# Community energy in Ethiopia

## An annotated bibliography

CESET
Community Energy and the Sustainable Energy Transition in Ethiopia, Malawi and Mozambique

# An annotated bibliography on community energy in Ethiopia

This annotated bibliography is one of a three-part series produced by the CESET team. The annotated bibliographies provide an opportunity to:

1) Survey the body of published research in the area of community energy in Malawi, Ethiopia and Mozambique;
2) Review key insights and considerations already well documented in the literature as of July 2020;
3) Explore areas overlooked in current debates to date and that may help to identify critical gaps.

The methodology employed consisted of literature searches in databases with the terms' community energy' and 'energy policy' paired with each country. Those references were then reviewed and organized according to a reading guide. Please not that these annotated bibliographies take stoke of the literature available on each country as of July 2020. These are meant to be living documents that will be regularly uptaded by the CESET team as more work on the topic gets published and as the project evolves.

If you are aware relevant work and references missing from the bibliographies, please feel free to contact us: ceset@sheffield.ac.uk

This annotated bibliography focuses on Ethiopia.

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## Theme list

# 1. Ethiopia overview

As Tucho, Weesie et al. (2014) describe it:

> "*Ethiopia is located in the horn of Africa between 3 and 15 degrees northern latitude and 33 and 48 degrees eastern longitude covering a land area of about one million square kilometers. Ethiopia has a population of about 83 million, of which 83% live in rural areas. Ethiopia is a highland country with 65% of its total area at an elevation of more than 1400 m above sea level, with some low land areas extending up to 120 m below sea level. The Great Rift Valley divides the country into two parts at the central highlands. The altitude goes on decreasing from the center outwards in almost all directions. Ethiopia has a diversified climate ranging from a semi-arid desert type in the lowlands to a humid and warm (temperate) type in the southwest. Mean annual rainfall distribution exceeds 2000 mm over the South-western highlands and is below 300 mm over the south-eastern and North-eastern lowlands. There is no clear distinction between seasons in Ethiopia, but based on rainfall, December to February are categorized as the dry season and June to August as the wet season. Since 2004, the country has achieved about 10% annual GDP growth. The growth in the energy sector, particularly with a conventional installed electricity capacity of hydro is also remarkable*."

As the paragraph above explains, Ethiopia is experiencing unprecedented population growth alongside food security, energy, and environmental challenges. Droughts, which currently occur every 3-5 years, will intensify under climate change and they have a substantial impact on the country, as agriculture is predominantly reliant on rainfall (Verhoeven 2013). Poverty rates have declined since the beginning of the 2000s. The country recorded double-digit growth between 2003 and 2017, and per capita GDP in 2018 was USD $890 / head. Construction and manufacturing are Ethiopia's fastest growing sectors. Demand for energy is increasing rapidly as "Ethiopia currently has the largest airline and the largest electric railway network in Africa, and is now also constructing the largest hydropower plant on the continent"(Okereke, Coke et al. 2019, p. 281).

# 2. Geopolitics and the political economy of energy in Ethiopia

Since the beginning of the 1990s, the Ethiopian state has embraced a state-led developmental agenda focused on industrialisation (Oqubay 2015, Okereke et al. 2019). The water-food-energy nexus is central to Ethiopia's contemporary state-building and development efforts, particularly in the context of climate change. Water security and access to hydrological resources for agriculture and energy production pose a geopolitical challenge in the region (Nasr and Neef 2016). Different rulers in Ethiopia have put water control at the heart of the state's development agenda because it is essential both for food and energy security. Since the 1970s, economic growth has gone hand in hand with an increase in electricity demand (Nyasha, Gwenhure et al. 2018). The Ethiopian dam-building program has attracted Western, Indian, and East Asian investment partners, and recently from China. However, the Grand Ethiopian Renaissance Dam, the largest dam in Africa, is funded almost entirely with domestic capital. Historically, international organizations such as the World Bank have also participated in these developments. The construction of dams has also raised new geopolitical tensions in the Nile Bassin, particularly with Egypt.

In 2012, the country adopted a Science, Technology and Innovation strategy that stresses the need to 'create local capabilities to learn about, adapt and adopt green technologies' (FDRE, 2012, p. 18). In 2013, the Ministry of Environment, Forest, Development and Climate Change was established with the mandate to implement the CRGE objectives through particular interventions focusing on the development of the Green Economy, with technical assistance from the UNDP. More recently, Okereke, Coke et al. (2019) have investigated the emergence of a green industrialization strategy in

Ethiopia in the context of the SDGs (particularly SDG 9) and the Agenda 2030. Green industrialization refers to attempts at decoupling manufacturing from environmental degradation, in contexts where institutional capacity and innovation systems may be found lacking (Mulugetta and Urban, 2010, Wakeford et al. 2017). The concept of sustainable development was enshrined as a right in the Ethiopian 1995 Constitution (Article 43) alongside with a right to a 'clean and healthy environment' (Article 44).

