Biogas Markets and Frameworks in Argentina, Ethiopia, Ghana, Indonesia, and South Africa

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Executive Summary of D3.3

Republic of Argentina

In Argentina, the biogas market has gained a solid foothold over the last five years and is massively industrial. However, its growth is slowing down. In 2015, Argentina has developed 100 biogas plants and has grown exponentially until 2020 through the RenovAr Programme. In 2015, INTA and PROBIOMASA have conducted a survey assessing 80 of the 100 plants built nationwide. INTA and PROBIOMASA have found that from the 80 plants surveyed, 76 of the 80 biogas plants developed up until 2015 were installed for environmental purposes, while 11 of the 80 biogas plants surveyed were utilised for energy development, consisting of large bio-digestion plants (1MW-2MW), consisting mostly of covered lagoon and mixed technologies utilising digesters, double membrane reactor, and a co-generation unit i.e. combined heat and power (CHP). It must be noted that at that time biogas was not widely used as a source of energy, rather, it was used for environmental purposes. The relatively slow growth of the biogas market until 2015 is also indicated by the low rate of biogas utilisation for the means of energy security. It is also worth highlighting that the dominating feedstock utilised for biogas in Argentina is industrial waste, followed by organic waste and virgin biomass.

To accelerate the growth of the biogas market, Argentina has been implementing government-led programs. The most notable program is the series of RenovAr programs i.e. round 1, round 1.5, and round 2) that was started from 2016 and continues until today with RenovAr 3 being implemented in August 2019. According to the World Bank IFC, RenovAR has succeeded in reaching 2.4 GW capacity of combined renewable energy alternatives in the end of 2016 and 4.4 GW of renewable energy projects in August 2017. The tenders foresee a minimum of 0.5 MW and a maximum of 10 MW of electricity capacity from each biogas project to achieve the overall goal. All in all, this program and national goal shows that biogas is seen as an important renewable energy alternative in Argentina.

It must also be noted that each country included in this report elaborates on a minimum of four variables of the PESTLE's framework depending on the degree of its relevancy and influence it has for the biogas sector. For Argentina, key national aspects that are most relevant and important for the biogas sector in the country are the following:

- ***Political:*** *Argentina's governance relies heavily on its decentralised system*, where provinces have a major role in enacting laws and legislations—fulfilling the minimum standards set by the national government. According to Transparency international, Argentina has an average corruption perception index of 44/100 in 2018 and has improved slightly in 2019 with a score of 45, ranking 66th worldwide in 2019.
- ***Economic:*** *Argentina has undergone additional economic adversity since the monetary crisis triggered in April 2018, adding to the already concerning economic condition prior to 2018.* The effects of this monetary crisis still persist today, with chronic governmental deficit causing foreign debt and massive inflation valued at 34.277 in 2018 and 53.548 in 2019 according to the World Bank. This rather fragile situation coupled with the recent health crisis triggered by the corona virus has heavily impacted the investment confidence level—with the country risk index categorised as CRT-5 by A.M. Best

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Company (2019)[1]. However, Argentina remains a major player in the global economy, especially concerning its agricultural production. This focus on agricultural production is also reflected in the industrial sector, which is still expanding, and represents 23% of GDP in Argentina. The industrial sector has as its main industries flour-milling, flour grinding and canning, and meat packing. These and other agro-industrial industries are potential feedstock sources for biogas production.

- ***Social:*** Due to the historical volatility of the economy, the country has prioritised social spending. However, taxes for pensions, cost for health care, and labor taxes remain high. Familial ties influence how business is conducted in the country and must be considered when conducting business in Argentina. Furthermore, Argentina also has a pool of highly skilled and trained experts supported by the quality education system.
- ***Technological:*** *Argentina ranks high in technological development regionally and globally*, with software development and data science being in the forefront. Argentina's government is also known for being tech-savvy, and the Argentinian technology community plays a major role in pioneering and contributing to the advancement of new technologies.
- ***Environmental:*** Awareness for sustainable development is high in Argentina, especially in the agriculture sector e.g. soybean production. In the business sector, social enterprise responsibility and certification schemes are prominent, and technological evolution has yielded improvements in the preservation of the environment. A list of these improvements for the agricultural sector is included in Argentina's section 2.1.5. *Regulations for environmental protection, also for biogas plants, are authorised by the provincial government.* However, provincial budget constraints are a challenge for provincial governments to implement the relatively strict environmental protection rules. This budgetary limitation calls for the dictation of a technical-regulatory guide which elaborates minimum environmental conditions for bioenergy plants (e.g. regulations for final use of digestates to reduce digestion costs).

For this report, Argentina's biogas sector was assessed based on Porter's Five Forces analysis (see introduction section). Strength and weaknesses of the biogas industry in Argentina, along with its level of competitiveness were analysed through categorisation of the following chosen variables:

- *Competition in the industry has been increasing steadily over the last four years* as can be seen in the extensive list of influential actors provided within the narrative. This calls for strategic adjustments for new entrants to mitigate moderate risks.
- *New Entrants in the industry should consider operational solutions based on assessments on available local technologies and materials, or conversely—components that are less likely to be sourced locally. For new entrants in the industry, there are not many suppliers for engines and generators in Argentina and thus this offers good market opportunities.* Other biogas-related technologies that can offer many opportunities for existing or new market participants are biogas upgrading, digestate upgrade into high value products, digestate use and application, as well as heat recovery and use.

[1] More on the report by A.M Best on Argentina's country risk based on Economic, Political, and Financial variables: http://www3.ambest.com/ratings/cr/reports/Argentina.pdf

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- *The bargaining power of suppliers is heavily influenced by the macroeconomic instability.* Incentives are available for national providers providing domestically produced components implemented in the plants—therefore increasing the bargaining power of technology suppliers. *Economic instability and the lack of incentives for foreign suppliers pose a high risk which requires strategic adjustment.*
- *The bargaining power of customers poses a moderate risk for new entrants.* This is due to the increasing ability of customers to drive the price lower as local options for technology and management increases and projects compete based on the lowest price of energy generated. Furthermore, due to currently high interest rates and inflation in Argentina, there is a drive to lower initial investments.
- *The threat from substitute products was ranked with a moderate risk, new entrants should consider strategic adjustment.* There is pressure from the competition between biogas and other renewables due to consistent cost reductions, for example, for PV and wind technologies. However, additional potential market opportunities that can be subject to extensive efforts are available e.g. in the development, application, and use of digestate, farm machinery industry for application of organic fertilizers, and solid phase digestate which is important for the dairy business.

Incentives for biogas projects in Argentina are strong. These incentives are administered through the RenovAr Program, MATER mechanism stipulated through Government Resolution MeyM 281-E/2017, and the incentive for renewable energy installers to save electricity costs as stipulated in Law No. 24,424 (2017), elaborated below:

- *The RenovAr Program started in 2016 (an overhaul of the previous GenRen Project) was implemented to attract investments for renewables through open calls for contracting and ensure better financial conditions for auction winners i.e. through removing subsidies from the retail electricity price, increased electricity price and utility tariff, and enables the option to fast track new contracts with energy companies*—signaling a positive signal to investors. The RenovAr Programme is funded by the World Bank with funds channeled to the Fund for the Development of Renewable Energies (FODER). In which, the World Bank provide guarantee in aggregate amount of USD 480 million to mitigate funding failure by the government for FODER. This mechanism enables guarantees by the World Bank for eligible renewable energy sub-projects through a transparent framework and promoting the financing of these potential projects. The RenovAr program also aims to support electricity buyer payments through the CAMMESA mechanism to mitigate systemic risks throughout the 20-year duration of the contract, and offers termination guarantees as stipulated in section 2.4.1[2].
- *The MATER opportunity provides incentives for self-generators through a minimum requirement for self-consumption of electricity and provides exclusion from extra costs available to produce electricity sourced from the utilisation of renewable energy.* Through this mechanism, electricity producers receive a discount on the maximum power requirement charges.
- *Law No. 24,424 provides an opportunity for renewable energy producers to be exempted partially from network supply for electrical power—saving some costs due to*

[2] More on the RenovAr Program and FODER: https://www.ifc.org/wps/wcm/connect/987eeec6-6259-4c00-8e21-fbf49813a47b/scaling-infra-argentina-08.pdf?MOD=AJPERES&CVID=mSCMXzz

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self-consumption. This law also established benefits through Tax Credit Certificate and also created the FODIS mechanism to grant loans, incentives, guarantees, capital contributions, and other financial instruments.

From a resource perspective, it was assessed by INTA and PROBIOMASA in 2018 that significant *feedstock potential in Argentina lies in biogas generation from pig effluents, feedlots, and dairy farms and dairy processing facilities.*

- *Pig effluents are mainly generated at pig farms located in Argentina's agricultural core zone.* It was found that the biggest concentration of pig slurry is located in the Southeast of the province of Córdoba, particularly in the departments of Unión and Marcos Juárez. The bioenergy potential of this basin as a whole is 5,861 Tn/year (~118,000 m^3/a of biogas, or ~70,000 m^3/a of methane per year) (PROBIOMASA, 2019).
- *Dairy processing facilities such as cheese, cream, and butter production processes are the main processes in the dairy industry that produce polluting residues.* Dairy industry wastewater in Argentina possesses a COD between 2000 – 4000mg / L, and a BOD between 2000 – 3000 mg / L. 69% of the effluent is commonly passing through the stabilisation lagoon, 29% is distributed in different paddocks, 25% directed into water bodies, 17% re-utilised for fertilisation, and 7% dumped into gutter channels—while the rest remains in the lagoon (PROBIOMASA, 2019).

Republic of Ethiopia

This report provides a thorough and in-depth elaboration of Ethiopia's biogas market, which despite of its potential currently remains at its early stage especially when compared to other RE resources. Biogas project implementation in Ethiopia is dominated by public-led investments and is far less funded by the private sector. This has, to some extent, attenuated the popularity and the advancement of existing biogas technologies. Furthermore, renewable energy (RE) governmental policies in Ethiopia are mainly directed towards investments into Hydropower, Solar, Wind and Geothermal energy production. In addition, in Ethiopia biogas is primarily used to fulfill energy demands in rural communities. Because of this, the biogas market also faces geographical challenges, due to being scattered across the country—mostly in rural areas.

Through the PESTLE analysis, it was assessed that in a macro-level perspective, the following elements influences the Ethiopian biogas sector:

- ***Political:*** *Ethiopia has undergone a transformative political process, which involved recent political reforms in 2018 which have improved the country's condition if compared to the previous 27 years in which the country was led by the EPRDF*. However, since 2018, the country is led by a reformist Prime Minister who has introduced democratic changes. As reported by the World Justice Project (2020), Ethiopia ranks 114th from 126 countries in terms of the perception of the rule of law in the country. Furthermore, in terms of corruption, Transparency International (2019) reported that Ethiopia scored 34 in its corruption perception index and was ranked 114th from 180 countries worldwide.
- ***Economic and business environment:*** *Ethiopia's economy has been growing rapidly between 2008 and 2018, triggered by extensive Foreign Direct Investment (FDI) and changes, which eased business dealings.* The World Bank reported that Ethiopia's GDP was valued at USD 27 billion in 2008 and has improved significantly from 2011

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(USD 31 billion) to 2018 USD 84 billion. However, the financial sector and few other sectors in the country are closed to foreign ownership. This has limited the level of competitiveness and growth of local enterprises including those specialised in biogas development.

- ***Environmental and legal environment:*** This aspect is governed by policies addressed under the "Ethiopian Environmental Pollution Control Proclamation (No. 300 of 2002)". Through this policy, Ethiopia's government has put in place waste, effluent, and pollution control directed at emitting factories. However, several issues persist in the country, such as the absence of corporate environmental responsibility, low enforcement of environmental standards, and lack of human and financial resources.

The attractiveness of the Ethiopian biogas sector is assessed through the Porter's 5 Forces analysis. Outlined below are several variables that need to be taken into account as they might impact how biogas developers perform in the country:

- *New entry of project developers is very unlikely in the biogas market.* As previously stated, involvement of the private sector in the biogas market has been minimal, instead it has been mostly state-led and targeting rural regions. Efforts to involve the private sector (e.g. through the GTP – Growth and Transformation Plan II), have been focused mainly on other renewable energy sources. Furthermore, there are seven categories listed within the report which reflects the various sectoral bottlenecks that have limited private sector investment, including: Planning/regulatory framework, institutional framework, institutional capacity, procurement, risk allocation, incentives, and investment promotion.
- *The biogas sector will face moderate pressure from electricity buyers.* The limited number of developers of biogas plants in Ethiopia do not leave much profit margin to electricity buyers. The primary buyer of electricity in the country is the Ethiopian Electric Authority, thus the public authorities play a significant role in biogas project development.
- *There is a moderate threat from substitute renewable energy sources influencing how the biogas sector could perform in the country.* The currently unmet electricity demand in the country provides huge opportunity for the development of biogas plants. However, there are still other plausible RE substitutes (e.g. solar, geothermal, wind energy). At the moment other RE sectors, such as solar energy, offer more private sector involvement potential, as Ethiopia has some new governmental initiatives for solar farms, and strong support by donors for solar PV. However, it is important to note that the large amount of unmet electricity demand leaves a lot of room for electricity production from biogas.
- *There is moderate pressure from suppliers of biogas technologies. This is highly influenced by the availability of biogas technologies in the country*— Ethiopia is currently importing most technical equipment from China, due to cost reasons. However, there are opportunities for European or American technology providers to sell equipment, especially in state or donor-sponsored biogas projects, as these projects have a higher emphasis of sustainability and technology reliability than on investment cost.
- *Low competition among existing biogas project developers is apparent due to the market opening up to independent power providers and sparse proper competitors*. However, as previously mentioned, cross-sector rivalry might exist with other RE alternatives.

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The report further outlines two legal bases on energy and investment, both are key towards easing business arrangements in the energy sector. These policies stipulate matters on licenses, incentives, and approval of electric power purchase and network service agreements. Furthermore, some incentive mechanisms are already in place for the energy sector—this was mainly due to the country's shift from government-held business sectors to private investments and services for the generation of energy. Two main incentive instruments apply; firstly, it includes one incentive of up to five years of income tax exemption and one customs incentive, which exempt taxes on imported capital goods, construction materials, spare parts, and logistic vehicles. Secondly, the Ethiopian Investment Commission also plays a vital role to provide import facilitation (e.g. customs incentives for imported capital goods, construction materials, spare parts, and operational vehicles), and aftercare services. These incentives promulgated by the Ethiopian Investment Commission could minimize risks and reducing duty and tax costs for project implementation.

The available resources in Ethiopia shows that the potential for energy-related usage of biomass remains considerable. The report further elaborates on *key feedstock types for biogas projects available in Ethiopia, which* includes among others crop residues, animal manure, woody biomass, municipal solid waste, and wastewater. Included in the analysis are elaborations on potential power yields and the value chains for the different substrates. To summarize, untapped feedstock potential is available from *woody biomass* and *agro-processing industries* (with only ~6% of the current potential being exploited at the moment) for *sugarcane, bagasse, cotton stalk, coffee hull and oil seed shells.* Another notable feedstock available in Ethiopia is undoubtedly sourced from *animal manure*, with a notable implementation of household-scale biodigesters that have already spread in various regions, enforced by the National Biogas Programme of Ethiopia (NBPE). Conversely, there's little indication regarding the current progress in the utilization of other feedstock, such as coffee and municipal waste. Nevertheless, details of its potential and possible energy generation are stipulated within this report as well.

Human resources available in Ethiopia with higher technical skills necessary for machine operation and middle and higher management jobs are minimal, which necessitates the acquisition of expensive labor from abroad for management, installation, and training for operation and maintenance. However, capacity-building programs exists as part of the government's national biogas program. Although these are mainly directed at users and technicians. *Industries in proximity* such as *industrial parks (including agro-industrial parks)* are also opportunities for biogas implementation in Ethiopia—especially those, which require wastewater treatment facilities.

Republic of Ghana

Ghana's main power supply sources are from hydroelectricity, thermal fueled by crude oil, natural gas, and diesel, and solar. Ghana also exports power to Togo, Benin, and Burkina Faso. On-going grid expansions would allow further exports to other neighbouring countries in the sub-region. Ghana has a vibrant power generation terrain with players from both the public and private sectors. Reforms in the Power Sector in the 1980's gradually removed barriers and created a level playing field for the participation of independent power producers (IPPs) in an area which hitherto had only public sector participants. The total installed capacity for existing power plants in Ghana is 4,132MW consisting of hydro 38%, thermal 61% and solar contributing less than 1% (Agyenim et al., 2020). The electricity sector in Ghana is commercialised with extensive private sector involvement. This electricity market structure is also supported

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by the Feed-in Tariff (FIT) Scheme for renewables such as Solar PV and wind, with net metering facility which enables the private sector to supply electricity into the main grid, further explanation of support mechanisms for private companies producing electricity can be seen in Ghana Section 4.3.2. Although market mechanisms are in place and are effectively in effect for renewables such as solar PV and wind, the biogas sector is still struggling. Biogas technology is not actively used for large-scale power generation, but it is used in smaller scale installations mainly for sanitation purposes—this is due to several challenges including inadequate feedstock and poor maintenance. Policies currently in place such as the 2018 Energy Outlook of Ghana also insufficiently referred to biogas (See Ghana's Section 4.1.1).
From a macro-level perspective, the Ghanaian biogas sector involves the following elements:

- ***Political:*** Ghana has been touted as one of the best democratic countries in the African Continent due to its strong adherence to democratic principles and respect for human rights. Ghana has enjoyed political stability for the last 10 years. World Economic Forum (2012), instability ranked as one of the last 15 problematic factors for doing business in the country. In terms of corruption, According to Transparency International, Ghana ranks 80th out of 180 countries worldwide in 2019 in terms of public sector corruption with a score of 41 out of 100. As a country, Ghana also put strong emphasis on the importance of the rule of law. As reported by the World Justice Project (2020), Ghana ranked 51st from 128 countries worldwide, with a score of 0.57. This strong emphasis on the rule of law also applies to the energy sector, with various governmental bodies acting as active policymakers and regulator of Ghana's energy sector (see Ghana section 4.3), successive governments have been able to address political barriers in the energy and renewable energy sector. Renewable energies are closely regulated by the government due to their strategic importance as a vital part of domestic livelihood and international electricity trade.
- ***Economic:*** In terms of economic growth, Ghana has experienced a drastic economic growth throughout 2018-2019, with GDP growth scoring at 6.7% on the first quarter of 2019 compared to 5.4% in the 1st quarter on 2018. Other than that, private sector credit also grew stronger, and the banking sector remained well-capitalised. Inflation in 2019 was valued at 9% in April 2019 (World Bank, 2019). Previously in 2016, inflation was valued at 17.4% and it has improved significantly in 2017 (12.3%) and 9.8 on 2018.[3] *Ghana's economy has experienced a lot of economic changes (improvement or otherwise) which adversely affect the energy sector including the biogas sector. The World Bank reported in 2019 that Ghana's energy sector is in dire financial conditions. Based on the report from Ghana's Ministry of Power in 2015, support from financial institutions for renewable energy projects has been insufficient especially for long-term project financing beyond 3-5 years.* In Ghana, investments for biogas development are mainly through the private sector, although there have been pockets of investments from the public sector. Private sector funding consists of a wide classification as it includes non-governmental source of financing, while public sector funding constitutes of grants derived from the national budget. Macroeconomic factors such as inflation, high interest rates, and foreign exchange volatility have contributed to the risks for investment—decreasing the confidence of private sector investors.

[3] Statistics of Ghana's inflation level up to 2018 can be accessed through: https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=GH&start=2013

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- ***Technological:*** *Technology utilized in Ghana is still underdeveloped, including several key infrastructures* such as biogas technology. This is partially due to the necessary biochemical processing. Foreign assistance will be necessary for parts of a development process and for training in management, operation, and maintenance.
- ***Environmental*****:** Biogas is primarily considered in the scope of sanitation and wastewater treatment in Ghana. This is also reflected in currently common usage of biogas by households and the use of human waste as feedstock. Environmental protection is mainly guided by the Draft Bioenergy Policy (2010), National Climate Change Policy (2014), and sustainable development objectives articulated in the Ghana Shared Growth and Development Agenda (GSGDA). These policies are strengthened by several laws related to waste management and pollution control, among others, includes Local Government Act, 462 (1993), National Water Policy (2007), and Environmental Sanitation Policy (2010). The complete list of these policies was elaborated in Ghana Section 4.3.

Through the Porter's Five Forces analysis, the report assesses the industry's attractiveness for new entries into Ghana's biogas market, based on the variables listed and summarized below.

- *Existing competition for biogas in the country poses a low risk.* Most of the companies in Ghana do not have the capacity to construct large-scale digesters. Large scale digesters are usually installed by foreign companies. Additionally, most biogas companies are ready to improve their technical capacity and in search for technology that will suit the Ghanaian context—thus, the risk of competition for biogas in Ghana is categorised as low. Currently, there are about 20 private companies and research institutes (Outlined in Table 17 Ghana section 4.2.2) that are actively involved in the design and construction of both domestic and institutional size biogas plants across the country. A few are purely focused on biogas or sanitation but most of them also have other business areas they are actively involved in. Businesses do not solely focus on biogas due to the slow market for biogas digesters. To date, Biogas Technologies Africa Limited (BTAL), now BTAL is one of the largely recognized biogas companies in the installation of fixed-dome digesters in Ghana. The only competition for new entrants might come from BTAL who is well established in the African continent with several large-scale digesters installed in various African countries funded by UN organizations.
- *Bargaining power of biogas players in Ghana will face moderate pressure from clients interested in biogas installations.* In Ghana, the technology is well known for its sanitation purpose. However, there is still a lack of information with regards to the utilization of the technology for energy purpose. Additionally, there is limited information on the potential clients for investments into biogas systems in Ghana. The benefit of the technology to the customer is more of environmental solution than creating additional income for organisations. An example is the plant installed by Sewerage System Ghana Limited, where an anaerobic system is used to treat human waste without harnessing the gas for usage. In sum, there are three categories of potential clients in Ghana, including food processors, landowners/farmers, and waste management companies (See Ghana Section 4.2.4).
- *High risk for biogas suppliers in Ghana which requires a straightforward operational solution.* No biogas equipment can be sourced locally. They are usually contracted to

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foreign companies. A prominent company in the biogas sector indicated that they normally source their supplies from Germany including biogas storage facilities and CHP equipment. However, there might be competition of products from China due to pricing as most Ghanaian companies prefer to acquire their products from China. The biogas technology is dominated by local companies installing small-scale digesters with the large-scale digesters constructed by foreign companies, usually from Europe. Lastly, external factors such as the fluctuation of the local currency and high exchange rates also contributes to the overall risk for biogas suppliers.

- *New entry is unlikely in the sector—signaling a low risk.* In Ghana, the government seems to be more focused on solar PV with little policy direction in the biogas sector as the current Bioenergy policy document is still in its draft stage since 2010. Most of the investment in the biogas sector has been driven by the private sector and donor funded projects specially to deal with waste management. The argument from the industries that are currently employing biogas technology to treat their waste is to comply with the standards sets by Environmental Protection Agency (EPA) in the discharge of waste into the environment. Due to the lack of prioritisation for biogas implementation in the country, new entry is unlikely. However, a straightforward operational solution is required to offset the lack of policy support for energy generation from biogas.
- *Institutional and market factors pose a high risk for biogas project developers which require strategic adjustment.* There are a myriad of factors that are critical for biogas development in the country. These factors are listed in Ghana section 4.2.3. In brief, these factors include: (1) high capital cost for renewable energy projects; (2) shortcomings of some financial mechanisms i.e. equity finance, venture capital fund, debt financing, and crowd financing; (3) Unfamiliarity with biogas technology; (4) lack of maintenance practice; (5) Unavailability of feed-in tariffs for biogas; (6) lack of successful reference projects and failed experience; and, (6) Lack of subsidies for bioenergy products. In sum, all of these factors elaborated extensively in section 4.2.3. require biogas project developers to strategically mitigate the aforementioned factors of risk.

Regulatory incentives are available for the biogas sector. The most straightforward incentive is the Feed in Tariffs mechanism available for all renewable sources. Incentives are also provided by international organisations such as UNEP. Through its REED programme, UNEP provides capital to small-medium enterprises operating in the clean energy sector, including biogas development. Incentives also come from government in a form of R&D support by increasing support for R&D to 2.5% of GDP from the current 0.25% including for renewable energy projects; the development of Renewable Energy Fund; and, the establishment of a Renewable Energy Demonstration Centre. However, it must be noted that direct initiatives by the government towards the renewable energy market are mostly in a form of plans, programs, and standards—in comparison, financial incentives are less available. In addition, policies that are specifically made for large-scale, power-generating biogas are less common and policies that are aimed at environmental protection and sanitation are more common (see Ghana section 4.3). As mentioned before, the renewable source priority for Ghana is solar PV and hydro whereas biogas is still considered a household venture for sanitation purposes.

