated with it, while receiving all returns from the investment.

6.4 Tariff Structures

The tariff structure is a primary input which needs to be defined in the financial model by the user, based on the regulations in a country. It affects the cost passed on to end-users, as well as the return on investment for developers. In some cases, tariff rates are fixed by the government and are not subject to influence by a developer. However, there are instances where tariff structures can be customised to meet the unique demand of a project site and its end-users. To this end, five types of tariff models, each with their structure of consumption rates, are included in the financial model. The table below (rates are representative) provides details on the tariff models and logic behind each of these models.

Table 5: Alternative tariff models (in USD)

Model	Simple tariff	Time of Use	Fixed packages	Inclining blocks	Multi-Tier
Description	Customers are charged per kilowatt-hour (kWh) consumed, regardless of consumption level	Different rates for different times of day	User pays fixed monthly amount based on desired consumption	Each block of consumption is more expensive than the previous, charges businesses and high energy consumers more than lower-end households	Differentiated rates per user segment
Rationale	Simple to communicate, simple to administer, does not ‘discriminate’ between user segments	Incentivises consumption during off-peak hours, or when generation capacity is maximal; Covers for the additional cost of battery storage during the night	Allows operator to plan generation capacity and maximises utilisation, driving down LCOE	Enables commercial/ productive user to subsidise low-end household users, **difficult to explain**	Enables **cross-subsidisation**, alignment of requirement with the cost of service, **ease of understanding**

Connection cost	$100	$100	$100	$100	$100
Fixed fee	0	$2.00 / month	0	0	0
Consumption charge	$0.06 / kWh	Daytime: $0.15 / kWh Night-time: $0.30 / kWh	≥10 kWh: $2.50 ≥25 kWh: $5.00 ≥ 60 kWh: $10.00	0-3 kWh: $0.06 / kWh 3-5 kWh: $0.12 / kWh 5-10 kWh: $0.20 / kWh ≥10kWh: $0.35 / kWh	Homes: $0.06 / kWh Souks: $0.12 / kWh Anchor: $0.35 / kWh

The last two columns are the most important tariff models in the context of Ethiopia, where grid tariff is heavily subsidised, and the ability and willingness (particularly from households) to pay is low. While both tariff models have inherent cross-subsidisation features, the inclining block best captures segments of customers that are willing to pay by charging them more for higher energy consumptions, whereas the multi-tier model identifies them in advance. The multi-tier model is simple and easy to understand as users will know beforehand which user segment they belong to and the rate of energy per kWh. By contrast, in the inclining blocks model, users will be charged different prices for each block of kWh consumed, which can be complicated to explain to consumers.

6.5 Case Study

A case study was performed to define some of the numbers graphically. The objective of the study was to highlight the difference between the financial feasibility of a mini-grid pre- and post-irrigation and to show the impact of productive use on the viability of a project. The selected village, Hana, is from EEU's tender for 25 mini-grid sites. Two discrete cases were assessed. In the first case, which is the actual case for Hana, no productive use was considered, while in the second case, 400 mango farms, that will require irrigation, were added. The number of consumers in each customer segment and their total energy demand per day is listed in the table below. Note that irrigated mango farms, in the last row of the table, are considered only in the second case.

Table 6: Energy demand per customer at Hana site

User Segment	# in site	kWh/user/day	Total kWh/day
Basic Consumer	880	0.15	132
Premium consumer	200	0.81	162
Souk	36	2.03	73
School	12	3.04	37
Micro-enterprise	24	5.07	122
Clinic	1	15.21	15
Religious centre	5	0.67	3
BTS	1	84	84
Government	3	5	15
Irrigated mango farms	400	2.2	891

Source: EEU tender for 25 sites, complemented by mango farms

As the load profile is being considered for this location, it should be noted that validation data feeds directly into the financial model and helps determine the mini-grid model design. It is cautioned that there is additional variability associated with the deployment of distribution lines since this is a separate exercise requiring manual mapping, which was done using geotag data mapped during the site validation stage. In designing the financial model, Powerhive estimated distribution line types and lengths required for the mini-grid by extrapolating data from approximately 9,000 sample mini-grid developments available in our database.

In off-grid mini-grids, accurately estimating demand is critical to the success of the model. There is a set amount of energy (kWh) available each day and, if unsold, each kWh is lost forever. Therefore, operators only want to build capacity they can sell, maximising utilisation, which is essential for good financial returns. At the same time, there is a need for ‘room to grow’ as energy demand will increase eventually. Thus, developers will need to estimate current energy demand and potential demand growth rates to determine the right generation capacity.