The Environmental Policy of Ethiopia, adopted in 1997, stipulated the importance of renewable energy use, and energy-efficient technologies. In 2016, the policy was updated to include emission reductions targets in line with the 2011 Climate Resilient Green Economy (CRGE) (FDRE 2011) strategy, which seeks to achieve high and inclusive economic growth without increasing GHG emissions. The CGRE also led to the creation of the Environmental Council, chaired by the Prime Minister and comprising members of Federal Ministries, Presidents of the National Regional States, and representatives from NGOs, private companies, and trade unions. The Environmental Council is in charge of recommending relevant laws and regulations to the Council of Ministers, as well as setting environmental standards and directives. Ethiopia's multi-sectoral Growth and Transformation Plan (GTP) (FDRE 2010) seeks to bring the country to middle-income status by 2025. The GTP puts manufacturing at the heart of Ethiopia's industrialization strategy. Cement is the sector where GHG emissions are the highest and where projected growth is exponential: from 2.7Mt in 2010 to more than 65Mt by 2030. The cement industry will require cleaner energy sources. The use of biomass, energy efficiency gains, and waste heat recovery are some of the technologies deployed within the cement industry. Renewable energy technologies will also be needed to power Ethiopia's green industrialization. The focus of green industrialization in Ethiopia, however, has been on climate change mitigation and does not address other pressing issues, including soil and water contamination, or biodiversity loss.

Finally, it is important to note that the political economy of land in Ethiopia is also closely related to the political economy of energy. In tracing the history of enclosures and the transformations of agrarian relations in Ethiopia throughout the 20th century, Makki (2012) explains how the emergence of large-scale capitalist agriculture and parallel dispossession of the small peasantry shaped Ethiopia's energy landscape and development trajectory over time. The paper analyses the 1974 revolution (with the end of the imperial monarchy) as a central event that granted the state 'plenipotentiary powers to determine the allocation and form of land use' (p. 84). The land reform decree of 1975 "abolished the mix of communal, church, state, and private tenures and replaced them with a centralized system of public ownership" (p. 87). Article 40 of the 1994 Constitution states 'the right to ownership of rural and urban land, as well as of natural resources, is exclusively vested in the state and the peoples of Ethiopia' (FDRE 1995). Over the past 30 years, Ethiopia experienced a transition to a market economy and the commercialization and enclosure of smallholder farming (Makki 2014) as well as the emergence of large-scale corporate agriculture. At the same time, the country has experienced the rise of an informal land rental market. Land reforms have a direct impact on energy development. Large scale enclosures of agricultural land threaten small scale farming, focusing on firewood production for subsistence. They are also linked to the enclosure of water resources for the commercial irrigation of biofuels fields and other agricultural products (Verhoeven 2013). Thus, biofuels debates link both energy and land challenges. In the early 2000s, the Ethiopian government embarked on a market-oriented developmental plan that employed market incentives to achieve developmental outcomes, while retaining ownership of the land. The plan included a land titling program granting small farmers the right to cultivate their land. Whilst most agricultural land is owned by domestic investors, foreign investors have been particularly involved in the biofuel sector. Increased demand for biofuel during the 2010s, infrastructure investments, and regulatory reforms that seek to incentivize FDIs (including tax breaks, unhindered repatriation of profits, asset sales) have supported the growth of international investments, especially for the production of biofuels. Saudi Arabia, German, Israeli, Dutch, Italian, and Chinese firms have invested in biofuels. The Ruchi Group from India was granted 27.000 hectares to cultivate biofuels (Hules and Singh 2017). Negash and Riera (2014) argue that the import of biofuels absorbs half of Ethiopia's foreign currency earnings. In 2007, the country launched a biofuel expansion strategy and invested in the production of two crops: castor and jatropha. Many were, at the time, enthralled by the prospect of biodiesel production in Ethiopia.

## 3. Energy Sectors in Ethiopia

### General energy mix

Regarding the country's energy budget, 93% of the total energy is consumed by households, followed by transportation (5%), industry, and services (1% each) (Tucho, Weesie et al. 2014). Despite Ethiopia's endowment with large pools of renewable energy (Asress, Simonovic et al. 2013, Tesfaye, Khader et al. 2015, Khan and Singh 2017), over 90% of the country's population relies on traditional biomass energy (firewood, crops residues/leaves, cows dungs) for domestic energy consumption (Tucho, Weesie et al. 2014). Electricity accounts for 2% of the energy used, mainly consumed by urban households and industries. Even when urban households have access to grid electricity, financial constraints might prevent them from accessing power from the network (Asress, Simonovic et al. 2013). Petroleum accounts for about 7% of the country's energy consumption, but it has to be imported "at the expense of huge foreign exchanges" (ibid. p. 424). Petroleum is mostly used for transportation.

Hydro infrastructures generate most electricity (90%) (Guta and Borner 2017), and to a lesser degree, diesel and geothermal power plants (Asress, Simonovic et al. 2013). Since 2013, Ethiopian Electric Power, a state-owned electricity producer, is responsible for the development, investment, construction, operation, and management of power plants, power generation, and power transmission. The company is a leading player in the Ethiopian energy sector as it owns and operates the national power grid. It is a quasi-state monopoly, although, since 2017, Independent Power Producers are allowed to construct and operate power plants for delivering electricity to the national grid.

Ethiopia is known as the 'Water Tower of Africa' (Degefu, He et al. 2015). Still, the majority of the population lives in rural areas, disconnected from the grid. Hydropower is vulnerable to the impacts of climate change (Block and Strzepek 2012). As explained above, the country is susceptible to drought, particularly Ethiopia's lowlands in the South (compared to its highlands in the North). These impacts take place alongside further impacts on agricultural production, soil degradation, energy production, and resource management, and migration (El Kenawy, McCabe et al. 2016). Observers have called for a diversification of the energy mix and emphasize the need to invest in alternative energy sources (Guta and Borner 2017), and for building on synergies between hydro, solar, and wind systems (Tucho, Weesie et al. 2014). Since 2012, wind farms have been installed to compensate for the shortfalls of hydroelectric power in the dry season, but wind energy remains marginal in the national energy mix (Tucho, Weesie et al. 2014). Energy diversification is crucial for Ethiopia to develop endogenous paths to sustainability (Teklu 2018).

