Improving Electricity Access to Reduce Food Losses in Ethiopia

1. Perspective on food production losses worldwide:

While as many as 828 million people around the world today are affected by hunger and 3.1 billion people do not have access to a healthy diet ("The State of Food Security and Nutrition in the World 2022"), approximately one third of the world's food goes uneaten and within that, 14% of the world's food (~$400 billion dollars per year) is lost after it is harvested and before it reaches a consumer. This is particularly important in developing countries where food insecurity is more prevalent and significant portions of the population rely on self-sufficiency or food exchange. A recent report estimated that 144 million tons of food could be saved annually if developing countries could reach the same level of food cold chain infrastructure as developed countries currently have ("Sustainable Food Cold Chains: Opportunities, Challenges and the Way Forward"). As a recognition of the importance of this topic, the third International Day of Awareness of Food Loss and Waste was celebrated on September 29th, 2022 and was marked by an event in Rome organized by the Food and Agriculture Organization of the United Nations (FAO) and the UN Environment Program (UNEP) to bring attention to this important and urgent topic.

The number of food insecure people in the world (345.2 million) has doubled since 2020. And one in every five Africans ("Five Reasons Why Africa Is Hungrier than Ever") lives in hunger. This food crisis is due to the combination of several factors including political and social conflicts, extreme weather events generated by climate change, higher fertilizer prices associated with conflicts in Europe and the increased cost of humanitarian aid support following the COVID pandemic ("A Global Food Crisis: World Food Programme"). Significant efforts have focused on improving food production to feed an increasingly hungrier world population. While this is certainly important, less attention has been given to decreasing food loss and waste to help appropriately feed more people using the same agricultural land and therefore simultaneously lessening environmental impacts. A 2021 study commissioned by the World Wildlife Fund (WWF) ("Driven to Waste: The Global Impact of Food Loss and Waste on Farms") showed that 2.6 billion tons of food goes uneaten around the world every year.

When thinking about food losses in general, it is important to consider the difference between food loss and food waste. These are two distinct problems that require different solutions. Food waste refers to food that is discarded before it is consumed due to negligence or system failure. On the other hand, food loss happens when the edible parts of plants and animals are not consumed due to spills, spoils, or abnormal reductions in quality during production, in the supply chain or during storage ("Food Loss & Waste Protocol"). Food loss and waste occur around the world and throughout the food chain but the reasons for those losses are different in different parts of the world. Across Africa, most of the losses occur during handling and storage although they also occur at all other steps of the supply chain. Until recently, lack of accurate data that quantified the amount of food that is lost before it reaches the supply chain, primarily within farms, prevented our understanding of the relevance of this problem and the urgency to try to solve it ("UNEP Food Waste Index Report 2021" and "Unpacking Postharvest

Losses in Sub-Saharan Africa: A Meta-Analysis" and "A Holistic Approach to Food Loss Reduction in Africa: Food Loss Analysis, Integrated Capacity Development and Policy Implications - Food Security")

When the United Nations (UN) General Assembly established Sustainable Development Goal 12 ("Ensure sustainable consumption and production patterns" - "Goal 12 | Department of Economic and Social Affairs") in 2015, one of their targets (12.3) was "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses". The UN defined food losses as those that occur from production up to (and not including) the retail level, whereas food waste covers the retail and consumption levels losses. These earlier studies put significant emphasis on the food wasted since farm losses are more difficult to estimate. Since then, the WWF report mentioned above quantified the global food loss on farms and it is now estimated that approximately 1.2 billion tons of food is lost per year which represents around 14% of total production ("Driven to Waste: The Global Impact of Food Loss and Waste on Farms"). An estimated $4 billion dollars' worth of grains alone are lost each year, primarily in the field after harvest in sub-Saharan Africa ("Unpacking Postharvest Losses in Sub-Saharan Africa: A Meta-Analysis"). This economic loss surpasses the total dollar amount received as food aid in sub-Saharan Africa over the last decade and is equivalent to the annual value of cereal imports ("Missing Food: The Case of Postharvest Grain Losses in Sub-Saharan Africa").

It is estimated that in 2020, approximately 100 million people faced high levels of food insecurity across Africa ("3 Ways to Tackle Food Loss and Waste in Africa"). In a continent where starvation and food insecurity are so prevalent, reducing food loss and waste could be one of the leading strategies for the continent to achieve a sustainable food future. Access to technologies such as cooling facilities within currently existing electric grids or through the implementation of creative systems and the expansion of clean energy solutions have the potential to substantially contribute to food loss reductions, primarily at the farmer and immediate distribution levels.