Figure 17 below shows the load profile for the Hana site for the case with 400 irrigated mango farms. The load profile gives a good overview of the high energy demand from irrigation compared to other user segments. For the studied case, the energy used for irrigation purpose between 11:00 and 15:00 makes up 58% of the energy consumption of the whole site over 24 hours.

Basic consumers use energy outside of working hours i.e. in the early morning and early evening hours. The premium consumers and souks have varying energy consumption levels between 06:00 and midnight with peak demand in the evening. Schools, micro-enterprises and the clinic use energy only during working hours, while religious centres, the BTS tower and government consume a constant amount of energy throughout the day.

The PV + battery generation and consumption load profiles for the cases with and without irrigation is presented in the figure below. Positive values indicate energy generated by the PV plant and the battery, while negative values indicate energy consumed by different user segments and the battery. The battery consumes energy when it is being charged between 10:00 and 17:00. The energy stored in the battery is used in early morning and evenings, and also during night-time. Most of the demand, which peaks during the daytime, is supplied by the energy generated by the PV plant.

As can be seen from the figure 18, the generation and load profiles change significantly between 11:00 and 15:00 due to the power demand from irrigation. In the case where no irrigation is used, a PV plant with 280 kilowatt-peak (kWp) and a battery with 482 kWh storage capacity are needed to meet the energy demand at Hana. In the case where 400 mango farms with irrigation are considered, the required generation capacity more than doubles and becomes 620 kWp with battery storage capacity of 402 kWh.

Figure 17: Load profiles

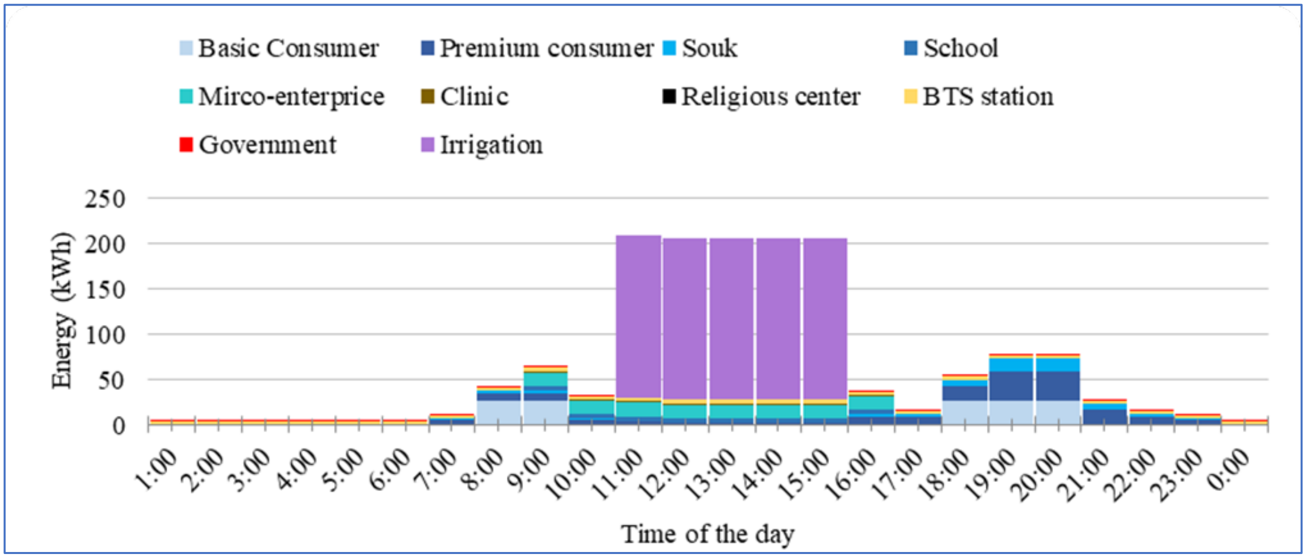
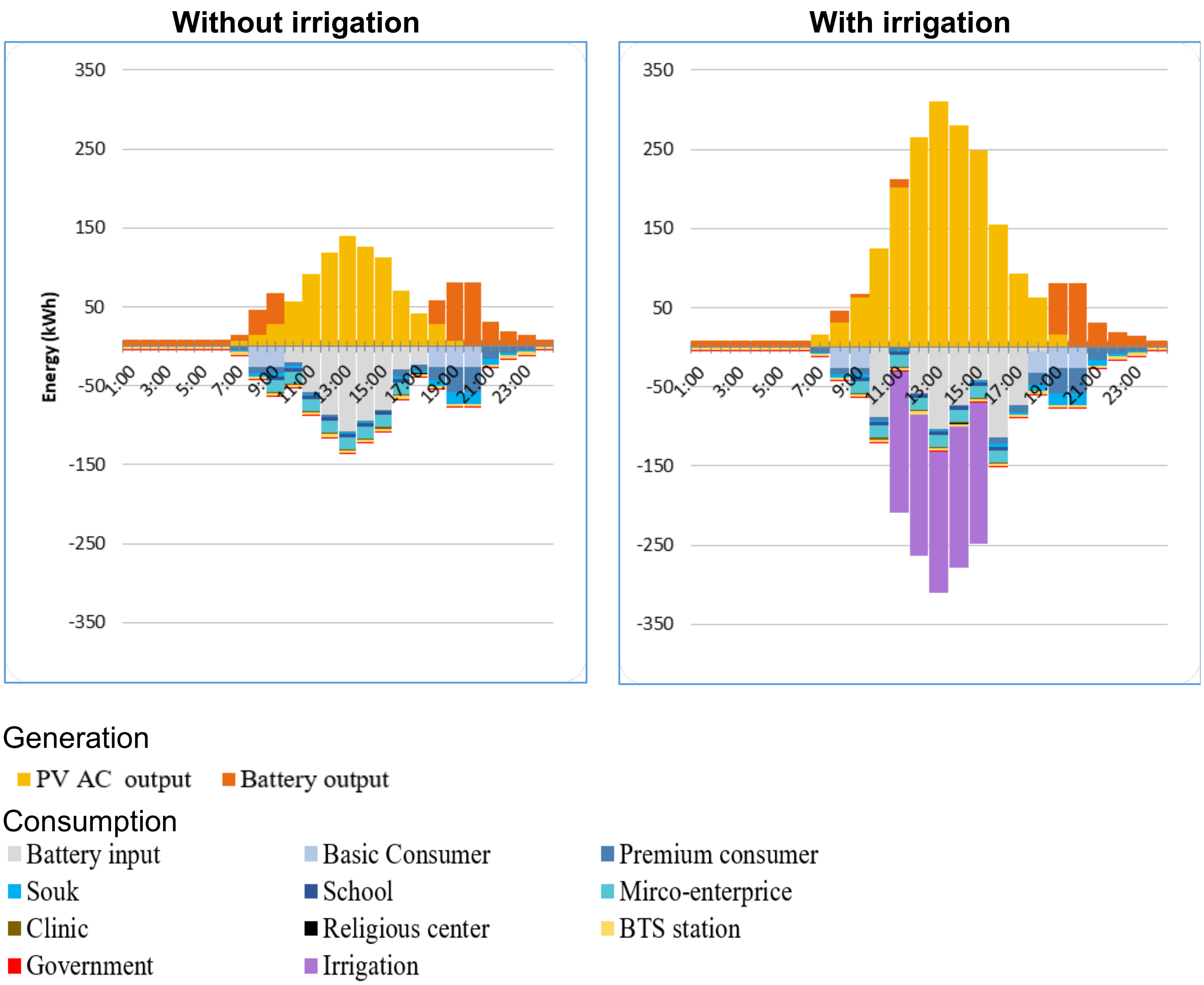