Several studies have looked at the potential of different renewable energy sources to increase energy access and generation capacity in Ethiopia. Mulugetta (1996) showed the potential for the development of wind and solar energy early on. Tucho, Weesie et al. (2014) and Tesfaye, Khader et al. (2015) both compared the potential of hydro, wind, and solar energy.

Hydropower has received a lot of scholarly attention (see for example: Degefu, He et al. 2015, Duguna, Januszkiewicz et al. 2019). Degefu, He et al. (2015) stress the potential of small scale, micro, or pico-hydro power plants to address energy needs in rural communities but also to supply baseline electricity in industrial/urban hubs and to export the remaining electricity (produced by larger dams) to neighboring countries. Hydraulic resources in Ethiopia could offer decentralized energy to communities living far off the grid (Mulugetta 2007). Small scale hydro-technologies can provide off-grid energy access to remote communities (e.g., hydrokinetic turbines for off-grid hydropower production (Tigabu, Guta et al. 2019).

The next subsections offer an overview of the insights from different research on energy generation in Ethiopia.

### Hydroelectricity

Dam-building has been a central component of Ethiopia's hydro-agricultural state-building. Dams are part of both developmental (Woldegebrael 2018) and energy strategies (Legese, Van Assche et al. 2018). Since the 2010s, the Ethiopian state has embarked on an extensive dam-building program, perhaps "the most ambitious dam programme in African history" (Verhoeven 2013; p. 5). Hydropower boosts domestic electricity production and consumption. Increases in generation capacity are also a means to access foreign exchange by exporting electricity to neighboring countries (for instance, Djibouti, Sudan, Kenya, Burundi, Tanzania, Rwanda, Uganda, Yemen, Egypt) (Asress, Simonovic et al. 2013). The role of dams in ensuring the country's water and food security, reducing its dependence on rainfall for irrigation, is a common pro-dam argument. However, research suggests that dam projects often have little benefits for local communities, many of which still lack access to electricity despite living close to them and suffering their negative impacts, such as the loss of grazing land and the destruction of forests (Legese, Van Assche et al. 2018).

The role of dams in local development is contradictory. For example, Mishra and Kahssay (2015) looked at the Gibe III dam project in Southern Ethiopia, in the Omo Gibe River Bassin, and its impact on the local communities and marginalized groups. Over 13 distinct ethnic groups live in the project area. Their livelihoods depend on livestock and complex land-use systems. The article offers a positive view of the impacts of the project for local communities, particularly in terms of supplying employment opportunities for men and women, school building programs, and access to reliable electricity for lighting (and developing commercial activities). In terms of environmental impacts, a Kenyan NGO (Friends of Lake Turkana) denounced the detrimental impact of the dam on river flows and water levels in nearby lakes (in this case Lake Turkana).

### Biogas

Several studies have assessed the impact of the National Biogas Program of Ethiopia and current efforts to disseminate biogas technologies. The program follows other efforts to accelerate the uptake of biogas technologies in African countries. For example, the African Biogas Partnership Programme (ABPP) funded by the Netherlands Development Organization (SNV) and the Humanist Institute for Development Cooperation (HIVOS) planned to build 70.000 biogas plants across Kenya, Burkina Faso, Ethiopia, Tanzania, Uganda, and Senegal. The existence of a large livestock population (cattle) makes biogas technologies particularly relevant in Ethiopia (Kamp and Forn 2016).

Mengistu, Simane et al. (2015) looked at the first phase 2009-2013 of the Programme, which distributed only 57.6% of the 14.000 domestic biogas plants planned for the period. The program followed the drive to expand a market-driven biogas sector nation-wide. Investments in biogas digesters came through the financial participation of farmers, the federal government, and regional governments that covered 42%, 4.4%, and 3.2% of the total program costs, respectively. International donors financed the rest. In terms of benefits, the paper highlight the efficacy of biogas combustion compared to biomass, employment opportunities in the biogas technology sector, environmental and health benefits through recycling of organic waste, and reduced air pollution (see also Gabisa and Gheewala 2019). The use of biogas digesters can reduce time spent on biomass collection from fields and forests, particularly for women and children, reduce the cost of buying fertilizer, and can provide a long-lasting lighting energy source for children studying in the evenings (Shallo, Ayele et al. 2020).

The paper highlights several barriers to biogas technology adoptions, in particular financial constraints and high initial investment costs in the technology for rural farming communities. Financial incentives such as soft loans and subsidies (justified by the environmental, social, and economic benefits from biogas technology adoption) emerge as potential ways to overcome these barriers. However, other barriers to technology diffusion exist. Barriers, in this case, also included lack of technology awareness, lack of private sector involvement (also noted by Kamp and Forn 2016), limited manure and water resources, and the stigma associated with using human excreta as input to biogas technology. Other studies found that technological failure and land availability were also barriers to biogas digestor adoption (Kelebe 2018).