From a resource perspective, the Ghanaian biogas sector still has a lot of untapped potential. As mentioned before, existing biogas practices use human waste as feedstock for household biogas installations. Aside from this, Ghana also has industrial feedstock available – industries with specific potential includes fruit plantations, breweries, and slaughterhouses. Despite the

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abundant of biomass resources for biogas generation, most of the resources are either yet to be exploited or are not fully exploited. The analysis presented here identified food processing, municipal solid and liquid waste as well as brewery processing waste as the major feedstocks for biogas development in Ghana. The report presents a strong case for municipal solid and liquid waste despite the feedstock collection problem posed by this feedstock. Human resources needed to operate the business are plentiful, but rarely meet the skill level required to maintain and operate biochemical processes and technology. The problem is exacerbated by the lack of workforce standardization for training curriculum, especially for industrial level operations.

Republic of Indonesia

This report will also provide an insight into Indonesia's biogas market. The analysis will be more heavily conducted on the specific segment of the biogas market i.e. the palm oil sector as the sector with the most biogas feedstock potential in the national biogas market. However, elaborations on other potential sectors such as municipal solid waste, agriculture waste, etc. were also included in the report.

From a macro-level perspective, Indonesian palm-based biogas sector involves the following elements:

- ***Political and legal****:* The development of biogas in Indonesia is inextricably tied to the nation's aspirations towards energy security. There is a state-owned enterprise namely PLN (*Perusahaan Listrik Negara*) which is the sole distributor for power in Indonesia. Coal has been the backbone as an energy source in Indonesia for years. Therefore, the regulations established by the government are more directed to attract more investment in coal-fired power plants than clean energy. Within the renewable sector, the Indonesian government has largely prioritized biofuel over biogas in its broader bioenergy strategy. The lack of administrative body for biogas development in Indonesia poses an issue for both Indonesia's aspirations towards energy security and disparity reduction. The Indonesian government lacks proactiveness in establishing, implementing, or promoting biogas projects in a tangible form. The current form of leadership provided by the government is hindered by overlapping priorities and jurisdictions, which slows the decision-making process.
- ***Economic:*** Feed-in tariffs (FITs) is the major policy support scheme for biogas development in Indonesia. They guarantee a fixed purchase price of renewable generation from producers and aims to cover the costs of RE development, while providing reasonable rates of return to investors and reduce investor risks from RE projects financing. The rates in which FITs are implemented in Indonesia are also biased towards fossil generation – unlike other countries who provide greater FITs to encourage RE transition.
- ***Technological:*** Anaerobic digesters (AD) are now being used as primary treatment for POME at Indonesia Palm Oil Mills (POMs) because aeration processes don´t need to be accommodated here, hence reducing cost and technical complexity effectively. Covered Lagoon is mostly used AD by Palm Oil Mill to treat POME in Indonesia but there are about 3 POMs using tank system or CSTR in 2015. Local technology provider for AD is mature.
- ***Environmental:*** The Government of Indonesia has implemented the Program for Pollution Control, Evaluation, and Rating (PROPER) to promote "clean technology" back

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in 1995. This mechanism helps enforce the industry to adopt "clean technology" practices by rating each company's performance based on the regulatory standard.

The Indonesian electricity market is a national-level market controlled by a state-owned monopoly, which is likely going to make a market entry for private sector actors with the plan of feeding electricity into the national grid challenging. There is no electricity shortage, and current demand is thus fulfilled. However, meeting the growing electricity demand from industrial and productive use is still challenging. On the other hand, there is the supplier sector of palm plantations and mills. It is a very concentrated industry (in Sumatra and Kalimantan) that produces commodified crude palm oils (CPOs). *The market is dominantly private*, so a clear business case and offering would be necessary. Palm plantations and mills have experienced impressive growth across the last few years, but the seasonal fluctuating nature of their product makes technological investment on renewable biogas projects rare.

Alternatives to the palm oil sector for biogas projects in Indonesia include among others, the following:

Table 1: Potential Industrial Waste Markets Feasible for biogas implementation in Indonesia

Feedstock Type	Region	Restrictions
Urban Waste	Sumatra and Java EW, Municipality	Non-existent sorting procedure
Rice Hulls	Java ECW, Regency	Biochemical properties limits yield
Sugarcane Solids	Java ECW, Regency	Biochemical properties limits yield
Livestock Dung	Java CW and Nusa Tenggara	Livestock management does not localize dung
Low-Graded Seaweed	Nusa Tenggara and Sulawesi	Smaller industry produces limited feed

Through the Porter's Five Forces analysis, the report assesses the industry's attractiveness for new entries into Indonesia's biogas market, based on the variables listed and summarized below.

- *Moderate to high chance for biogas developers of having to compete as rivals*, Indonesia's Section 5.4.1 utilises two variables to assess the risk for rivalry among competitors: Sectoral growth and capital costs. Growth of the biogas sector in Indonesia has been concluded as not significant and is being negatively affected by seven or more years before actual financial returns which led to project owners rarely committing into additional development. While the capital costs for biogas development in Indonesia remain high—this is the main risk factor limiting competition in the sector. One biogas project in Indonesia could cost approximately 1 million USD—with costs mainly incurred for technology components i.e. digesters, engines, and auxiliary components.
- *Biogas developers as buyers will face considerable pressure carrying moderate risks*. In section 5.4.2, the bargaining power of buyers was assessed through two variables: effect on industrial processes, and Buyer Costs. In terms of industrial processes, a vast majority of biogas developers only utilize biogas for electricity generation – be it internal or to be bought by PLN. Benefits of biogas implementation tends to be a 'saving' than creating additional income, which is a lost opportunity for companies. Furthermore, the costs of biogas development pose a moderate risk for project developers. These costs

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include those related to technology price, installation, logistics, land clearing, feasibility studies, etc.

- *Risks towards biogas component suppliers are low in terms of competition with other substitute products, and existing supplier concentration poses a moderate risk for potential suppliers.* In the context of substitute biogas components, once a project is initiated, technology can rarely be replaced. But substitute biogas technologies for projects can be provided by other EPCs (bundled with their own services) or by pure tech supplier/reseller—this pose a low risk for new biogas suppliers. Furthermore, concentrations of major international manufacturer (whose products are used in Indonesia) are all foreign – US, Europe, China, India. This will inevitably cause additional cost and time. This means that Biogas technology is almost exclusively imported. This adds inevitable cost and time for EPCs or suppliers to stock up (or start a project). Trade routes are also prone to disputes, taxation, and exchange loss from dealing with a foreign currency. Fortunately, it appears that technology exporters also found value in the Indonesian market as no EPCs or suppliers have experienced a debilitating shortage of technology.
- *New entrants of biogas competitors in the national market are very unlikely in the sector—carrying low risks for new stakeholders interested in developing biogas.* Technical knowledge and high capital are a must have, so not everyone can just jump ship and become a biogas EPC. However, some of these entry barriers will also affect project developers– for example, how the industry tends to prefer experienced EPCs with existing local portfolio.
- *The possibility of substitution is also a problem carrying moderate risk which requires straightforward operational solutions*, this is mainly due to the existing price gap between biogas and biomass development, but the yield-to-cost ratio is in favor to biogas. In Indonesia biogas is 1:1, biomass incinerators 1:2, and MSW landfill gas 1:4. The ratio mentioned is also based on Covered Lagoon technology, which is generally subpar in everything but price. CSTR biogas exists in Indonesia, but information on its development and associated costs are very limited. Other than that, buyer sensitivity, product performance, and sub-sector trends are all affecting the degree of substitute products have the potential to replace biogas e.g. biofuel (see Indonesia's section 4.5.4.)

We have also identified several notable EPCs that may fill the role as competitors in the biogas markets (see Indonesia's section 5.4.6.). They are developers who became known for achieving certain milestones in biogas development – ranging from the success in creating a high-yield power plant, successfully creating a sustainable business dealing with PLN, or by surviving financially.

Regulatory incentives are available for the biogas sector. Import tax waivers are applicable for renewable infrastructures. Indonesian Sustainable Palm Oil Certification System (ISPO) certifications give benefits for companies that fulfil the standards, and a governmental directive was given to the effect that banks would start providing soft loans for renewable energy projects. However, the number of directives available in Indonesia still outweigh the available monetary incentives. In addition, directives available in Indonesia often overlaps with one another and are prone to changes in every administration period.

From a resource perspective, the Indonesian biogas sector has risks but also potentials. Natural resources, which provide feedstock, are plentiful, and energy utilization of palm waste is

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still minimal. Conventional supply chains for these wastes exist, and it may be difficult to redirect the flow to biogas generation. The issue of palm oil plants maturity also existed, as Indonesian plantations tend to expand rather than replant. This can also be inferred from the low productivity per acre of Indonesian palm companies. Human resource who operate the business are plentiful, but rarely meet the skill level required to install, manage, maintain, and operate biochemical processes and technologies.

Republic of South Africa

The Republic of South Africa (RSA) section of the report will provide a thorough assessment of *South Africa's biogas market which in its current state relies heavily on the economic viability and bankability of projects. In which, bankability of project depends on its revenue streams influenced by feedstock security. Furthermore, other factors such as the influence of existing regulatory environment of the country, and the project stakeholder's need to understand and follow viable project models are key aspects to ensure the bankability of projects*. Historically, the biogas market in RSA has a low rate of uptake, and the current nascent state of the market makes the development of local expertise coupled with higher uptake of biogas technology key aspects for a commercially sustainable biogas industry. In terms of structure of the electricity sector, the feed-in-tariffs mechanism is in place for IPPs. In which, the IPPs compete on price tariff (70%) to be charged to Eskom and economic development contributions (30%) to local communities within 50km radius from project location. Preferred bidders sell power to single buyer Eskom (RSA's national power utility company), over the 20-year PPA.

From a macro-level perspective, the biogas sector in the RSA involves these elements:

- ***Political and Legal*:** Due to historical precedent, policies in RSA currently put large emphasis on the development of local enterprises and small, medium, and micro-sized enterprises (SMMEs). Therefore, *it is ideal for exporting partners to identify and work with local partners. An understanding of recently promulgated policies and legislations, especially those focused on environmental protection and green economy sectors is pivotal*—since there has been an increase in new policies and regulations, due to a growing interest in investments in waste management infrastructures. The RSA section of the report elaborates several recently updated legislations and policies e.g. the Carbon Tax Act (CTA), National Water Act (NWA), Electricity Regulation Act of 2006, and the Integrated Resource Plan (IRP) 20191. In terms of corruption, Transparency International (2018) has reported that the country ranked 73rd from 180 countries worldwide, with its corruption perception index valued at 43/100. Lastly, in terms of rule of law, the World Justice Project report (2020) valued South Africa's rule of law index for 0.59, ranked 45th from 126 countries worldwide and 5th from 16 countries in Sub-Saharan Africa.
- ***Economic:*** The economy of RSA is highly developed, characterised by a wide range of industries producing goods for both local and export markets. The country relies heavily on exports and there are current efforts to reduce the import bill to bolster export income—this was reflected by a strong *growth in foreign direct investment (FDI)*. According to the World Bank[4], inflation in South Africa was valued at 4.1% in 2019, a

[4] Inflation, consumer prices (annual %) statistics for South Africa is based on the World Bank database: https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?locations=ZA&start=2013

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massive improvement from 6.5 % in 2016. Furthermore, albeit its past economic adversities, the country is gearing towards accelerated growth—and an increased momentum in competitiveness. The World Bank reported that RSA's GDP in 2016 is 296.3 billion and the economy grew by 1.3% in 2017 and 0.8% in 2018. It was also projected that the economy will grow further in 2019 with 1.3% growth and 1.7% growth in 2020. *With this constant acceleration of growth, the fulfillment of energy and electricity demands is pivotal, thus the country also has a good prospect for renewable energy development.* In RSA's section of the report, indicators outlining RSA's market attractiveness are elaborated, and several deficiencies are highlighted.

- ***Social:*** RSA's population growth has gradually increased throughout 2013-2018. The latest statistics available from the World Bank reported that the number of total populations in 2013 is 53 million. Meanwhile, RSA's population in 2018 is 57 million.[5] Additionally, increasing immigration from other African countries and rural-to-urban migration are expected to cause increasing waste generation. Coupled with its current emphasis towards energy mix diversification and positive perception towards waste management practices, *Anaerobic Digestion is identified as a good technology to be implemented in RSA as a potential solution to address social discrepancies on energy access.*
- ***Technological:*** The need for energy provision, waste management, and sanitation should be the main aims of the development of biogas projects*. An abundance of lower cost energy sources i.e. electricity from coal and also low cost of landfilling waste has limited the development of biogas technology. Biogas as a by-product from wastewater sanitation has in most cases not been captured and used further. Instead wastewater sanitation installations were mostly designed to treat sewerage and flare off gas without emphasising on energy production. However, there are ample opportunities for biogas in areas with homogeneous solid waste feedstock, especially in the farming and agricultural sectors.* Coordinated large-scale R&D programmes is also one of the basic requirements in place for the development of biogas projects, by following the basic pre-requisites of R&D outlined in RSA's section 6.5.1.6, the prospect of biogas potential can also be accelerated.
- ***Environmental:*** Increasing awareness of environmental and climate change impact and commitment towards achieving the SDGs has led to an increasing demand for environmentally friendly technologies. *The country's focus towards sustainable development, reflected by its policies and plans supporting environmental protection and sustainable waste management, provides an opportunity for AD***,** by addressing issues such as effluent control in water bodies and poor air quality due to coal fired power plants.

Through the Porter's Five Forces analysis, the report assesses the industry's attractiveness for new entries into RSA's biogas market, based on the variables listed and summarized below.

- *Barriers to entry include risks, which requires strategic adjustment***-** It was found that industry barriers encountered by new entrants are industry-specific. *Main challenges that require adjustments include high upfront investment costs for renewable energy*

[5] RSA's population statistics is based on the world bank database: https://data.worldbank.org/indicator/SP.POP.TOTL?end=2018&locations=ZA&start=2013

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technologies, high capital requirements and transaction costs related to market research. Macro-level barriers include high governmental debt, as well as external threats such as other country's trade policies, foreign exchange rates, and the recent threat of corona virus pandemic.

- *Available institutional and market factors pose a moderate risk,* among other listed notable factors, some are worth highlighting: (1) Limited subsidies and incentives; (2) High capital cost, especially for costs of AD systems—which are beyond the reach of most farmers and small-medium companies; (3) Precedent of failed or less than successful systems, e.g. non-operational systems in municipal wastewater treatment plants, and several unsuccessful commercial projects; (4) high development cost to reach financial close.
- *Economies of scale leads to low risk that can be tackled with straightforward operational solutions.* This is the case due to higher attractiveness of larger projects due to better ROIs and lower cost-time ratio if small, medium, and large projects. *Two industries that could benefit from economies of scale are the chicken broiler and layer poultry industries.*
- *Brand royalty poses some risk which requires strategic adjustment.* New market entrants are unlikely to do well without the support of a reputable South African partner, and international technology partners may need to support local companies by ensuring the technology's liability.
- *Capital requirement in the country poses a high risk for new entrants.* This is one of the few factors which pose the highest risk, due to the long development lead time, high cost of equipment, and long project payback periods.
- *Current government policies are viewed as a major barrier; thus, this factor was ranked with high risk.* An extensive list of policies and acts that are also listed within the report—generally deters new entrants, and extensive effort with local support must be done to ensure compliance towards legal instruments.
- The threat of substitute products is categorised threefold:
    a. *Number of substitute products poses a moderate risk, which can involve straightforward operational solutions.* This is due to low competitiveness of electricity price generated from biogas. However, Section 6.5.3.1 outlines five products which has the potential to be substituted with biogas due to several factors of motivation. For example, the lower cost of green fuel for transportation, less GHG emission for electricity production from coal and diesel power generation, etc. These five products outlined in Table 45 reflects that there are still valid factors to motivate biogas development in the near future.
    b. *Buyer propensity to substitute: poses a moderate risk, which can involve straightforward operational solution.* This is due to lower representation of biogas in the national energy mix plan—the lack of biogas regulatory framework limits the possibility for technology buyers to substitute.
    c. *Relative price performance of substitute poses moderate risk level, which require strategic adjustment.* The biogas electricity price is on par with mid-merit coal and the CAPEX cost of a biogas electricity generating plant is much higher that of an equivalent PV plant.
- *The bargaining power of suppliers was assessed with two variables:*
    a. *Number and size of suppliers poses a moderate risk level, which require strategic adjustment.* Most of the local biogas technology and equipment providers

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are contracted to overseas suppliers, which are predominantly European companies.

b. *Uniqueness of each supplier's product poses a moderate risk, which can involve straightforward operational solution.* Perceived through the perspective of quality versus price, *the South African market is quality conscious enough. However, less costly lower quality systems have found a foothold.* This is apparent in the competition between European and suppliers from the East.

- *Rivalry among existing competitors carries a low risk which requires strategic adjustment.* Even though the local market is very competitive, the majority of project developers is competing for a very small number of projects per year. This is the result of high capital cost and long return of investment for projects. *Proof of concepts and successful local applications are key factors that can strengthen competitiveness.*

We have identified and listed competitors divided into three categories: direct competitors, indirect competitors, and potential competitors. For the direct competitors, a SWOT analysis is provided within Table 47, which analyses sectors including:

- Sugar Estates
- Dairy Farms
- Piggeries
- Broiler farms
- Layer farms
- WWTW

Meanwhile, the indirect competitor's analysis is divided into three sectors: Waste, energy, and water. In the waste sector**,** *the largest competitors for biogas are waste handlers and municipalities. Furthermore, in the energy sector, competition is difficult with other energy sources such as solar, wind and coal—this is mainly due to the high cost of biogas compared to other renewable energy technologies, and lacking regulations and policies on biogas* (see section 6.7.2 RSA). Lastly, potential competitors listed within the report are: Composting, Black soldier fly farms, Water treatment, Piggeries, Electric vehicles, and other RE technologies such as solar PV and wind.

Several notable policies and incentives are listed in this report. Some that are worth highlighting include: *(1)* the National Environmental Management (NEM) Act which highlights project requirements in terms of environmental impacts; *(2)* National Heritage Resource Act which is key for environmental impact control, and The National Water Act which regulates water usage and efficiency of projects. Furthermore, two incentives must be highlighted:

- *Carbon Tax Act:* establishes a tax rate of 120 ZAR/tCO2e for direct emissions at large industrial emitters, aimed at reducing direct emissions
- *Small-scale embedded generation (SSEG) feed in tariffs* applies in certain municipalities and offers feed in tariffs to projects up to 1 MW scale—with projects being the net users of the electricity generated.

A thorough elaboration on available natural resources and human resources is also included within RSA's section 6.8. *The natural resources section provides detailed data regarding the availability and production capacity potential for agricultural feedstock, livestock manure and abattoir, food processing waste, breweries, wineries, and WWTW.*

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Summary of the DiBiCoo Project

The *Digital Global Biogas Cooperation (DiBiCoo)* project is part of the EU's Horizon 2020 Societal Challenge 'Secure, clean and efficient energy', under the call 'Market Uptake Support'.

The target importing emerging and developing countries are Argentina, Ethiopia, Ghana, South Africa and Indonesia. Additionally, the project involves partners from Germany, Austria, Belgium and Latvia. The project started in October 2019 with a 33 months-timeline and a budget of 3 Million Euros. It is implemented by the consortium and coordinated by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

The overall objective of the project is to prepare markets in developing and emerging countries for the import of sustainable biogas/biomethane technologies from Europe. DiBiCoo aims to mutually benefit importing and exporting countries through facilitating dialogue between European biogas industries and biogas stakeholders or developers from emerging and developing markets. The consortium works to advance knowledge transfer and experience sharing to improve local policies that allow increased market uptake by target countries. This will be facilitated through a digital matchmaking platform and classical capacity development mechanisms for improved networking, information sharing, and technical/financial competences. Furthermore, DiBiCoo will identify five demo cases up to investment stages in the 5 importing countries. Thus, the project will help mitigate GHG emissions and increase the share of global renewable energy generation. The project also contributes to the UN Sustainable Development Goals (SDG 7) for 'Affordable and clean energy", among others.

Further information can be found on the DiBiCoo website: www.dibicoo.org.

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List of Abbreviations (General)

AD	Anaerobic Digestion
B2B	Business-to-Business
BioCNG	Bio-Compressed Natural Gas
BN	Billion
BOE	Barrels of Oil Equivalent
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CSTR	Continuous stirred tank reactor
D	Deliverable
EU	European Union
EPC	Engineering, Procurement, and Construction
FDI	Foreign Direct Investment
FIT	Feed-in Tariffs
GDP	Gross Domestic Product
GJ	Gigajoule
GW	Gigawatt
GWh	Gigawatt-hours
HR	Human Resource
ICT	Information and Communication Technology
IMF	International Monetary Fund
IPPs	independent power producers
ISCC	International Sustainability and Carbon Certification
kT	Kilo tonnes
kV	Kilovolt
kVA	kilovolt-amperes
kW	Kilowatt

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KWh	Kilowatt/hour
MW	Megawatt
Min.	Minimum
MJ	Megajoule
MT	Metric tonnes
MW	Megawatt
Mwe	Megawatt electric
MWh	Megawatt-hour
NGOs	Non-governmental Organisations
O&M	Operation and Maintenance
OPEX	Operating Expenses
PESTLE	Political, Economic, Social, Technical, Legal, Environmental
POMs	Palm oil mills
POME	Palm oil mill effluent
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PV	Photovoltaic
RE	Renewable Energy
R&D	Research and Development
R&DDD	Research, Development, Demonstration and Deployment
SDGs	Sustainable Development Goals
SC	Steering Committee
SHS	Solar household systems
SMEs	Small and medium-sized enterprise
SMEEs	Small, Medium and Micro-sized Enterprises
SNV	Netherlands Development Organisation
SPB	Special Purpose Vehicle
SWOT	Strengths, Weaknesses, Opportunities, Threats
T	Task
t/CO¬2e	Tonnes of Carbon Dioxide equivalent

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t/d	Ton/day
t/y	Ton/year
Tn	Tonnes
Tep/year	Tonne petroleum equivalent/year
US	United States
UN	United Nations
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
Viz.	Videre licet (which is)
WEF	World Economic Forum
WWTWs	Wastewater Treatment Works

List of Abbreviations (Country-Specific): Argentina

AACREA	*Asociación Argentina de Consorcios Regionales de Experimentación Agrícola*
AAPRESID	*Argentina Association of Producers with Direct Soowing*
AFIP	*Administración Federal de Ingresos*
ASAGA	*Asociación Argentina de Grasas y Aceites*
CAMMESA	Wholesale Electricity Market
CARBIO	*Cámara Argentina de Biocombustibles*
EIA	Environmental Impact Evaluation
FODER	Fund for the Development of Renewable Energy
FODIS	*Fondo Para La Generación Distribuida De Energías Renovables*
GUH	Large Authorized Users
GUDI	*Grandes Usuarios en Distrubución Mayores*
IEDER	Indicator of direct use of renewable energy
INDEC	*Instituto Nacional de Estadisticas y Censos*
INTA	National Agricultural Technology Institute
INTI	National Institute of Industrial Technology
MAIZAR	*Asociación Maíz y Sorgo Argentino*

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MEM	Wholesale Electricity Market
MATER	*Mercado a Término de Energía Eléctrica de Fuente Renovable*
OAT	*Ordenamiento Ambiental del Territoria*
PROBIO-MASA	*Proyecto para la promoción de la energía derivada de biomasa*
PROSOJA	*Profecionales especialisados en cultivo de Soja*
RENUGER	*Registro Nacional De Usuarios-Generadores De Energías Renovables*
RSB	Roundtable on Sustainable Biomaterials
RTRS	Round Table Responsible Soy
SGE	Secretary of Government for Energy
SSYER-YEE	*Subsecretaría De Energías Renovables Y Eficiencia Energética*

List of Abbreviations (Country-Specific): Ethiopia

CRGE	Climate Resilient Green Economy
EEA	Ethiopian Electric Agency
EEP	Ethiopia Electric Power
EEPCO	Ethiopian Electric Power Corporation
EPRDF	Ethiopian People's Revolutionary Democratic Front
GER	Grand Ethiopian Renaissance Dam
GoE	Government of Ethiopia
GTP	Growth and Transformation plan
IAIP	Integrated agro-industrial park
IDA	International Development Association
MPA	Multi-phased Programmatic Approach
NBPE	National Biogas Program of Ethiopia
REGREP	Renewable Energy Guarantees Program
TVET	Technical Vocational Education Training Programs
WBISPP	Woody Biomass Inventory and Strategic Planning Project

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List of Abbreviations (Country-Specific): Ghana