Figure 18: Generation and load profiles



The table below summarises the key financial outputs for the project for an investment period of 20 years. The project will incur a loss of USD $2.75m without any productive use, but if irrigation productive use were to be included, the project would have a net profit of USD $1.05m.

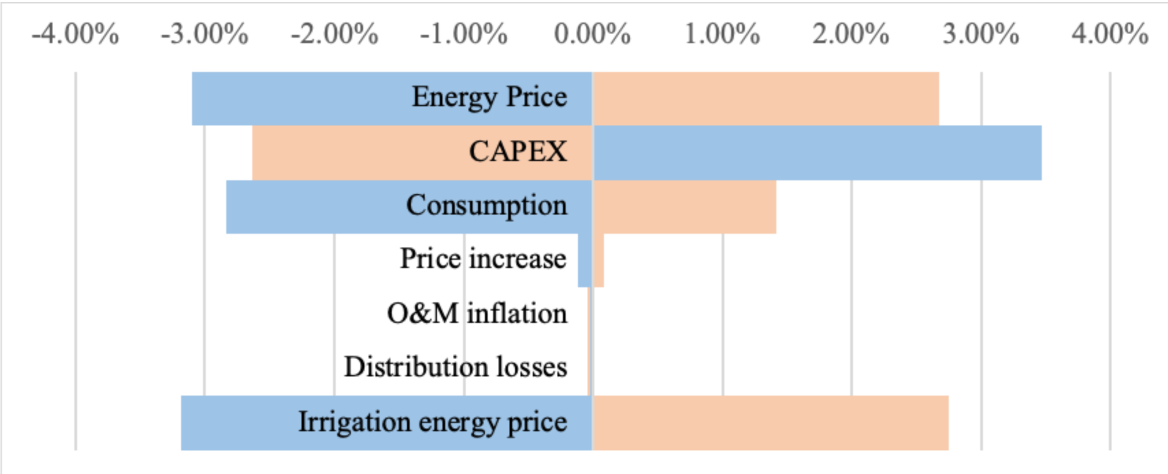
Figure 19: Comparable financial outcomes (in USD)