In another study, Mengistu, Simane et al. (2016) explore the factors influencing the household decision to switch to biogas technology in Olfa and Mecha Districts in Northern Ethiopia, using a user survey. The research indicates that male-headed households are more likely to adopt the technology than female-headed households (similar to Shallo, Ayele et al. 2020). Other studies, however, have found that women are, in fact, more likely to adopt biogas technology than men (Kelebe, Ayimut et al. 2017). Meginstu and colleagues (2016b) conclude that:

> "*Educational level, heads of cattle, income level, access to credit, distance to the main fuelwood source, and number of planted trees have significant positive influences on adoption of biogas technology*"

Involving female users in potential solutions is a crucial strategy for technology adoption:

> "*Empowering females and female-headed households, improving educational levels of the household heads, increasing cattle size, raising income levels, improving access to credit, and encouraging households to plant more trees are likely to be some of the way forward to increase the adoption of the technology*."

Biogas technologies in these contexts are directly linked to health benefits (Abadi, Gebrehiwot et al. 2017, Lansche and Muller 2017). Another study by the same authors looks at the environmental benefits of biogas technology (Mengistu, Simane et al. 2016). It concludes that biogas-users reduce their GHG emissions compared to non-users. GHGs emissions reductions happen because households use non-chemical fertilizers for farming. Biomass removal also appears to support carbon sequestration, improve soil fertility, and reduce the depletion of woody biomass. The article also stresses the need for people to be able to access technicians and maintenance and after-sale services at a reasonable distance to ensure households can benefit from the technology in the long run. These findings resonate with Kelebe and Olorunnisola (2016)'s study of biogas deployment in Northern Ethiopia based on a household survey. They found that the use of biogas (animal and human manure) can help reduce 45% usage of fuelwood and charcoal and it can help absorb feces, urine and cattle dung that would otherwise be unsafely discharged into the local environment.

However, the impacts of biogas digesters adoption are mixed. More educated and comparatively, more affluent households tend to adopt biogas technologies in Ethiopia (Shallo, Ayele et al. 2020). In a survey of 300 farmers in the Tigray region, Berhe, Hoag et al. (2017) found that the transition to biogas increased energy consumption, including biomass energy consumption. They concluded that:

> "*overall household energy consumption increases with the availability of biogas digesters*."

Other studies also find that users of biogas digester still consume less biomass energy than non-users (Seboka 2019). Kelebe, Ayimut et al. (2017) reviewed the adoption of biogas technologies in rural households in Ethiopia. They found that cultural, economic, gender-based and geographical factors, such as distance from sources of biomass energy or distance from biomass markets, shaped the use of biogas among different groups. They concluded with a call for a spatially-sensitive and gender-sensitive approach to biogas technology deployment.

### Wind energy

Across Eastern and Southern Africa, Ethiopia, Kenya, and South Africa have the most significant wind potential. From 2011 to 2015, the 'Growth and Transformation Plan' for the Ethiopian government investments included eight wind farms. A recent research project has examined the potential of wind energy conversion systems for water pumping in three locations in Northern Ethiopia (Kodicherla, Gaddada et al. 2017) and the Tigray Region (Kodicherla 2018, Kodicherla and Gaddada 2018). However, the lack of relevant data regarding generation capacity in Ethiopia hinders wind energy development (Asress, Simonovic et al. 2013). Wind also competes with dam building and hydroelectricity.

### Solar energy

Ethiopia benefits from high solar radiation all year long (Kebede and Mitsufuji 2014). Mahmud, Kahsay et al. (2014) have looked at the potential for solar energy generation in the Northern part of Ethiopia. Venkatachalam, Mariam et al. (2019) have explored the potential of solar radiation for Adama city. Solar energy has long been part of Ethiopia's energy landscape. In the mid-1980s, the first solar PV standalone system was installed in Central Ethiopia (Mito). Kebede and Mitsufuji (2017) have traced the history of solar energy policies and associated industrial developments in Ethiopia. They find that international organizations, the private sector, and the state have supported the few solar PV innovations across the country, particularly since the early 2000s. Regardless of its potential, solar technology uptake has remained slow, and future growth will depend on further partnerships between universities, governments, and private sector actors (Kebede and Mitsufuji 2017). Government strategies, such as the Climate-Resilient Green Economy, have directly promoted the solar industry. For example, the Climate-Resilient Green Economy promised the dissemination of

> "*150.000 solar home systems, three million solar lanterns and 10, 000 solar cookers to the community by 2015*" (Kebede and Mitsufuji 2014).

Kebede and Mitsufuji (2014) use an innovation systems framework to assess Ethiopia's solar market and the diffusion of solar innovations (including solar PV and solar thermal technologies). There are cultural barriers, for example, when rural users find food cooked with solar cooking technologies not as good as food cooked with firewood. There is also a lack of coordination between solar actors and a lack of clear and comprehensive standards for importing solar products. Finally, they also find financial bottlenecks along the supply chain, including unclear taxation regime for solar products and the limited availability of skills for the installation and maintenance of solar technologies. In a more recent paper, the same authors propose domestic innovation systems as a means to facilitate solar PV diffusion in Ethiopia (Kebede and Mitsufuji 2017). It is unlikely that solar energy will entirely substitute energy derived from biomass, particularly for cooking (Tucho, Weesie et al. 2014). However, scholars have observed that solar energy provides energy services that complement existing ones, particularly in rural areas where it provides lighting and communal energy services. Girma, Assefa et al. (2015) investigated the potential of solar PV water pumping systems to supply clean drinking water to rural communities. Jariso, Khan et al. (2017) deployed a prospective design and modeling design for a standalone PV system for health centers in Addis Boder, South West Ethiopia. PV solar systems are more economically viable and environmentally sound than diesel generators. Bricca, Bocci et al. (2019) analyzed the potential for small scale solar PV systems for irrigation in rural areas in Soddo, Wolayta Region. They argued that solar PV systems provide a solid base to build off-grid modular solar systems, without requiring a high investment in the beginning. Endale (2019) stressed the potential of solar water heating systems in urban areas in terms of energy savings and power generation capacity.