ABL	Accra Brewery Ltd
AB	Anheuser-Busch
AFD	*Agence Française De Développement*
BTAL	Biogas Technologies Africa Limited
CHRAJ	Commission on Human rights and Administrative Justice
CAP	Country Action Plan
CIF	Climate Investment Fund
CSIR-IIR	Council for Scientific and Industrial Research
EC	Energy Commission
EPA	Environmental Protection Agency
GGBL	Guinness Ghana Breweries Limited
GIPC	Ghana Investment Promotions Centre
GOPDC	Ghana Oil Palm Development Corporation
GPRS	Ghana Poverty Reduction Strategy
GRIDCo	Ghana Grid Company
GSGDA	Ghana Shared Growth Development Agenda
IIR	Institute of Industrial Research
KITE	Institute of technology and Environment (KITE)
KVIP	Kumasi Ventilated Improved Pit
MMDAs	Municipal and District Assemblies
MoE	Ministry of Energy
NAMAs	Nationally Appropriate Mitigation Actions
NEDCo	Northern Electricity Distribution Company
PURC	The Public Utility Regulatory Commission
REFIT	Renewable Energy Feed-in Tariffs
REPO	Renewable Energy Purchase Obligation
SE4ALL	Sustainable Energy for All
SFO	Serious Fraud Office

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SNEP	Strategic National Energy Plan
SNNPR	Southern Nations, Nationalities, and People's Region
SPO	Special Prosecutors Office
SREP	Scaling-up Renewable Energy Program
SUNREF	Sustainable Use of Natural Resources and Energy Finance programme
VRA	Volta River Authority

List of Abbreviations (Country-Specific): Indonesia

AANE	Austindo Aufwind New Energy
AMDAL	Analysis on Environmental Impact
BAPEDAL	Environmental Impact Control Council
BOOT	Build, Own, Operate, Transfer
BPDP-KS	Oil Palm Plantation Fund Management Agency
BPPT	National Agency of Technology Implementation
COD	Commercial Operation Date
CPO	Crude Palm Oil
DPL	Environmental Control Strategy
GAPKI	Indonesian Palm Oil Association
GmbH	Aufwind Schmack Asia Holding
GOI	Government of Indonesia
IDR	Indonesian Rupiah
ISPO	Indonesian Sustainable Palm Oil Certification System
KEN	National Energy Policy
LCO	Levelized Cost of Energy
MSW	Municipal Solid Waste
PKO	Palm Kernel Oil
PLTA	Hydroelectric Power Plant
PLTBg	Biogas Power Plant
PLTBm	Biomass Power Plant

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PLTM	Mini-Hydro Power Plant
PLN	State Electricity Company
PLTP	Geothermal Power Plant
PLTS	Solar Power Plant
PLTSa	Garbage Power Plant
PROPER	Program for Pollution Control, Evaluation, and Rating
SEMDAL	Studies on Environmental Impact Evaluation
RSPO	Roundtable of Sustainable Palm Oil
SPV	Special Purpose Vehicle
STP	Segment Target Position
RUPTL	The General Electric Generation Plan
RUEN	General Energy Plan
SNI	Indonesian Standard
UKL	Environmental Management Intent Standards
UPL	Environmental Control Intent Standards
UU	Indonesian Law

List of Abbreviations (Country-Specific): South Africa

BBBE	Broad-Based Black Economic Empowerment
CARA	Conservation of Agricultural Resources Act
CRSES	Centre for Renewable Energy and Sustainability
CSIR	Council for Scientific and Industrial Research
CSP	Concentrated Solar Power
CTA	Carbon Tax Act
C&I	Commercial and Industrial
C:N	Carbon to Nitrogen
DBSA	Development Bank of Southern Africa
D:E	Debt to Equity Ratio
DEA	Department of Environmental Affairs

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DEFF	Department of Environment, Forestry and Fisheries
DFID	Department for International Development
DMRE	Department of Mineral Resources and Energy
DSCR	Debt Service Coverage Ratio
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
ERA	Electricity Regulation Act
EWSETA	Energy and Water Services Sector Education and Training Authority
FMCG	Fast-moving Consumer Goods
GSFA	Government Support Framework Agreement
IA	Implementation Agreement
IBBK	International Biogas and Bioenergy Competence Center
IDC	Industrial Development Cooperation of South Africa Limited
IPPO	Independent Power Producers Procurement Office
IRP	Integrated Resource Plan
IRR	Internal Rate of Return
LCA	Life Cycle Analysis
LFG	Landfill Gas
LPG	Liquefied Petroleum Gas
NCPC	National Cleaner Production Centre
NEMA	National Environmental Management Act
NEM:AQA	National Environmental Management: Air Quality Act
NEM:BA	National Environmental Management: Biodiversity Act
NEM:PAA	National Environmental Management: Protected Areas Act
NEM:WA	National Environmental Management: Waste Act
NERSA	National Energy Regulator of South Africa
Nm^3	Normal m^3
NPAs	Non-performing Assets
NQF	National Qualifications Framework

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NRF	National Research Foundation
NT	National Treasury
NWA	National Water Act
OCGTs	Open Cycle Gas Turbines
OEM	Original Equipment Manufacture
OFO	Organizing Framework for Occupations
OSH	Occupational Health and Safety
PR	Performance Ratio
Pty	Proprietary
QCTO	Quality Council for Trade and Occupations
REIPPP	Renewable Energy Independent Power Producers Procurement
RFP	Request for Proposal
ROIs	Return of Investments
RSA	Republic of South Africa
SALA	Subdivision of Agricultural Act
SANEDI	South Africa National Energy Development Institute
SAQA	South African Qualifications Authority
SARETEC	South African Renewable Energy Technology Centre
SCPF	Strategic Climate Policy Fund
SSEG	Small Scale Embedded Generation
TMR	Total Mixed Ration

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1 Introduction

Biogas remains as one of the renewable energy solutions with high potential to meet increasing energy demands while also countering environmental degradation and biodiversity loss. In its 2019 report, the World Biogas Association (WBA) emphasised that only 2% of global wastes and feedstocks suitable for energy generation from biogas are currently being used (Dr. Jain, S. et al., 2019), although feedstocks from food waste, sewage, animal wastes, crops and crop residues are widely and readily available to be used for energy generation. Biogas is also one of the key alternatives in combatting environmental degradation, and ultimately contributing towards the struggle in combatting climate change. In this regard, biogas can play a major role by treating and processing biological wastes that are otherwise will decompose and emits methane to the atmosphere when left untreated. The Intergovernmental Panel on Climate Change (IPCC) reported in 2013 that biogas installations can deliver the greatest impact in terms of greenhouse gas emission reductions, since methane (CH_4) causes 28-34 times more global warming than CO_2 (Richter et al., 2017). Therefore, its capture and utilisation can reduce total emissions by 25 to 40 times the level of an equivalent capacity of solar or wind power (WBA, 2019).

Furthermore, WBA also reported that biogas has the potential to contribute to a circular economy—mainly through improving the sustainability of industries by enabling them to utilise their own effluents as sources of self-generated electricity and/or heat. In addition, bi-products generated from biogas or Anaerobic Digestion processes such as digestate bio-fertilisers can bolster the sustainability of industries (especially in the agricultural sector), since by products such as fertilisers can be circulated back to the soil, returning organic matter and nutrients. It is also imperative to highlight that biogas installations can create job opportunities such as in raw material cultivation and collection—vital within the biogas process chain. By creating local energy production, income also stays in the local area instead of being channeled into the global energy markets (Fagerström, et al., 2018). In addition, biogas installations can also bolster employment and the economy through encouraging long-term equipment manufacturing, providing job opportunities for maintenance and operations, and improving local economies, which ultimately may reduce migration.

As a part of the Digital global Biogas Cooperation (DiBiCoo) project, this Report on Biogas Markets and Frameworks in Argentina, Ethiopia, Ghana, Indonesia, and South Africa aims to provide thorough and extensive assessments of the current progress of biogas and market conditions in each of these countries. The report includes concrete facts on legislation, permitting procedures, financing, infrastructure, available expertise, and social, cultural, and sustainability issues. Within the analyses for each country, the market and framework assessment were fulfilled through several key aspects. Divided into several sub-chapters, aspects that are covered in the analysis can be seen in figure 1 below.

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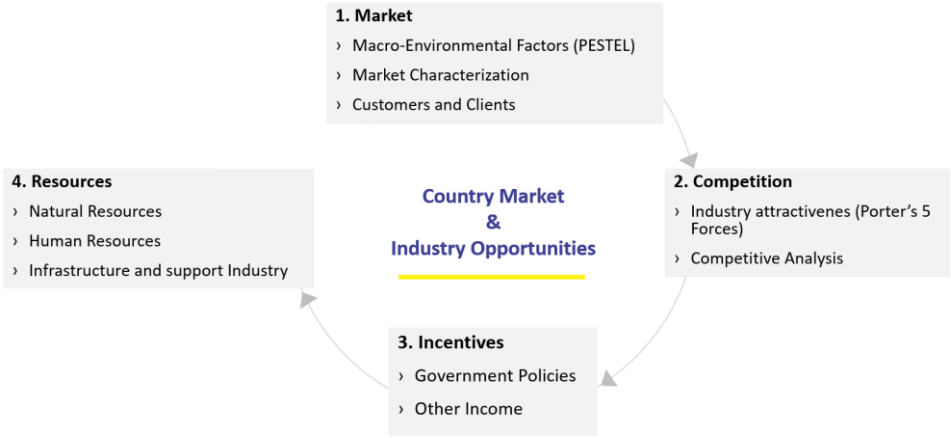

Figure 1: Overall structure and basis of the Market and Framework Analysis (Philippe Lassere, 2003)

The market analysis was done through the consideration of three factors: **(1) PESTLE analysis; (2) Market Characterisation; and, (3) Customers and Clients.** Each factor is elaborated briefly in the following:

1) **The PESTLE framework** is a multifaceted approach to assess the external macro-environment, which includes **political, economic, social, technological, legal, and environmental factors**. This framework is used to map and analyze how the macro-environmental factors influence an industry (Song JB et. al., 2013 as cited in Song et. al, 2017, p. 277). Since DiBiCoo requires an understanding of the local market dynamics, it is appropriate to use PESTLE as the cornerstone of the market research. This framework is excellent in describing multi-dimensional aspects and serving as a generalized foundation for further market assessment. However, due to its qualitative nature PESTLE's ability to analyze is restricted to identifying and evaluating contextual issues (Buchanan & Gibb, 1998 as cited in Iacovidou et. al., 2017). *In the PESTLE analysis section for each of the countries, a minimum of three factors were analysed based on what is most relevant and important to elaborate according to the existing conditions in Argentina, Ethiopia, Ghana, Indonesia, and South Africa.*

2) **Market characterization** (Richard Lynch, 2015) includes the elaboration of the following factors:
   a. **Market form:** what stage is the market currently in i.e. early stage, takeoff, peaking, declining, or stabilizing. Includes elaborations on whether the market is concentrated or sporadic, while noting industrial regions or the lack thereof.
   b. **Market Size:** how large is the aggregated demand of biogas, how valuable is biogas as a market commodity, including information on price and monetary improvement in users.
   c. **Market Growth:** how is the biogas market growth rate (amount of biogas installed nationwide or in a certain region, within 5-10 years), and the growth trend of the market i.e. is the market expanding, declining, or stagnating.
   d. **Market Share:** how big is the share of biogas in the RE market or how much is electricity represented in the national energy usage, and what are the local authorities or industry players' expectations on future market shares.

3) **Customers and Clients** section includes a simple value chain analysis i.e. a description of services that biogas 'customers' provide and the goods they sell to gather in-

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come, along with an elaboration of the source of their goods, the process being done, and to which 'clients' (e.g. energy off-takers) the customers arrange business dealings with.

In the second section of the report, the biogas market attractiveness in all five countries is analyzed through the lens of the Porter's 5 forces. Analysis of the overall Porter's components were done in the analysis of countries such as Argentina, Ethiopia, and Ghana. While analysis of countries such as Indonesia and South Africa utilises a minimum of three sub-factors for each force, based on which ones are most important and relevant given the country's biogas market condition. The overview of the Porter's Five Forces is outlined in Figure 2.

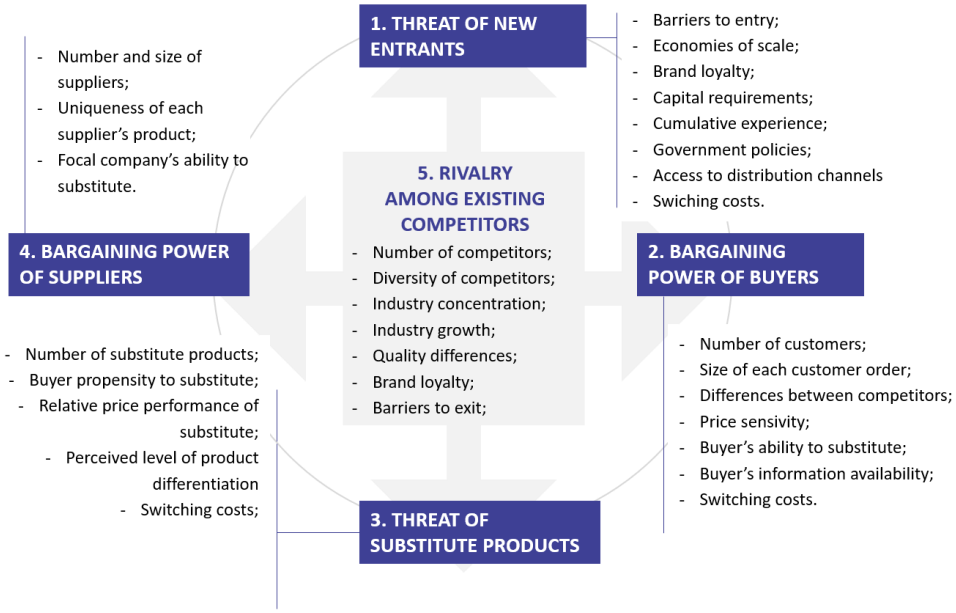

Figure 2: Porter's Five Forces and its sub-factors (Michael E. Porter, 1979)

Consequently, each of the sub-factors selected for each country based on the five forces were rated with the following scale based on the evidence gathered[6]:

1. Is absolute zero risk
2. Is low risk[7]
3. Is low risk with straightforward operational solution
4. Is low risk which require strategic adjustment
5. Is moderate risk
6. Is moderate risk with straightforward operational solution
7. Is moderate risk which require strategic adjustment
8. Is high risk
9. Is high risk with straightforward operational solution
10. Is high risk which require strategic adjustment

[6] Straightforward operational solution is defined as measures taken by business actors in the short term, for the most part addressing specific elements of a market e.g. technical aspects. Conversely, strategic adjustment is defined as long-term measures taken by business actors which involves an end-to-end approach.
[7] 'Is high risk', 'is moderate risk', and 'is high risk' are external risk factors that cannot be directly addressed. These risks require business actors to adapt to these existing external issues.

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The next section substantiated within the report is a thorough elaboration of **market policies and incentives** available in the five countries. This section is imperative for project developers, since knowledge and understanding of local policies and programs available in each country is vital for securing the project development process. A list of incentives established through public policies and programs provided within this section could also be key for project developers to ensure the success and viability of biogas projects despite its financial challenges. Government policies and programs which offer incentives could enable biogas developers to secure investment for project initiation, and to increase economic feasibility by offsetting costs (especially due to high capital costs) and generating revenue streams for long-term operations (Global Methane Initiative, 2014). In sum, this section will provide:

1. A list of regulations and policies that can affect local steps of biogas development i.e. bureaucratic or administrative regulations, fiscal policies, and regulations, and those that are related to the technical aspect of biogas project development.
2. A thorough analysis on available public incentives supporting the development of biogas projects i.e. incentives which provide advantages through streamlined project period and incentives that cut financial costs.

The 'resources' section of each country's report outlines available natural resources that could be utilized by biogas, available human resources that could support the initiation of biogas development and its long-term operation and maintenance, along with available infrastructure and support industry that are vital throughout the value chain. The contents of this section are threefold:

1. Natural Resources: Includes elaboration on available resources that could be utilised by biogas installations as feedstock. This section details the notable biogas feedstocks in each country along with a further description of its related industries, key locations of feedstocks in regions, chemical composition, rate of supply, and subsequent power yield from available feedstock i.e. in its current state and/or future projection;
2. Human Resources: This section provides an elaboration of available human resources that are qualified for biogas development;
3. Infrastructure and Support Industry.

Lastly, the authors would like to emphasize that this report was mostly written during the start of the 2020 COVID-19 Pandemic—which has, to some extent limited our ability to fully conduct additional surveys and interviews. Nevertheless, it can be assured that data gained through phone interviews, along with the distribution of surveys and face-to-face interviews conducted prior to April 2020, is more than sufficient to establish evidence for the written analysis.

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2 Argentine Republic

2.1 PESTLE or Macro Analysis

2.1.1 Political framework

Argentina has been shifting between different parties and policies in the last 60 years. Socio-democratic and liberal policies take turns to be independently in power depending on the party in charge. This situation does not permit a long-term framework and influences the confidence of the different economic actors.

Society's perception is strongly divided between these different concepts and perceptions of the country. Policies are also mostly influenced by external economic factors. During the last 60 years, the governmental sector has faced growing poverty increased segregation. There is a big bureaucracy that hampers new investments and the growth of new activities as the biogas sector.

The current composition of the Executive Branch includes only the Head of State and President, formally given the power over the Administration to follow through according to the interests of the Nation. The President is also the Chief of the Argentina Armed Forces. The President and the Vice President are elected through universal suffrage.

The national government system is organized in ministries and secretaries of state. In the following table lists ministries that have been selected with influence and decisions regarding the biogas sector in Argentina.

Table 2: Key government actor ministries

Ministry	Website
Ministry of Transport	www.transporte.gob.ar
Ministry of Territorial Development and Habitat	
Ministry of Science, Technology and Innovation	argentina.gob.ar/ciencia
Ministry of Productive Development	www.produccion.gob.ar
Ministry of Labor, Employment and Social Security	argentina.gob.ar/trabajo
Ministry of Health	www.desarrollosocial.gob.ar
Ministry of Foreign Affairs, International Trade and Worship	www.cancilleria.gob.ar
Ministry of Environment and Sustainable Development	argentina.gob.ar/ambiente
Ministry of Economy	www.minhacienda.gob.ar
Ministry of Agriculture, Livestock and Fisheries	argentina.gob.ar/agricultura-ganaderia-y-pesca

The National Congress (Spanish: Congreso Nacional) constitutes the legislative branch of the government. The Congress consists of the Senate (72 seats), presided by the Vice-President of the Nation, and the Chamber of Deputies (257 seats). Senators stay in office for six years, whereas deputies have four years in office.

Each of the Provinces and the Autonomous City of Buenos Aires elect deputies and senators directly. Deputies are elected to represent the people, while Senators represent their districts.

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Each district elects a number of deputies roughly proportional to their overall population by proportional representation, and three senators: two allocated to the party holding the majority of votes, and one to the second most voted. Members of both chambers can participate in indefinite re-elections. Within this system a great consensus was built around the key legislation pieces regulating renewable energy. Bioenergy and renewables in Argentina are by nature decentralised and political representatives of the provinces are always willing to support legislative measures to promote them. Within this system, consensus was built around renewable energy principal laws which directly or indirectly affects biogas projects and governmental programs established and implemented by the executive power in charge.

Argentina is divided into 23 districts called Provinces and one autonomous district, which hosts the national capital: the Autonomous City of Buenos Aires (Province of Buenos Aires). Each of the provinces has its own constitution, laws, and authorities, forms of government, etc., though all local governments must above all comply with the national constitution and laws. This is a key aspect for biogas developers since each province develops their own promotional framework and specific requirements related to environmental issues.

The government of each province has three branches. The Executive, Legislative and Judiciary. The Executive branch is led by a governor. The Legislative branch may be organized as a unicameral or a bicameral system (that is, either one or two chambers or houses). Each province, except for Buenos Aires Province, is divided into districts called departments. Departments are merely administrative divisions; they do not have governing structures or authorities of their own. They are in turn divided into municipalities (cities, towns and villages). Each province has its own laws and government systems for different kinds of municipalities. For example, Córdoba Province has *municipios* and *comunas* (towns); Santa Fe Province further distinguishes between first- and second-tier *municipios*. The Province of Buenos Aires has a different system. Its territory is divided into 134 districts called *partidos*, each of which usually contains several cities and towns.

Regardless of the province, each department or *partido* has a head town (*cabecera*), often though not necessarily the largest urban center, and in some provinces often named the same as their parent district. Municipalities are ruled by mayors, usually called Intendant (intendente) in the case of cities and towns (the larger categories). A city has a legislative body called the Deliberative Council (*Concejo Deliberante*). The smaller towns have simpler systems, often ruled by commissions presided by a communal president (*presidente communal*) or a similarly named authority. This is an important aspect in the case of biogas developments especially those that are aimed to treat municipal solid waste (MSW) and water treatment plants.

It is important to note that only minimum requirement laws, rules and legislation are enacted at the national level and provinces are autonomous and may promulgate their own legislation, which must comply with the minimum requirements of the federal legislation. This is particularly important in the case of activities such as biogas and digestate that are related with environmental issues especially those that lies under the provincial government's responsibility.

In the sixties, an increasing percentage of the population are below the poverty line and there has been an increase of governmental support for this part of the population. There is a con-

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tinuous deficit of the national government that leads to externa debt and inflation. As the government is an important actor which absorbs money, interest rates are generally high affecting risk investments for new construction of biogas plants.

Regarding the perception towards corruption, Argentina is in a region with an average score of 44/100 for three consecutive years. South America continues to fail in making any serious inroads against corruption. In Argentina, corruption levels have decreased one point since 2017 and 8 points since 2015, showing some significant improvement. The country has reached a score of 40/100 during the last administration according to Transparency International. However, public perception of this index is worsening. There are uncertainties of the future trend with the recent change of administration. The liberation of prominent corrupt politicians has not been a good signal.

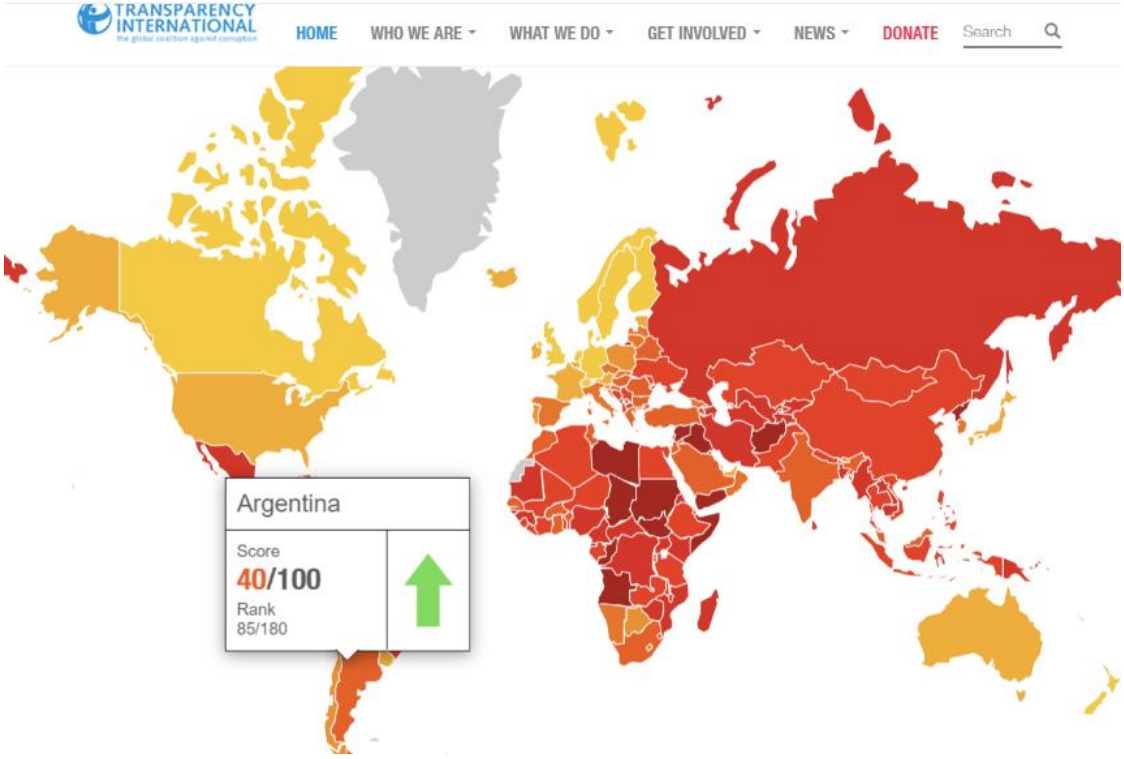

Figure 3: Argentina's Transparency index (Transparency International)

Argentina also face another challenge: the need to continue strengthening the independence of its judicial systems to ensure impartial prosecutions, and to ensure that those found guilty of corruption receive appropriate punishment.

Although freedom of the media and access to information is more robust in the country, it could be stronger. These fundamental rights are essential for curbing corruption and contributing to a more aware and involved society that includes minorities and vulnerable groups, and that can demand accountability from those in power.

Despite the political stability over the years, the country is still under the pressure of immense economic stress. Since the return to democracy, the system has been able to cope with severe crisis without interrupting elections and civil rights since the beginning of the early eighties.

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2.1.2 Economic situation

One of the historic crucial issues for Argentina is its macroeconomic situation with periodic crises, and loss of confidence of the economic actors.