	Without Irrigation	With Irrigation
Power Station	280 kWp + 482 kWh	620 kWp + 402 kWh
CapEx	$ 1.52mm	$ 2.18mm
Total OpEx (20y)	$ 1,838,166	$ 1,965,724
Total Revenue (20y)	$ 985,701	$ 5,431,506
Total Net Profit (Loss) (20y)	$ (2,749,717)	$ 1,055,322

6.6 Sensitivity Analysis

Sensitivity analysis determines how output financial metrics are affected by changes in input variables.

Figure 20: Sensitivity analysis



Sensitivity analysis provides crucial information for policymakers as it indicates the implications of changes in different variables (such as tariff and subsidy) on the financial return of a mini-grid project. Thus, the analysis assists policymakers in quantifying the impact of policy decisions and helps them understand where to focus policy adjustments without having significant ramifications on a project's financial return.

All told, the feedback has been that this is an exceptionally robust tool for users. During the current training stage, public officials have expressed great interest in applying the financial model for their work. Over time, some consideration may be taken to strip down some of the higher-level uses, customising it to MoWIE, EEU and EEA needs, and potential upcoming EPC tenders will serve as reliable indicators for customisation requirements.

7 SUMMARY AND WHAT COMES NEXT

The objectives of this engagement were to: a) perform a market assessment of the mini-grid investment which would include the identification of productive uses of energy in Ethiopia; b) develop a robust financial model that incorporates the identified productive uses across various scenarios and business models; and c) recommend appropriate policy and market interventions to accelerate the introduction of private sector mini-grid development in the country.

The work that underpins this report was rigorously reviewed by MoWIE, EEA, EEU, private sector actors, development partners and parallel public sector stakeholders; to the extent that policy measures are being discussed that will align with the findings of this report and key development funders for the sector are beginning to design investments around the principals identified, there is indication that the study has succeeded in its principal objectives.

In the market assessment task, a critical finding, needing greater exploration, was EEA's willingness to begin considering the application of an ABC tariff structure for private investments. This helps to address a key constraint for private investment – grid tariff rates are exceptionally low and traditional rural consumers' willingness to pay a premium to that rate was negligible, as was the government's willingness to allow a premium.

In this same phase of work, the research team identified two pools of potential communities where anchor customers could be identified. It bears noting that while the concept of the ABC tariff structure is not new, its applicability has been limited in other countries since large numbers of anchor customers in rural communities are not particularly common. The first pool of communities was identified through more traditional mini-grid site selection methods – to collect broad socio-economic data and overlay it with household and power generation characteristics to identify a 'long-list' of potential development sites. Using this method, approximately 1,500 sites were identified.

The second pool of sites was identified using a top-down selection methodology. Here, large-scale public and development initiatives that aim to benefit rural areas were identified. Four programmes were shortlisted, the ACCs, IAIPs, MCCs, and the WTP. The ambitious scale and scope of these programmes are not readily evident elsewhere in Sub-Saharan Africa. The accelerated development of the ACCs and their inclusion in the NEP 2.0 made these sites a natural source of concentrated research. As it relates to power, ACCs with horticulture crops presented a particularly compelling profile. With up to 400 farmers in a narrow catchment area requiring substantial irrigation and demonstrating their willingness to pay appreciating costs for diesel generation, these ACC sites provided a particularly appealing profile.

To further support and enrich this work, 65 site validations were conducted. These validations helped to:

i. confirm the hypothesis of what the typical rural community across the country looks like
ii. serve as validations for future tenders that EEU will be publishing

iii. provide inputs to assess the viability of commercial investment specifically for horticulture ACCs. Ten pilots are now planned based on the research and the validations

The development of the sector, however, cannot proceed without well-informed and capacitated oversight and regulatory institutions. The absence of such capacity can, and historically in Ethiopia has, resulted in over-regulation and restrictions based on an over-abundance of caution; the asymmetry of information between uninformed rural consumers on the one hand, and seasoned investors on the other, cannot be ignored by authorities. To this end, MoWIE has been a steadfast and involved stakeholder in this project. Together with EEA and EEU, it is also the principal beneficiary of the financial model that was developed for this programme.