2. Access to electricity in Africa and the connection with prosperity and food security:

Access to electricity is a critical step toward improving people's opportunities and choices and a basic requirement to allow social and economic prosperity. As described by Sustainable Development Goals 7.1 ("By 2030, ensure universal access to affordable, reliable and modern energy services") and 7.2 ("By 2030, increase substantially the share of renewable energy in the global energy mix") ("Goal 7 | Department of Economic and Social Affairs"), the urgency of this topic is obvious. Unfortunately, most African countries only have access to electricity in less than 50% of their households (Figure 1) and for many of those households and countries, the cost of having access to refrigeration as a percentage of their gross domestic product (GDP) per capita is very substantial (Figure 2).

Figure 1. Access to electricity in countries in the Sub-Saharan region of Africa (from: "Figure of the Week: Electricity Access in Africa"

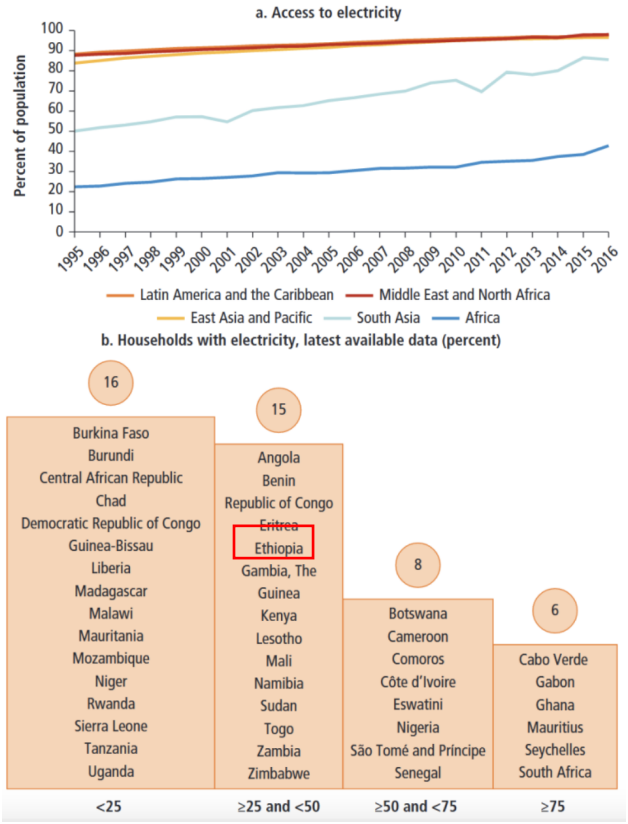
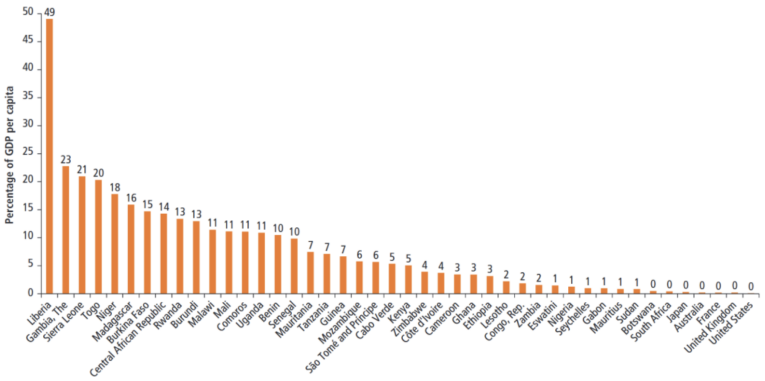


Figure 2. Price of powering a refrigerator for a year as a percentage of each country gross domestic product (GDP) per capita (from: "Figure of the Week: Electricity Access in Africa")



Unfortunately, only three countries in West and Central Africa (Ghana, Kenya and Rwanda), are on track to provide electricity to every one of their citizens by 2030. Only approximately 42% of the total population, and only 8% of rural residents in West Africa have access to electricity. One of the lowest rates in the world ("Key Findings – Africa Energy Outlook 2022 – Analysis").