Kebede (2015) explored the financial viability of grid-connected solar PV systems in Ethiopia across 35 locations – concluding that even though these systems are economically viable, they are not necessarily attractive for private investors without incentives. Berger (2017) reviewed the potential of standalone PV systems in rural areas, particularly with regards to problems of maintenance and battery up keeping. The study compared 31 stand-alone PV systems in remote health posts in North Gondar Zone from installation to system failure. Factors leading to failure included: regular job rotation among health workers and lack of upfront gender-sensitive training, lack of feeling of responsibility for the system, lack of equipment for maintenance, slow and unreliable chains of information in case of system failure. Failed PV systems also threatened the reputation of the technology by word of mouth.

Guta (2018) examined the determinants of household adoption of solar technology in rural central Ethiopia, focusing on the town of Woliso. The study revealed income and gender variation in the adoption of solar technology. The study concluded:

> "*that wealthy and more educated households are more likely to adopt solar energy technology compared to poorer ones. Male-headed households are less likely to adopt solar energy technology compared to female-headed counterparts. The main implication of this study is that there is a scope for poverty reduction policies and adult education that targets household heads and spouses to promote the adoption of solar energy technology*."

Muggenburg, Tillmans et al. (2012) looked at the adoption of Pico Photovoltaic systems. The study investigated users' preferences to inform future commercial developments in the area for selling pico PV systems to rural households. Nine different lamps were distributed among 24 different families that tested them to understand user preferences and expected impact of the technology. The study concluded:

> "*Apart from expected benefits in health, work and education, people also notice improvements in the autonomy of children, flexibility, security, family life and the reduction of stress*."

Specific organizations, such as schools, can support the dissemination of solar energy technologies and build capacity for technology use in rural areas. Dalelo (2011) looks at grassroots energy initiatives to disseminate solar energy technologies. The study focused on the adoption of solar technologies for rural electrification, summarising findings from a pilot project led in 2004 by a faith-based organization to use schools to disseminate solar energy know-how. Schools here are seen as places of innovation to generate new learning and pilot new technologies. NGOs and NPOs support the development of innovation systems for the diffusion of renewable energy technology in Ethiopia. For example, Kebede, Mitsufuji et al. (2015) explained the role of the Solar Energy Foundation in the diffusion of solar home systems in the mid-2000s, as they established a solar training school, a micro-credit system, and solar centers.

### Biofuel energy

As explained above, the focus of analysis on the production of biofuels in Ethiopia tends to be land grabbing and food security at a national scale. Several studies have looked at the impact of biofuel cultivation on rural communities' livelihoods.

Negash and Swinnen (2013) look at the impact of Castor production on poor and food insecure rural households. The paper finds a positive relationship between biofuel production by poor farmers and their perception of food security. Riera and Swinnen (2016) explored the effect of biofuels derived from castor on food security and poverty. They argued that castor production could improve the food productivity of rural households who produce raw material for biofuel production, notably through enhanced access to agricultural 'inputs' and technical assistance. In another study, Rogers, Sovacool et al. (2013) looked at 'Project Gaia,' a small scale project that used byproducts of the sugar industry to create ethanol fuel that can be used by improved cookstoves for displaced refugee populations. Backed by the Shell Foundation, the project distributed 4000 cookstoves to refugees in camps in Ethiopia. The article concluded that the programme helped to reduce deforestation and the burden of collecting fuelwood for refugees, despite outstanding cultural, economic and educational barriers to the use of improved cookstoves. Benka-Coker, Tadele et al. (2018) explored the potential for scaling up ethanol CleanCook stoves in Ethiopia – particularly in refugee camps and urban settings. They found that the price of ethanol remains a barrier to improved cookstoves uptake for low-income neighborhoods in cities like Addis Ababa, and called for subsidies to support uptake.

The commercial use of agricultural residues is also part of biofuel development strategies. For instance, Woldesenbet, Woldeyes et al. (2016) investigated the potential of coffee residues, which generally would be discharged to a river leading to toxic pollution, to produce bioethanol. Wet coffee processing waste can be used to produce bio-ethanol as an alternative energy source. The study concluded that reusing the waste from the coffee industry may have both environmental and economic benefits. Berhanu, Jabasingh et al. (2017) assessed the potential for biofuel conversion derived from agricultural waste, forest product residue, urban and animal waste. The estimated total amount of biomass resources available for energy in Ethiopia in 2014-2015 is 1120 million tons, with the annual energy potential of 46.91 million tons of coal equivalent and the annually exploitable agro-wastes account for 18 million tons. Biofuel development strategies have potential in Ethiopia.

However, biofuel has also come associated with conflicts. Wendimu (2016) explains that biofuel projects such as jatropha, often fail to deliver their promises as they often use untested planting material with low productivity and create conflicts with local communities over the land (Tufa, Amsalu et al. 2018).

### Biomass

In Ethiopia, 95% of rural households and 20% of urban households collect their biomass from forests, and the majority of the population uses traditional biomass stoves (Tucho, Weesie et al. 2014). The penetration of improved cookstoves has remained low. Biomass is the primary energy consumed in Ethiopia, particularly for cooking. In rural areas, 100% of the population relies on biomass for cooking, and in urban areas, 90% (Tucho, Weesie et al. 2014). Beyond questions of access, other studies have stressed the impacts of biomass energy combustion on human health. Indoor air pollution is responsible for more than 50,000 deaths annually and causes nearly 5% of the burden of disease in Ethiopia (Sanbata, Asfaw et al. 2014).