As an immediate next step, there will be continued support in training staff at all three institutions on making full use of all of the tools afforded by the financial model. Some, if not all, of the 50 sites validated for EEU will likely be tendered in coming periods.

The bulk of the next steps being undertaken, however, concern the ten pilot sites that are designed to be commissioned at ACC horticulture sites. At this stage, all of the sites are validated, and the investment cases completed. There are four sites in Oromia region, three in Amhara, two in SNNP, and one in Tigray; these are the four regions where the ACCs were launched, and sites were selected in close discussions with ATA and its regional cluster coordinators. Several dynamics are beginning to develop on the structure that these pilots will take. First, development partners have expressed a keen interest to de-risk part of the investment to ensure that lessons learned can be robustly captured. Second, MoWIE has expressed an interest in applying various operating models to the pilots. Additional modalities would look at the long-term role that EEU can play. One probable scenario is that EEU is a distributor that applies a wheeling tariff. Ultimately, these pilots will provide proven cashflow scenarios, customer willingness-to-pay assessments, identification of regulatory challenges in close cooperation with MoWIE, and the development of operational design frameworks and their level of viability.

Over the intermediate-term, it is anticipated that this report provides a compelling road map for private mini-grid operators to identify scalable opportunities in Ethiopia. The ACCs, even in their pilot stage, have over 400 communities with aggregated horticulture farmers with substantial irrigation-related power needs. The IAIPs promise to be among the largest agri-business feed-in programmes on the continent and the MCCs address the largest livestock population on the continent. The WTP (when scaled) provides ready-made communities with a plethora of productive uses introduced through various stakeholders.

8 ANNEX 1: SITE SURVEY DATA

This section provides some of the detailed findings of the site surveys conducted for four communities: Kara Gora and Balawajo kebeles in Kersa woreda in Oromia region, and Tsayite and Zeyise Demibele kebeles in SNNP. Of the four kebeles, despite pre-survey interviews indicating otherwise, it was discovered that Balawajo was recently connected to the grid while the others are 14-17 kilometres off-grid. The survey of Balawajo proceeded as it was believed that the electrified village would provide a good reference point for post-electrification realities. As a reminder, these four sites were surveyed to ascertain baseline data that could be applied to the financial model. To confirm the field data in these surveys, desk research was conducted on similar assessments across the region, and finally compared against Powerhive's observations in communities where they installed mini-grids.

Therefore, it is advised that this data be used for general referencing and that further studies should be conducted in each of the areas that readers have a particular interest.

Figure 21 below provides a demographic breakdown of the 38 households interviewed across the four sites. The identified head of the household was the interviewed party. Additionally, the total number of households was ascertained from interviews with kebele officials.