In most regions of Africa, power providers are cash-strapped and must deal with a run-down infrastructure and old generation fleet. It is estimated that fewer than half of the utilities in Sub-Saharan Africa recover their operating costs and this results in significant economic losses for those countries. The financial insolvency of these energy providers limits the ability to deliver reliable and affordable electricity to their customers. In addition to that, the infrastructure is very scarce in rural areas where significant portions of the food production effort take place. Therefore, enhancing the performance of national utilities and introducing green energy technologies is critical to lower the costs of supply and therefore expanding electricity access to a greater proportion of the population, particularly lower-income and frequently remote households, mostly located in rural areas.

It has been suggested that many African regions need to look beyond country borders to expand utilities and grids and increase energy production efficiency. The Economic Community of West African States (ECOWAS - ECOWAPP, 14 Nov. 2022) is an example of such an effort. Their ambitious program involves developing a cross-border interconnection project to bring energy to countries in the region. If successful, this project promises by 2030 to double the share of electricity consumption traded across borders from 8% to about 17% for those countries that take full advantage of this grid. The objective of this regional power trade is to lower the lifecycle cost of West Africa's power generation system by approximately 10% and increase the adoption of greener energy sources (including solar systems and mini-grids) deployed in the region ("Putting Africa on the Path to Universal Electricity Access").

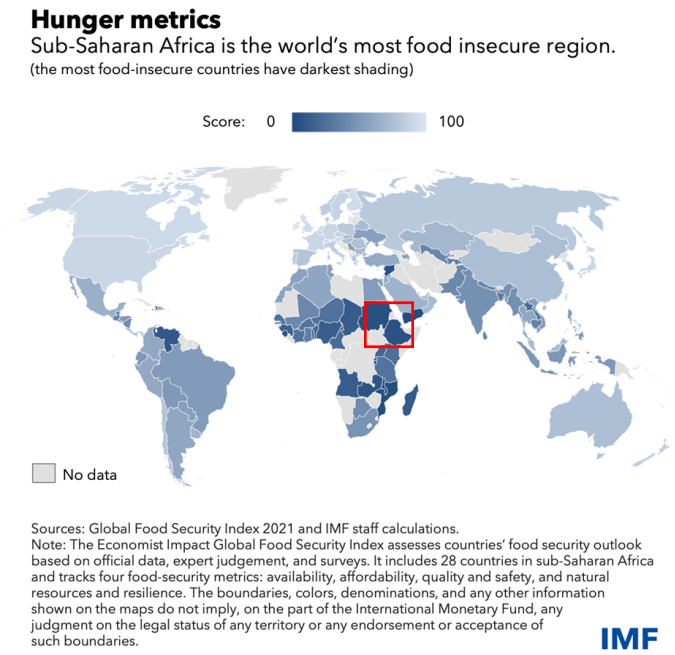
The World Bank, among a number of other groups, have provided significant investments to increase electricity access in many regions in Africa, but they continually call attention to the need to involve other sources of investment to achieve this urgent goal. They suggest that private investors can help if enabling conditions are in place. On the other hand, in regions where there is not a commercial interest, philanthropic capital will need to become involved in order to achieve the goals of increasing access to energy across the continent ("World Bank Group Provides $465 Million to Expand Energy Access and Renewable Energy Integration in West Africa").

3. Ethiopia, people, geography, economy and energy access

Ethiopia is in the Horn of Africa and has a population of over 120 million people, which makes it the second-most populous country in Africa after Nigeria and the fastest growing economy in the region, with a 6.3% growth in 2021 ("Overview" World Bank). Population growth rate is above the world average and is among the highest in the continent. Life expectancy is approximately 66 years of age, which is close to the average for the African continent but lower than the average in the rest of the world ("What Is the Average Life Expectancy in Africa? - How Many"). While the overall population age has increased in the last decades, more than two-fifth of the population is under the age of 15 ("42.4 Percent of Ethiopia's Population Is Below the Age of 15: CSA Study 2021"). Although the urban population has increased at least 2% per year since the 1970's, the Ethiopian population is primarily rural with only approximately 23% of the

population living in urban areas. (“Ethiopia Urban Population, 1960-2022”). The country's population is quite diverse, with over 80 different ethnic groups (“Ethiopia.” Encyclopedia Britannica). The population of the country speaks more than 100 different languages which are all accepted under their constitution, and five of them considered official languages: Afar, Amharic, Oromo, Somali and Tigrinya (“Languages in Ethiopia: Ethiopia Language Facts, Figures and More”). Geographically, Ethiopia is a landlocked country with an area of over 1.1 million square kilometers. It is bordered by Eritrea to the north, Djibouti to the northeast, Somalia to the east, Kenya to the south, and Sudan and South Sudan to the west.