The economy remained in the doldrums in the final quarter of 2019. Economic activities shriveled in October-November 2019, while consumer confidence was rather pessimistic and export growth have cooled down in the fourth quarter. On a more positive note, industrial production expanded for the first time in 20 months in December. Meanwhile, in early February, the Senate ratified the lower house's decision to grant the government the power to restructure around USD 100 billion of the country's foreign-denominated sovereign debt. Around USD 44 billion of this is owed to the IMF.

Due to its fragile situation and a lengthy lockdown due to the 2020 health crisis, the impacts over the economy have been very significant. This is also being reflected by the confidence levels raising the country risk index over 2000. Banks have also found its financing efforts interrupted, and biogas projects currently under construction are being affected. There is an awfully long negotiation process with creditors, and deadlines are being postponed since the end of March.

Government deficit results in foreign debt and inflation crisis due to hard currency loans to fill the financial gap. However, inflation has seen a low temporal decline at an extremely high level valued at 53.9%. Predictions by economic experts before the COVID-19 pandemic initially expected inflations to reach 41,7% in 2020 and 28,1% in 2021. Due to an enormous increase in government aid, this numbers are now very conservative, and some expect hyper-inflation rates in the near future.

The monthly indicator for economic activity *Estimador Mensual de Actividad Económica* (EMAE) dipped by 0.3% in December, after logging a 2.0% contraction in November. In terms of productive sectors, the softer contraction in December 2019 was largely driven by rebounds in the fishing, manufacturing, and internal trade sectors. This was also partly the offset of a downturn in the agricultural sector and by sharper contractions in the construction and financial sectors. A month-on-month comparison showed that economic activity ticked up 0.2% in December according to a seasonally adjusted data, in contrast to the November 1.6% drop. Notwithstanding, the average annual variation in economic activity improved from a 2.7% contraction in November to a 2.1% decrease in December.

Latest numbers of industry contraction are significant, since the main economic area of Buenos Aires province and the federal district are in strict lockdown conditions.

GDP dropped a second year in a row in 2019, as high inflation and prohibitive interest rates linked to the monetary crisis triggered in April 2018 were still present, prevailing over the robust rebound in agriculture (following the 2018 historic drought). Indeed, the crisis gained further momentum after the presidential election primary of August 2019, when the strong showing by the current President Fernandez unleashed a new round of Peso (ARS) sell-off. Analyst predicts that the economy seems destined to remain in recession in 2020. The uncertainty regarding the economic policies of the newly elected government and to how it will handle the unsustainable public debt, should imply a continuing low level of private investments (notably for the moribund construction with some minimal impact in the biogas industry). Moreover, the fiscal deficit will limit policymakers' capacity to implement a desirable expansionary policy. Besides that, the skyrocketing inflation is not likely to ease significantly and will continue to erode real

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income (causing knock on effects on household consumption). Finally, net foreign trade is likely to contribute positively to GDP, as imports should continue to drop and exports to benefit from a relatively higher economic activity in Brazil. There are many risks to the economic scenario, with the sensitive fiscal situation and the possible failure in renegotiating public debt likely to trigger new pressures on the exchange rate which ultimately affect the economy through higher inflation and possibly a tightening of capital controls. This scenario has become worse due to coronavirus and its multiple impact is seen in many crucial areas of the economy.

The current deficit registered a strong narrowing in 2019. It was mainly driven by a rebound in trade balance, from a large deficit of 2.3% of GDP to a surplus estimated at 2.9% of GDP (due to collapsing imports and recovering agrarian exports). Moreover, the services deficit (of roughly 2.1% of GDP) also registered an improvement (mainly driven by a narrowing of the travel imbalance). Alongside, the lower deficit also started to be fully covered again by foreign direct investments (estimated at 1.3% of GDP in 2019). Overall, the current account is likely to become slightly positive in 2020, as the economy is to remain in recession (thus implying low import level) and export is likely to continue climbing as a result of expected good crops this year and higher economic momentum in Brazil (Cronista commercial, 2020).

However, the fiscal scenario is more challenging. Although the previous government was able to reduce the budget deficit in the last two years (a condition of the IMF loan deal), a lot still needs to be done. As majority of the public debt is in foreign currency (roughly 81%), it is highly sensitive to strong exchange rate movements. Its amortization will be very high in the upcoming years (estimated at 16% of GDP in 2020 only) (Clarin económico, 2020). In December 2019, the new government of President Fernandez unilaterally postponed the payment of USD 9.1 billion short-term treasury bills issued under local legislation until August 2020. He also announced his intention to restructure long bonds term issued under local and foreign law in early 2020 (Ambito Financiero, 2020).

Argentina's economic freedom score is 53.1, making its economy the 149th freest in the 2020 Index. Its overall score has increased by 0.9 point, primarily because of a higher government integrity score. Argentina is ranked 26th among 32 countries in the Americas region, and its overall score is well below the regional and world averages. Alongisde that fact, a more interventionist and fiscal expansionary approach that is expected could make the negotiations with the IMF difficult. Most Importantly, considering the hard debt payment schedule ahead, with capital controls which came into force since September 2019 and were tightened after the presidential elections. This capital control is not likely to be eased in the short term and could even be strengthened. That is because of the strong slump in foreign exchange reserves in 2019 (net reserves give import coverage of roughly three months of imports). This strong slump in foreign exchange reserves was the consequence of the people's reaction after the primary elections in which they were inclined to purchase foreign currencies (i.e. the US Dollar). Two weeks in power the new government got congressional approval for his emergency plan, which includes measures to increase tax revenue, a 30% tax on hard currency purchases and higher taxes on agricultural exports. It also gives the government increased regulatory powers in areas such as service rates public and pensions.

Despite recent economic struggles, Argentina continues to play an important role within the global economy, especially with regards to its agricultural production (BCR, 2019). The sector is mainly based on livestock farming, cereal cultivation (wheat, corn, and soy), citrus fruits, tobacco, tea, and grapes (mostly for the production of wine) with an overall profit of 28.800

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million dollars per year. Argentina is the world's largest exporter of soy-derived products and the world's third largest producer of such products. Soy and sugar cane and corn byproducts are also used for bio-fuel production. As a result, the country is the world's largest exporter and fourth largest producer of biodiesel. The agricultural sector represents 6% of the country's GDP, but it only employs 0.1% of the population. Additionally, given that the country is rich in energy resources, Argentina also has a great potential in terms of raw materials: it is the fourth largest natural gas producer in Latin America, and it has the world's third largest shale gas reserve and the fourth largest lithium reserve (BCR, 2019).

The industrial sector has vastly expanded in recent years: it represents 23% of GDP and employs 22.4% of the population. Food processing and packaging - in particular, meat packing, flour grinding and canning - and flour-milling are the country's main industries. The industrial sector also demonstrates strength in motor vehicles and auto parts, consumer durables, textiles, chemicals and petrochemicals, pharmaceuticals, printing, metallurgy and steel, industrial and farm machinery, electronics, and home appliances.

The biogas sector with its small dimension does not alter national figures although it can have a measurable impact at county levels (Secretary of energy, 2020). Looking at its overall potential in the country a significative expansion at great scale similar to Germany example could produce higher impacts. This impact would affect fuel imports. Such strategy needs a great consensus since these are strong forces that consider shale oil and gas a solution for the country deficit.

The service sector has followed the same upward trajectory as the industrial sector. It contributes almost 56.9% of the GDP and employs 77.6% of the active workforce. Argentina has specialized in areas of high-tech services and is highly competitive in software development, call centers, nuclear energy, and tourism. The telephone and ITC sectors are also developing dynamically, as well as tourism, which is increasingly becoming an important sector.

2.1.3 Social situation

With a Gross Domestic Product (GDP) of approximately US$470 billion, Argentina is one of the largest economies in Latin America (World Bank, 2020). The size, historic background and potential of the country creates an image of unreal richness of the country in the urban population and the standard of living surpasses the actual capacity of the economy.

Argentina has vast natural resources in energy and agriculture. Within its 2.8 million square kilometers of territory, Argentina is endowed with extraordinary fertile lands, gas, and lithium reserves, and has great potential for renewable energy. It is a leading food producer with large-scale agricultural and livestock industries. In addition, the country has significant opportunities in some manufacturing subsectors, and innovative services in high tech industries.

However, the historical volatility of economic growth and the accumulation of institutional obstacles have impeded the country's development. INDEC reported that Urban poverty in Argentina remains high and reaches 35.4% of population, while poverty in children rises to 52.6% (Buenos Aires Times, 2019).

To deal with this situation, the country has prioritized social spending through various programs, including the Universal Child Allowance, a cash transfer program that reaches approximately 4 million children and adolescents up to age 18, representing 9.3% of the population.

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In 2018, Argentina was hit hard by a series of external and internal factors including severe droughts, global financial volatility in emerging markets following the Federal reserve adjustment of the interest rate, and market perceptions on the pace of fiscal reforms.

The last administration has improved the protection of intellectual property rights, but deficiencies persist within the regimes for protection of patent and regulatory data. Secured interests in real property are recognized and enforced. The Marci administration's "Justice 2020" initiative was intended to improve transparency and rule of law, but the weakness of anticorruption bodies and politicization of the judicial system have hampered progress.

According to INDEC, the total value of exports and imports of goods and services is 30.8% of GDP. Other taxes include value-added, wealth, and financial transactions taxes. The overall tax burden equals 30.3% of total domestic income. Government spending has amounted to 40.5% of the country's output (GDP) over the past three years, and budget deficits have averaged 6.1% of GDP. Public debt is equivalent to 86.3% of GDP (BCR, 2020).

Procedures for establishing limited liability companies have been streamlined, but economic and political hurdles have blocked other pro-business reforms. Argentina has a highly skilled and well-educated workforce, but taxes for pensions, the cost of health care, and other labor taxes remain high.

The total value of exports and imports of goods and services equals 30.8% of GDP. The average applied tariff rate is 7.9%, and 139 nontariff measures are in force. Foreign investment in various sectors remains regulated. The government exercises considerable control of financial activities.

In Argentina, as in most Latin American countries, family ties are notably broader than in North America and northern Europe. The North American and northern European families usually consist of one's spouse and children (and occasionally one's parents). In Argentina, family ties remain remarkably close for most kinship relationships. Cousins, in-laws, uncles and aunts, nephews, nieces, and godparent relationships are customarily considered part of one's immediate family.

Consequently, Argentine family ties furnish much stronger admission (than in North America or northern Europe) to business joint ventures, to amiable terms in negotiations, and to access to relatives in high positions. The result is that in some cases North American or north European business visitors to Argentina find themselves unable to contact those in authority because they may not realize the importance of such connections.

Argentina has a comparatively egalitarian distribution of wealth, especially compared to other Latin American nations. At $9,700 per capita GDP, Argentina has the highest per capita income distribution in Latin America. (INDEC, 2020) In this regard, Argentina has very little of the economic class stratification that so characterizes Mexico, Brazil, and other major Latin American trade powers. Instead, the vast majority of Argentines belong to the middle class, as is the case in North America, Japan, and Europe.

Regarding the educational level in Argentina, 96.2% of the population is able to read, Argentina has one of the highest literacy rates in the world, and the second highest (after Uruguay) in the Spanish-speaking world. The country has one of the highest primary school enrollment rates in the world, with just under 100%. Argentina has the highest percentage of university graduates in Latin America, with a rate of over three times the number of university students per

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100,000 of Brazil or Mexico. Four out of five Argentinian adults have completed grade school, over a third have completed their secondary education and one in nine Argentine adults have college degrees (INDEC, 2020). Likewise, Argentina has the highest rate of university students in Latin America. It has also the highest number of professors and institutions awarded prestigious prizes and fellowships from philanthropic institutions within the Southern hemisphere.

This aspect is especially important in relation with the possibility of finding well educated labor force to work in biogas facilities along the country. It is also important since people are looking for new jobs that require higher levels of literacy.

2.1.4 Technology

The most important aspects of science and technology in Argentina concern medicine, nuclear physics, biotechnology, nanotechnology, space and rocket technology and several fields related to the country's main economic activities. According to the World Bank, Argentinian exports in high technology are products with high R&D intensity, including aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. The sector takes advantage from Latin America's highest literacy rates. Argentinian researchers and professionals at home and abroad continue to enjoy a high standing in their fields. Argentinian Bernardo Houssay was the first Latin American awarded with a Nobel Prize in sciences. Educated in a National University, Houssay went on to establish Argentina's National Research Council, a centerpiece in Argentine scientific and technological development, fifty years ago. Many other Argentinians have contributed to scientific development around the world, though sometimes having to emigrate to do so.

All this important skills and research capabilities make possible to rapidly adapt, improve and innovate in biogas or other renewable energy technologies. There have been several institutional research biogas projects along the country. The knowledge of biogas systems behavior and operation has grown steadily in the last seven years. In the 2020 National Bioenergy Awards, a significant number of biogas research thesis were presented with outstanding quality.

Research on biogas has also been conducted in a vast network of Universities and some specific technological institutions including the National Institute of Industrial Technology (INTI) and the National Agricultural Technology Institute (INTA). Both institutes have extensive branches of experimental stations and extension agencies that cover the whole country. The institutes also have biogas programs with a vast territorial reach.

Argentine scientists also contributed to bioscience in efforts like the Human Genome Project, where they successfully mapped the genome of a living being, a world first. Argentina has its own satellite program, nuclear power station designs (4th generation), and public nuclear energy company INVAP, which provides several countries with nuclear reactors.

Other projects are focusing on IS, nanotechnology, biotechnology, helicopters, farming machinery and defense systems. Established in 1991, the CONAE has launched 8 indigenous built satellites successfully, AMSAT, MuSat, SAC-B, SAC-A, SAC-C, SAC-D/Aquarius, ARSAT I and ARSAT-2.

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Among the public institutions devoted to research and development in Argentina are:

- CITEDEF: Defense Scientific and Technical Research Institute
- CNEA: National Atomic Energy Commission
- CONAE: National Space Activities Commission
- CONICET: The National Research Council
- INTA: National Agricultural Technology Institute
- INTI: National Industrial Technology Institute
- INVAP: Argentine high-technology research & development company

Coursera published the Global Skills Index (GSI) and ranked Argentina as the number 1 country in technological skills, obtaining a percentile of 100% within this category. This report emphasizes why Argentina is a highly developed country highly developed in terms of technological progress. As for Argentina's performance, it ranks first in technology, both in the region and in the world. This shows that the country offers a vast advantage in the most popular and required discipline in the world, providing advanced knowledge and technical skills of excellence which can take this field to another level. Reports show that Argentina stands out with a strong performance in Software Engineering with a score of 100% and in Operating Systems with a score of 95% (INDEC, 2020). Argentina outshines all its neighbors by a wide margin. This reflects the country's strong technology community and tech-savvy government, as well as its ambitious goal to be the center of the Fourth Industrial Revolution." These facts place the country remarkably high when it comes to outsourcing IT or software services. The software industry is positioned as the fourth largest exporter in the country. Other interesting data are provided by the Chamber of Software and Information Technology Companies (CESSI) in its latest annual report (Spa)[8] published last year. It mentions that during 2017, Argentina reached a historical record of exports, with US$ 1.699 million surpassing the record of 2012 (US$ 1.533 million), and as a result, foreign revenues in dollars increased by 26.5%.

2.1.5 Environment

Argentina faces serious environmental challenges, but it is one of the countries in the region that has developed a sophisticated body of environmental jurisprudence, from cases on mining and other industrial pollution to community water supplies. Argentina has developed a particularly important and sophisticated network of institutions related to agriculture and the agribusiness. The increasing influence of several organizations has been significant. Just to name the most important ones: INTA, *Asociación Argentina de Consorcios Regionales de Experimentación Agrícola* (AACREA), *Profesionales especializados en cultivo de Soja* (PROSOJA) and Argentina Association of Producers with Direct Soowing (AAPRESID) mainly focused on the primary production; INTI, *Asociación de la Cadena de la Soja Argentina* (ACSOJA), *Asociación Maíz y Sorgo Argentino* (MAIZAR), *Asociación Argentina de Grasas y Aceites* (ASAGA), *Cámara Argentina de Biocombustibles* (CARBIO) & ABH more orientated to the agroindustry and agribusiness.

An enormous evolution regarding sustainable development awareness is in place in the whole agricultural system with special emphasis in soybean production. This materializes in the

[8] Latest Annual report of the software and computer services sector of the Argentine Republic, can be accessed in: http://www.cessi.org.ar/opssi-reportes-949/index.html

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whole research made by the above-mentioned organizations. The increasing awareness on these aspects is incredibly positive for biogas projects, as they could improve the current situation specially in animal production farms.

There is also a parallel concern on social aspects coming from the public side (municipal, province and federal governments) and the private sector through new trends in enterprise management as fair trade, social enterprise responsibility and certification schemes.

The progress achieved is allowing premises promoting sustainable development to put in practice concrete initiatives:

- Criteria, development indicators
- Good agricultural and agro-industrial practices
- Certified agriculture
- Certification of biofuel schemes, International Sustainability and Carbon Certification (ISCC), CARBIO, Round Table Responsible Soy Round Table Responsible Soy (RTRS), Roundtable on Sustainable Biomaterials (RSB) among others.

Technological evolution has allowed unquestionable improvements in the preservation of the environment. Just to name a few:

- Reduction of agrochemicals toxicity
- Applied technologies (Good agricultural practices)
- Direct seeding technologies
- Precision farming
- Higher production intensity, reducing pressure over extension of land-use.

The development advance of the regulatory framework context has allowed a better control and the future development of land usage. In Argentina's case the Minimum Budget Law of minimum budget is an example towards that direction. Over the last decades, soybean cultivation has had an unprecedented evolution with no precedents. Since the 70's plantations implanted areas have grown, from sustain representing 37.000 hectares in the 1970/71 campaign to more than 17 million at the present (INTA & Ministry of Agriculture, 2020).

In Argentina, the no-till farming system has been developed in the late 1980s. Its first objective was to reduce soil erosion and degradation. This method is a way of growing crops from year to year without disturbing the soil through tillage, a system of conservation that lets on the soil the weeds from the precedent crop. This emergent agricultural technique prevents soil erosion and degradation, and improves physical, chemical, and biological soil conditions. Moreover, it has shown great results on the efficiency of water use, which is an especially important parameter and usually a limiting production factor.

Increased regulation has allowed for better control on the future development of land use. In Argentina's case Law Number 26.331 (The Native Forest Minimum Budget Law), is an example towards that direction, though implementation has been less effective. It is structured on the base of two central measures: one that strives to immediately stop deforestation, and the other producing an environmental territorial code for each province's land uses, including native forests. Its objective is to achieve conservation, sustainable forest use, and payment for ecosystem services, which are given to the local community. Thus, the code should reflect the different conservation categories - I (red), II (yellow) and III (green) – which reflect the environmental value of the different native forest units and environmental services provided.

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In February 2009, the National Executive Power dictated the Decree N° 91/2009 that implements the Native Forest Law. Unfortunately, this Decree did not adequately finance the National Fund for the Enrichments and Conservation of Native Forests, whose purpose is to contract for the payment of environmental services (Di Paola et al., 2009). This fund has yet to be adequately supported since then, raising serious concerns about the implementation of Law Number 26.331.

Regarding pesticide use, glyphosate use is widely used. While it is less aggressive to the environment and human health than alternatives for large application volumes coming from soy expansion, it is essential to enforce the handling and application recommendations. We care for this technology making relevant studies to understand its action on the environment and human health and to optimize its therapeutic action and minimize its harmful effects. There had been isolated accidents with glyphosate bad handling. There are improvements in technologies, handling trainings and techniques. The main recommendations for safer handling that are followed are i) adjust timing, dose and avoid precipitation close to applications, ii) crop rotations and / or implementation of cover crops to reduce the amount and concentration of glyphosate and in surface runoff or deep drainage iii) buffer zones for protection of biodiversity, surface freshwater bodies and population in urban areas and to prevent contamination by drift, (INTA, 2011).

As part of the Paris Agreement on climate change, Argentina committed to reducing its greenhouse gas emissions by 18% unconditionally, with the possibility of increasing that figure to 37%, based on the availability of international funding. According to studies, Argentine is responsible for 0.7% of global emissions (Argentina.gob.ar, n.d.).

Though Argentina's commitment is considered as one of the more ambitious compared to other nations, is nonetheless still seen as insufficient by most climate organizations, whose say it is not in line with the goal outlined in the Paris Agreement: limiting global warming to a maximum of two degrees Celsius (2ºC) above pre-industrial levels. With current pledges taken into account, experts warn, global warming would reach four degrees Celsius (4ºC).

According to Argentina last inventory report published in 2017, the energy sector accounts for 53% of emissions in the country. Cattle represents 20.7%, followed by transportation with 15%. In these three sectors, biogas could play an important role if a significant development is achieved in these three sectors.

There are other groups in several rural towns concerned about agrochemical extensive use and their actions have led to several regulations at municipal and provincial level regarding restrictions to the use over small village's schools etc.

2.1.6 Environmental requirements applied to biogas plants[9]

In environmental matters, there are no regulations that specifically apply to projects of production or use of biogas. By application of the precepts of the National Constitution (Article 124), the competence in environmental matters corresponds to the provinces, with the limitations established in favor of the Nation. In this sense, the Nation has powers to dictate the minimum

[9] A complete description of all the laws regulations, etc. applicable to biogas plants and artifacts can be downloaded from the PROBIOMASA project site http://www.probiomasa.gob.ar/_pdf/01CEARE-InformeTecnico-web.pdf

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budget standards for environmental protection, that impose a uniform floor throughout the national territory. In these cases, the provinces have complementary powers, without being able to establish legislation or parameters of protection that are lower than those established by the Nation, and are also obliged to adapt the provincial regulations that do not meet the minimum budgets. Thus, by application of the General Environmental Law, all projects that have risk of environmental degradation or affect the quality of life of the population in a significant way must have an Environmental Impact Evaluation (EIA). However, there is no national minimum budget standard for the performance of the EIA. The procedure is currently subject to the provincial regulations. Therefore, the elaboration of a technical regulatory guide is recommended. It would be important if in the coming years federal minimum environmental protection requirements are to be developed to give the provinces the chance to adopt them in their territory.

In addition to the relevant environmental conditions for the installation and operation of biogas production plants, the use of the digestate as fertilizer should be regulated, since, on the one hand, its nutrient content can contaminate the soil and water by eutrophication, and on the other hand, the soil on which the digest is applied may not be suitable for such application. Transport and adequate distribution can be awfully expensive since it is made up of 90% water and requires considerable expenses to transport it in tank trucks. Therefore, it is necessary to establish procedural rules for the final disposal of the digestate, whose absence are currently acting as a limiting factor for biogas projects.

2.2 Market Characterization and Definition

2.2.1 Traditional market

According to a report published by PROBIOMASA in 2020[10], *in Argentina, the biogas market has gained a solid foothold over the last five years and is massively industrial. However, its growth is slowing down.* In 2015, Argentina has developed 100 biogas plants and has grown exponentially until 2020 through the RenovAr Programme. During 2020, INTA and PROBIOMASA has conducted a survey assessing 80 of the 100 plants built nationwide. INTA and PROBIOMASA has found that from the 80 plants surveyed, 76 of the 80 biogas plants developed up until 2015 were installed for environmental purposes, while 11 of the 80 biogas plants surveyed were utilised for energy development, consisting of large bio-digestion plants (1MW-2MW), consisting mostly of covered lagoon and mixed technologies utilising digesters, double membrane reactor, and a co-generation unit i.e. combined heat and power (CHP). This situation translates into a low rate of biogas utilization as renewable energy and underutilization of facilities. The study also found the existence of technical flaws in the construction, materials used, lack of safety and operation procedures of the installations and poor training of qualified personnel for handling of the plants. Such shortcomings correspond, in some cases, to norms or standards such as those related to safety conditions, environmental regulations and materials. Furthermore, a low use of thermal insulators, agitators, and control of key parameters among others were detected.

The most used substrates were industrial waste (37.5%); urban organic waste (28.1%); and virgin biomass (1.6%) (PROBIOMASA, 2020). Important shortcomings were observed in terms of security measures appropriate to the type of process and, also, in terms of standards that

[10] The complete PROBIOMASA report can be accessed in: http://www.probiomasa.gob.ar/_pdf/12-valoracion-externalidades-biomasa-seca-biogas.pdf

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regulate these aspects. In addition, there are deviations in the design of the plants with respect to the environmental conditions.

2.2.2 New market in development

In the last five years, the implementation of the RenovAr program has called for the development of a new professional and high-tech market. There was an important development of the technology with providers principally coming from Europe. There has been a rapid increase in the capacity of local developers in construction start up and operation of complex plants.

The RenovAr program was framed within the national plan of the Undersecretary for Renewable Energies. It responds to Law 27,191 which aims to achieve a 20% renewable energy penetration into the energy mix by 2025. Four rounds of the program have already been carried out successfully, RenovAr 1, RenovAr 1.5 and RenovAr 2 and miniRenovAr3. A more detailed explanation of the RenovAr program can be found in section 2.4.1.

