3 Federal Democratic Republic of Ethiopia

3.1 PESTLE or Macro Analysis

In the last decade, several changes have been put in place to reduce poverty and reach middle-income country level by 2025. With about 109 million people (2018), Ethiopia is the second most populous nation in Africa after Nigeria, and the fastest growing economy in the region (World Bank, 2019). Despite its fast growth, however, poverty remains a big challenge in Ethiopia.

3.1.1 Political Environment

The government of Ethiopia is structured in the form of a federal parliamentary republic, whereby the Prime Minister is the head of government. Executive power is exercised by the government while legislative power is vested in the Parliament. The Judiciary is more or less independent of the executive and the legislature. Prior to transitioning to a Federal Republic, Ethiopia was a socialist nation. After the throw of the socialist regime by a rebel group, Ethiopia developed an ethnic based multipartite system under a united front, the Ethiopian People's Revolutionary Democratic Front (EPRDF). As Ethiopia is a multi-ethnic nation, the 9 regional administrations enjoy a strong autonomy to self-govern with the governance of the Federal government.

- *Recent Political Reforms*: The last 27 years under the leadership of EPRDF; various political unrests were common due mostly to rigged elections; unbalanced distribution of power among ethnicities; mass imprisonment of journalists or protesters. Since 2018, a reformist team from the ruling party and pressure from strong opposition by the youth, has allowed a reformist Prime Minister to introduce democratic changes.
- *Political instability in the last two years*: Despite many favorable political decisions and steps towards democratization, the last two years have seen several ethnic conflicts, unrests and internal displacements that affected investments and prohibited others from investing. These turbulences are expected to lessen after an election in August 29,2020 (Postponed due to COVID-19) and the formation of a legitimate government.

3.1.2 Economic and Business Environment

Ethiopia's economy has been one of the fastest growing in Africa. The World Bank reports the economy grew by an average of 9.9% between 2008 to 2018, compared to a regional average of 5.4% (World Bank, 2019). This is mostly due to extensive public led investments in infrastructure and industrialization. Ethiopia extensively encourages Foreign Direct Investment (FDI) and is constantly introducing changes focused on ease of doing business, despite its 159 position out of 193 economies However, the financial sector and few other sectors are closed to foreign ownership, which has limited its competitiveness and growth of local enterprises. To support business in energy sectors the government developed different policies and strategies i.e. The Rural Electrification Fund (2003), Ethiopian Rural Energy Development and Promotion Centre (2002), National Energy Policy (2013), Growth and Transformation Plan II (2016-2020), Climate Resilient Green Economy Strategy (2011), the Biofuel Development and Utilization Strategy (2007), National Domestic Biogas Programme (2007) and Biomass Energy

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Strategy (2013) and supported by energy law under Energy Proclamation No. 810/2013 (ECAE, 2016)[17].

Table 8: Ethiopia Country Overview

Government	Federal Republic	**Population (Millions, 2018)**	109.22
Urban vs. rural: (2014 estimate)	20% vs. 80%	**GDP (Bn US$, 2018)**	84.4
Surface area (sq. km) (thousands)	1,104.3	**CO_2 Emissions (MT per capita, 2014)**	0.118
Religion	Ethiopian Orthodox (43%+), Muslim (34%+), Protestant (c. 18%) (2007 census)	**Inflation, GDP deflator (annual %, 2018)**	12.5%
Neighbors:	Sudan (civil war), Eritrea ('no war, no peace'), Djibouti, Somalia (civil war), Kenya, South Sudan (civil war)	**Time required to start a business (days, 2018)**	32

3.1.3 Environmental and legal environment

Ethiopia's environmental policies are addressed under the 'Ethiopian Environmental Pollution Control Proclamation (No. 300 of 2002)'. Based on this proclamation, a regulation issued in 2009 requires authorities to assess some factories to control their pollution, waste management and disposal, effluent discharge, and freshwater pollution. The competent organ for the issuing of a business license will only issue a license after verifying that the effluent is not a pollutant or will not exceed the limit set under the relevant environmental standard and it will not entail damage if released to streams. The regional Environment, Forest and Climate Change Commission would supervise compliance to the national regulations and guidelines of the regional laboratories by conducting statutory review of environmental/social screening and ensure that all the environmental concerns are mainstreamed into the sub-project activities to minimize negative impacts[18].

- Although there are laws as above, the majority of large-scale industries do not show considerable effort in protecting the environment responsibly. The reasons identified are among others the absence of corporate environmental responsibility, low pressure from the enforcing institutions, and lack of financial and human resources.
- Deforestation is a major cause of loss of biodiversity, and habitat conservation is vital for stemming this loss. Conservation efforts have focused on protecting areas of high biodiversity.

[17] CKDN, 2018, Mapping of Energy Institutions and Initiatives in Ethiopia. https://cdkn.org/wp-content/uploads/2018/02/Inventory-of-Energy-Initatives.pdf

[18] Document is available in: http://www.eca-e.com/files/NQIDP_ESMF-Dec_12_2016_final.pdf

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Key Environment Figures - 2018 (World Bank Country Profile)
- Forest area (sq. km) (thousands): 125.4
- Terrestrial and marine protected areas (% of total territorial area): 18.5
- Urban population growth (annual %): 4.8

3.2 Market Characterization and Definition

The government of Ethiopia has highly prioritized the need for energy and sees the private sector, mainly foreign direct investments, as pivotal in meeting intended targets. With a growing population and plans to export energy to neighboring countries, on-grid power generation, off-grid and mini-grid systems are open for private sector development. Below are excerpts from the Ethiopian Investment Commission on key power market trends.

Key reasons for investing
Source: Ethiopian Investment Commission Website
- Rapidly growing electricity demand at 30-35% annually mainly as a result of
  - Growing population forecasted to reach 120 million by 2020;
  - A bold industrialization agenda driving power demand; 13+ industrial parks requiring more than 1700 MW of electricity to operate;
  - Over 4,500 KM of electric powered national railway to cover around 4,744 km imposing large electricity demand; and
  - Plans of exporting power to Kenya, Tanzania, Sudan, and Djibouti as part of the East African Power Pool
- More than 80 GW of exploitable renewable energy reserves;
  - 45 GW of Hydro power exploitable energy reserves of which more than 80% is unexploited;
  - 7 GW of Geothermal exploitable energy reserves of which more than 86% is unexploited; and
  - An average of 5.5 kwh/m^2/day of Solar energy capability of which more than 98% is unexploited
- Low electricity access provides opportunity for off-grid solutions to thrive because
  - Over 95% of rural areas are without electricity; and
  - Over 14.3 million households are without the access to power
- Trainable workforce with competitive wages

3.2.1 Market Definition and Size

Energy in Ethiopia is mostly a public led investment with the private sector increasingly involved in the supply of solar power and recent foreign investments in geothermal energy. Existing power sources relevant in Ethiopia are biomass, hydropower, solar (Photovoltaic), wind, fossil fuel and geothermal and biogas/biomass. Ethiopian Energy Authority (EEA) established in 2014 as an energy sector regulator under the oversight of the Minister of Water, Irrigation and Energy (MoWIE). Ethiopian Electric Power (EEP) established in 2013 responsible for generation, transmission and system operation, and Ethiopian Electric Utility (EEU) established in 2013 responsible for power distribution after the unbundling of the Ethiopia Electric Power Corporation (EEPC) (World Bank, 2018).

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Renewable Energy Potential: Ethiopia has one of the largest potentials for renewable energy generation, but it is estimated only 5% of this potential has been utilized so far (National Planning Commission, 2016)[19]. Ethiopia primarily focused on the following three sources of renewable energy: hydropower, wind and geothermal. The country's major development document, the Growth and Transformation Plan, sets the target to increase the aggregated power generation from existing 4,100 MW to 17,200 MW from all sources by end of 2020 (National Planning Commission, 2016).

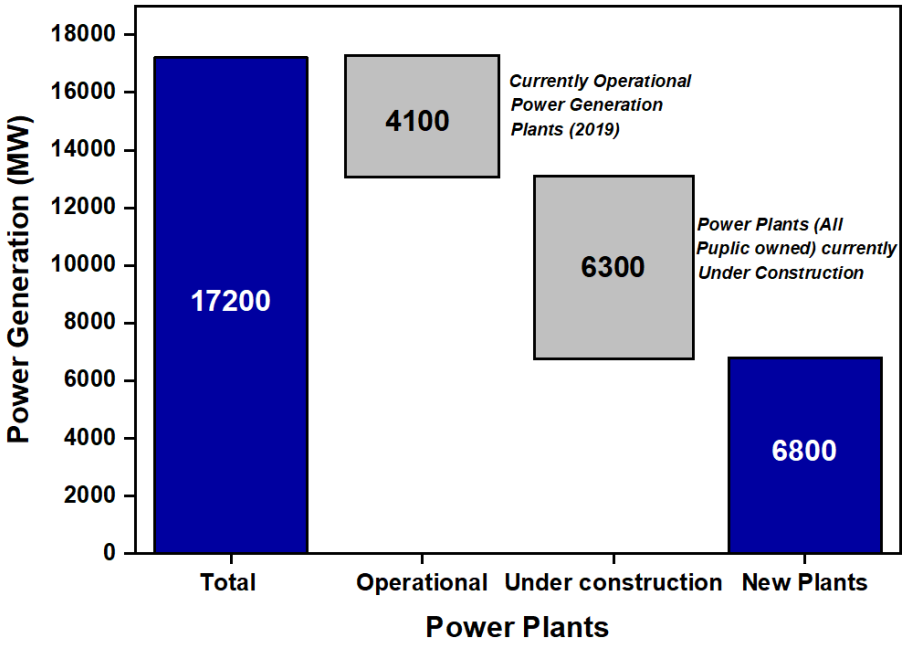

Figure 14: Number of Power Plants in Ethiopia

The major sources of energy, characteristics and their size are detailed below.