As a result of the persistence of biomass as a primary energy source, Ethiopia faces challenges of resource erosion due to population growth and increased demand in fuelwood, contributing to widescale deforestation (Teka, Welday et al. 2018). Also, dung cakes or crop residues used as fuel are not used to fertilize the soil. Over time, those practices reduce soil quality (Negash, Abegaz et al. 2017). Household-level tree planting programs are a possible response to these problems (Bewket 2003).

Improved biomass energy technologies can help reduce the consumption of biomass, but a rebound effect (increased energy demand) is also anticipated (Yurnaidi and Kim 2018). Improved cookstoves reduce the amount of fuel, and hence, can help to reduce deforestation and deliver health co-benefits (Adem and Ambie 2017). Gebreegziabher, Beyene et al. (2018) showed that improved cookstoves (Mirt brand) for baking injera (which accounts for half the primary energy consumed in the country) could help users to reduce the time they spend cooking and allows cost savings on fuelwood buying. Gizachew and Tolera (2018) looked at the adoption of improved cookstoves in the Bale Eco-Region, Southeastern Ethiopia, showing that education, gender, household size, and type of housing all play a role in households' likely adoption of improved cookstoves. For instance, households with higher levels of education, larger family size, and living in a house with a separate kitchen were more likely to buy improved cookstoves. Men-headed households are less likely to purchase improved cookstoves.

Studies of potential bioenergy production from biomass (municipal solid waste, crop residues, forest, and livestock waste) conclude that these resources are insufficiently used and have the potential to produce energy without further environmental degradation (Gabisa and Gheewala 2018).

### Hybrid off-grid systems

Several studies have looked at the potential of hybrid off-grid systems to address energy needs in remote areas. Kebede and Beyene (2018) looked into the feasibility of a PV-Wind-Fuel cell power hybrid system for the electrification of a rural village, Nifasso. Nigussie, Bogale et al. (2017) demonstrated the operation of an 'off-grid hybrid micro hydro-PV-Diesel Generator-battery bank energy system.' They find that complex hybrid systems provide a cost-effective and more sustainable solutions to deliver energy to rural, off-grid communities. Gebrehiwot, Mondal et al. (2019) show that hybrid systems are potentially better suited than solar PV systems for rural electrification because solar energy has an intermittent power supply. A hybrid system combining PV, wind, battery, and diesel generator is the best economic option and still reduces carbon emissions compared with diesel-only generators.

## 4. Ethiopia's energy access challenges

In Ethiopia, there are substantial geographical variations in energy usage. According to Tucho, Weesie et al. (2014), almost all rural households rely on traditional biomass for cooking (83% of the population lives in rural areas, far from the grid). Almost 90% of urban households have access to networked electricity for lighting, but this does not mean that they can afford electricity tariffs for all domestic usage. The most important energy needs are for cooking, but existing transmission systems do not allow efficient and large-scale renewable energy use for cooking. Ethiopia does not produce oil and gas, and thus hydroelectricity is an essential feature of the energy mix. Ethiopia's strategy has focused on the mobilization of hydraulic power for electricity and biomass for domestic consumption, and this puts pressure on available resources, as explained above. Growth in the agricultural sector is likely to increase hydraulic energy and irrigation water needs. Population growth puts pressure on biomass resources for energy consumption, as the country is currently hitting a biomass ceiling where demand for biomass equals annual increments in biomass for all terrestrial ecosystems (Karlberg, Hoff et al. 2015, Mengistu, Simane et al. 2015). A central challenge for the country relates to the nature and availability of different renewable energy sources and technologies, and their adequacy in different socio-spatial environments and for different usage.

Energy access, particularly for rural communities and low-income urban dwellers, has been a central challenge for Ethiopia over the past decades. Ethiopia's development thinking neglected the electrification of rural areas to focus instead on investing in large-scale infrastructures to supply the most productive sectors of the economy and urban areas (Mulugetta 2007). As a result, the majority of Ethiopians lack access to modern energy fuels such as electricity and LPG and are locked in a 'biomass-based' energy system (Mulugetta 2008). Energy access challenges mean that the cost of accessing energy is unevenly distributed within and across communities. For instance, women and children spend more time collecting woodfuel, and in urban areas, urban poor households have to use up their income for energy. Some have shown that renewable energy technologies could play a key role in enhancing access in rural areas but also in cities where the most deprived households still lack access to modern energy (Mulugetta 2008). Blending grid and off-grid solutions to improve energy access across the country appear as essential alternatives to challengee this status quo (Mulugetta 2007, Mentis, Andersson et al. 2016).

Tessema, Mainali et al. (2014) have stressed the difficulties in mainstreaming sustainable energy access into national development planning, looking at institutional, sectoral, and financial bottlenecks. Since 2003, the Government of Ethiopia has developed strategies to enhance energy access, particularly in rural areas. The Ministry of Water and Energy, in 2003, devised an off-grid electrification strategy (2003), and the national utility launched a Universal Access Programme in 2006. The most recent

Indeed, various programs, such as those discussed in the previous sections, have sought to disseminate renewable and clean energy technologies to improve energy access gaps. For instance, between 2005 and 2011, 2.7 million improved biomass stoves were distributed, with the national universal access program planning to distribute 3 million solar cookers, 65 micro-hydro power plants, and 26.000 biogas digesters in 2014 (Tucho, Weesie et al. 2014).