Figure 21: Survey demographics

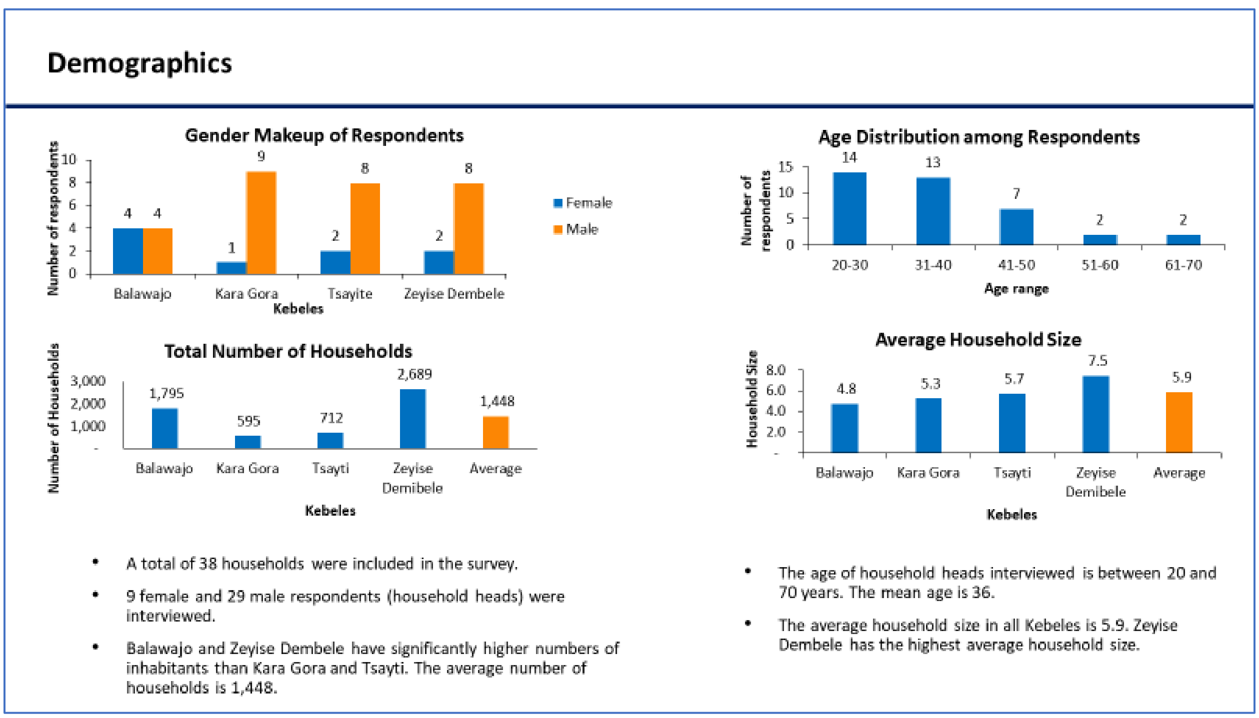
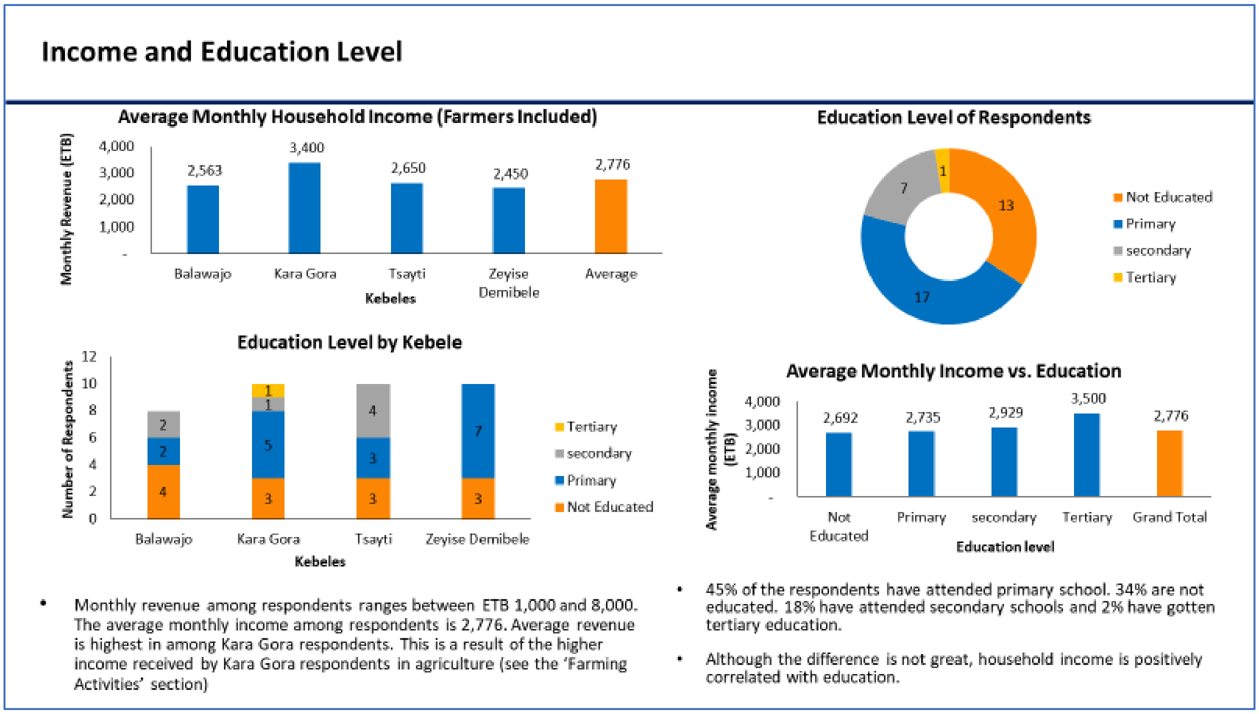


Figure 22 details the education levels of the heads of households and the household income levels. The majority of the respondents had at least a primary school level of education, and their average income is ETB 2,776 (USD $87) per month. There is a casual correlation between education levels and income levels; respondents with a secondary education reported earning 8.8% more.

Figure 22: Respondent's income and education



Since the principal economic activity in these rural areas is farming, Figure 23 begins to assess farming activities. Nearly all of the respondents rotated across various crops throughout the year, with maize being the most popular. None of the farms practiced irrigation, and thus there is a very limited horticulture footprint in these communities.