Figure 3. Level of food insecurity in the world and highlighting Ethiopia (from: “How Africa Can Escape Chronic Food Insecurity amid Climate Change”)



Ethiopia is also one of the poorest countries in Africa, with a gross national income of $960 per capita (“Overview.” World Bank) and chronic food insecurity (Figure 3). Its economy is predominantly agricultural, with the sector employing over 70% of the population and contributing around 40% to the country's GDP, 80% of exports, and involving approximately 75% of the country's workforce. Despite its dependence of agriculture, only about 5% of land is irrigated and overall productivity from farms, which are typically quite small, are below continental regional averages primarily due to limited access to improved cultivars and livestock and other types of input like fertilizer, pesticides, animal health resources and limited access to market channels (“Agriculture and Food Security: Ethiopia”).

Droughts have affected that general region of Africa significantly particularly since 2021 and have put Ethiopia in the Watchlist 2023 of the International Rescue Committee (https://www.rescue.org/press-release/somalia-ethiopia-and-afghanistan-top-ircs-emergency-watchlist-2023). This article highlights the extremely dicey situation of Amin Abdrurhaman Ali, a

coffee farmer from Ethiopia, who has seen his coffee trees blasted by the intense drought. The United Nations estimate that 20 million people in Ethiopia are unable to afford the food needed to live (https://reliefweb.int/report/ethiopia/ethiopia-situation-report-17-nov-2022).

Despite its widespread poverty and food insecurity, Ethiopia's GDP has been rapidly growing over the last decade and therefore, demand for electricity has been increasing accordingly. The potential capabilities of this country to produce energy are tremendous, but most of the population routinely experiences energy shortages and the current infrastructure and systems struggle to serve its population. Ethiopia has made significant progress in increasing access to electricity over the past decade through initiatives such as the National Electrification program launched in 2017 and by rapidly expanding its power generation capacity in recent years ("Ethiopia - Countries & Regions"), but still lags behind many other African countries in terms of overall electrification rates and certainly compared to other parts of the world. According to the International Energy Agency (IEA), as of 2020, approximately 51% of Ethiopia's population had access to electricity. However, this represents a significant increase from just 25% in 2010 ("Access to Electricity (% of Population) – Ethiopia").

Based on Ethiopia's abundant renewable energy resources, it is estimated that the country has the potential to generate more than 60,000 megawatts (MW) of electric power from hydroelectric, wind, solar and geothermal sources. The government has set a target of achieving universal electricity access by 2025 and has been implementing policies and programs to support this goal, including the National Electrification Program 2.0 which "focuses on integrated—grid and off-grid electricity access—and provides an implementation framework for the achievement of 35 percent of off-grid access by 2025" ("Power Generation News and Jobs in Coal, Gas, Nuclear, Renewables").

Despite the abundance of available clean energy resources, Ethiopia has one of the lowest access levels to clean energy in the world. In a recent evaluation, it was shown that the country has the capability to produce 45,000MW of hydropower and only exploiting approximately 5%, 100>7 GW m/s of wind power speed and exploiting less than 1% and approximately 10,000 MW of geothermal and exploiting less than 1% ("Ethiopia - Energy"). Regarding solar energy, the International Renewable Energy Agency (IRENA) estimated that, as of 2022, Ethiopia had a total installed solar power capacity of around 224 MW. This is a significant increase from just 10 MW in 2014, but it is still only around 1% of the country's total installed capacity ("Energy Profile Ethiopia – Irena"). On the other hand, despite the abundance of all these sources, the country depends heavily on biomass, particularly wood with 1,120 million tons and exploiting approximately 50% and agricultural waste with 15 to 20 million tons and exploiting about 30% ("Ethiopia - Energy").