Most off-grid energy developments in rural areas have been led by private and community actors, managed on a project basis, which prevents large-scale, comprehensive planning and country-wide energy access (Tessema, Mainali et al. 2014). Coordinating across sectors and governmental agencies will be paramount to the development of energy access plans. The public utility, Ethio-Telecom (National telecommunication agency) is a critical player in the sector. It deploys off-grid solar systems as part of its rural mobile infrastructure program (in 2012, it possessed more than 85% of the nation-wide installed solar systems) (Kebede and Mitsufuji 2014).

The 2030 Agenda for Sustainable Development has pushed countries, including Ethiopia, to integrate the SDGs, and SDG7 specifically. Universal energy access objectives, for example, have been incorporated in the Ethiopian Intended Nationally Determined Contribution, which can help to mainstream energy access objectives into national plans (Selvakkumaran and Silveira 2019). The latest **Power Sector Reform Proposed Roadmap (MOWIE Sept. 2020) identifies the following key issues for the Ethiopian energy sector:**

- Financial sustainability issues for utility companies;
- Poor quality of service -- frequent power interruptions all over the country (16-18 hours a day encountering power cuts/interruptions problems, as per 2009 data);
- In terms of absolute number of people, largest electricity access deficit in Africa (over 60 million people, 96% people access the grid in cities, but only 27% in rural areas)
- Inadequate generation capacity -- willingness to generate more power
- Poor efficiencies in investment and operation -- problems of power loss;
- Weak capacity to leverage PPP to mobilize resources (new structures for channelling financial resources will be created)
- Large debt overhang
- Tariffs are not effective to cover operating expenses and financing costs -- tariffs are so low that it gives disincentives to private investment;
- Unsustainable finance for long gestation projects

The roadmap's key objectives include **moving from public investments to Independent Power Producers (IPPs)** -- this is supported by the public-private-partnership (PPP) proclamation passed by the Parliament in 2018 (new PPP framework with a dedicated PPP unit at the Ministry of Finance, in charge of allowing/refusing PPP transactions across sectors); the creation of **an auction based procurement process** which will become the default process to involve IPPs.Through this roadmap, Ethiopia also seeks to achieve universal electricity access by 2025 with 65% ongrid connections / 35% off-grid connections and to become a key electricity exporter in the region, maintaining creditworthy companies.

## Energy access in urban areas

Studies have explored the factors shaping urban households' energy choices and access to clean energy. Kebede, Bekele et al. (2002) have shown that income levels prevent the urban poor from moving away from traditional fuels (including kerosene) towards modern fuels. Providing credit facilities to increase access to electricity and support shift from kerosene could be one way to overcome this issue (Kebede 2006). Ali and Megento (2017) looked at the relationship between poverty and energy consumption in urban and peri-urban areas in Arba-Minch Town, Southern Ethiopia. Regardless of their economic status, the majority of households depend on wood fuels as their primary source of cooking energy. The study reveals that commercial cooking fuels become increasingly expensive and that a significant portion of urban and peri-urban households continue to suffer as their incomes have not kept pace with the rising prices.

Several studies have focused on the adoption of improved stoves. Gebreegziabher, Mekonnen et al. (2012) have shown that both education levels and levels of income shape whether or not urban households are likely to adopt clean energy technologies. Takama, Tsephel et al. (2012) used discrete choice modeling to show that that consumer preference for higher quality fuels and stoves in Addis Ababa increases with wealth. Weldegiorgis and Adem (2018) looked at the adoption of electric cookstoves in urban Tigrai. They surveyed 109 households showing that household's adoption of an electric stove related to different factors including age, education level, type of employment of household head, family size, household expenditure and prices of related goods. In addition to the cost of electricity vs. firewood and levels of income, Alem, Hassen et al. (2014) found that access to credit influenced the adoption of electric cookstoves.

The use of qualitative methods helps to understand the enduring use of firewood as the main energy source in urban areas. In a study held in Debre Markos Town (Northwest of Ethiopia), Geremew, Gedefaw et al. (2014) found that 95% of households still use traditional biomass for cooking. People who have less knowledge of the adverse health and environmental impacts of biomass fuels are more likely to use those for cooking. People also have strong beliefs regarding the benefits of using biomass fuels for cooking. For example, they find that food cooked with charcoal tastes better. The study concludes that education is key to a transition to clean cooking technologies. Arega and Tadesse (2017) studied 300 households' willingness to pay for green electricity in urban and peri-urban Tigray (Northern Ethiopia). Factors influencing willingness to pay for green electricity included income levels, gender, distance to wood, and charcoal markets.

## Energy access in rural areas

Studies have sought to understand biomass use and energy substitution in rural households. Guta (2014) shows that households use multiple fuel sources to satisfy their energy needs, comfirming recent studies on the importance of fuel stacking. People showed a preference for forms of energy that are thought of as modern but could not always access it because of price and income levels. The study concludes that energy strategies should focus on increasing access to modern energy technologies alongside afforestation programs to increase biomass supply.

There are proposals for specific energy solutions. For instance, Gwavuya, Abele et al. (2012) explored the potential to switch to biogas as an energy source in rural households, arguing for maintaining subsidies to encourage such switch to avoid deforestation and increase food security. Tucho and Nonhebel (2015) explored the potential of bioenergy to address energy needs in rural Ethiopia, particularly energy derived from straw and manure. They concluded that

> "*even when modern, energy-efficient techniques are used the largest share of the population is not able to generate enough energy for cooking from their own land and/or cattle*."