The program is intended to generate 400 MW of power from different renewable electric generation technologies. In the case of the last call in 2019, Mini Ren 3, 10 MW are those destined for a tender for electricity generation from BIOGAS. The minimum power for each of the projects must be 0.5 MW, while the maximum accepted power is 10 MW.

The program has many benefits and incentives. In the first instance, the most important is the fact of signing an energy supply contract or Power Purchase Agreement (PPA) with the Management Company of the Wholesale Electricity Market (CAMMESA), for a term of 20 years. In this contract, the BIOGAS project undertakes to supply a certain amount of electrical energy to the national distribution network monthly against a payment in US Dollars by the provincial energy distributor in agreement with CAMMESA. In the case of biogas, the maximum price accepted to submit in the tender per MW-h of committed energy is USD 160.

It is the obligation of the entities responsible for the distribution of electrical energy in each province to accept the rate, committing to pay said rate, with the acceptance by CAMMESA. The provincial entities are responsible for the payment with the joint acceptance of CAMMESA.

This program produced an increasing market with the evolution of the calls, which were made friendlier with biogas technology.

In general, projects carried out by companies of national capital and financing in most cases, was structured with Banco BICE and the *Banco Nación de la República Argentina*. The loan structuring problem is observed in guarantees requested by banks, which do not consider supply contracts signed with CAMMESA as sufficient. To overcome this problem, the Fund for the Development of Renewable Energy (FODER) was created as an additional guarantee. In recent years, an important local knowledge base has been generated for dry biomass and biogas, which includes local developers, technologists, science agencies and technology, universities, input suppliers, financing sectors, distributors of energy, like users and communities. The conditions are in place to generate synergies to this strategic and fundamental sector for rural development and circular economies at the national level.

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At the present stage there are in total 65 biogas projects in round 1, there are a total of 37 signed contracts for a total amount of 64,9 MW with an average price of 159,7 USD/MW[11].

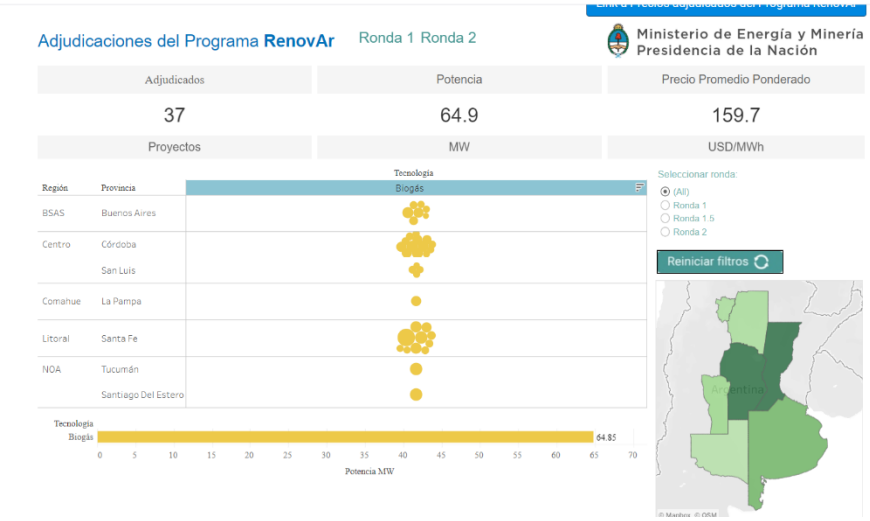

Figure 4: Print screen of the official ministry of energy page

[11] Live information of biogas projects can be accessed through the Secretary of Energy webpage: https://www.minem.gob.ar/www/833/25897/proyectos-adjudicados-del-programa-renovar.

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Table 3: Biogas projects approved (partly operating and partly in construction)

ID	Name of project	Company	Province	Región	Price & Power sec row
BG-01	C.T. Río Cuarto 1	BIOMAS CROP	Córdoba	Centro	160
BG-01	C.T. Río Cuarto 1	BIOMAS CROP	Córdoba	Centro	2
BG-02	C.T. Río Cuarto 2	BIOMAS CROP	Córdoba	Centro	160
BG-02	C.T. Río Cuarto 2	BIOMAS CROP	Córdoba	Centro	1.2
BG-03	C.T. Yanquetruz	ACA / FERSI	San Luis	Centro	160
BG-03	C.T. Yanquetruz	ACA / FERSI	San Luis	Centro	1.2
BG-04	C.T. San Pedro Verde	ADECO AGRO	Santa Fe	Litoral	158.92
BG-04	C.T. San Pedro Verde	ADECO AGRO	Santa Fe	Litoral	1.415
BG-05	C.T. Huinca Renancó	FECOFE / COOP. HUINCA RENANCÓ	Córdoba	Centro	160
BG-05	C.T. Huinca Renancó	FECOFE / COOP. HUINCA RENANCÓ	Córdoba	Centro	1.62
BG-06	C.T. Biogás Ricardone	MARTÍN NACARATO / OTROS	Santa Fe	Litoral	118
BG-06	C.T. Biogás Ricardone	MARTÍN NACARATO / OTROS	Santa Fe	Litoral	1.2
BG-500	C.T. Bombal Biogas	TANONI HNOS S.A.	Santa Fe	Litoral	165
BG-500	C.T. Bombal Biogas	TANONI HNOS S.A.	Santa Fe	Litoral	1.2
BG-501	C.T. Arrebeef Energia	ARREBEEF S.A.	Buenos Aires	BSAS	150
BG-501	C.T. Arrebeef Energia	ARREBEEF S.A.	Buenos Aires	BSAS	1.5
BG-502	C.T. Pollos San Mateo	POLLOS SAN MATEO S.A.	Córdoba	Centro	156
BG-502	C.T. Pollos San Mateo	POLLOS SAN MATEO S.A.	Córdoba	Centro	2.4
BG-503	C.T. James Craik	ACZIA BIOGAS, S.L.	Córdoba	Centro	156
BG-503	C.T. James Craik	ACZIA BIOGAS, S.L.	Córdoba	Centro	2.4
BG-504	C.T. Recreo	ACZIA BIOGAS, S.L.	Santa Fe	Litoral	156
BG-504	C.T. Recreo	ACZIA BIOGAS, S.L.	Santa Fe	Litoral	2.4
BG-505	C.T. San Francisco	ACZIA BIOGAS, S.L.	Córdoba	Centro	156
BG-505	C.T. San Francisco	ACZIA BIOGAS, S.L.	Córdoba	Centro	2.4
BG-506	C.T. Bella Italia	ACZIA BIOGAS, S.L.	Santa Fe	Litoral	156
BG-506	C.T. Bella Italia	ACZIA BIOGAS, S.L.	Santa Fe	Litoral	2.4
BG-507	C.T. Pacuca Bio Energia	PACUCA S.A.	Buenos Aires	BSAS	171.85
BG-507	C.T. Pacuca Bio Energia	PACUCA S.A.	Buenos Aires	BSAS	1
BG-508	C.T. Ab Energia	AB AGRO S.A.	La Pampa	Comahue	156.85
BG-508	C.T. Ab Energia	AB AGRO S.A.	La Pampa	Comahue	2
BG-510	C.T. Resener I	INMADE S.A.	Buenos Aires	BSAS	176.4
BG-510	C.T. Resener I	INMADE S.A.	Buenos Aires	BSAS	0.72
BG-511	C.T. Enreco	CECILIA DEBENEDETTI	Córdoba	Centro	156.85
BG-511	C.T. Enreco	CECILIA DEBENEDETTI	Córdoba	Centro	2
BG-512	C.T. Santiago Energías Re	LOS AMORES S.A.	Santiago Del Estero	NOA	156.85
BG-512	C.T. Santiago Energías Re	LOS AMORES S.A.	Santiago Del Estero	NOA	3
BG-513	C.T. General Villegas	MARÍA ELENA S.A	Buenos Aires	BSAS	169
BG-513	C.T. General Villegas	MARÍA ELENA S.A	Buenos Aires	BSAS	1.2
BG-514	Ampliacion 2 Central Bioe	BIOMASS CROP S.A.	Córdoba	Centro	169
BG-514	Ampliacion 2 Central Bioe	BIOMASS CROP S.A.	Córdoba	Centro	1.2
BG-515	Ampliacion Bioelectrica D	BIOELECTRICA DOS S.A.	Córdoba	Centro	169
BG-515	Ampliacion Bioelectrica D	BIOELECTRICA DOS S.A.	Córdoba	Centro	1.2
BG-516	C.T. Bio Justo Daract	BIOMASS CROP S.A.	San Luis	Centro	175
BG-516	C.T. Bio Justo Daract	BIOMASS CROP S.A.	San Luis	Centro	1
BG-517	C.T. Biogeneradora Santa	BIOGENERADORA CENTRO S.A	Córdoba	Centro	156.85
BG-517	C.T. Biogeneradora Santa	BIOGENERADORA CENTRO S.A	Córdoba	Centro	2
BG-518	C.T. Yanquetruz Ii	BIO ENERGIA YANQUETRUZ	San Luis	Centro	177.85
BG-518	C.T. Yanquetruz Ii	BIO ENERGIA YANQUETRUZ	San Luis	Centro	0.8
BG-519	C.T. El Alegre Bio	ANTIGUAS ESTANCIAS DON ROBERT	Córdoba	Centro	175
BG-519	C.T. El Alegre Bio	ANTIGUAS ESTANCIAS DON ROBERT	Córdoba	Centro	1
BG-520	C.T. Don Roberto Bio	ANTIGUAS ESTANCIAS DON ROBERT	San Luis	Centro	175
BG-520	C.T. Don Roberto Bio	ANTIGUAS ESTANCIAS DON ROBERT	San Luis	Centro	1
BG-521	C.T. Biocaña	SESNICH, NESTOR OMAR	Santa Fe	Litoral	156.85
BG-521	C.T. Biocaña	SESNICH, NESTOR OMAR	Santa Fe	Litoral	3
BG-522	C.T. Pergamino	SEEDS ENERGY	Buenos Aires	BSAS	156.85
BG-522	C.T. Pergamino	SEEDS ENERGY	Buenos Aires	BSAS	2.4
BG-523	C.T. Venado Tuerto	SEEDS ENERGY DE VENADO TUERTO	Santa Fe	Litoral	156.85
BG-523	C.T. Venado Tuerto	SEEDS ENERGY DE VENADO TUERTO	Santa Fe	Litoral	1.998
BG-524	C.T. General Alvear	CARNES DE LA PATAGONIA NEUQUII	Buenos Aires	BSAS	171.85
BG-524	C.T. General Alvear	CARNES DE LA PATAGONIA NEUQUII	Buenos Aires	BSAS	1
BG-525	C.T. El Mangrullo	CARNES DE LA PATAGONIA NEUQUII	Buenos Aires	BSAS	156.85
BG-525	C.T. El Mangrullo	CARNES DE LA PATAGONIA NEUQUII	Buenos Aires	BSAS	2
BG-526	C.T. Avellaneda	INDUSTRIAS JUAN F. SECCO S.A.	Santa Fe	Litoral	160
BG-526	C.T. Avellaneda	INDUSTRIAS JUAN F. SECCO S.A.	Santa Fe	Litoral	6
BG-527	C.T. Citrusvil	CITRUSVIL S.A.	Tucumán	NOA	153
BG-527	C.T. Citrusvil	CITRUSVIL S.A.	Tucumán	NOA	3
BG-528	C.T. Jigena I	CLEANERGY RENOVABLES S.A.	Córdoba	Centro	171
BG-528	C.T. Jigena I	CLEANERGY RENOVABLES S.A.	Córdoba	Centro	1
BG-529	C.T. Villa del Rosario	CLEANERGY RENOVABLES S.A.	Córdoba	Centro	174.5
BG-529	C.T. Villa del Rosario	CLEANERGY RENOVABLES S.A.	Córdoba	Centro	1
BG-530	C.T. del Rey	SILVINA HACEN	Santa Fe	Litoral	169
BG-530	C.T. del Rey	SILVINA HACEN	Santa Fe	Litoral	1
BG-531	C.T. Don Nicanor	SILVINA HACEN	Santa Fe	Litoral	169
BG-531	C.T. Don Nicanor	SILVINA HACEN	Santa Fe	Litoral	1

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Regarding the operation and performance of the plants, there is an online page called CAMMESA that monitors the production and operation of all the renewable energy plants (https://despachorenovables.cammesa.com/renovables/). Unfortunately, the biogas sector is not separated from biomass.

Figure 5: CAMMESA live generation information of Argentina

Detailed information of generation contracts and dispatch priority can be accessed in the annual reports of CAMMESA. The latest 2019 report can be downloaded from: https://portalweb.cammesa.com/Documentos%20compartidos/Noticias/Mater/Informe%20Renovables%20DIC%202019.pdf

According to this report biogas plants have generated a total of 231 GWh in 2019 with an increase of 57% compared to 2018. At the current stage, there are already 17 biogas projects running and delivering electricity according to the reports of CAMMESA.

Table 4: Electric energy generation from different sources

FUENTE DE ENERGÍA	AÑO 2011	AÑO 2012	AÑO 2013	AÑO 2014	AÑO 2015	AÑO 2016	AÑO 2017	AÑO 2018	AÑO 2019
BIODIESEL	32.5	170.2	2.2	1.6	0.0	0.9	0.0	0.0	0.0
BIOMASA	97.6	127.0	133.9	113.7	154.7	193.0	242.6	241.4	274.0
EOLICO	16.0	348.4	446.9	613.3	593.0	546.8	615.8	1443.9	4390.3
HIDRO <= 50MW	1255.4	1452.6	1274.0	1456.9	1623.8	1820	1695.9	1430.7	1312.4
SOLAR	1.76	8.1	15.0	15.7	14.7	14.3	16.4	109.3	677.6
BIOGAS	0.0	35.6	108.5	103.0	83.6	57.5	64.1	146.7	231.0
Total GWh	1403.2	2141.9	1980.6	2304.3	2469.7	2632.5	2634.8	3372.0	6885.4

DEMANDA MEM vs GEN RENOVABLE	AÑO 2011	AÑO 2012	AÑO 2013	AÑO 2014	AÑO 2015	AÑO 2016	AÑO 2017	AÑO 2018	AÑO 2019
Demanda MEM [GWh]	116349	121293	125166	126467	132107	132961	132507	132889	117744
Ren MEM / Dem MEM	1.2%	1.8%	1.6%	1.8%	1.9%	2.0%	2.0%	2.5%	5.8%

There is an online map locating all biogas plants in operation, this information can be accessed in: https://aplic.cammesa.com/geosadi/

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2.2.3 Credit and financial constraints

Currently, banks do not accept only PPA as a guarantee to finance energy projects, and require also personal guarantees, financial guarantees or instruments that are difficult for some investors to comply with, even in cases where producers of agricultural and agro-industrial establishments have important patrimonial endorsements.

Financial engineering and knowledge of the banking sector has evolved. The sector has been trained in the analysis of biogas projects and biomass, which have their own peculiarities. The evolution will most likely make a clear differentiation in requirements between well-structured projects and those that are not, which will surely allow for a greater accessibility to financing for the best proposals.

In projects where investments are of significant size, the financial entities promote the project's development through the formation of Special Purpose Entities (SPEs). Through these, the promoters generate a new company, formed with initial contributions (initial share capital) not significant compared to the size of the investment. This company is in charge of signing the financing agreements, which determine the scheme and conditions of the debt to be provided by the creditors for the execution of the project, and to be the vehicle for the signing and administration of construction contracts, works, equipment and operation; necessary for the development of the project.

Specific Purpose Entities must be adapted to enhance the use of residual resources or produced by some companies without becoming a fiscal and economic obstacle to development and project financing.

The requirement of the SPE beneficiary by the incentive prosecutors separated from the main activities of the SMEs have limited the presentation of offers in past tenders. The agro-industrial entrepreneurs receive differential treatment when they come from the biomass and biogas sectors. Participants from these sectors come from agricultural and agro-industrial SMEs, which do not have experience in large scale energy commercial sector.

Another important pending subject for the sector remains in the differential treatment of imported components that are necessary for the construction of biogas plants. Due to the strategic energy generation from waste and effluents, biogas not only produces an important contribution to the trade balance during the cycle of projects but contributes to mitigation of CO_2 emissions, which favors the fulfillment of the objectives on climate change set by Argentina.

Furthermore, there is a major challenge in communicating the needs of the sector to key decision makers, so that the mechanisms are improved and implemented to continue consolidating achievements and promoting new projects.

The diversity of the situations in the biogas sector makes the definition very dynamic and complex for stimulus mechanisms, which are an important step for the sector to achieve further consolidation.

Another important challenge is to achieve a synergy between different organisms and the public-private dynamics to consolidate actions that enhance the development of the sector as well as highlighting the positive impacts of biogas on the environment.

As the sector evolves, it generates new and sophisticated demands that require new skills. The need to accompany developers has evolved, from the initial basic promotion of the sector, to a higher focus on operational aspects, quality services and security standards.

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Key factors detected to secure and enlarge the biogas market in Argentina:

- Biomethane Law: promotion and regulation with a mandatory quota for cutting Natural Gas and bottled gas sold in Argentina (mandatory for large users and cargo and passenger vehicles).
- Optimization of financing mechanisms based on the experience gained.
- Improvement of tax compensation mechanisms also based on experience acquired.
- Expansion of quotas for biomass and biogas projects and new bidding rounds.
- Optimization of mechanisms for receiving biomass and biogas projects.
- Definition of incentives for the development of thermal exploitation (biogas and dry biomass in industrial and residential heat generation), and promotion of technology transfer for the takeoff of the sector.

2.3 Porter's 5 Forces

Each force indicator will be analyzed, scored with these following specifications, and illustrated using figure below[12]:

1. Is absolute zero risk
2. Is low risk[13]
3. Is low risk with straightforward operational solution
4. Is low risk which require strategic adjustment
5. Is moderate risk
6. Is moderate risk with straightforward operational solution
7. Is moderate risk which require strategic adjustment
8. Is high risk
9. Is high risk with straightforward operational solution
10. Is high risk which require strategic adjustment

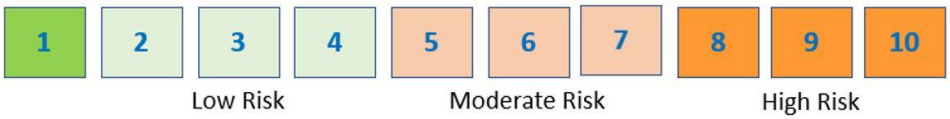

Figure 6: Porter's Five Forces Scoring Diagram

2.3.1 Competition in the industry

Competition in the biogas sector has been steadily increasing in the last four years. There are local and European actors competing in the market and some joint ventures. The following table represents the main actors detected in the market in 2020.

[12] Straightforward operational solution is defined as measures taken by business actors in the short term, for the most part addressing specific elements of a market e.g. technical aspects. Conversely, strategic adjustment is defined as long-term measures taken by business actors which involves an end-to-end approach.
[13] 'Is high risk', 'is moderate risk', and 'is high risk' are external risk factors that cannot be directly addressed. These risks require business actors to adapt to these existing external issues.

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Table 5: Principal biogas actors in the argentine biogas market

Name of the Company	Main Knowledge	Principal Business
GRUPO IFES	Biogas development projects building and initiation, consultant, training, capacity building	Industry, farmers, municipalities
Tecnored	Biogas development projects building and initiation, consultant	Industry farmers municipalities government
CEAMSE	Residue treatment operation in the largest landfill in Buenos Aires	Municipalities and Buenos Aires federal district CABA, other residue generation companies
BERTOTTO BOGLIONE	Tanks and liquid transport devices	Transport farms and industry
ECS - ENGIE	Contract energy negotiations, infrastructure studies, market studies forecast	Services
ECOPRENEUR	Water treatment, industrial effluents, renewable energy	Industry municipalities, local governments farms
BGA Energía Sustentable SRL Biogás Argentina	Biodigesters and solar systems	Farms industry
Industrias J F Secco	Electric generators, gas compression, material movements	Public and private sector industry, mining, oil & gas
Mtu Detroit Diesel Allison Argentina S. A	Big engines of different brands, services of maintenance and repair	Public and private sector, industry, mining, oil & gas
IES Biogas	Biogas plants in many countries	Farms industry
Adecoagro	Milk biogas and bioethanol production	General customers of their products
Seeds Energy	Biogas development projects building and starting up, consultant	Farmers
Bio Argentina Sa (Bioelectrica)	Biogas development, projects building and starting up, consultant, and operation	Farmers and agroindustry
Fertec SRL	Farm machinery for spreading biofertilizers	Farmers
Benito Roggio Ambiental	Recycling, residue collection, transport and treatment, land fill energy recovery	Municipalities, other residue, generation companies
ARINCO	Cement tanks platforms, construction	
EG Ingeniería	Biogas development projects, building and starting up, consultant and operation	Farmers and agroindustry
TYSA	Recycling, residue collection transport and treatment, land fill, energy recovery	Municipalities different type of cities residue generators

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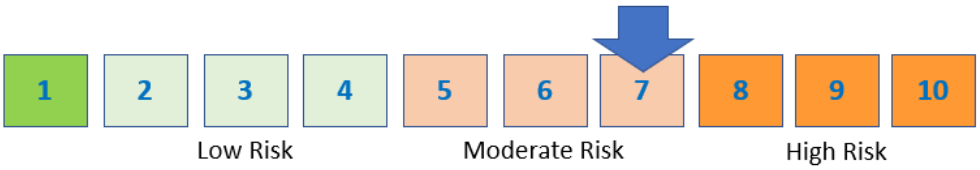
SOLAMB	Treatment of solids and liquids by different technologies including biogas	Municipalities, different type of cities, residue generators
YPFTECNOLOGIA YTEC	Tec	Research and development of new technologies
OPENER SRL	Tec	Different sources of renewable energy
ACZIA BIOGAS	Tec	Biogas plants in many countries
BTS	Tec	Biogas plants in many countries



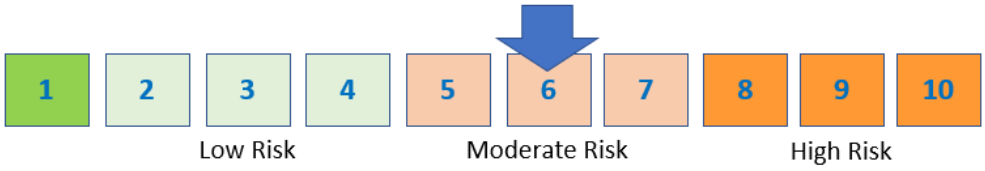
1 absolute zero risk **2** low risk **3** straightforward operational solution **4** require strategic adjustment **5** moderate risk **6** straightforward operational solution **7** require strategic adjustment **8** high risk **9** straightforward operational solution **10** require strategic adjustment

2.3.2 Potential of new entrants into the industry

The potential of new entrants is affected by the technology and materials supplied. The greater window is for engines and generators that are not locally provided. Mixers, specific pumps, electric material, covers, and feeders have a shrinking share in the local market. As the potential new customers increase and the experience in constructing and operation plants enlarges more local companies start to develop and offer their products in the market.

There are some key technologies that have still not been developed in the country and could be a good area to explore and offer. These technologies are related to:

- Biogas upgrade in use
- Digestate upgrade into high value products
- Digestate use and application
- Heat recovery and use



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

2.3.3 Power of suppliers

Suppliers in Argentina are much affected by the macroeconomic instability. External providers need to cope with unpredictable strong changes in the value of the local currency. Although the revenue of biogas projects is mainly linked to contracts in dollars, there are strong variations between local and external prices.

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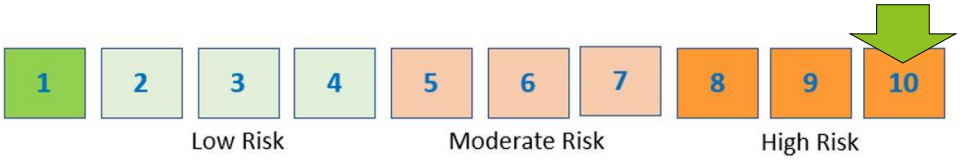
This is mainly caused by strong variations in the labor and local costs expressed in hard currency. There are also incentives for national components in the plants in favor of local providers.

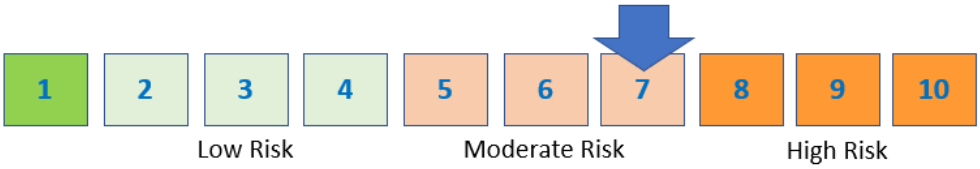


1 absolute zero risk 2 low risk 3 straightforward operational solution 4 require strategic adjustment 5 moderate risk 6 straightforward operational solution 7 require strategic adjustment 8 high risk 9 straightforward operational solution 10 require strategic adjustment

2.3.4 Power of customers

The ability of customers driving prices down is increasing, influenced by national options of technology and project management. Since projects must compete and they are chosen based on the lowest energy price they can achieve reducing Capital Expenditure (CAPEX), CAPEX is one of the most important factors. This has a bigger importance in a market that suffers limitations in finance options. Interest rates are big, and this increases the importance of maintaining initial investment as low as possible.