One famous project that promises to make a big difference for energy accessibility to the Ethiopian population is the Grand Ethiopian Renaissance Dam. This is a massive hydropower project on the Blue Nile river that is expected to generate up to 6,000 MW of electricity once completed ("Grand Ethiopian Renaissance Dam"). The project has faced controversy and tensions with neighboring countries such as Egypt and Sudan due to concerns over water rights

and downstream impacts, but the Ethiopian government sees it as a critical component of the country's economic development and energy security and new developments are showing that the dam could provide resources for the three countries (“A Row Is Raging over Africa's Largest Dam - Science Has a Solution”), minimizing opportunity for further conflict. In addition to large-scale projects like the Grand Ethiopian Renaissance Dam, Ethiopia has also been working to expand access to decentralized energy solutions such as solar home systems and mini-grids, but progress has been slow.

Ethiopia has significant potential for hydropower, wind, solar, and geothermal power generation. However, challenges remain in terms of expanding the electricity grid to reach rural areas and ensuring the affordability and reliability of electricity supply. Numerous different efforts are currently underway to improve agriculture as an important foundation for economic growth and to provide solutions to Ethiopia’s widespread level of food insecurity (“Feed the Future: Ethiopia”) but limited infrastructure, including energy accessibility, is a major restriction to prosperity and hunger reduction.

4. Post-harvest refrigeration to reduce food losses:

Post-harvest losses of perishable crops are a major problem in Ethiopia, where a large proportion of the population relies on agriculture for their livelihoods. One way to reduce these losses is through the use of post-harvest refrigeration. Refrigeration can help to extend the shelf life of perishable crops. This can allow farmers to transport their produce to markets further away, where they can make greater profits.

Access to food refrigeration in Ethiopia is limited, particularly in rural areas where most of the population lives and works. The lack of refrigeration infrastructure in rural areas means that farmers often have to sell their products soon after harvest, at lower prices, rather than storing it to transport to markets further away. Lack of refrigeration not only increases food insecurity, but it also severely limits access to appropriately nutritious diets. While the production of fruits and vegetables Ethiopia has significantly increased in recent decades, which would have the potential to contribute to better diets. most of the population is still not having access to them. The rural population is particularly affected by this, including smallholder farmers who do not have access to electricity (and therefore refrigeration) and limited access to viable markets. Most of their harvest are cereal crops (mostly teff, corn and sorghum). Fruits and vegetables are typically out of reach for this portion of the population (“The Cold Truth about Ethiopia's Nutrition Gap”).

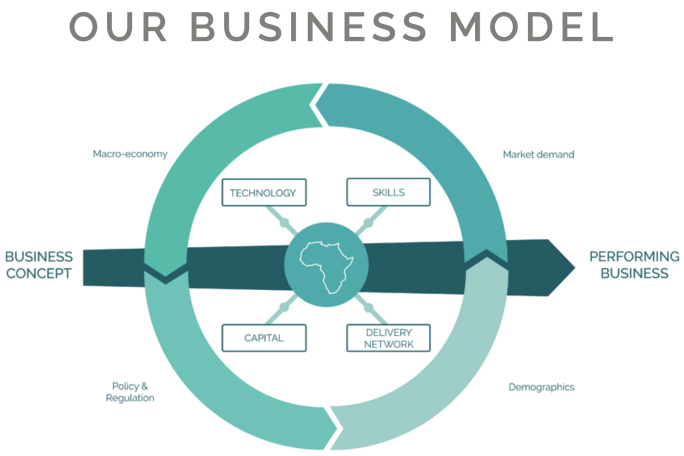
In urban areas, access to refrigeration is somewhat better, with some small-scale refrigeration units available in markets and shops. However, larger cold storage facilities are still relatively scarce and accessible mostly to larger corporations focused on the export market. This has an impact on the nutritional content of the food that the population has access to even in urban areas (“The Cold Truth about Ethiopia's Nutrition Gap”). And it has been shown that access to appropriately nutritious diets is highly correlated with the economic strata of the population

("The Social Stratification of Availability, Affordability, and Consumption of Food in Families with Preschoolers in Addis Ababa; The Eat Addis Study in Ethiopia"). The urgency for advancing projects that focus on increasing access to refrigeration cannot be understated. With a rapidly growing population in a region of the world that is simultaneously getting drier and hotter due to climate change, Ethiopia can significantly benefit from minimizing food loss and increasing access to more nutritious food sources for the entire population of the country.