Biofuel: The world bank reports that close to 80% of the Ethiopian population lives in the rural areas with agriculture as the primary source of income. About 88% of these rural households rely on woody biomass, agricultural residue, and sundried livestock manure mostly for cooking (World Bank, 2018). This prevalent dependence on woody biomass has led to a large-scale deforestation and environmental crisis in the country. Woody charcoal is also sold to urban populations as an important energy source for heating and cooking.

Hydropower: Focus and investment by the Ethiopian Government is made on hydropower energy as a primary source of energy to power households and the growing industry. Ethiopia has a potential to generate 45,000 MW although it currently has 3,810 MW[20] installed hydropower capacity (2016). Several hydropower dams are built on waters across the country, including GIBE III (1, 870 MW installed capacity). The construction of the largest Grand Ethiopian Renaissance Dam (GERD) on the Nile river has been completed above 50% and is expected

[19] The Growth and Transformation Plan document can be accessed in: https://www.greengrowthknowledge.org/national-documents/ethiopia-growth-and-transformation-plan-ii-gtp-ii

[20] Data | The World Bank - World Bank Data - World Bank Group." https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS%3Fname_desc%3Dfalse. Accessed 25 May. 2020.

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to produce 6,500 MW. Hydropower is entirely a public led investment in Ethiopia and is currently the primary source of power in the country. Generated power is distributed by the government through the Ethiopian Electric Power Authority to households and industry.

Solar (Photovoltaic): Solar power access is implemented in the form of small mini-grid systems as Solar Household Systems, Solar lamp (lanterns) and heating systems. The private sector plays an important role in importing and distributing these systems to mostly rural households. Large-scale solar farms have not been the focus neither by the government nor by the private sector. The potential for solar energy stands at 5.2 kwh/m^2/day.[21] As of 2016, installed capacity reached 7MW although the government planned to reach 300MW by 2020.

Wind: Ethiopia has the potential to produce more than 10,000 MW of power through wind turbines, although the existing installed capacity is only 324 MW. The country has good wind resources with velocities ranging from 7 to 9 m/s^3 Up until now, no commercial wind power plants existed, and future plans are expected to be public investments.

Fossil Fuel: Ethiopia is currently not an oil producing country. However, explorations conducted over the years indicate several hundred million tons of coal and oil shale, and over 70 billion cubic meters of natural gas[22]. The Ogaden desert and the western part of Ethiopia (Gambella area) are among the potential parts of the country. Although explorations started in the Ogaden desert, Ethiopia could not realize its dream of benefiting from oil as most of the wells dug turned out to have no reservoirs and due to recurring political unrest in the region.

Geothermal: Geothermal energy is another alternative with Ethiopia having 700 MW of geothermal resources suitable for electricity generation. Aluto Langano, the single existing plant, has an installed capacity of 7.2 MW although it has not been delivering as expected due to technical problems. However, the country is currently encouraging foreign direct investment (mostly from the United States) in the sector. Some of these investments include the recently launched Tullu Moye plant expected to produce 500 MW with an investment of $2.5 Billion[23].

3.2.2 Market Development and Stage

Despite its rich potential and national focus, the biogas market remains at its early stage in Ethiopia, especially compared to other RE sources. This is evident due to the reasons below:

- Private sector involvement is almost non-existent. Most of the developments are public or donor financed. Industrial use of biogas plants is limited to few institutions owning plants as energy complements
- Although policy is in place, the government directs investment to Hydropower, Solar, Wind and Geothermal energy production. Biogas is primarily used to alleviate the energy needs of the rural communities
- Limited advancement of existing technologies and awareness in the market has affected its popularity. For example, Solar technologies have gained high popularity and consistent technology importations by the private sector

[21] Description was acquired from: https://energypedia.info/wiki/Ethiopia_Energy_Situation#Solar_Energy
[22] Op.Cit., Data | The World Bank - World Bank Data - World Bank Group." https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS%3Fname_desc%3Dfalse. Accessed 25 May. 2020.
[23] Data was acquired from: https://projects.worldbank.org/en/projects-operations/project-detail/P133613?lang=en

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- Geographically, biogas markets are scattered across the country and mostly in rural areas.

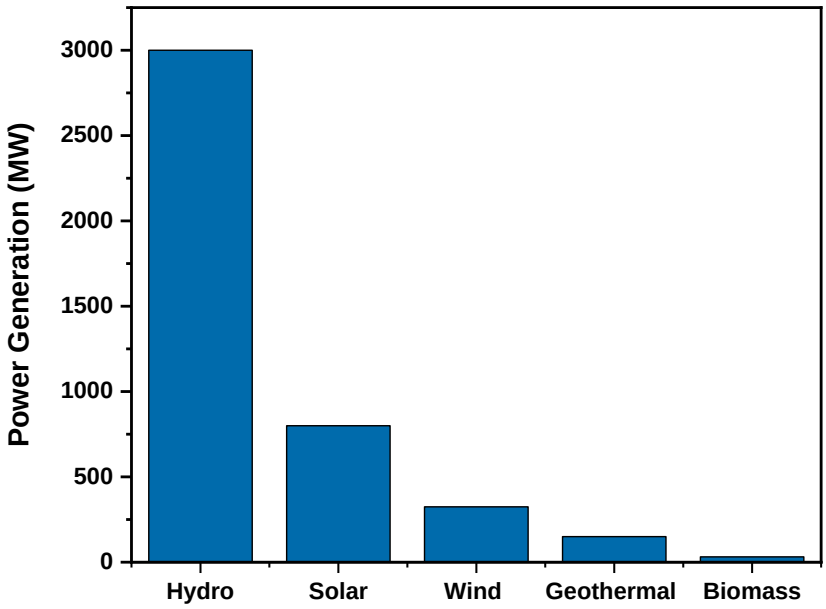

Figure 15: RE National Targets for Private Sector - Energy Development by 2020 (MW)

3.2.3 Market Size and Growth Trend

Ethiopia has an estimated agricultural waste of 15-20 Mil tonnes per annum, out of which only 30% is exploited. Related data for the rural community has identified a potential of 4 to 5 million households based on livestock holding and water supply (Getasew M, 2020). Urban and industrial waste is also claimed to be a significant amount although clear data is hardly available. Reppie Waste to Energy Plant of Ethiopia is generating 25 MW of net electricity. The plant processes 1400 tonnes municipal solid waste daily collected from the capital city of Ethiopia, Addis Ababa[24]. Biofuels are being blended with conventional fuels since 2007. There are two ethanol plants producing about 30 million liters per year. Ethiopia has an ambitious target to achieve production of 1,7 billion liters of biofuels per year from sugarcane molasses (RSB, 2018)[25].

There is, however, an energy production potential from agro-processing industries (processing sugar cane bagasse, cotton stalk, coffee hull and oil seed shells).

[24] More information on the waste-to-energy power plant project can be accessed in: https://www.africawte.com/
[25] This data was acquired from the Roundtable on Sustainable Biomaterials (RSB) “RSB Aviation Biofuel Summit in 2018. The event summary can be acquired in: https://rsb.org/2018/03/28/event-summary-a-successful-rsb-aviation-biofuel-summit-in-ethiopia/

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3.3 Customers and Clients

The use of domestic biogas has been triggered by the energy crisis in Ethiopia and the suitability of the technology with the physical geography. Compared to other energy sources, the biogas/biomethane sector in Ethiopia is at an early stage and largely implemented through government led investments focused on rural households. However, there exist institutional biogas plants developed by private institutions and with donor involvements. Based on available data, below are key customer segments in the biogas market.

1. **Rural Households:** government led programs, mostly targeting small household digesters to rural households and farmers
2. **Institutional users:** some institutions like universities and businesses developing their own plants in their compounds for self-consumption using their own waste

3.3.1 Rural Households (government led domestic biodigester programs)

As part of its rural energy program the Government of Ethiopia (GoE), together with the Netherlands Development Organisation (SNV) launched one of its first multi stakeholder national programs. This National Biogas Program of Ethiopia (NBPE I) was launched in 2008 and ended in 2013. This was followed by two consecutive 5-year programs namely NBPE II (2014 - 2019) and the currently active NBPE+ (2017 - 2022). The key beneficiaries of these programs are designed to be rural households with more than few livestock and the technology was the dome based small bio-digesters. These programs triggered the creation of the National Biogas Program Coordination Unit (at the national level) under the Ministry of Water, Irrigation & Energy (MoWIE), with corresponding regional coordination offices for on the ground implementation. All three programs targeted to build close to 66,000 household size bio-digesters but were only able to build almost 27,000 (~40% achievement) until the end of December 2019 (Kamp and Forn, 2016 pp. 475-488).