This factor is being affected by the relatively small number of buyers or customers a provider company has—therefore, each customer is important. The cost that must be paid for a company to find new customers or markets for its output is increasing. A smaller and more powerful client base means that each customer has more power to negotiate for lower prices and better deals.



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

2.3.5 Threat of substitute products

The main risk in the specific electricity market comes from the increasing competitiveness of alternative renewable options such as solar and wind energy. Although there have been improvements in the valorization of indirect impacts of biogas technologies, there are always discussions and different pressures concerning prices between biogas electricity and the other renewables.

There is significant potential in the further use and application of digestate. The agricultural sector in Argentina has a chronical deficiency in nutrient reposition. With high costs, this represents an enormous potential market for the development of bio fertilizers based on digestate transformation.

There is also an important farm machinery industry that could develop specific machinery for the application of different organic fertilizers.

Another possible product for solid digestate could be bedding for animals since free stalls are growing in the dairy business.

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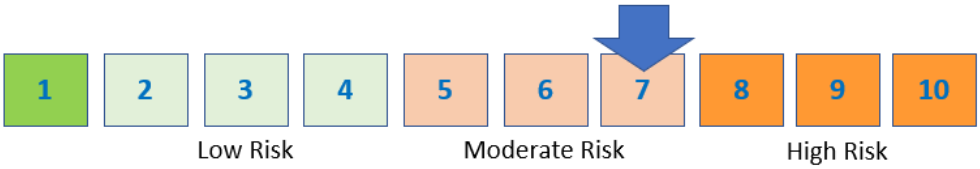

1 absolute zero risk **2** low risk **3** straightforward operational solution **4** require strategic adjustment **5** moderate risk **6** straightforward operational solution **7** require strategic adjustment **8** high risk **9** straightforward operational solution **10** require strategic adjustment

2.4 Market Policies and Incentives

Law 27191, approved in September 2015 with a broad political consensus, set goals for the development of renewable energy and created a legal framework allowing long-term market planning and providing visibility for investments. The rule establishes two contracting mechanisms: joint purchases through public tenders, and free and direct contracting between generators and Large Authorized Users (GUH), defined as those whose average power demand per year is 300 kW or more.

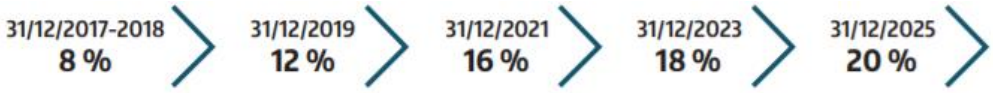

Figure 7: Argentina renewable energy targets

2.4.1 Renovar Program[14]

In May 2016, the former Ministry of Energy and Mining now Secretary of Energy launched the first round of the RenovAr Program, with the aim of attracting investments for the development of renewable energy projects that would allow meeting the established objectives. RenovAr is a plan for incorporating sources of renewables to the energy matrix, through an open call process for contracting, in the Wholesale Electricity Market (MEM), of electrical energy from renewable sources, based on the use of the sun, wind, water and biomass.

The RenovAr mechanism strives to address and overcome some of the problems that arose in the 2009 GENREN Program, which had a poor percentage of execution of awarded projects. The major change aimed at ensuring better financial conditions for auction winners through the Fund for the Development of Renewable Energy (FODER) and the World Bank guarantees made available to potential bidders. This guarantee scheme sought to offer a transparent framework and to promote the financing of these projects, which had a double objective: support buyer payments through the Administrative Company for the Wholesale Electricity Market (CAMMESA) and mitigate any systemic risk that may arise throughout the 20-year duration of the contract, also offering termination guarantees. The bidders were able to request these risk mitigators of the two tenders beforehand. Also, to decrease future transmission, capacity and availability of the connection nodes, the capacity was made available through public access to annexes 3.1 and 3.2 by the tender.

[14] All detailed information on the RenovAr program and different calls can be accessed in https://www.argentina.gob.ar/energia/energia-electrica/renovables/renovar

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2.4.2 Mater Opportunity

As stated, Law 27191, National Development Regime for the use of renewable energy sources for energy production (which amended Law 26190/2006), establishes that all users must contribute with the targets for increasing use of renewable sources in the consumption of electrical energy, until it reaches the following goals: 8% at the end of 2017; 12% by the end of 2019; 16% by the end of 2021; 18% by the end of 2023 and 20% at end of 2025. At the same time, in its article 9, the law provides that self-generators, the large users of the Market Wholesale Electric (GUMA and GUME users) and the *Grandes Usuarios en Distrubución Mayores* (GUDI users), with demands for power equal to or greater than 300 kW, must individually meet these objectives. These users are called Large Enabled Users (GUH) and represent an average annual demand of 31.4 TWh. Therefore, in 2025, they should consume a minimum of 6.3 TWh of renewable energy to comply with the objective of Law 27191.[15]

Large users (GU) have three ways to fulfil that obligation:

1. Generation, self-generation, or co-generation (own project covering such requirements).
2. Contracting the supply with the owner of a power plant from renewable sources (usually called Private PPA)
3. Joint purchases through rounds bidding for the RenovAr program, for those GU who choose such an alternative or refrain from exercising a given option (solution by default)

PPA lies within the process of renewable energy contracting between private companies where important improvements have been generated. Indeed, in the third quarter of 2017 the Energy Term Market Regime was disclosed. Electric Renewable Source Electrical (MATER, Resolution MEyM 281-E / 2017), which establishes the conditions to manage contracts between the new generation or renewable self-generation and large users of the MEM. CAMMESA has defined that this regime reaches about 2,000 GUH (19 with power greater than 20 MW; 92 with power between 5 and 20 MW, and 1,959 between 0.3 and 5 MW), through a list that will be updated in February of each year.

The option of exclusion from this mechanism is granted twice a year, in May and November. When communicating in exercising this option, the GUH must inform the estimated percentage of demand to self-generate or acquire through MATER, which must not be less than that required by the objectives of Law 27191. After exercising the option, the GUH will have 6 months to roll back and return to the joint purchasing mechanism. In case of confirming the exercise of the option, you can re-enter the purchasing mechanism jointly after a period of 5 years. To ensure compliance with the objectives of the law, CAMMESA will carry out an audit on those GUH that fall outside the joint purchases, on an annual basis, on the accumulated results of monthly transactions. As a benefit, those GUH who choose to leave of the joint purchasing mechanism shall not pay the administration and marketing charges, which began to apply from January 2019. These charges are applicable to the monthly energy supplied by the joint purchase contracts, up to the percentage corresponding to the objective of Law 27191.

[15] A comprehensive elaboration of the MATER program can be accessed in: http://minaaysp.cba.gov.ar/wp-content/uploads/2018/06/AIRECweek-2018-The-Argentina-Report.pdf pg. 31

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The marketing charge will be applied depending on the GUH monthly average power and the maximum charge established for each biannual period. Those GUH with higher monthly average power at 20 MW must pay 100% of the maximum charge, while GUHs with lower power will have a linearly proportional reduction in charge at its monthly power, reaching 20% for 0 MW.

In turn, those GUH who choose to be excluded from the joint purchasing mechanism will receive a discount on the power reserve charge, associated with firm power costs: at total value of firm power that they require, the average monthly power supplied by MATER, multiplied by the adjustment factor of the corresponding biannual period. As of May 2018, the approximate value of this charge without reduction was 7 USD/MWh.

The regime encourages the abandonment of the joint purchases to the extent that those who choose so decide and develop a renewable energy generation project (or contract with one of them through del MATER), which will not pay the marketing and administration charges. Meanwhile, your energy supplied from renewable sources will not pay extra costs energy and can also receive a discount on the maximum power requirement charges in depending on the renewable energy power and the moment of the option (100% until 2018, 25% in 2020; the bonus remains fixed according to the time chosen to exit joint purchases and while keep out of the joint purchasing regime). Those GUs who choose to exit the joint purchasing regime will receive oversight to verify compliance with the legal minimums:

1. Per year past due;
2. With a 10% tolerance margin a compensate in the following year;
3. subject to a specific penalty from the valuation of the deviation to the price of electricity generation with diesel (that is, the most expensive generation; diesel cost equivalent – CGOEQ– 2017: approximately, 100 USD / Mwh); 4) prior to the imposition of the penalty, the GU may wield his defense.

In order to manage the scarcity recognized by the transmission system, a priority access regime was established, in the case where two projects of renewable generation are competing for a single access (otherwise, the priority of the renewable source is already given by article 18 of Law 27191).

Beyond GUHs, GUs integrated into MEM -in general - they will be able to celebrate PPA private even if they have not chosen to leave the joint purchasing regime. GUHs will only receive the detailed incentives to the extent that exercise the option of supplying through MATER, leaving the joint purchase regime.

2.4.3 Distributed Electricity as A New Market

According to the current national regulatory framework, distributed generation of electrical energy is considered generated by renewable energy sources, at the point of consumption, and by the users themselves that are connected to the electrical network of distribution.

Distributed generation generally occurs through systems designed for self-consumption with eventual injection of surplus energy to the existing distribution network. Users who adopt this generation modality have the capacity to produce electrical energy, remaining in turn connected to the supply provided by the electrical distribution network. This is the model adopted in Argentina by Law No. 27,424 published in 2017.

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The installation of a renewable distributed generation system enables the user to cover part of demand for electrical energy without the need resorting to the network supply, which results in economic savings due to self-consumption. In turn, if there is a surplus of electrical energy generated by the renewable source, the user-generator can perceive an economic benefit from the injection of surplus to the network.

In early 2018, the law was regulated by decree 986, where the objective was to incorporate 1,000 MW of power from Distributed generation installations by 2030. In addition, the Secretary of Government for Energy (SGE) was designated as the Enforcement Authority. At the end of 2018, Resolution 314 of the SGE created the *Registro Nacional De Usuarios-Generadores De Energías Renovables* (RENUGER), which is the National Registry of Users-Generators of renewable energy categorizing them in three groups small (up to 3kW), medium (up to 300 kW) and large (up to 2MW). This resolution established the procedure for User-Generator Connection and standards for basic contract between the actors.

Law 27,424 establishes a promotional benefits regime, including a Tax Credit Certificate, also creates the *Fondo Para La Generación Distribuida De Energías Renovables* FODIS in order to grant loans, incentives, guarantees, capital contributions and acquisition of other financial instruments, all intended to enhance the implementation of distributed generation systems from renewable sources.

To implement one of these benefits, provision 48 of the *Subsecretaría De Energías Renovables Y Eficiencia Energética* (SSERyEE) in April 2019 was developed. It provides that the SSERyEE and the Administración Federal de Ingresos (AFIP) will be in charge of the instrumentation and application of the Certificates of Tax Credit under the Electronic Bonus modality, which may be applied to the payment of National Taxes.

In July 2019, Provision No. 83 is issued, by which the procedure defined fixing the amounts and the conditions for obtaining the Tax Credit Certificate for user-generators.

This document details a validity of 5 years for the certificate once granted and describes the mode of a fixed amount for each unit of installed power.

On the website of the Distributed Generation Directorate, it is possible to find information on the progress in the implementation of the law, as well as instructions for the use of the Digital Platform, a Solar Calculator and information on promotional benefits.

Some provinces had already implemented their own regimes and laws, such as: Mendoza (Law 7459), Salta (Law 7824 Net Balance), Santa Fe (Prosumers Program), San Luis (Law 921), Neuquén (Law 3006), Misiones (Law 97 of Net Balance), and Jujuy (Law 6023), which, in some cases, have been already implemented. The different provincial regimes may vary conceptually in relation to the national law.

Industrial parks, shops of large cities and the rural sector from all over the country were interested since the possibility of clean energy brings them a solution to two problems: increased cost of the tariff and the security of supply of electrical energy.

2.5 Resources

2.5.1 Natural Resources

Availability and characteristics of feedstock source

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In 2018 INTA and PROBIOMASA (described in section 2.1.5), carried out 12 WISDOM-type studies[16] that included the provinces of Tucuman, Salta, La Pampa, Mendoza, Cordoba, Buenos Aires, Corrientes, Santa Fe, Chubut, Chaco y Misiones. WISDOM analysis includes a section to evaluate humid biomass for biogas purposes. These studies generated knowledge about the significant potential for biogas generation from **pig, dairy and feedlot manure**, which highlighted the environmental assessment of the waste generated in establishments, such as less pollution due to effluent management and/or fossil fuel replacement (PROBIOMASA, 2019).

Pig Farm

Pig production is concentrated in the agricultural core zone, although it is also dispersed throughout the national territory (Figure 8).

The physical-chemical composition of the pig manure varies depending on the production system, the type of exploitation, the age of the animal, the diet, and the management of the farms. Of each gram of protein consumed by an animal, only 33% is used for the formation of tissue (meat) and the rest is eliminated through feces and urine. The slurry has 12% dry matter (DM), of which between 85 and 90% is organic matter. Regarding the power generation potential, the conversion of pig slurry into biogas is 0.06 cubic meters per kilogram of total solids (m^3/kg ST). This numbers will finally depend on the implemented manure management system.

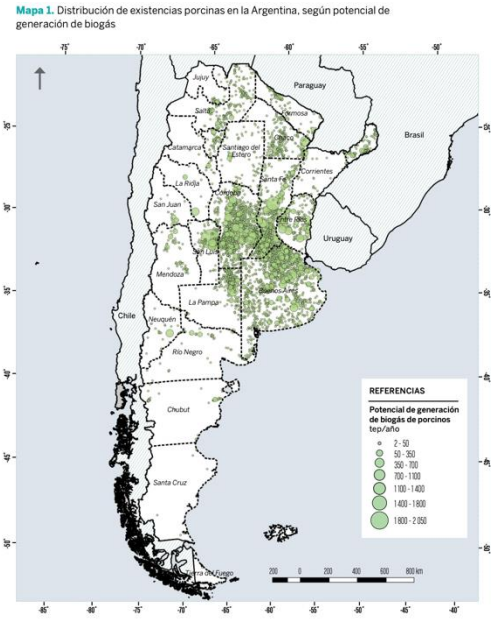

Figure 8: Swine manure feedstock (PROBIOMASA, 2019)

[16] The complete document of the study can be accessed through: http://www.probiomasa.gob.ar/_pdf/Informe%20Tecnico%20Nro4-Estudio%20de%20cuencas%20de%20biogas-19-08-22.pdf (In Spanish).

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Beef Feedlots

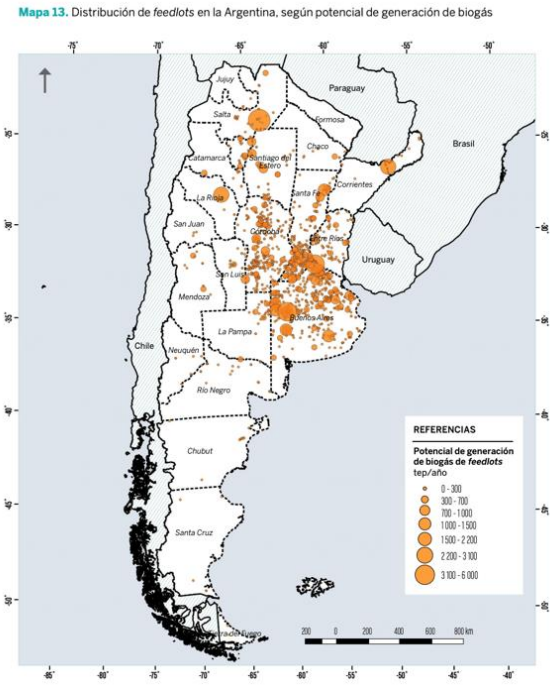

Figure 9: cattle manure in feedlots (PROBIOMASA, 2019)

The fattening to farmyard (feedlot) has been developed in the last twenty years in Argentina as a complement in the finishing of beef cattle and has achieved a significant insertion in the chain. Currently, in the country there are more than 1900 feedlots, of various sizes with beef feedlots being the most common. Figure 9 shows the distribution of feedlots in Argentina according to the biogas generation potential.

In the pen, fecal matter and urine form a single type of inseparable waste, called manure. A cow excretes about 5 to 6% of its live weight per day, so a 400 kg steer produces 20 to 25 kg of manure per day.

Given its moist content (from 80 to 85%), there are 3 kg of dry residue per animal per day, on average. Depending on the digestibility of the diet, a 5,000 head feedlot can produce 6,000 to 9,000 tons of manure annually. The farmyard cattle fattening establishments in 2015 totaled 1,320,000 head, estimating their biogas generation potential at 198,748 toe/ year, or 361,360,077 m^3 / year of biogas (PROBIOMASA, 2018).

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Dairy Farms

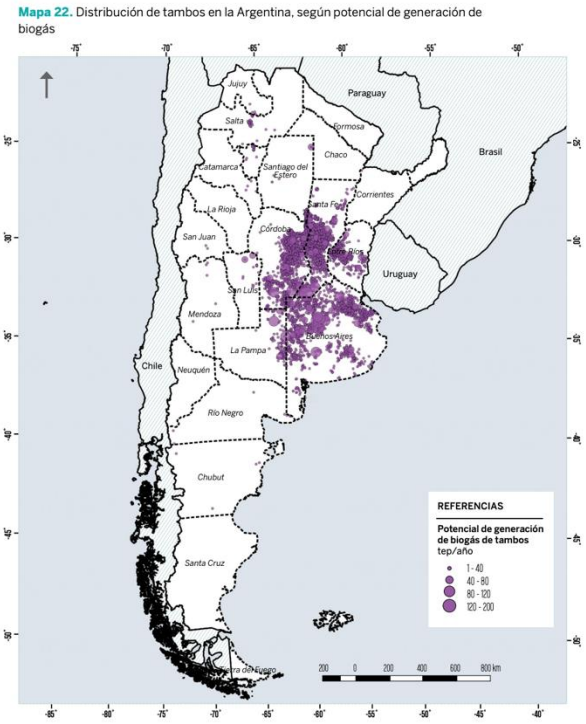

Figure 10: Dairy farms distribution (PROBIOMASA, 2019)

Although there is milk production in the provinces of La Pampa, Tucumán, and Santiago del Estero, 80% is concentrated in the provinces of Buenos Aires, Santa Fe and Córdoba (Figure 10). The main processes in the dairy industry that produce polluting residues are the cheese-, cream- and butter production processes, the washing of drying towers and alkaline cleaning solutions. Dairy industry wastewater is generally neutral or low-alkaline, but it tends to become acidic very quickly because of the fermentation of milk sugar producing lactic acid, especially in the absence of oxygen and the simultaneous formation of butyric acid, lowering the pH to 4.5 - 5.0. The composition of these waters includes dissolved organic substances such as lactose, mineral salts, and colloidal protein suspensions (casein, albumins, and globulins) with a COD between 2000 - 4000 mg/l and a BOD between 2000 - 3000 mg/l.

Water consumption in the dairy industries ranges from 8.0 - 35 l/kg of milk. There are different destinations for effluents. Of the 69% of effluents that pass through the stabilization lagoon, 29% is distributed in different paddocks, 25% is directed to water bodies, 17% is reused for fertilization, and 7% is dumped into gutter channels and the rest remains in the lagoon (22%).

Productive Biogas Catchment Areas (Basins)

In 2015, a diagnostic study of biogas plants in Argentina was conducted by INTI and PROBIOMASA, in which 62 biogas plants were surveyed (although more than 105 were identified). Different aspects of the sector were quantified, identifying that most plants implement complete mixture technology treating residues from agribusinesses. An important result from this study is that 83% of plants aim to treat effluents rather than generate energy. Other results revealed that 53.1% are private, 52.4% are rural plants and 59.9% do not have imported components in equipment.

As a result of biogas national potential evaluation, productive biogas basins were conducted, considering residual biomass in different intensive livestock productions. This document was produced by the Bioenergy Sector of the Secretariat of Agribusiness and Institutional Strengthening of PROBIOMASA. The study aims to identify and classify the main basins producing effluents or residual biomass that can be transformed into biogas to provide basic information to drive the development of biogas generation projects.

To evaluate the potential for biogas generation at local scale, five main basins of each productive sector analyzed was evaluated:

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Table 6: Locations of the Evaluation of the Local Biogas Generation

a) Pig companies:	• Basin Unión – Marcos Juárez, • Basin Juárez Celman – Río Cuarto • Basin Roque Pérez – Saladillo • Basin San Andrés de Giles • Basin Bolívar
b) Feedlot companies	• Basin Saladillo – Roque Pérez • Basin Villa Constitución • Basin Rivadavia – Gral. Villegas • Basin Colón (Córdoba) • Basin Trenque Lauquen
c) Dairy companies	• Basin Central de Santa Fe • Basin Este Córdoba • Basin Oeste Buenos Aires • Basin Abasto Sur Buenos Aires • Basin Abasto Norte Buenos Aires.

The estimates of biogas potential were made based on information provided by National Service of Agri-Food Health and Quality (SENASA). The location of each plant and its number of animals were considered. Based on this information, the residual biomass production was estimated by type of activity: cattle (feedlots and dairy) and pig (Flores et al., 2009). The main results of this study are the following.

Pig Basins

In the southeast of the province of Córdoba, particularly in the departments of Unión and Marcos Juárez, PROBIOMASA has found that the pig-farm basin with the greatest bioenergetic potential from pig slurry. This basin, which covers an area of 5,072 km^2, contains 280 pig farms, which together have 173,421 animals. Although in numbers of plants it constitutes 3.23% of the national total, in terms of number of animals it represents 5.20% of the national total.

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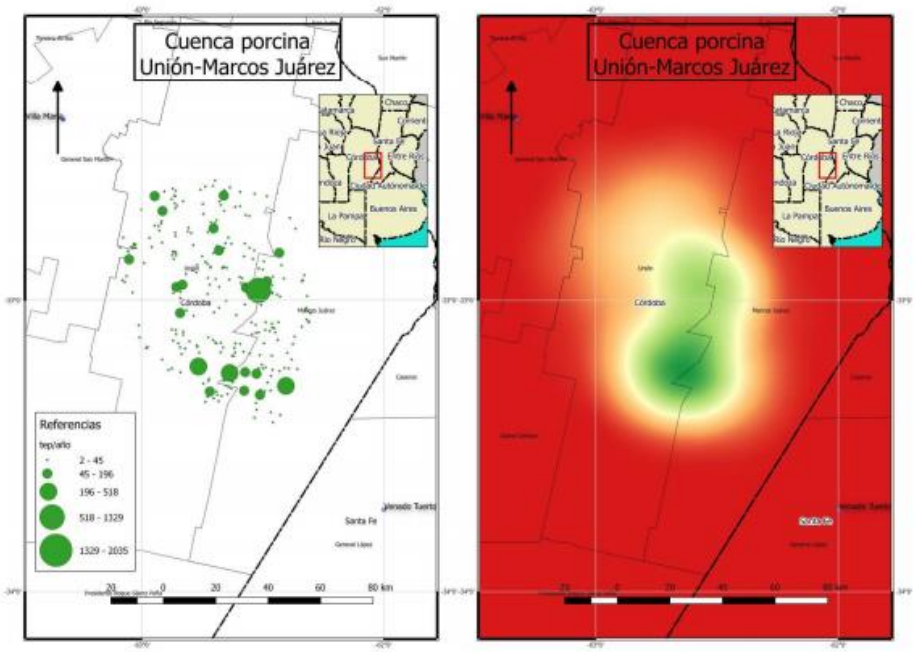

Figure 11: Example of a swine production concentrated area in Cordoba province (PROBIOMASA, 2019)

The bioenergy potential of this basin as a whole is 5,861 Tn/year 5,861 Tn/year (~118,000 m³/a of biogas, or ~70,000 m³/a of methane per year).

Feedlot Basins

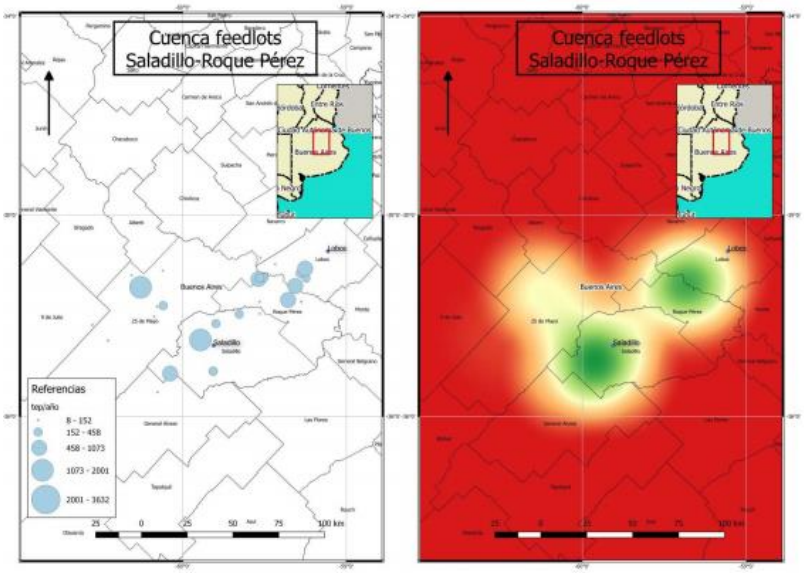

Figure 12: Example of feedlot concentration un Cordoba province (PROBIOMASA, 2019)

There are more than 1,700 feedlots of different sizes and technologies, most of them are open with no floors although this is changing in the new companies entering the business. The feedlot basin, which has the greatest bioenergetic potential from the generation of biogas, covers the Buenos Aires province, including Saladillo, Roque Pérez, 25 de Mayo and Lobos.