The article thus stresses the limits of such strategies to fully address energy needs in rural areas. Alemayehu (2015) reviewed ongoing efforts to introduce improved cookstoves in rural areas in Ethiopia (see also Hassen and Kohlin 2017) alongside projects for biomass conversion using animal waste. The Ethiopian government had installed around 860 biogas digesters at the time of the article. The article concludes that these projects are promising but have not always benefited rural households. Entele, Emodi et al. (2018) looked at consumer preferences for solar PV and micro-hydro electricity sources in East Shewa and Arsi. According to their discrete choice modeling exercise, solar PV solutions are more popular than small scale hydroelectricity in rural areas (as also argued by Entele 2020). Rural electrification and energy solutions' uptake will depend on collaboration with rural community organisations including schools (Dalelo 2011) and cooperatives (Gezahegn, Gebregiorgis et al. 2018).

## 5. Renewable energy developments in Ethiopia

In their exploration of the future of green energy in Ethiopia, Khan and Singh (2017) note that the country's vast renewable energy potential remains under-utilized, particularly when it comes to enhancing rural energy access. Mulugetta (2007) identified the following barriers to renewables: financial constraints, lack of knowledge about renewable energy resources endowment, limited expertise in planning, siting and implementation, lack of inter-governmental and intersectoral coordination, and lack of private and non-for-profit sector involvement. Tesfaye, Khader et al. (2015) observed similar issues alongside a lack of clear regulatory framework to incentivize private investments into wind and solar energy, a lack of financial resources for feasibility studies and subsequent interventions, limited institutional capacity and skills available to the design and implementation of renewable energy projects, a lack of information about the potential demand for renewable energy (including off-grid market data), high costs and limited information related to particular technologies (e.g., solar PV), limited development of public-private partnerships for renewable energy projects, limited knowledge transfer, reduced household demand for renewable energy and high reliance on biomass, lack of financial incentives such as subsidies and feed-in tariff policies, lack of domestic manufacturing capacity and technology transfer.

Observers have long advocated for strategies focusing on the uptake of decentralized, smaller-scale, renewable energy technologies to address energy access and energy security challenges in Ethiopia. The deployment of these technologies would allow the country to achieve energy security and broader access because these imply that

> "*the resources are local and readily available, and most importantly, people become custodians of their energy situation*" (Mulugetta 2007. P. 7)

Ethiopia's recent Energy Roadmap addresses this imperation, putting off-grid solutions at the heart of universal electrification efforts.

## 6. Community energy in Ethiopia

There are very few studies on community energy development in Ethiopia. Most of them are feasibility studies for hybrid energy technology deployments in different areas. Bekele and Palm (2009) studied the wind energy potential of four sites, Addis Ababa, Mekele, Nazret, and Debrezeit. Three sites were found suitable for wind electricity generation. The study was part of a broader project that looked at hybrid solar/wind systems and explored the potential of having hybrid standalone energy supply systems, including a wind turbine, PV, diesel, generator, and battery in these communities (Bekele and Palm 2009). A second study from the same group looked at solar-wind-based hybrid energy systems to supply electricity for communities living off the grid in Ethiopia. The main results concerned a community in Addis Abbaba, comprising of 1000 people in 200 families, community school, and health post, with energy usage concerning lighting, water pumps, radio receivers, and clinical equipment (Bekele and Palm 2010). A third study explored the feasibility of a small hydro-solar-wind hybrid system for off-grid rural electrification in Ethiopia (Bekele and Palm 2010). Tucho and Nonhebel (2017) also looked at the potential for community energy systems based on a mix of biogas and solar energy in rural villages. They offered recommendations related to their economic viability that also explored the different trade-offs involved in developing both solutions. Colombo, Romeo et al. (2018) developed an Impact Evaluation Framework to assess energy projects' impact on the livelihoods of communities.

# 7. Key insights

The review above demonstrates that there is limited research on the potential for community energy in Ethiopia. Existing analysis of off-grid systems has, for the most part, focused on the needs of rural areas and examining the barriers to renewable energy development. Research agendas have also developed alongside the requirements for the deployment of different technologies.

For example, large scale infrastructures for hydropower have been linked to the political strategies of the government, closely linked to geopolitical conflicts as well as conflicts related to their enormous impacts on those areas where they are built. Small scale technologies such as solar and biogas have been examined in a little more detail, particularly looking into the complex contradictions of adoption and the actors and resources that support diffusion. Because of the continued dependence on biomass, improved cookstoves are a go-to technology for many organizations involved in advancing the SDG7 in Ethiopia and have received a lot of attention in the literature.

Community energy research in Ethiopia needs further development, building on some pioneering experiences such as those reported by Bekele and Palm. A few pressing questions emerge in the literature that may become more important in further work. In particular:

1) A large body of research on energy in Ethiopia, more generally, highlights the contradictions between the aim of technology diffusion at the local level and the contradictions that emerge when those technologies are considered in the broader political economy of the country. These contradictions entry points for further analysis.
2) A few studies point towards the specific vulnerabilities of certain groups, particularly women and children. Some studies, in particular, also consider vulnerabilities associated with the status of some groups as refugees or with specific ethnic groups. These studies are sensitive to our concerns with intersectionality, and it will be essential to link up with them.
3) At least two studies have suggested the possibility of developing gender-sensitive training in energy. What is 'gender-sensitive' training, what would it involve? Can we make it an aim of the project to develop such gender-sensitive training ourselves?

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