Table 9: Details of NBPE Programmes

	NBPE I (2009-2013)	NBPE II (2014- March 2019)	NBPE+ (2017-2022)
Targets	10,000 Household bio-digesters installed	20,000 Household bio-digesters installed	36,000 Household and 40 Large size plants
Achievement	8,161 installed	12,585 installed	6,121 Household size bio-digesters installed (until Dec. 2019)
Implementing Partners	Financing: Donors (DGIS/Hivos) Implementer: MoWIE and regions Technical Assistance: SNV	Financing: GoE & Donors (DGIS/Hivos) Implementer: MoWIE and regions Technical Assistance: SNV	Project Management & Financing: SNV (EU Funding) Implementer: MoWIE and regions Technical Assistance: SNV

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Key Characteristics of the National biogas programs

- **Targeted beneficiaries**: the overall target of the program is to improve the livelihood of the rural Ethiopian community and make them owners of bio-digesters. In recent developments, attention has also been given to the use of bio-slurry for fertilization.
- **Business Model**: in terms of financing cost is shared between the program and the farmers. The program links households with Micro Finance Institutions to allow instalments. Individual technical people are also trained to provide maintenance services as masons.
- **Private Sector involvement**: developing a functional private sector has also been an important part of the objective, although doing so has been a constant challenge.
- **Technology and biogas use**: main uses are for cooking, basic lighting, and bio-slurry for fertilizer use. Sizes range between 6 - 10 m^3; feedstock of livestock manure and human excreta.
- **Challenges and status**: A key challenge for the program in the early years has been the low adoption. Additionally, the increased focus on other renewable energy sources, for example Solar and the coordination of the program have been further challenges. The NBPE+ is yet to implement the target of developing 40 mid-to-large size plants.

Picture 1: The Government builds small bio-digesters for rural households

3.3.2 Institutional Users

Institutional biogas clients are public, private, or civic organizations usually with their own industrial or waste feedstock, hiring developers to build suitable digesters for internal power generation and/or waste stabilization (in some cases for Bio-slurry). Although current data is difficult to get, a study by the GIZ in 2009 provides a comprehensive overview of institutional biogas clients, technologies used and status. Below is a summary of their assessment done on 92 institutions out of a total 120 institutional users.

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Table 10: Institutional Biogas in Ethiopia

Key Aspect	Remarks
Total number of institutional biogas users in Ethiopia (2009)	120
Institutions assessed with the study	92 - across three major regions and 2 city administrations across the country
Capacity of plants assessed	12 - 350 m^3
Status of Operation	The study reveals that: - 53% of plants are functional while the remaining - 47% are non-functional; of which 56% stopped functioning in less than 3 years.
Technology	- Majority (77) use **Fixed Dome Type (Chinese, CAMARTEC, Deenbandhu, and other models;** - **the remaining 15 plants are of the vertical floating drum types**
Type of Institutions	- 26% of the biogas systems are placed in academic institutions including schools, colleges, and universities - 16% are being used in prisons; - 13% in farms and - 13% in hotels
Size of Plants	- 100 m^3 - 20 % - 30 m^3 – 11 %, - 150m^3 – 10 %, - 20 m^3 – 7 % and - 50 m^3 and 65 m^3 each 5%
Type of Feedstock	Most plants were using human waste, animal dung and kitchen waste as feedstock in 57, 50 and 28 number of institutions, respectively.

3.4 Industry Attractiveness through Porter's Forces

Biogas in Ethiopia is a niche technology, at an early stage and commercialized developers are in limited supply. Despite the government's efforts to involve the private sector, the sector has not been successful in engaging several actors. As such, the competitive landscape is quite low, as most industries focus on other RE, like Solar technologies.

In performing competitiveness analysis in the Ethiopian biogas sector, it is important to note two key points. First, as mentioned in earlier sections, the private sector is not allowed for distribution, but supplies it to the power Authority. Second, although power retail is not allowed, developers can develop for institutions, for their own consumption. Below is a review of the industry through Porter's famous forces. We assigned three general ratings for each of low, medium, and high to indicate importance for our market.

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3.4.1 Threat of New Entrants: LOW

The Ethiopian biogas sector has not been highly commercialised and the primary developer has been state-led, to reach off-grid population and targeting the rural households. Even institutionally developed biogas projects reviewed are mostly initiated by the public sector and NGOs, as part of developing the sector.

Despite plans to engage the private sector, various sectoral bottlenecks have limited investment for private developers. Even in its efforts to involve the private sector, the national growth roadmap (GTP - Growth and Transformation Plan II) largely focuses on other RE energy sources compared to the lowest development targets for biogas.

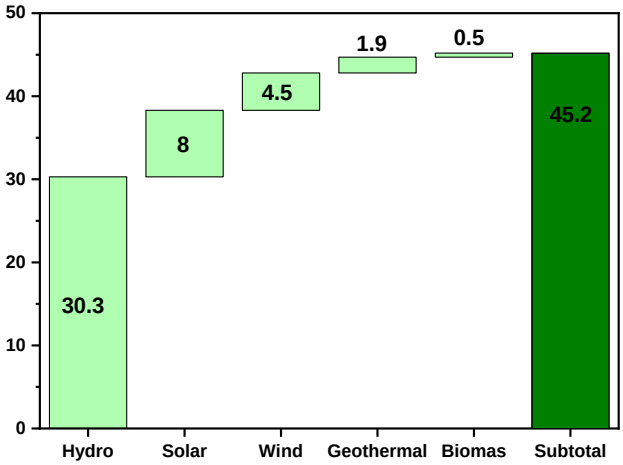

Figure 16: Ethiopia's Government Plan for Private Sector Power Generation (2015-2020)

An analysis by one of the development consultants that work with the government have identified the following key bottlenecks for the involvement of the private sector in the power/energy generation sector.

Various sectorial bottlenecks have limited private sector investment and are mapped to 7 categories

- Planning/Regulatory Framework: Lack of detailed power sector plans, project pipelines, and unbundling of functions. Poor regulatory framework with non-consistent and conflicting proclamations and directives
- Institutional Framework: Lack of clarity and understanding of institutional roles, mandates and responsibilities amongst institutions and absence of institutions that are important for the sector
- Institutional Capacity: Lack of Institutional Capacity at various institutions, in regard to private sector engagement and power sector handling
- Procurement: Inefficient bidding and tendering processes and absence of internationally bankable standard PPA contracts templates
- Risk Allocation: Poorly studied risk allocation to private investors and absence of efficient risk mitigation methods
- Incentives: Gaps in the incentives provided to investors in the power sector
- Investment Promotion: Limitations in the investment promotion strategy, approach, and tasks

Source: TBI - Strategic Consultant to the Government of Ethiopia

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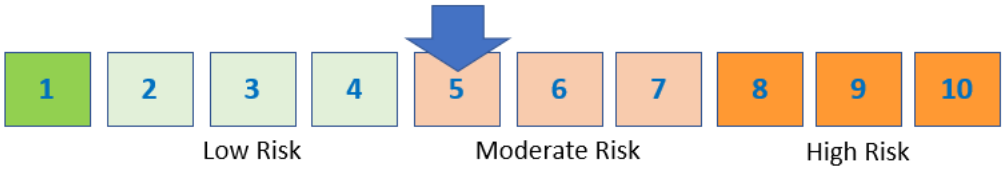
3.4.2 Bargaining power of Buyers: Medium

The severe shortage of energy, particularly power, and the limited developers of biogas in the market don´t leave much leverage to buyers. Buyers in the Ethiopian case could be the Ethiopian Electric Authority, who is the only mandated body to distribute power; or institutions who utilize the energy themselves.

It is important to note, however, Solar based (PV) technologies have become widely popular, and as such could pose a relevant threat to switch to other renewable energy sources especially wind and biomass energy. However, 80% of the population of Ethiopia lives in rural areas and most of them are farmers with a huge agricultural waste (Musse et al., 2019 pp. 92-97). Thus, adopting Biomass to Energy Technology may be an economical option in those areas. This section is related to the next force (threat of substitute products) and the discussion will continue in detail.



1 absolute zero risk **2** low risk **3** straightforward operational solution **4** require strategic adjustment **5** moderate risk **6** straightforward operational solution **7** require strategic adjustment **8** high risk **9** straightforward operational solution **10** require strategic adjustment

3.4.3 Threat of Substitute products: Medium

In the grand scheme of things, Ethiopia has a large gap of energy production, particularly for industry power, electricity distributed and for cooking. As of 2018, access to electricity was 45% and 7% is for clean cooking (IEA, 2019).[26] As repeatedly mentioned, energy produced could either be sold to the Ethiopian Electric Agency (EEA) for distribution or self consumption for institutions. It is our belief; developers can sell power to EEA to add it into the grid or institutions will be happy to get rid of their waste. As such, one can predict no energy produced will go to waste.