The area covered is 5,634 km² and contains 93 establishments (almost 5% of the national total), and in terms of the number of animals, the stock is around 87,000 heads. The estimate potential of biogas production from cattle excreta is 13.195 tep/year (Tonne petroleum equivalent), which represents almost 7% of the national potential.

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Dairy Basins

The main dairy basin in the Province of Santa Fe, contains 4,150 dairy farms (42% of dairy farms in the country). The extension of the basin is 39,380 km^2 and has a potential of biogas generation estimated at 24.413 tep/year, representing a little more than a third of the total national estimate.

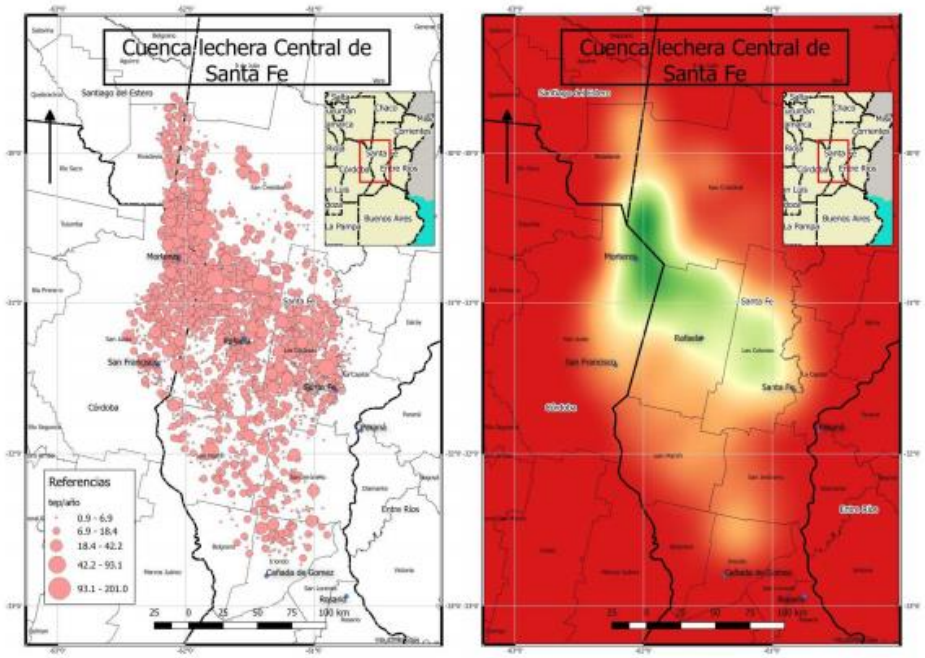

Figure 13: Example of dairy farm concentration in the south of the province of Santa FE (PROBIOMASA, 2019)

In these basins, there are 3 important projects, that together they add 7.2 MW of power to the grid, with a contribution of 2.4 MW each.

It is important to remark the following topics as conclusions from this pilot study:

- The Argentine Republic, and particularly the Pampa Region, has an important potential for generation of biogas from pig and milk production and feedlots.
- Of the three productive activities, the potential supply from the effluents of feedlots is the one that offers the greatest amount of bioenergy.
- Around 86% of pig farms hold between 1,000 - 5,000 animals, which represent a great potential for generating distributed energy.
- The potential resulting from the dairy basins is significantly lower in comparison to the pig and feedlot basins.
- Finally, the assessment of each basin not only involves the individual plants, but also the inter-relationship among them.

2.5.2 Human resources

Human resources are not an important constraint in any region in Argentina. There are Universities that cover the whole country with specific curricula on engineering, agronomy, and biology. The career offer is important, and the university population is one of the greatest in Latin America.

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Regarding other non-specific skills and tank construction, piping, assembly etc. there are companies available with great experience in other industries that rapidly adapt to the specific requirements of biogas plants. There has not been any major limitation in the construction and assembly of large and complex plants.

Although there are professionals available in the biological sector, further specific training is needed. The number of specific biogas laboratories that give support and prepare professionals in this area is still low but increasing rapidly.

Both locally and internationally, it has been shown that the biogas sector acts as a generator of added value in the communities and regions where the projects are located. The experience of biogas plants in Argentina is that they provide skilled and high-income jobs to young professionals that find a way to stay in their communities without migrating to large cities.

In Argentina, the experience and knowledge that builds up as new biogas plants are constructed and start to run allow different local companies metalworking, construction, and process to grow and enlarge their personal. In this way, increasing amount of equipment and components are provided by the national industry complementing and / or competing with the international providers.

The employment multiplier differs according to the technology assumed, being more intensive in those related to biogas plants. However, it is noteworthy that throughout its range the sector requires technical specialization and professionalization that entails the creation of quality jobs and in some cases of high added value where the intervention of the education, science and technology ecosystem is necessary to continue going forward. The relevance of the industry in the regional economies has implied the opening of specializations and technicities in national and regional universities, and it begins to take shape as an alternative productive niche to the traditional careers. As noted in section 2.4.1, the sector has a federal character, where although in 7 of the 24 jurisdictions there are projects awarded under the national calls for the RenovAr program, in all of them there are developments related to the biogas energy industry. The samples range from pilot experiences in national universities, through laboratory facilities. In all cases, local capacities and investments have been strengthened and a learning path has begun with positive impacts at the public and private levels.

The Argentina 2040 energy scenarios platform to quantify jobs in the electricity sector of the different scenarios built, used an econometric model developed by the New Climate Institute of Germany.

Given that in August 2018 the sub secretariat of Renewable Energies of the Nation published the document "Job creation: renewable energy" (Sec. of energy, 2018) that analyzes the employment data declared by the bidders at the time of the tender, it was decided that for this work this document would be the starting point for calculating externalities and macroeconomic advantages related to employment. It is important to highlight that the data source of this document arises from the sworn statement of the bidders whose projects were submitted to

round 2 of the RenovAr and that the reported jobs only include those within the limits of the generation project without considering the jobs that are generated to manufacture the components that are installed in the energy project. The aforementioned document builds the direct employment Indicator of direct use of renewable energy (IEDER) in Argentina per MW. It accounts for the jobs required for the construction, maintenance and operation of 1 MW of installed power for each renewable technology for electricity generation (jobs / MW), based on

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what has been declared by the projects submitted to the tender of the RenovAr Round 2 program.

As can be seen in the next table, biogas technology generates the highest impact on employment during the construction and operation & maintenance phase.

Table 7: Direct employment generation per Mw of renewable energies (Sec of energy and PROBIOMASA, 2018)

Technology	Construction			Operation & Maintenance
	Year 1	Year 2	Year 3	
Biogas	9.7	13.1	3.2	4.6
Biomass	4.3	7.3	4.4	2.2
Wind	1.6	1.9	0.7	0.2
Solar	2.3	2.8	0.2	0.2

According to the inquiries made with qualified sources in the case of biogas plants, the demand for personnel generated by a plant with an installed capacity of less than one MW is greater than that generated by a two MW plant. This is due to greater automation in larger plants. Therefore, the scale affects the generation of employment of each plant, although the impact is not proportional since some jobs are not duplicated by the doubling of power. Thus, for biogas plants with an installed capacity of less than 1 MW, the O&M IEDER can be 7 instead of 4.6.

The direct jobs are those required for the operation of the biogas plant during its commercial operation, and include administration, operation, maintenance, and management. For the case under study, the direct human resources identified were the following:

- Organic substrates loading area operator: 1
- Biogas plant operator: 3
- Electric-thermal energy generation plant operator: 1
- Administration: 1
- Direction / Management / Engineering: 1

Projects awarded less than 2 MW are 55% of total projects, so this consideration must be taken into account when deciding to support smaller-scale projects. However, the indicator of 4.6 per MW is used to keep the analysis homogeneous regarding the information base. The IEDER was prepared based on the information on the projects submitted to the bid for Round 2 of the RenovAr Program. Therefore, it is not an indicator that can be used for a particular project to estimate the human resources employed, but it does allow estimating the average labor force employed per MW for each type of technology. Based on the data collected from bioenergy projects in operation and / or execution, we can conclude that the biogas IEDER of 4.6 jobs per MW represents projects with an installed capacity between 1.5 and 2.4 MW.

2.5.3 Infrastructure and support industry

Argentina has a world known agroindustry, car manufacturing, nuclear, space and other new technologies development and use. There are many companies serving those sectors and the adaptation to biogas plant needs is not critical.

Product and services available include tank construction in different types of materials, piping, liquid pumps, transforms, power lines and electronic equipment. There is local capacity to develop and improve different technologies applied in biogas plants.

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This situation is valid for all the main areas, which have biomass availability in either agriculture, agroindustry, or urban sector.

One of the characteristics of local providers is their speed of adaptation and the continuous innovative capacity to cope with new challenges.

Looking for external support infrastructure as roads, power lines and waste management there are local companies that can provide construction and maintenance in the main productive areas of Argentina at competitive costs.

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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).

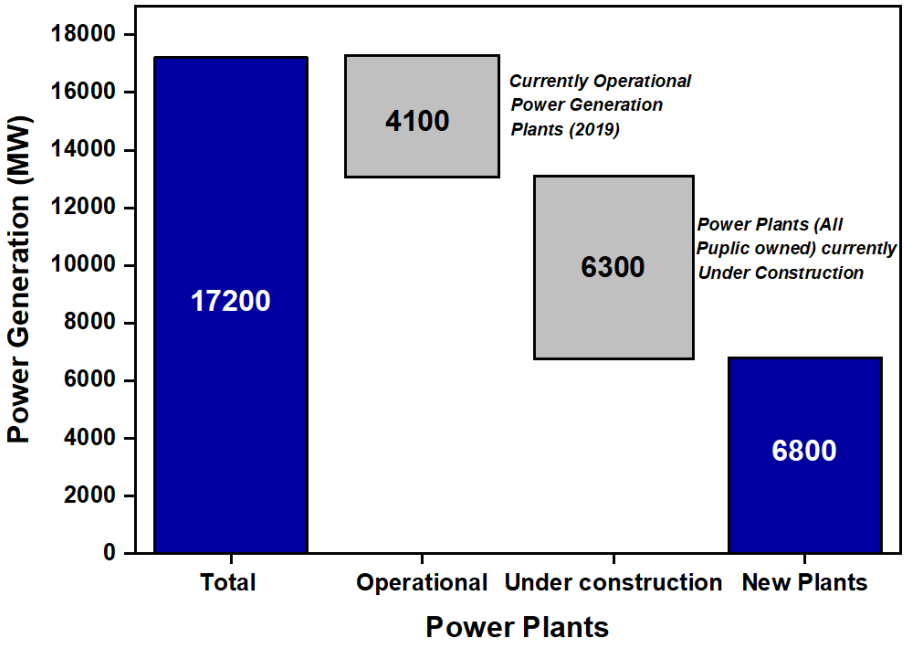

Figure 14: Number of Power Plants in Ethiopia

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.

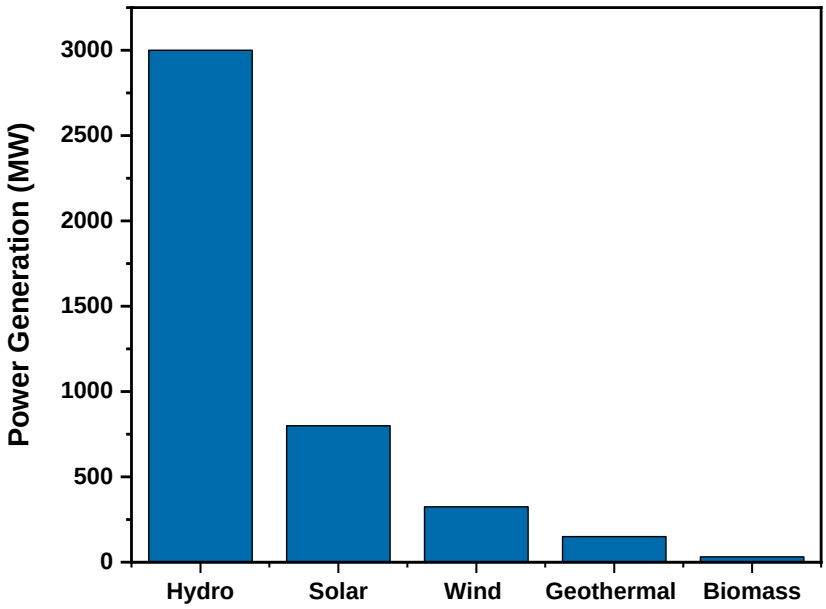

Figure 15: RE National Targets for Private Sector - Energy Development by 2020 (MW)

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.

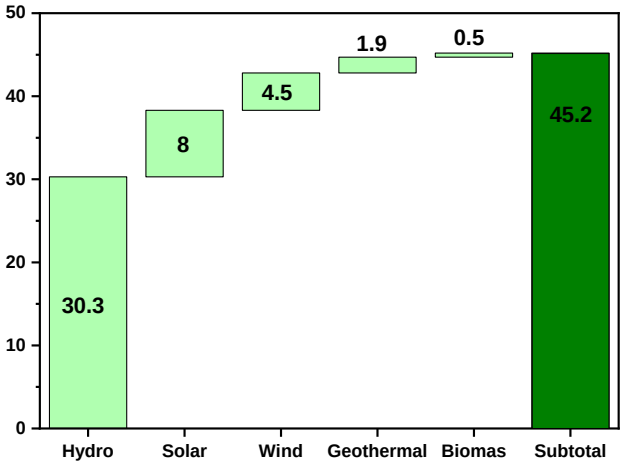

Figure 16: Ethiopia's Government Plan for Private Sector Power Generation (2015-2020)

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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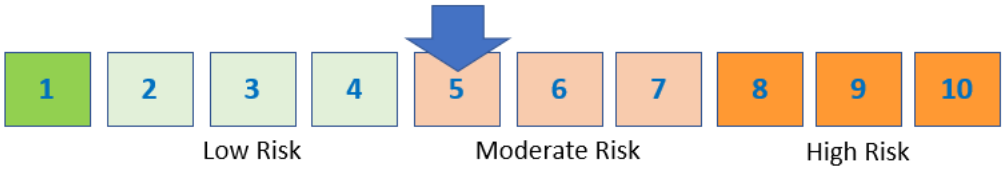
3.4.2 Bargaining power of Buyers: Medium

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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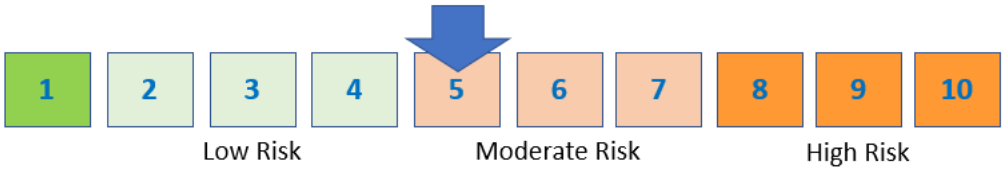
etc.

- **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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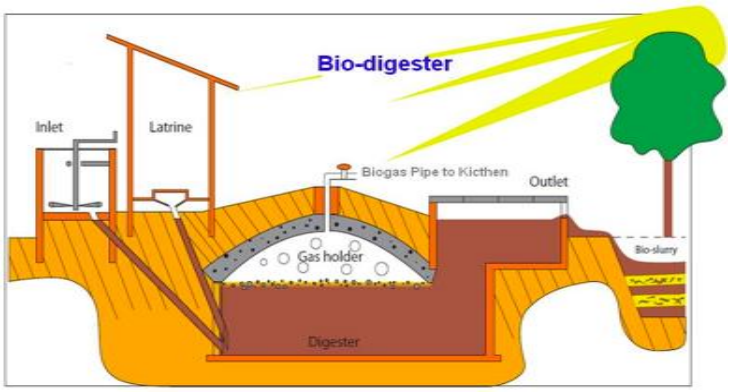
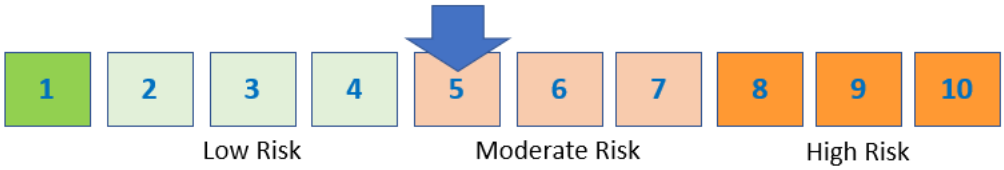


Figure 17: Domestic Biodigester Description in Ethiopia, Source: Kumar A .et al 2015[30]

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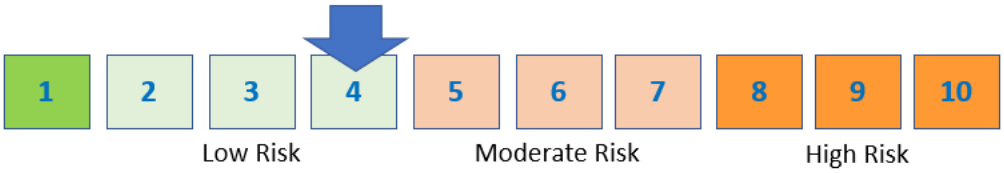
Table 11: Price of Fuel and Electricity in Ethiopia as of June 26, 2020[31]

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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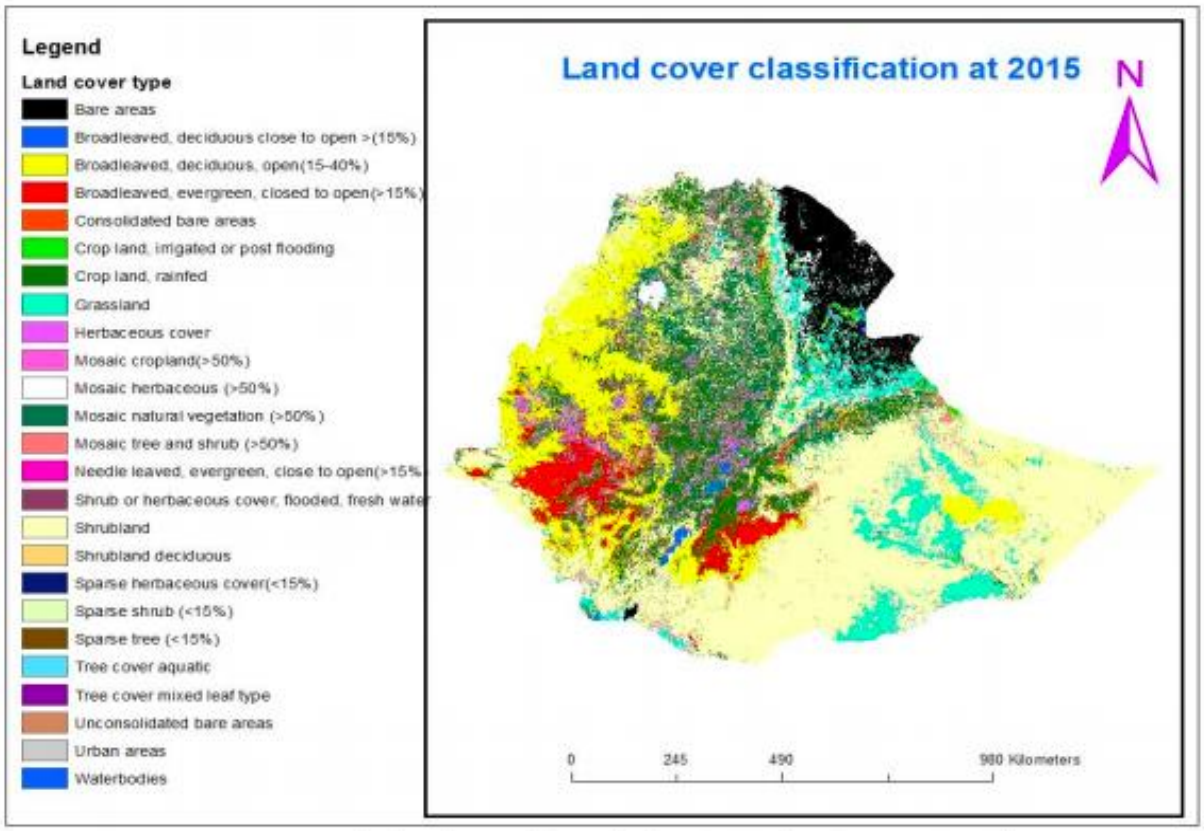

Figure 18: Ethiopia's Land Cover Classification Source: ICPAC, 2015[36]

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.

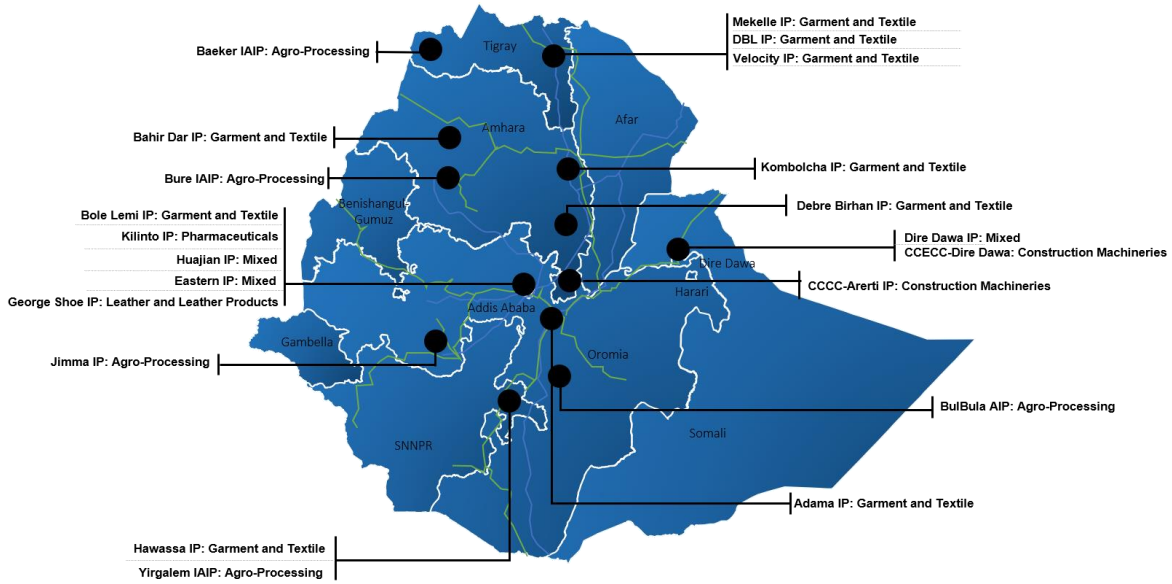

Figure 19: Industrial Parks in Ethiopia

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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4 Republic of Ghana

4.1 PESTLE or Macro Analysis

Introduction

Despite the abundant availability of feedstock for biogas generations in Ghana, the country is yet to develop a major programme that will promote the dissemination of biogas plants on a larger scale. The successful implementation of a biogas projects will depend on macro-environmental factors including financial and economic, policy and regulatory, socio-cultural, as well as technological and environmental challenges. Currently, there is no suitable financing mechanism available for renewable energy projects in Ghana, specifically biogas. Further, the lack of biogas specific technical, operational and management expertise hinders the implementation and demonstration of successful biogas plants on a large scale.

Interest in biogas technology in Ghana began in the late 1960s but it was not until the middle 1980s that biogas technology received the needed attention from government. Dissemination programmes before the mid-1980s focused on the provision of energy for domestic cooking. Most plants, however, collapsed shortly after the duration of projects due to immature technologies and poor dissemination strategies. Generally, biogas technology dissemination has faced several challenges, many of which may have discouraged the widespread dissemination of the technology. Some of these challenges among others include; poor level of construction, lack of skilled attendants, and poor maintenance (Bensah et al., 2015). These challenges cut across political, economic, social, technological, legal, and environmental spheres of our daily lives.

A PESTLE analysis is a framework or tool used to analyse and monitor the macro-environmental factors that may have a profound impact on an organisation's performance (see introduction section for more explanation). This framework is being used to analyze the political, economic, social, technological, legal, and environmental factors affecting the bioenergy industry in Ghana.