Figure 23: Farming practises

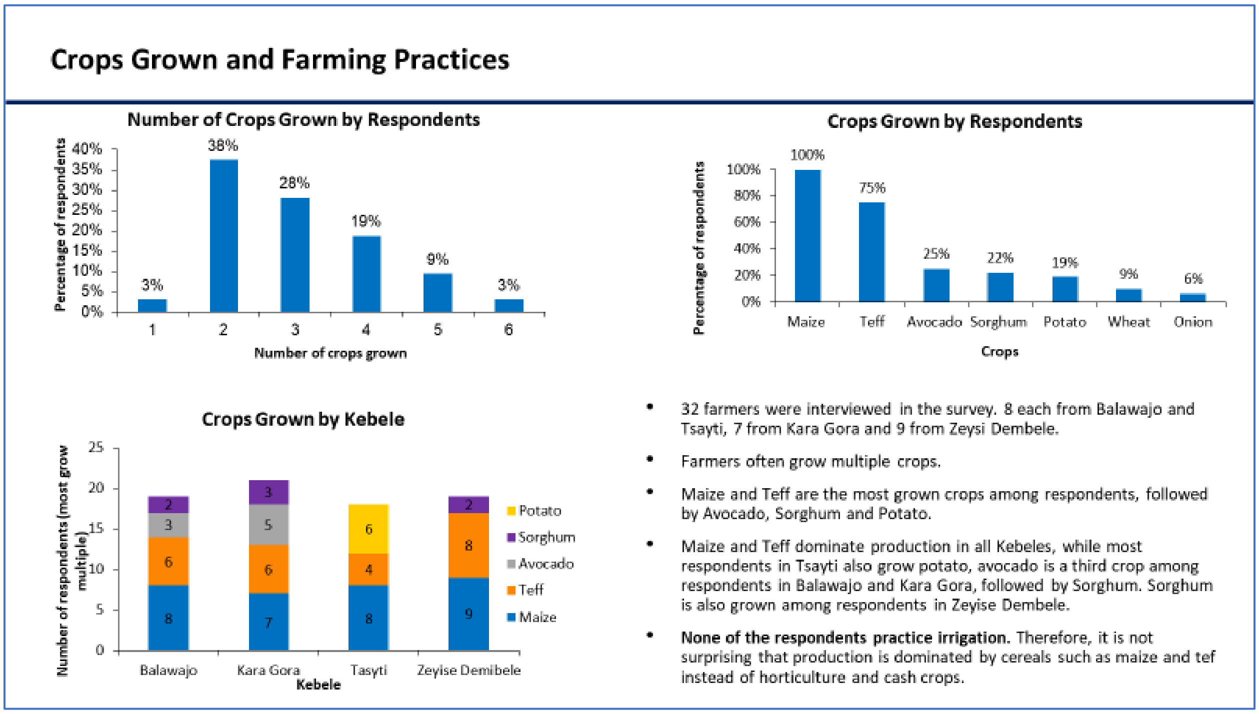


Figure 24 reviews the profitability of business enterprises in the communities. Notable outliers are grain mills and barber shops, with high relative incomes, and coffee houses which are on the lower end of the spectrum. There is a notable correlation between town size and income levels.