However, there are plausible RE substitutes such as Solar household technologies and new private investments into Geothermal and Wind energy. The aggressive market penetration in off-grid electrification and heating technologies, especially Solar, pauses a credible substitution effect. The exhibit below attempts to show the investments around Solar PV as opposed to biogas.

Multidimensional Investments and Frameworks Supporting the growing Solar PV/other energy markets as opposed to Biogas

- **Much better involvement of the private sector**: compared to biogas sector, several importers have imported and distributed millions of Solar Household Systems (SHS) to power TV, mobile charging, and even productive use as irrigation pumps

[26] A complete energy outlook of Ethiopia by the IEA can be accessed in: https://www.iea.org/articles/ethiopia-energy-outlook

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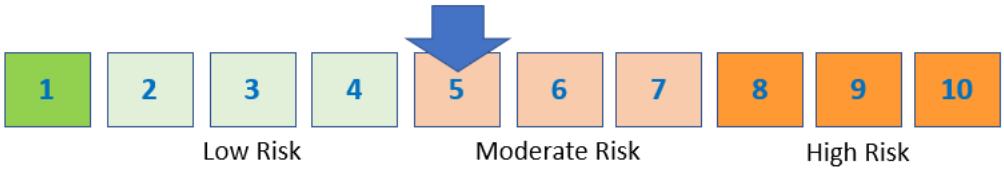
etc.

- **Recent government based solar farms announced for investors**: the government recently announced bids for solar farm projects to produce close to 1,000 MW of energy with an estimated cost of more than a billion US dollars.[27] There are even two agreements signed for Geothermal energy production (500MW each)
- **Strong Support by the Donors for Solar PV energy**: the World Bank, through its Off-Grid Solar Lighting up Ethiopia, is even making finance guarantee schemes available for RE investments through local Ethiopian banks.[28] There are also various other initiatives supporting Solar PV more than any other RE source.

Despite aggressive investments discussed above, the gap for power/energy remains large and several industries/institutions will need to take care of their waste and support their energy needs with off-grid options. If we can offer a comparatively better alternative, the biogas sector still has enough share to fill.



1 absolute zero risk 2 low risk 3 straightforward operational solution 4 require strategic adjustment 5 moderate risk 6 straightforward operational solution 7 require strategic adjustment 8 high risk 9 straightforward operational solution 10 require strategic adjustment

3.4.4 Bargaining Power of Suppliers: Medium

Although there are several inputs for the biogas development, our primary focus in suppliers relates to supply of the technology. The most common technology so far in Ethiopia is the domestic biodigester. The fixed-dome digester consists of a stationary underground structure made from cement, bricks or stones, sand, and aggregates. The biogas piping system can be con- structed with PVC pipes, flexible hose pipes or metal pipes[29].

[27] "Ethiopia seeks to install four solar PV projects | ESI-Africa.com." 13 Feb. 2019, https://www.esi-africa.com/industry-sectors/renewable-energy/ethiopia-seeks-to-install-four-solar-pv-projects/. Accessed 30 Apr. 2020.
[28] "Off-Grid Solar Lighting Up Ethiopia - World Bank Group." 15 Aug. 2016, https://www.worldbank.org/en/news/feature/2016/08/15/off-grid-solar-lighting-up-ethiopia. Accessed 30 Apr. 2020.
[29] "(PDF) Ethiopia's emerging domestic biogas sector: Current ...." 3 Jun. 2016, https://www.researchgate.net/publication/293329498_Ethiopias_emerging_domestic_biogas_sector_Current_status_bottlenecks_and_drivers. Accessed 30 Apr. 2020.

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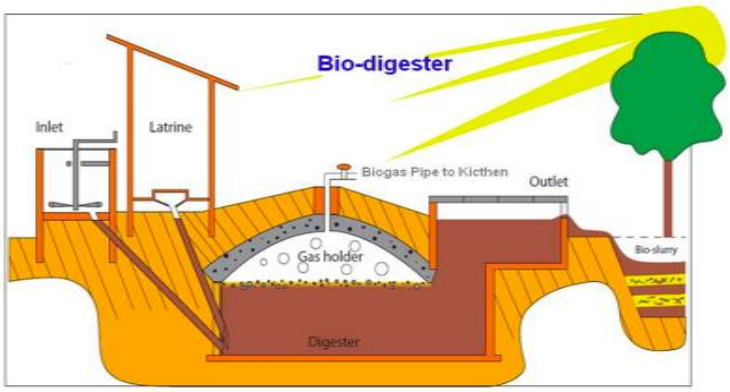
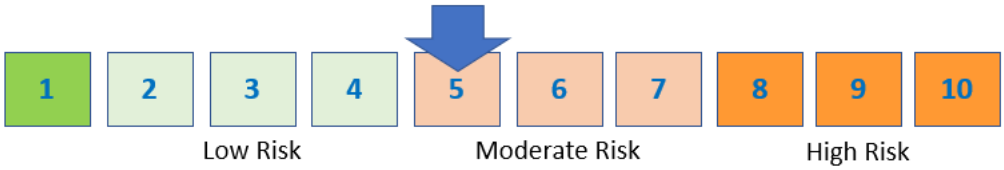


Figure 17: Domestic Biodigester Description in Ethiopia, Source: Kumar A .et al 2015[30]

Existing technologies are supplied by importers, mostly on demand. This is because there are limited to non-existent exclusive suppliers for the technology. And those who supply the market usually are cost-conscious and source cheaper technologies from China. These technologies are very cheaper and prevalent in Ethiopia but pose a challenge as they are often less reliable and of lower quality.

Luckily, the cost factor is greatly diminished for larger state-sponsored projects or multinational institutions as quality of technology is given a greater focus than costs. In addition, there are no significant utility/large scale systems that are established yet. Therefore, if the focus is on industrial level energy production by institutions or government contracts, the threat of other suppliers is sufficiently hedged.



1 absolute zero risk **2** low risk **3** straightforward operational solution **4** require strategic adjustment **5** moderate risk **6** straightforward operational solution **7** require strategic adjustment **8** high risk **9** straightforward operational solution **10** require strategic adjustment

3.4.5 Rivalry among existing competitors: Low

As Ethiopia is opening the power sector to Independent Power Providers (IPP) and presence of few proper competitors in the biogas sector means extremely low competition. However, rivalry might still exist with alternate RE competitors and as the sector is opened to more potential providers. Thus, having healthy competition will develop the energy sector of Ethiopia. The government of Ethiopia subsidies fuel as well as electricity.

[30] Kumar, A., Mandal, B. and Sharma, A., 2015. Advancement in biogas digester. In Energy sustainability through green energy (pp. 351-382). Springer, New Delhi.

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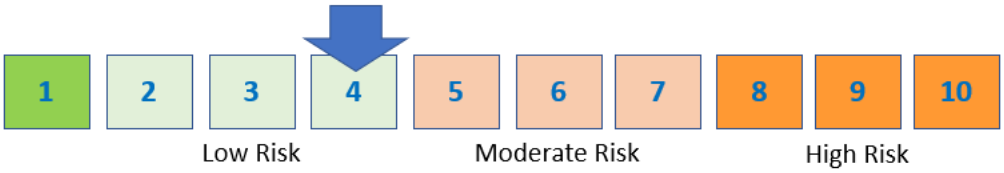
Table 11: Price of Fuel and Electricity in Ethiopia as of June 26, 2020[31]

Price of Fuel		
Commodity	**Price/liter - USD**	**Price/Gallon - USD**
Gasoline	0.630	2.385
Diesel	0.550	2.080
LPG	0.540	2.040
Price of Electricity (Dollar /kwh)		
Electricity	**Birr (Ethiopian Currency)/kwh**	**Dollar /kwh**
Up to 50 kwh	0.273	0.008
Up to 100 kwh	0.767	0.022
Up to 200 kwh	1.625	0.047
Up to 300 kwh	2	0.058
Up to 400 kwh	2.2	0.064
Up to 500 kwh	2.405	0.070
Above 500 kwh	2.481	0.072



1 absolute zero risk 2 low risk 3 straightforward operational solution 4 require strategic adjustment 5 moderate risk 6 straightforward operational solution 7 require strategic adjustment 8 high risk 9 straightforward operational solution 10 require strategic adjustment

3.5 Market Policies and Incentives

Regulations and policies: All proclamations regarding the power sector make it clear that the private sector can be engaged in all aspects of the electricity segments through the provision of licenses from EEA (Ethiopian Energy Authority). But the investment proclamation from 2002 reserves transmission and distribution for the public sector.

3.5.1 Regulators and regulations

The proper public authority to regulate the Power sector in Ethiopia is the Ethiopian Energy Authority (EEA). The authority has taken this mandate since 2013, after a proclamation to separate the Ethiopian Electric Power Corporation (EEPCO) into Ethiopian Electric Utility and Ethiopia Electric Power (EEP).