There are several challenges to implementing post-harvest refrigeration, including the high cost of equipment and energy, and the lack of infrastructure in rural areas but with green energy resources such as solar energy, implementation of such alternatives is plausible. Non-profit organizations (NGO), including different foundations, and private companies are currently working on developing solutions to provide energy for remote clinics and schools in different areas of Africa ("Projects." Fundacion Eki). Similar technologies could be implemented to identify affordable, energy-efficient refrigeration technologies that can be used in rural areas, including solar-powered refrigeration units adapted for agricultural use.

Among the biggest limitations to the implementation of these technologies are identifying resources of the initial purchase of materials, but also technical support once the technology is installed. Projects such as the Energy4Impact (https://energy4impact.org/) from the Mercy Corps organization (https://www.mercycorps.org/) provides support to improve business investment in technology access for energy in Africa. Figure 4 (https://energy4impact.org/what-we-do/what-we-do) shows their business model and plan for improving business investment to support improving the livelihood of different African countries, including Ethiopia.

Figure 4. Business model proposed by energy4impact to increase access to energy in Africa



The Ethiopian government has set a target to significantly increase solar power capacity by 2030, as part of its broader goal of achieving universal access to electricity. To support this goal, the government has launched a number of initiatives to promote the development of solar power projects, including offering tax incentives and financing support for investors ("Private

Sector Partners: Power Africa"). There are also a few off-grid solar initiatives underway in Ethiopia, particularly in rural areas where the grid is not available. These initiatives typically involve the installation of small-scale solar panels and batteries to power households, schools, and health clinics ("The Cold Truth about Ethiopia's Nutrition Gap.").

Solar-powered refrigeration, also known as solar cooling, is a technology that uses either photovoltaic (PV) cells to convert sunlight into electricity, which is then used to power a refrigeration system or solar thermal energy to produce ice that can then be used to refresh products ("Indicators : Www.fao.org"). The photovoltaic technology is particularly well-suited for use in off-grid areas, where access to electricity is limited, but where refrigeration is essential for storing perishable foods, vaccines, and medicines. There are a number of different types of solar-powered refrigeration systems available, including direct refrigeration systems, which use PV cells to power a conventional refrigeration compressor, and absorption refrigeration systems, which use heat from the sun to drive a refrigeration cycle.
One of the key advantages of solar-powered refrigeration is that it is environmentally friendly, as it does not rely on fossil fuels for power. It can also be cost-effective in the long run, as the cost of solar panels has been steadily declining in recent years ("Beyond the Grid: Power Africa" and "Claim: Solar Powered Refrigerators Would Solve African Food Waste").

However, there are also a number of challenges associated with solar-powered refrigeration, including the high upfront cost of equipment, the need for battery storage to ensure reliable operation, and the need for regular maintenance to ensure optimal performance.
Despite these challenges, solar-powered refrigeration has shown promise in a number of contexts, including in several countries in Africa, mostly focused on providing energy to schools and hospitals ("Projects." Fundacion Eki). Also, the expectation is that solar-powered refrigeration technologies will continue to be developed which will make it even more affordable and efficient for use in the future.

5. Expanding refrigeration in Ethiopia to reduce food losses:

This report focused on describing the importance of reducing food losses as a way to reduce food insecurity primarily in developing regions of the world ("Amid Food and Climate Crises, Investing in Sustainable Food Cold Chains Crucial"). This work proposes the expansion of energy accessibility as an efficient means to do that. This report focuses on Ethiopia given its large population, but at the same time its relatively weak economy and heavy reliance on agriculture. Ethiopia is also the perfect case study as it possesses enormous energy production potential given its natural resources, but still has reduced development of the appropriate infrastructure. Solutions to this limitation in this country have the potential to have a large impact.

Private investment to improve energy access in Ethiopia has been increasing in recent years, driven by a combination of government policies and growing interest from international investors. One of the key drivers of private investment in Ethiopia's energy sector has been the government's emphasis on public-private partnerships to develop energy infrastructure. In

recent years, the government has launched a number of public-private partnership projects to expand the country's power generation capacity and improve access to electricity.

In addition, there has been growing interest from international investors in Ethiopia's energy sector, particularly in the development of renewable energy projects. The government has established a number of incentives to attract foreign investment, including tax exemptions and other financial incentives for investors. There have also been a number of smaller-scale investments in off-grid solar projects in rural areas, aimed at improving access to electricity in communities that are not connected to the national grid. We propose that additional efforts are made to further develop those connections while at the same time promoting the presence of NGO interested in providing the necessary support, primarily for the expansion of clean energy options off-grid.

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