Figure 24: Business profiles

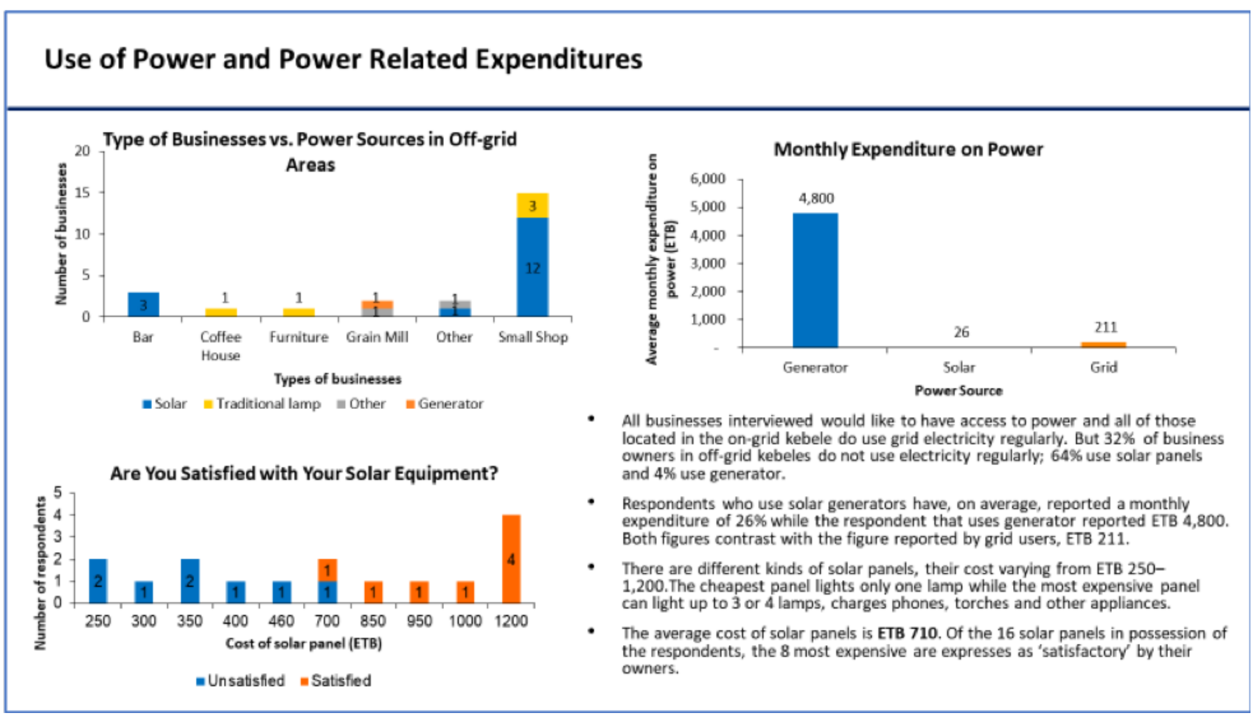
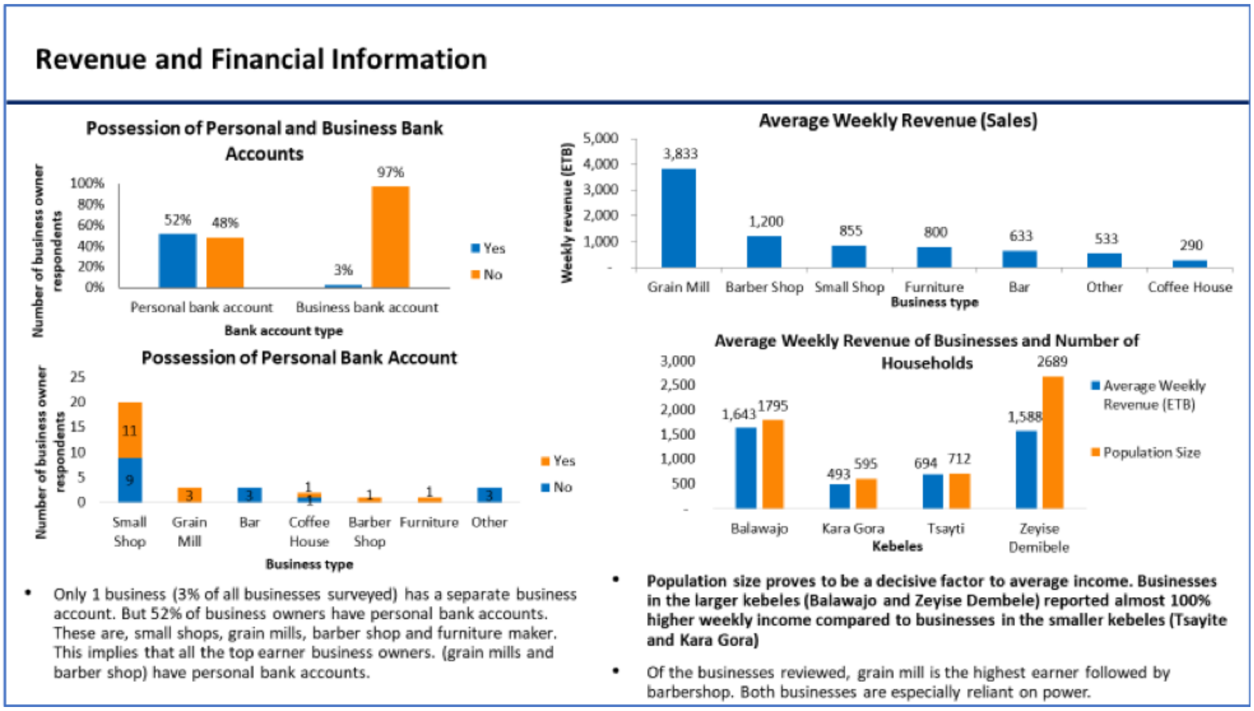


Figure 25 looks at the current power uses by businesses. In this case the electrified village is removed. Solar panels and lanterns are the most prevalent power alternative, and those who paid over ETB 700 for their equipment are pleased with it and those that paid under ETB 700 are dissatisfied with their product. The one grain mill in these three communities uses a generator.

Figure 25: Power alternatives for businesses



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