[31] Data of fuel and electricity price in Ethiopia were acquired from https://www.globalpetrolprices.com/ and http://www.eeu.gov.et/index.php/current-tariff

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Ethiopian laws are produced in two major steps. The House of Representatives examines and ratifies public *proclamations*; providing details on certain issues and assigning Council of Ministers or public authority to further develop *regulations*; to detail out implementation laws within the scope of the proclamations. Proclamations are publicly available, while regulations might not. In our analysis, we will focus on two important proclamations and corresponding regulations among others:

1. **Investment Proclamation - No. 1180/2020**
2. **Energy Proclamation - No. 810/2013**

Table 12: Ethiopia's Investment and Energy Proclamations

Investment Proclamation - No. 1180/2020	Energy Proclamation - No. 810/2013
- Increasing the role of private sector investment in all sectors become necessary to accelerate the economic development of the country to enhance the competitiveness of the national economy by promoting investments. - License issuance, renewals, amendments etc. are done by the Ethiopian Investment Commission except for the generation and transmission of electricity, where the EEA has the mandate - Provides incentives at different levels to energy investments as well	- Establishes and gives authority to the Ethiopian Energy Authority - Mandate includes issuing and renewing licenses; supervise and regulate investments; provide review and recommendations for grid tariffs among others - Also approves electric power purchase and network service agreements - Recently partly amended with Proclamation No.1085/2018

Setting up an energy plant: every foreign or local company engaged in energy production needs a license. It is advisable for any investor to review the complete regulations; access links to more detailed and comprehensive information are provided in later sections.

3.5.2 Incentives

More than ever, Ethiopia is realizing and opening several sectors previously held by the government to the private sector. The Ethiopian Investment Commission issues the investments and services below for any investor engaged in the generation of Energy[32].

I. **Income Tax Exemption (up to 5 years)**: Business Income Tax exemption in Electricity generation, transmission and distribution can go up to five years. This will be reduced by one year if investment is in Addis Ababa and the Special Zone of Oromia surrounding Addis Ababa. In addition, loss incurred during the income tax exemption period can be carried forward for half of the exemption period after expiry, the maximum limit being five income tax periods.
II. **Customs incentives**: customs incentives include exemptions from customs duties and other taxes (VAT, surtax, withholding and excise tax) on

[32] "Incentive Package - Ethiopia Investment Commission." http://www.investethiopia.gov.et/index.php/investment-process/incentive-package.html. Accessed 30 Apr. 2020.

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A. Imported capital goods (Machinery, equipment necessary to produce product)
B. Imported construction materials (inputs necessary for the construction of investment projects)
C. Imported spare parts (limit of five years from the date of issuance of business license, and the value should not be more than 15% of the total value of the capital goods.
D. On vehicles for work (type and number of vehicles that can be imported duty free varies depending on investment sector, size, nature, and location of investment)

The Investment commission also provides facilitation and aftercare services to support successful implementation of projects. It is believed that these incentives could assist any investor in minimizing the risk and reducing duty and tax costs.

Furthermore, several non-governmental institutions and financiers such as the World Bank (IFC) also have guarantee schemes for investments in RE as shown briefly below.

Exhibit: World Bank - Renewable Energy Guarantees Program (Fiscal Year (FY) 2018 – FY 2020)

The World Bank's Board of Executive Directors approved a $200 million Renewable Energy Guarantees Program (REGREP) to mobilize International Development Association (IDA) guarantees under a Multi-phased Programmatic Approach (MPA). The program will support the Government of Ethiopia's on-going power sector reforms and leverage private sector financing for renewable energy generation. The Ethiopian government received the money as a long-term loan. The government of Ethiopia through development bank of Ethiopia. Development Bank of Ethiopia borrows this money for those who want to work on renewable energy sectors, and they will return the money with 4 – 5 years. The following requirement must be fulfilled to get the loan: License, Company Address and Location, Marriage Certificate/Sole Proprietorship, Track Record, Management (Company General Manager & Project Manager), Collateral and Support Letter from Ministry of Water Irrigation & Energy about the Technology.

Guarantee: US $10 million equivalent

Source: The World Bank Group[33]

Links to important Proclamations and Resources:

- https://chilot.me/2020/04/council-of-ministers-energy-regulation-no-447-2019/2/
- https://chilot.me/wp-content/uploads/2014/09/proclamation-no-810-2013-energy-proclamation.pdf
- http://www.ethiopia.gov.et/-/federal-negarit-gazeta-establishment-proclamation
- https://chilot.me/2020/04/investment-proclamation-no-1180-2020/

[33] "Official PDF, 110 pages - World Bank Documents." 23 May. 2019, http://documents.worldbank.org/curated/en/363131558922556843/pdf/Ethiopia-Renewable-Energy-Guarantees-Program-Project.pdf. Accessed 1 May. 2020.

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3.6 Resources

3.6.1 Natural Resources: Feedstock availability & Characteristics

Although aggregated and accurate data is very difficult to find, several reports indicate that Ethiopia's biomass energy resource potential is considerable. This report has summarized and discussed key information on availability and characteristics of available feedstock with a focus on crop residues (agri-crops), animal manure, woody biomass, municipal solid waste, and wastewater. For each type of feedstock, geographic distributions, power yields and their value chain are discussed as much as the availability of information.

3.6.1.1 Woody Biomass

Most of the energy use for Ethiopia, as discussed above, comes from sustainable use of woody biomass; and research shows there is a large potential. According to estimates by **Woody Biomass Inventory and Strategic Planning Project (WBISPP)**, national woody biomass stock was 1,149 million tons with an annual yield of 50 million tons in the year 2000.[34] Thermochemical conversion technologies (Combustion, gasification and pyrolysis) is a recommended technology to generate energy from woody Biomass (Panwar et.al, 2012).[35]

Regarding the regional distribution of biomass energy resources, Energypedia provides the following analysis: "The northern highlands and eastern lowlands have lower woody biomass cover. The spatial distribution of the "deficit" indicated that areas with severe woody biomass deficit are in eastern Tigray, East and West Harerghe, East Shewa and East Wellega Zones of Oromiya and Jigjiga Zone of Somali Region. Most of Amhara Region has a moderate deficit but a small number of Woredas along the crest of the Eastern Escarpment have a severe deficit".

[34] "Ethiopia Energy Situation - energypedia.info." Accessed May 3, 2020. https://energypedia.info/wiki/Ethiopia_Energy_Situation.

[35] Panwar. et. al, 2012. Thermo chemical conversion of biomass – Eco friendly energy routes. Journal of Renewable and Sustainable Energy Reviews 16 1801-1916. http://www.debiq.eel.usp.br/aferraz/Tecnologia%20de%20convers%C3%A3o%20de%20biomassa/aula%2013%20review%20com%20algumas%20fotos%20e%20desenhos%20de%20reator.pdf

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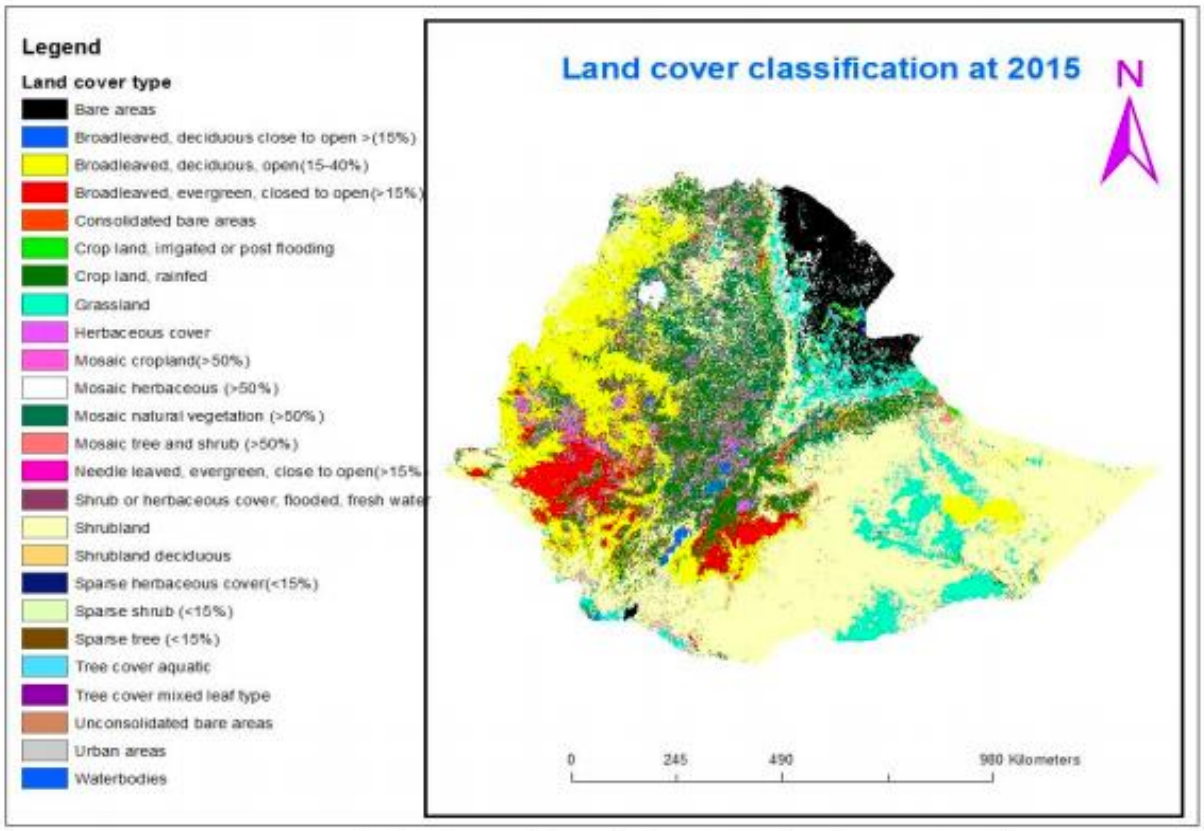

Figure 18: Ethiopia's Land Cover Classification Source: ICPAC, 2015[36]

The annual volume of wood harvested for wood fuel was around 120.4 million m^3 of roundwood equivalent in 2015, and in 2035 it will reach 157.79 million m^3. Currently, more than 90% of the domestic supplies of fuel wood come from diverse sources such as natural high forests and woodlands, industrial plantations, and private forests (trees outside forests including woodlots). To fill the indicated gap, there is a great need to establish additional fuelwood plantations across the country[37].

3.6.1.2 Crop Residue (Agri-residues)

There is an energy production potential from agro-processing industries (processing sugar cane bagasse, cotton stalk, coffee hull and oil seed shells). Up to date, no grid-connected biomass power plants exist. According to the global methane initiative report (2011),[38] agricultural waste in Ethiopia is estimated at 15 - 20 million tons and only ~6% is exploited. Below is a review of potential crops for biogas development.

[36] Ethiopian Land Cover 2015, http://geoportal.icpac.net/layers/geonode%3Aethiopia_landcover2015_4
[37] "Ethiopia - UN Environment Document Repository Home - UNEP." 4 Nov. 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/30564/GBEPEthiopia.pdf?sequence=1&isAllowed=y. Accessed 3 May 2020.
[38] Global Methane Initiative, 2011. Ethiopia Methane Emissions from Agricultural Waste Country Resource Assessment, 2010. https://www.globalmethane.org/documents/ag_ethiopia_res_assessment.pdf.

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Conversion
Total consumption of agricultural residues as a biomass fuel was around 19.7 million tons per year in Ethiopia in 2013 (Geissler et al. 2013). A biogas yield of 0.3-0.6 m^3 /kg is mostly reported for cereal crop residues (Rajendran et al. 2012).

Sugar cane Vinasse: The country is said to have high potential for biodiesel production and has been producing biofuel from its large sugar plantations. The current biofuel development strategy in the country emphasizes the production of bioethanol from sugar beet, sugar cane, sweet sorghum and others, and biodiesel from jatropha, castor bean plants, and palm (MoME 2007). However, Biogas can be produced from sugar cane vinasse since in Ethiopia it has not been used for Biogas production[39].

Previously, there was only one biofuel factory in Ethiopia, a power alcohol plant that has been producing bioethanol as a by-product at Finchaa Sugar Factory. Several sugar factories have, however, been using sugar cane bagasse for station supply since the 1950s. Considering one of the sugar cane factories, i.e. Wonji sugar factory, currently it is generating 31 MW of electricity from dried bagasse.

Although the recently launched Climate Resilient Green Economy (CRGE) strategy of Ethiopia (2011) envisages 5% biodiesel blending in transport fuel by 2030 (FDRE 2011), biodiesel blending in transport fuel has not yet started in Ethiopia. As part of the planned large-scale expansion in the sugar industry that is stipulated in Ethiopia's national Growth and Transformation Plan (GTP), the country also aims to produce large amounts of bioethanol from sugar by-products (from molasses). In addition, constructing bioethanol plants in conjunction with existing and upcoming sugar factories is underway. According to the Survey data is obtained from a biofuels investment survey in Ethiopia conducted by Environmental Economics Policy Forum for Ethiopia (EEPFE) at the Ethiopian Development Research Institute (EDRI) in 2010, there are about 15 biofuels companies, including NGOs, involved in biofuels production in Ethiopia (Ferede Tadele et. Al, 2013)[40].

Coffee farms and coffee processing waste: Ethiopia is known to be the origin of and gene pool for Coffee Arabica. In the last decade, Ethiopia has been the largest coffee producer in Africa, and it remains fifth in the world, contributing a share of about 4.5% to the world production. A potential conversion and analysis for the coffee farm biogas case was conducted by Chala and Ochsner in 2018.[41] Below is an excerpt from the main findings that shows the potential for husk, pulp, parchment, and mucilage.

"The dry method generates husk as a by-product, while the wet method generates pulp, parchment, mucilage, and wastewater. In this study, characterization, as well as the potential of husk, pulp, parchment, and mucilage for methane production were examined in biochemical methane potential assays performed at 37 ◦C. Pulp, husk, and mucilage had similar cellu-

[39] Dametie, A., Fantaye, A. and Teshome, Z., 2014. Estimating effect of vinasse on sugarcane through application of potassium chloride at Metahara Sugarcane Plantation. Advances in Crop Science and Technology.
[40] Ferede, Tadele, et al. Biofuels, Economic Growth, and the External Sector in Ethiopia: A Computable General Equilibrium Analysis. Environment for Development Initiative, 2013, www.jstor.org/stable/resrep14980. Accessed 10 June 2020.
[41] "Biogas Potential of Coffee Processing Waste in Ethiopia - MDPI." Accessed May 3, 2020. https://www.mdpi.com/2071-1050/10/8/2678/pdf.

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lose contents (32%). The lignin contents in pulp and husk were 15.5% and 17.5%, respectively. Mucilage had the lowest hemicellulose (0.8%) and lignin (5%) contents. The parchment showed substantially higher lignin (32%) and neutral detergent fiber (96%) contents. The mean specific methane yields from husk, pulp, parchment, and mucilage were 159.4 ± 1.8, 244.7 ± 6.4, 31.1 ± 2.0, and 294.5 ± 9.6 L kg−1 VS, respectively. The anaerobic performance of parchment was very low, and therefore was found not to be suitable for anaerobic fermentation. It was estimated that, in Ethiopia, anaerobic digestion of husk, pulp, and mucilage could generate as much as 68 × 106 m^3 methane per year, which could be converted to 238,000 MWh of electricity and 273,000 MWh of thermal energy in combined heat and power units. Coffee processing facilities can utilize both electricity and thermal energy for their own productive purposes. "

3.6.1.3 Animal Manure

Ethiopia's livestock population is considered the largest in Africa and the tenth largest in the world. The sector accounts for around 10% of Ethiopia's export income, with leather and leather products constituting around 7.5% and live animals 3.1%. The country is home to about 17 million head of sheep, 22 million head of goats, 49 million head of cattle and 38 million chickens (Deressa T.T., 2007)[42]. The National Biogas Energy Program reported that each head of cattle can generate 5 kg of dung daily (only collectable out of dung generated in a shed). The average dung generation of a household was estimated to be 30 kg/day (6x5 kg) while the average dung utilization of households for bio digestion was 20 kg day.[43] The biogas yield of cow's dung is influenced by the type of feed and the digester's process conditions (Zinoviev et al. 2010). Seyoum (2018) reported that 2.83 m^3 of biogas can be produced daily by loading 45 kg of dung daily into a 6 m^3 SINIDU model biogas digester in Ethiopia. Biogas production also depends on the size of the biodigester. Below are estimated gas productions for certain sizes of plants from dung.

Table 13: Ethiopia's Biogas Plants from Animal Manure (Workneh and Eshete, 2008).[44]

Plant size (m^3)	Daily fresh dung (kg)		Daily water (L)		No. of cattle required		Min estimated gas production (L)		Min estimated stove hrs (400 L/h)	
	min	max	min	max	min	max	min	max	min	max
4	20	40	20	40	4	8	680	1 600	1.7	4.0
6	30	60	30	60	6	12	1 020	2 400	2.6	6.0
8	40	80	40	80	8	16	1 360	3 200	3.4	8.0
10	50	100	50	100	10	20	1 700	4 000	4.3	10.0

Among the regions selected by the government´s national biogas program four major regions in Ethiopia have been prioritized: Oromia, Amhara, SNNPR (Southern Nations, Nationalities,

[42] Deressa, Temesgen Tadesse. Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach. The World Bank, 2007. https://openknowledge.worldbank.org/handle/10986/7290

[43] "The Economics of Biodiesel Production in East Africa: The ...." Accessed May 3, 2020. https://efdinitiative.org/publications/economics-biodiesel-production-east-africa-case-ethiopia.

[44] Workneh, K. and Eshete, G. (2008). National Biogas Programme Ethiopia, programme implementation document. Ethiopian Rural Energy Development and Promotion Centre. http://www.bibalex.org/search4dev/files/338816/172299.pdf

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and Peoples' Region) and Tigray.[45] The rationale for starting in these four regions is based on several factors:

a. the four regions have most of the human (>70%) and livestock population (~ 70%);
b. the loss of vegetative cover because of severe deforestation, resulting in a huge rural household energy imbalance;
c. the regions' status with regard to educated human resources and technology adoption experience;
d. the availability of relatively well documented information;
e. Most of the woody biomass consumed as a fuel in the highland areas of Ethiopia

However, the program has expanded to include more regions and city administrations. In this regard, the technical potential included an analysis of the rural or national water coverage, as well as cattle ownership of the average smallholder household. See table below.

Table 14: Details of Ethiopia's National Biogas Programme, Source: Eshete and Camilla 2007[46]

Region/City	Total households with 4 and above heads of cattle	Technical Potential (Discounted depending on water availability)	
		Minimum (Rural access to safe water=23%)	Maximum (National water coverage=68.45%)
Afar	65,792	15,132	Afar
Amhara	1,663,170	382,529	Amhara
Benishangul-Gumuz	53,530	12,312	Benishangul-Gumuz
Gambela	16,842	3,874	Gambela
Oromia	2,467,361	567,493	Oromia
SNNP	1,164,894	267,926	SNNP
Somali	58,357	13,422	Somali
Tigray	436,231	100,333	Tigray
Harari	6,005	1,381	Harari
Dire Dawa	4,612	1,061	Dire Dawa
Ethiopia	**5,936,794**	**1,365,463**	**Ethiopia**

Feedstock Production Possibilities: Ethiopia is a country with a total land mass of 1.2 million

[45] "Ethiopian National Biogas Program." http://www.bibalex.org/Search4Dev/files/284294/116537.pdf. Accessed 3 May. 2020.
[46] EREDPC. (2007): "National Biogas Programme, Ethiopia: Biogas for Better Life, Brief Programme Profile." http://www.bibalex.org/Search4Dev/files/284294/116537.pdf

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km^2 and is said to have an estimated potential area of about 25 million hectares of land suitable for the production of feedstock[47].

3.6.1.4 Municipal Solid Waste & Wastewater

The municipal waste generated from Addis Ababa city of Ethiopia is sent to Reppie Waste-to-Energy plant. The plant has a daily capacity of 1,400 tonnes of municipal waste, representing an annual waste-disposal capacity of 420,000 tonnes. The plant is generating 25 MW of net electricity.[48]

Addis Ababa has two secondary sewage treatment plants.[49] The first one, called Kality treatment plant, runs under its designed capacity of 7,600 m^3/day. The other treatment plant, called Kotebe treatment plant, receives only sludge from vacuum trucks that empty septic tanks, with an estimated annual volume of 85,000 m^3 (NEDECO, 2002).

3.6.1.5 Organic Waste

Based on the report (Negede, B. M., & Eremed, W. B, 2018) report, around 44,000 tons of organic waste is generated daily in Ethiopia. The estimated electricity generation from organic waste based on their report was 430.4 MW.

3.6.1.6 Water hyacinth

Water hyacinth (Eichhornia crassipes), locally known as 'Enboch', is an invasive aquatic weed plant with broad, thick, glossy, ovate leaves and breeds very quickly. The weed adversely affects the environmental such as river blockages, biodiversity loss, and fish endangerment due to depletion of the amount of dissolved oxygen in the water. Water hyacinth floats in water due to presence of large air cavities in the parenchyma tissue called Aerenchyma. Thus, it covers a large area of water surface, reduce underwater light intensity and hinder air exchange at the water-air interface, thus negatively affecting water ecosystem.

Lake Tana is one of Africa's most unique aquatic ecosystems and the source of 50 % of Ethiopia's freshwater . Since June 2015, Lake Tana designated as a World Heritage site by UNESCO for its unique ecological biosphere reserve. The weed is introduced to the lake in 2011 and now covers about 40 thousand hectares. Water hyacinth in Lake Tana is destroying the fishery industry, destroying maize, Cereal crops, making cattle sick and creating serious environmental imbalance. One hectare of water hyacinths could produce sufficient biomass to generate approximately 58,400 m^3 of biogas containing 35,100 m^3 of methane.[50]

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[47] "Bioenergies in East Africa (PDF file) - ENERGY AGRO-FOOD." http://www.edulink-energyagrofood.eu/wp-content/uploads/2016/10/eBook-Bioenergies-in-East-Africa.pdf. Accessed 3 May. 2020.

[48] Adebe, M.A., 2018. Challenges of Waste to Energy Facility in Reppi (Koshe), Addis Ababa City. International Research Journal of Pharmacy and Medical Sciences, 1(4), pp.9-16.

[49] "Wastewater production, treatment and agricultural use in ...." Accessed May 3, 2020. https://www.ais.unwater.org/ais/pluginfile.php/231/mod_page/content/188/ethiopia_country_report.pdf.

[50] Ofoefule, A.U., Uzodinma, E.O. and Onukwuli, O.D., 2009. Comparative Study of The Effect of Different Pretreatment Methods on Biogas Yield from Water Hyacinth (Eichhornia Crassipes).

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3.6.1.7 Sewerage wastes

The metro area population of Addis Ababa in 2019 was 4,592,000, a 4.36% increase from 2018.[51] Thus, the city has an enormous amount of sewerage waste. Thus, considering one of the Water treatment facilities at the outskirt of the city, Kaliti Waste Water Treatment Plant, installed and managed by Addis Ababa Water and Sewerage Authority Treatment Plant, the plant has a maximum Biogas production capacity of 542 Nm^3/h with Maximum daily water treatment capacity of 100,000 m^3/day.

3.6.1.8 Industrial park waste

Around 55,500 m^3/day waste is generated from Industrial park of Ethiopia and about 16,965 Nm3/day can be generated.

3.6.1.9 Abattoir waste

Addis Ababa Abattoirs Enterprise of Ethiopia (Kera): This is the largest abattoir in Ethiopia, and it is located in the capital city, Addis Ababa near a location called Kera. Annually, it discharges 27,922,200 kg untreated waste to the environment which is comprise of an estimated 48,240 kg/day of intestinal matter alone and 12,060kg/day of blood[52] and approximately 184,285m^3 Biogas can be generated.

Table 15: Abattoir Waste in Ethiopia

No.	Types of Waste	Daily Waste Generation	Estimation of Biogas Potential
1	Organic Waste	44,000 tonnes/day	430.4 MW[53] of electricity generation potential.
2	Water hyacinth or Enboch	40 thousand hectares of Lake Tana is covered by Water hyacinth in Ethiopia[54]	1-hectare Water hyacinth ≈ 58,400 m^3 of biogas containing 35,100 m^3 of methane[55]
3	Kaliti Wastewater Treatment Plant of Addis Ababa, Ethiopia	Maximum daily water treatment capacity of 100,000 m^3/day.	Maximum Biogas production capacity of 542 Nm^3/h

[51] https://www.macrotrends.net/cities/20921/addis-ababa/population

[52] Genet Tsegaye, Optimization of Biogas Production from Slaughterhouse Waste and Digester Sizing: A case in Addis Ababa Abattoirs Enterprise,2016

[53] Negede, B. M., & Eremed, W. B. Renewable Energy for Climate Change Mitigation: An Overview of Biogas Energy in East Africa. *Bioenergies in East Africa between challenges and opportunities*, 15.

[54] Dersseh, M.G., Kibret, A.A., Tilahun, S.A., Worqlul, A.W., Moges, M.A., Dagnew, D.C., Abebe, W.B. and Melesse, A.M., 2019. Potential of Water Hyacinth Infestation on Lake Tana, Ethiopia: A Prediction Using a GIS-Based Multi-Criteria Technique. *Water*, *11*(9), p.1921.

[55] Ofoefule, A.U., Uzodinma, E.O. and Onukwuli, O.D., 2009. Comparative Study of The Effect of Different Pretreatment Methods on Biogas Yield from Water Hyacinth (Eichhornia Crassipes.

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4	Coffee Husk	In Ethiopia 192, 000 metric tons of coffee is Husk cast adrift as by product per year.[56]	68 Mm^3methane per year, which could be converted to 238,000 MWh of electricity and 273,000 MWh of thermal energy in combined heat and power units can be generated from coffee husk, pulp, and mucilage[57].
5	Industrial park waste	55,500 m^3/day is generated	16,965 Nm^3 Biogas/day
6	Abattoir waste (Kera Abattoir, i.e. the largest Abattoir in Ethiopia)	27,922 tonnes/year	184,285 m^3 Biogas

3.6.2 Human Resource - availability and Characteristics of Skills

There are many engineering and technical trainees graduating from technical and engineering institutions. Most are looking for a job and are easily trainable with technologies like biogas. However, specific biogas technology training and skill sets need to be done by developers or trained as part of the national biogas program. One key technical skill supply for the biogas industry is the Technical & Vocational youth graduates in Ethiopia.

3.6.2.1 Technical Vocational Education Training Programs (TVET):

Every year around 936,304 graduates are searching for work[58]. The government also has extensive training programs to prepare youth for employment and self-employment. By concentrating on connecting skills development with job opportunities in an integrated manner, young men and women will be supported to find a decent job, take control of their lives, and build better prospects for themselves, their families and their communities.

Despite the 30/70 policy that states 30% of TVET education should be theoretical, and 70% should be practical, the TVET education remains highly theoretical. As such, the practical skills demanded in the labour market are not sufficiently taught. Key informants highlighted that particularly the higher technical skills, such as machine operation, are lacking. Consequently, expensive labour is at times brought in from abroad for machine operation and middle- and higher management jobs.

3.6.2.2 Selam Technical Vocational Training Centre

Based in Addis Ababa, Selam is a leading Technical Vocational Training Centre, with a significant production capacity. Inspired by Christopher Kellner, Selam embarked up on biogas technology some 30 years ago. The Centre mainly constructs larger fixed dome installations (up

[56] Awoke, W., Coffee Husk Highly Available in Ethiopia as an Alternative Waste Source for Biofuel Production.
[57] Chala, B., Oechsner, H., Latif, S. and Müller, J., 2018. Biogas potential of coffee processing waste in Ethiopia. Sustainability, 10(8), p.2678.
[58] Federal Democratic Republic of Ethiopia Ministry of Education (2019). Education Statistics Annual Abstract 2011 E.C. (2018/19).

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to 200 m^3), turn-key, for the bio-industry around Addis Ababa, but they have been involved in some domestic installations as well. Selam operates three biogas plants on its own premises. In general, Selam, over the past 30 years or so, has built a solid reputation on quality and this shows in their biogas plants (Eshete, Sonder and Heegde 2006).

3.6.2.3 Capacity Building Programs

NPBE Program Training: as part of the government's national biogas program, the government provides training to local Biogas Construction Enterprise (BCE) together with SNV as its partners. The program also provides training to users of household Biogas systems and technical masons.

- **Biogas constructors (Masons) and local district energy expert trainings**: District technicians (*Woreda* in Ethiopia, is the third-level administrative divisions of Ethiopia) are the most important actors in serving the biogas users at grassroots level, as they are at the lowest structure of the program and have direct contact with biogas users. Several biodigesters have been constructed by masons in the different regions of Ethiopia. However, the fact that there is limited use and supply of technology means the masons cannot fully rely on maintaining digesters and must find additional work in other machine maintenance areas. Existing technicians also need training skill enhancement to better serve the biogas users.
- **User training**: 2 days pre-construction and post- construction use training. The topics include operating biogas (93%), using biogas co-products (90%), advantages of biogas technology (89%), maintaining and troubleshooting biogas problems (63%) and obtaining assistance from biogas service providers (61%).
- **After-Sales Service**: after-sale services have also been emphasized including proper instruction of the user on the operation of the plant and maintenance as well as a guarantee of one year on appliances and two years on the civil structure of the plant.

3.6.3 Infrastructure and Support Industry

Ethiopia has come a long way to achieve its industrialization agenda of becoming a middle-income country by 2025. The industrialization movement has built and commenced operation to boost manufacturing and agricultural processing. Below are important industrial developments with possible ties with biogas project developments.

3.6.3.1 Industrial Parks

The Ethiopian Investment Commission provides the overview on Ethiopia's industrial park development project, provided below[59].

> **Overview:** With the vision to make Ethiopia a leading manufacturing hub in Africa by 2025, the Government of Ethiopia had placed a high focus on industrial park development and expansion. The GoE has so far constructed and operationalized over 20

[59] "INTEGRATED AGRO-INDUSTRIAL PARKS (IAIPS) IN ... - UNIDO." https://www.unido.org/sites/default/files/files/2018-08/Integrated-Agro-Industrial-Parks-in-Ethiopia-booklet.pdf. Accessed 3 May. 2020

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state-of-the-art industrial parks which are located along key development corridors – each with a distinct specialty in priority sectors.

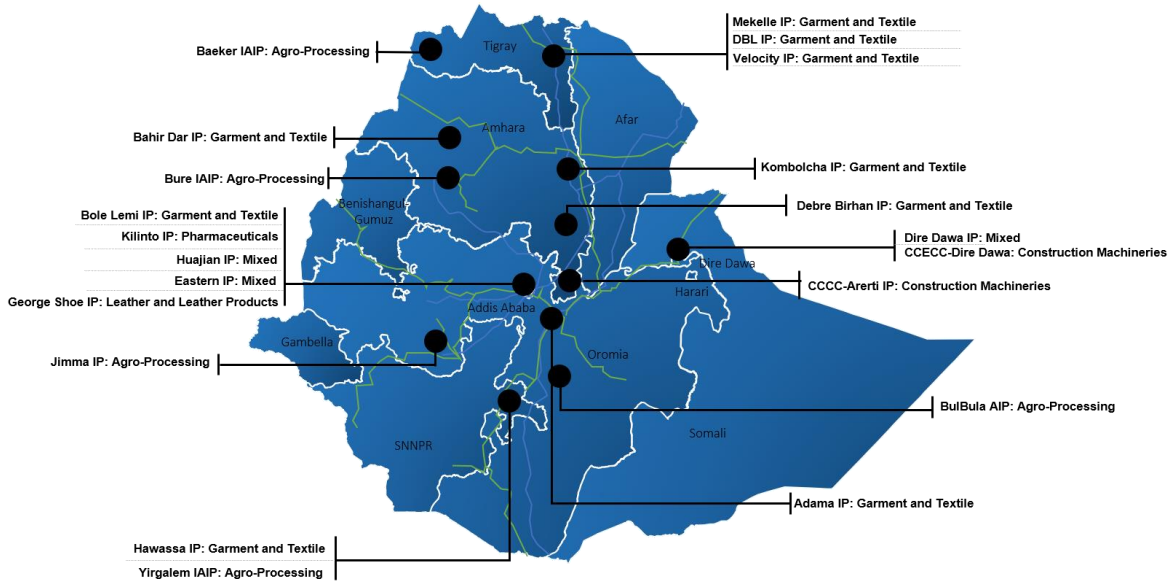

Figure 19: Industrial Parks in Ethiopia

Opportunity: All industrial parks require waste treatment facilities which presents a potential partnership. The sustainability wing of the parks requires maintaining high environmental standards through the utilization of environment-friendly technologies, zero liquid discharge systems and other socially sustainable facilities such as housing accommodations for staff through various loan schemes, etc.

3.6.3.2 Integrated Agro Industrial Parks in Ethiopia

According to United Nations Industrial Development Organization (UNIDO), an integrated agro-industrial park (IAIP) is a geographic cluster of independent firms grouped together to gain economies of scale and positive externalities by sharing infrastructure and taking advantage of opportunities for bulk purchasing and selling, training courses and extension services[60]. IAIPs will include open area production zones, controlled environment growing, precision farming, knowledge hubs and research facilities, rural hubs, agri-infrastructure, collection centres, primary processing hubs, social infrastructure, and agri-marketing infrastructure, among others.

Opportunity: agricultural waste from the parks would present a centrally available feedstock for a biogas plant.

[60] "INTEGRATED AGRO-INDUSTRIAL PARKS (IAIPs) IN ... - UNIDO." https://www.unido.org/sites/default/files/files/2018-08/Integrated-Agro-Industrial-Parks-in-Ethiopia-booklet.pdf. Accessed 3 May. 2020.

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3.6.3.3 Infrastructure in Ethiopia

Ethiopia has invested extensively on infrastructure including roads, railway systems to port (Djibouti) and is home to a world class Airline, Ethiopian Airlines. Below is a summary of the key infrastructure in Ethiopia[61]:

- Power production has increased steadily over the last ten years, with 99% sourced from clean energy in the form of hydropower. Ethiopia has the second largest hydropower potential in Africa (Deloitte, 2014), and the country's installed electricity generating capacity is expected to reach 10,000 MW by mid-2015. The Grand Ethiopian Renaissance Dam – the largest hydroelectric power dam in Africa being built on the Nile river - is expected to generate 6,000MW electricity. This coupled with Gilgel-gibe III (1,870MW) and Genale-Dawa III (254MW) and other wind power projects will make Ethiopia a regional powerhouse.
- Cheapest electricity rate in Africa and the whole world.
- Expanding and improving telecommunication service.
- Expanding road networks connecting national and regional markets.
- Newly built Addis-Djibouti electric-powered railway - making access to port Djibouti much easier. Other standard gauge networks (A standard-gauge railway is a railway with a track gauge of 1,435mm) mare in pipeline. As a significant portion of Ethiopia's import/export trade passes through port Djibouti, the railway construction is a huge efficiency enhancer for producers and traders. As part of this big project, a 34 km Addis Ababa light rail is operational while a new 756 km Addis Ababa-Djibouti electrified railway route was completed in 2016.
- Africa's world class and star alliance member Ethiopia Airlines´ passenger network covers more than 90 international destinations in the five continents in Africa, Asia, Europe, South- and North America. As an African Airline, Ethiopian Airlines flies to more than 50 destinations in Africa alone.

[61] Team, T., 2011. Federal democratic republic of Ethiopia country strategy paper.

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