4.1.1 Political Aspects

National target and strategies

Generally, high political stability provides a stable and friendly business environment with predictable market growth trends. However, when there is political chaos, it deters investors and harms the stakeholders' trust in economic and consequent organizational performance. Ghana was the first in the Sub-Saharan African countries to gain political independence in 1957. The country has experienced the overthrown of government through high incidence of various military coup d'états. The 1992 election saw the first democratic government been elected to office and since then the country has seen a stable governance over the last two decades with successive elections. The country is ruled by two main political parties changing hands every two election cycles (eight years). Ghana has been touted as one of the best democratic countries in the African continent due to its strong adherence to democratic principles and respect

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for human rights[62]. This assertion is further collaborated in a global competitiveness report which indicated government instability as the least problematic in Ghana[63]. Despite these political gains the country is still plunged with high infrastructure deficit like roads and hospitals, as well as high inflation rate and unemployment (Fox, L., et al., 2011). The country is still battling with high levels of corruption with the country scoring 41% (80th country out of 180 countries) out of a possible clean score of 100 in 2019, according to Transparency International[64]. To deal with this, government has put certain mechanisms in place including the establishment of anti-corruption agencies such as the Commission on Human rights and Administrative Justice (CHRAJ), the Audit service, Economic and Organize crime Office (EOCO), Serious Fraud Office (SFO), the Special Prosecutors Office (SPO) and others.

Successive government has been able to put policies and programmes in place to mitigate measures to address political barriers in the energy and renewable energy sector. This is to avoid the disruption of projects in the case of government change over. Unfortunately, biofuels (biogas, biodiesel, and bioethanol) have not been adequately developed to play a major role in the energy mix of Ghana. For instance, in the Strategic National Energy Plan (SNEP) 2006-2020, the potential contribution of biogas technology towards the growth of the energy sector was not represented compared to other renewable energy options such as wind and solar. Renewable energy installations have seen a dramatic increase from about 3 MW in 2013 to about 43 MWp by end of 2017. In 2017, Installations by registered vendors totaled about 5 MW with over 85% in grid-connected areas[65]. In 2018, a 20 MWp solar PV plant was built, commissioned, and connected to the national grid. In order to realize a reduction in the share of wood fuel in the national energy mix from 60% in 2006 to 40% in 2020 as stipulated in SNEP, there is the need to promote research and development in other renewable energy options including biogas technology.

Energy: Ghana's power supply sources are from hydroelectricity, thermal fueled by crude oil, natural gas, and diesel, and solar. Ghana also exports power to Togo, Benin, and Burkina Faso. Ongoing grid expansions would allow further exports to other neighbouring countries in the sub region. Ghana has a vibrant power generation terrain with players from both the public and private sectors. Reforms in the Power Sector in the 1980's gradually removed barriers and created a level playing field for the participation of independent power producers (IPPs) in an area which hitherto had only public sector participants. The total installed capacity for existing power plants in Ghana is 4,132MW consisting of hydro 38%, thermal 61% and solar contributing less than 1% (Agyenim et al., 2020).

As at the end of 2017, the **installed electricity generation capacity** supplying the main grid of the country was about **4,310 Megawatt (MW)**. The installed capacity increases to **4,398.5**

[62] Kwesi Anning et al. (2012). Managing Election – Related Violence for Democratic Stability in Ghana. Friedrich-Ebert-Stiftung. ISBN: 9988-572-26-3

[63] http://www3.weforum.org/docs/GCR2017-2018/05FullReport/TheGlobalCompetitivenessReport2017–2018.pdf

[64] https://tikenya.org/wp-content/uploads/2019/01/2018-Corruption-Perception-Index.pdf

[65] Mohammed, Mutala; Agyenim, Francis; Dzamboe, Pax; Bawakyillenuo, Simon; Okrofu, Raymond; Decker, Edward; Agyemang, Victor; Nyarko, Eric. (2020). Powering communities using hybrid solar biogas in Ghana, a feasibility study. Environmental Technology & Innovation

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MW if primary embedded generation including the two major solar power plants at the sub-transmission (distribution grid) level is added. This was an expansion about 16% over the installed capacity in 2016. Total grid electricity generation in the country including the embedded generation was **14,069** Gigawatt-hours (GWh), comprising 39.9% hydro, 59.9% thermal and about 0.2% solar power (Energy Commission, 2018).

Table 16: Installed Grid Electricity Generation Capacity (Agyenim et al., 2020)

GENERATION PLANT		FUEL TYPE	CAPACITY (MW)				TOTAL GENERATION		
			Installed (name plate)	% Share	Average Dependable	Average Available	GWh	% Share (incl.embedd)	% Share (excl.embedd)
Hydro Power Plants	Akosombo	Hydro	1,020		900	505	4,282	*30.5*	*30.6*
	Bui	Hydro	400		340	205	582	*4.1*	*4.2*
	Kpong	Hydro	160		140	115	752	*5.3*	*5.4*
		Sub-Total	***1,580***	***35.9*[@] 36.7***	***1,380***	***825***	***5,616***	***39.9***	***40.2***
Thermal Power Plants[11]									
Takoradi Power Company (TAPCO)		Oil/NG	330		300	200	686	*4.9*	*4.9*
Takoradi Inter. Company (TICO)		Oil/NG	340		320	260	1,880	*13.4*	*13.4*
Sunon–Asogli Power (SAPP)		NG	560		520	180	1,417	*10.1*	*10.1*
Kpone Thermal Power Plant(KTPP)		Oil/DFO	220		200	20	124	*0.9*	*0.9*
Tema Thermal Plant1 (TT1P)		Oil/NG	110[12]		100	70	365	*2.6*	*2.6*
Tema Thermal Plant2 (TT2P)		Oil/NG	80		70	1	0.5	*0.0*	*0*
CENIT Energy Ltd (CEL)		Oil/NG	110[12]		100	30	59	*0.4*	*0.4*
AMERI		NG	250		230	200	1,229	*8.7*	*8.8*
Karpower		HFO	470		450	225	1,814	*12.9*	*13.0*
AKSA		HFO	260		220	100	799	*5.7*	*5.7*
		Sub – Total	***2,730***	***63.3***	**2,510**	**1,286**	**8,373.5**		
	Trojan*	Diesel/NG	44		40	30	52	*0.4*	-
	Genser*	Coal/LPG	22		18	0	0	*0*	-
Sub-total (including embedded generation)			***2,796***	***63.6***	***2,568***	***1,316***	***8,425.5***	***59.9***	
Renewables*	VRA Solar	Solar	2.5		1.5	1.5	3.0	0.02	
	BXC Solar	Solar	20		16	10	25	0.18	
		Sub – Total	*22.5*	*0.5*	11.5	11.5	***28.0***	***0.2***	
Total *(including embedded generation+ Solar)*			**4,398.5**		***3966***	**2,198**	**14,069**		
Total *(excluding embedded generation and solar)*			**4,310**		**3,890**	**2,156**	**13,989**		

*NG is Natural gas. * Sub-transmission (primary embedded) connection. [@]Including embedded generation and solar.*

Transmission of power is under the responsibility of the Ghana Grid Company (GRIDCo) which was established in 2006. GRIDCo operates in accordance with the Energy Commission Act, 1997 (Act 541) and the Volta River Development (Amendment) Act, 2005 (Act 692). These guarantee the establishment and exclusive operation of the National Interconnected Transmission System by an independent public utility and the separation of transmission functions of the Volta River Authority (VRA) from its other activities within the framework of the Power Sector Reforms. Government through the Ministry of Energy is embarking on major projects aimed at addressing transmission challenges through progressive replacement of outdated and obsolete equipment and reinforcement of others including the construction of 161KV and 330KV transmission lines, construction of new substations across the country, as well as the expansion of some existing substations and installation of capacity banks.

Lack of Prioritization of Biogas for Energy Generation: In 2018 the Energy Outlook of Ghana was published by the Energy Commission, but the document insufficiently referred to

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biogas. Biogas is largely seen as an intervention in the sanitation sector. In Ghana, the prevalent type of biogas plants is that of small to medium sized scale. An assessment of the Energy Commission in 2018 on the state of biogas installations in Ghana revealed that the vast majority is using it only for sanitation purposes. One of the main associated challenges identified was inadequate feedstock for the needed gas and poor maintenance. As a result, the vast majority of users only adopt for sanitation purposes.

Governance: Ghana's Energy Commission is a technical regulator of Ghana's electricity, natural gas and renewable energy industries, advisor to the Government on energy matters and responsible for facilitating the implementation of the Sustainable Energy for All (SE4ALL) Country Action Plan (CAP). An activity was formulated within the SE4ALL CAP "*to conduct a feasibility study to establish institutional biogas systems for 200 boarding schools, hospitals and prisons*" with 2012-2015 as reference for the implementation timeline. The purpose of this activity was to bring the use of biogas as a low carbon energy source to a significant higher level in Ghana. The 200 systems were to act as a catalyst to stimulate and accommodate further implementation of biogas for productive usage in the country, with a long-term objective of developing a self-sustaining biogas market in Ghana. However, due to lack of government commitment and investment, the project is yet to be implemented. Notwithstanding, some institutions have initiated to install biogas projects to deal with their waste management such as the 200m^3 biogas facility at Mfantsipim Senior High School located in Cape Coast, the 70m^3 biogas plant at Tamale SOS Village Biogas Plant and the biogas plant at Ankaful Maximum Prison Centre in Cape Coast.

4.1.2 Economic Aspects

The economic stability of a country indicates the country's financial system characterized by little fluctuations in the macro-economy (output growth) and fairly consistent low inflation (Business Dictionary 2012). Ghana was the second-fastest growing economy in Africa in 2017, with growth of 8.1%, driven by the mining and oil sectors (Macrotrends, n.d.). Ghana's economic stability can be attributed to factors such as inflation rates, taxes, interest rates, exchange rates, trading regulations and excise duties. The economy continued to expand in 2019, with real GDP growth estimated at 7.1%. High growth momentum since 2017 has consistently placed Ghana among Africa's 10 fastest-growing economies[66]. However, rebasing of the year (Ghana rebased its economic calculations from the base year of 2006 to 2013, determining GDP to be GHS257bn ($53bn) in 2017, a 26% increase from the GHS204bn ($42bn) the IMF calculated previously[67]) and effective macro-economic policies are the main economic factors with monetary policy considered as more powerful in promoting economic growth in Ghana. The current government has adopted several macro-economic policies such as the Public Financial Management Act, 2019 (L.I. 2378) to ensure prudent management of the economy. These measures have enhanced the economic growth of the country from 7.9% year-on-year in the fourth quarter of 2019 from that of the previous year's 5.6% (Macrotrends, n.d.). In the 2019 'Doing Business' Report published by the World Bank (2019)[68], Ghana has improved its worldwide ranking to 114 out of 190 economies up six places from being ranked 120th in the

[66] https://www.afdb.org/en/countries/west-africa/ghana/ghana-economic-outlook
[67] https://oxfordbusinessgroup.com/news/gdp-rebasing-improves-ghana's-economic-outlook
[68] https://www.doingbusiness.org/content/dam/doingBusiness/media/Annual-Reports/English/DB2019-report_web-version.pdf

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2018. The country's ease of doing business score formerly called distance to frontier has also increased by 2.06 to 59.22. The report indicates Ghana's progress reforms in three key areas. Firstly, government has made it easier to deal with construction permits by strengthening construction quality control by imposing stricter qualification requirements for professionals in charge of technical inspections. Secondly, the government has made it easier to pay taxes, by allowing financial losses to be fully carried forward during any of the following five years of assessment; and lastly, the government has made it easier to trade across borders, by implementing a paperless customs clearance processing system. Furthermore, investor confidence has increased due to the government's prudent fiscal and monetary measures which has resulted in a decrease in the interest rate with a corresponding increase in the banks' lending rate—which ultimately bolster investor confidence. Inflation and exchange rate of the local currency have also seen some fluctuation over the years. Inflation has seen a sharp decline of 7.31% from 2014 to 2018. It continues to fall from its peak of 19.2% in March 2016 to 9.4% in December 2018[69]. Additionally, the fluctuations in the exchange rate have had an impact on the economy. The Ghanaian cedi has come under considerable pressure over the last decade. At the end of 2018, the cedi had depreciated against the US dollar by 8.9%, cumulatively. Figure 20 below shows Ghana's GDP growth whereas Figure 21 indicates the inflation rate.

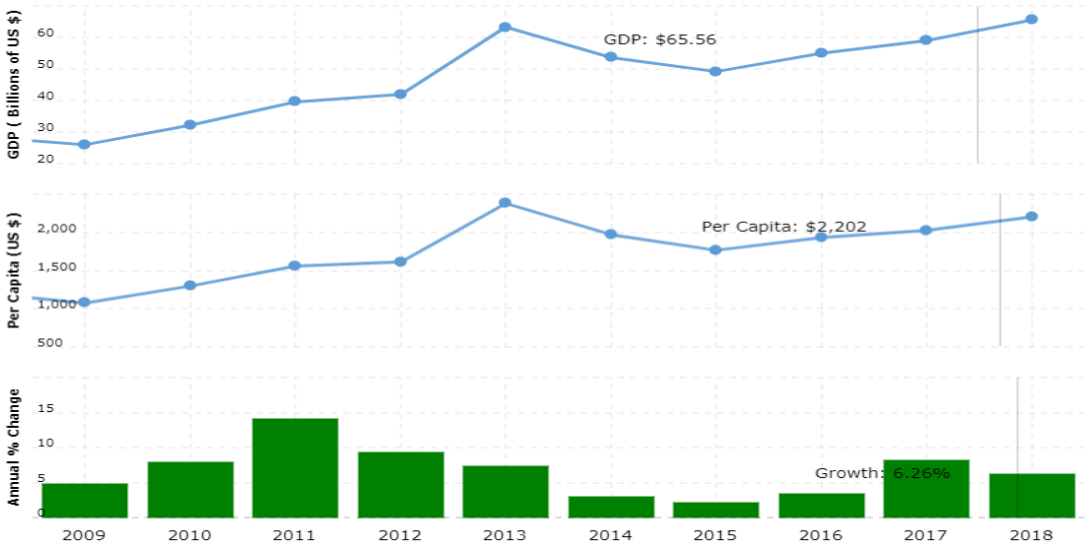

Figure 20: Ghana Real GDP Growth 2009 - 2018[70]

[69] Ghana's inflation rate can be accessed through: https://www.macrotrends.net/countries/GHA/ghana/inflation-rate-cpi

[70] Ghana's GDP (1960-2020) can be accessed through: https://www.macrotrends.net/countries/GHA/ghana/gdp-gross-domestic-produ ct'>Ghana GDP 1960-2020

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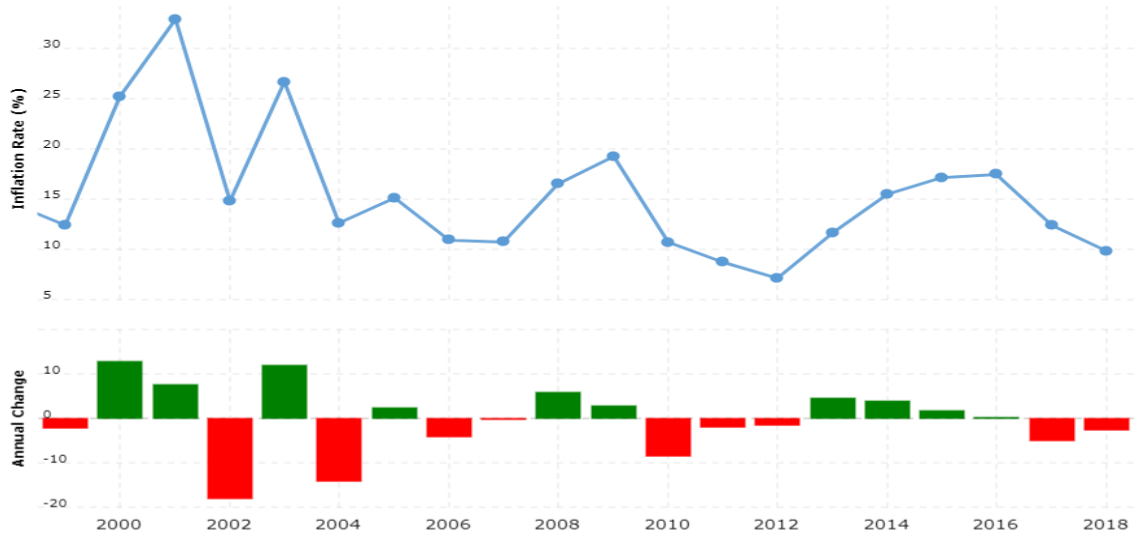

Figure 21: The rate of inflation 2000 - 2018[71]

In Ghana, investments for biogas development are mainly through the private sector, although there have been pockets of investments from the public sector. Private sector funding consists of a wide classification as it includes non-governmental source of financing, while public sector funding constitutes of grants derived from the national budget. One of the main barriers to sustained investment in the sector is change in government. In Ghana, governments are mainly run with a manifesto. So, if there is a change of the ruling government, investments made by the previous government are mostly redirected to new projects which align with their manifesto pledges. Additionally, the macroeconomic factors in Ghana such as inflation, high interest rates and foreign exchange volatility have largely hindered the ability of local banks to provide long-term financing beyond 3-5 years. Consequently, the support of the financial institutions to renewable energy projects has been very poor, and a wide gap exists between available local financing options and the special financing demands of renewable energy projects, such as non-recourse financing, longer tenors and lower interest rates (Ministry of Power, 2015).

4.1.3 Technological Aspect

Technology is considered one of the most critical areas of development in this modern era. The success of any business depends largely on how well it has positioned itself technologically with the rapid pace of technology development. Technologies also enable changes impacting the market to come from unexpected sources. Unfortunately, Ghana is suffering from an underdeveloped technological infrastructure (Energy Commission & UNDP, 2015). However, there are recent positive developments e.g., mobile telecommunications have seen a significant growth rate over the past decade. Ghana is presently among the top 10 countries projected to rule Africa ‘s Information and Communication Technology (ICT) sector in next five years and the telecommunication industry is estimated to be worth $1.1 trillion according to recent World Bank statistics. Ghana imports most of its technology products such as electrical and electronic equipment from abroad with the majority coming from China.

[71] Ghana’s inflation rate can be accessed through: https://www.macrotrends.net/countries/GHA/ghana/inflation-rate-cpi

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In spite of the promulgation of the Renewable Energy Act (832) of 2011, the technologies developed for some sectors related to renewable energy sources have not been fully developed yet—with the biogas sector being one of the specific examples. Renewable energy became a critical source of alternative energy during the persistent, irregular, and unscheduled power outages, popularly known as “dumsor” in 1983, 1998, 2006/7 and as recently as the past years (2013-2016). Government supports the development of the renewable energy sector through financing and other related support to research institutions including the Institute of Industrial Research of the Council for Scientific and Industrial Research (CSIR-IIR), Kumasi Institute of Technology and Environment (KITE), The Energy Centre as well as other private research institutions.

The development of biogas projects in Ghana is expected to remedy the waste management situation and increase the share of renewable energy mix in the country’s energy generation. The pre-dominant types of digesters installed in Ghana are the fixed-dome, floating drum and Puxin technologies (Osei-Marfo et al., 2018). The main reason of constructing biogas systems is to improve the sanitation situation. Although there are several issues with existing biogas systems, many of these systems are functioning well. Recent activities have sought to introduce technologies directly constructed by foreign companies or with a lot of foreign assistance. Examples include the concrete plant at Adeiso, owned by the fruit processing company HPW Fresh and Dry for the production of biogas for electricity generation. The plant was built by a foreign company but is wholly operated by local workers and maintained by Ghanaian biogas experts. The Ghana Oil Palm Development Corporation (GOPDC) also commissioned a biogas plant in 2014 at their mill for extraction of methane from palm oil mill effluent (POME). The system was built to increase renewable energy utilization through the capture and combustion of methane and to avoid the discharge of effluents that do not meet environmental standards into watercourses. The 2000 m^3 plant has an electricity generation capacity of 4 MW.

4.1.4 Environmental Aspects

According to the 1992 Constitution of the Republic of Ghana article 36(9): “*the State shall take appropriate measures needed to protect and safeguard the national environment for posterity; and shall seek co-operation with other states and bodies for purposes of protecting the wider international environment for mankind*”. Ghana is endowed with abundant natural resources including gold, timber, industrial diamonds, bauxite, manganese, fish, rubber, hydropower, petroleum, silver, salt, limestone, oil, etc. In the same vein, the country has abundant renewable energy resources which are yet to be fully exploited. These major potentials include biomass, hydropower, wind, along the coast and high solar irradiation. As of 2019, renewable energy contributes 1% to the energy mix. The main objective of the Renewable Energy Act of 2011 is to achieve 10% renewable in the energy mix by 2020. Rural households rely on land and other natural resources for their livelihoods; fisheries and wildlife provide important sources of protein in the Ghanaian diets. On the other hand, urban economic activities are highly depended on reliable hydroelectric power and fuel. Ghana has established a body known as the Environmental Protection Agency (EPA) under the laws of Ghana Act, 1994 (Act 490). The EPA is mandated by law to oversee all environmental issues and advice government accordingly.

In Ghana, measures (in terms of local bylaws) have been put in place to ensure the environmental safety during biogas installations. Depending on the designs, operation and mainte-

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nance are mostly carried out with ease to prevent any negative environmental impacts. In recent years, biogas systems were built as waste treatment facilities for toilets. Institutions that opted for biogas digester technology instead of the commonly used digesters such as the Kumasi Ventilated Improved Pit (KVIP) and toilet facilities with septic tanks, wanted to address the issues of odor and desludging. The use of biogas systems for sanitation has been stimulated partly by the Environmental Protection Agency because newly built structures are instructed to use anaerobic digesters as a standard technology.

4.2 Competition Overview through the PORTER's Five Forces

Despite the promotion of biogas technology development by the Government, the technology is still at the adoption stage mainly adopted for bio-sanitation purpose with the produced biogas usually released into the air without flaring. The government has identified biogas technology as one of the five key energy-related priorities stipulated in the Nationally Appropriate Mitigation Actions (NAMAs). These priorities are in line with the country's pursuit for low carbon development options in the national climate change policy (2014) as well as the sustainable development objectives articulated in the Ghana Shared Growth Development Agenda (GSGDA). The GSGDA is a series of medium-term national development policy frameworks prepared under the 4th Republic containing specific strategies to be implemented to systematically position the country towards the attainment of the country's vision and goal under the CPESDP (Coordinated Programme of Economic and Social Development Policies)[72]. DiBiCoo is in line with Ghana's Sustainable Energy for All (SE4ALL) action plan intended to promote the establishment of large-scale biogas systems both at institutional and industrial level with the aim of improving access to modern energy for productive uses.

Ghana as a developing country gained interest in biogas technology in the late 1960s but it was not until the middle 1980s that the technology received the needed attention from government. The Ghana government's intervention in the dissemination programmes before the mid of 1980s focused on the provision of energy for domestic cooking. As a result, the first biogas project by government was the Appolonia Electrification project in 1992. The Apollonia Biogas Plant had a 12.5 kW generator to provide electric power for street and home lighting as well as cooking while the bio-slurry was used for agriculture with animal dung and human excreta as feedstocks. As part of a dissemination programme, the Ministry of Energy constructed a total of nineteen fixed-dome digesters comprising six 15 m^3 and two 30 m^3 Deenbandhu digesters, and eight 10 m^3 and three 25 m^3 Chinese dome digesters by engineers from the Ministry of Energy (MoE) and the Institute of Industrial Research (IIR). Since these events, the biogas sector has mainly been supported by donors with the Netherlands Development Organisation (SNV) and the United Nations Development Programme (UNDP) playing a key role in the sector. Subsequent to the low involvement of biogas projects by the Ghanaian government, a number of private biogas companies have been marketing the technology purely on business grounds, demonstrating the ability of biogas plants to improve sanitation. The focus of biogas technology shifted from provision of energy (use of biogas) to improvement in sanitation (treatment of waste). This development has created a situation where most plants have been constructed without adequate arrangements for the usage or proper handling of the biogas produced.

[72] For the complete document of Ghana's Shared Growth and Development Agenda, see: https://www.un-page.org/files/public/gsgda.pdf

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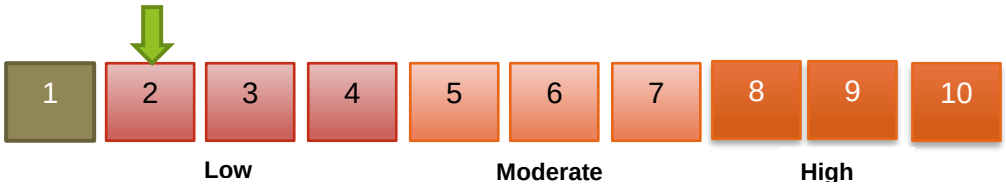
4.2.1 Economy

Ghana continues to be a beacon for democracy in Africa. Despite the political gains, the country is still plunged with several economic challenges with some significant economic gains over the last two decades. Peak economic growth was recorded in 2011, partially due to a competitive business environment, good government investment policies and a fast-growing private sector. The country's real GDP growth slowed down from the peak of 14% in 2011 to 9.3% in 2012, 7.3% in 2013, 2.9% in 2014, dropped further to 2.18% in 2015. Ghana's GDP is US$67.07 billion (2019) with inflation 9.16% year-on-year in January 2020. The current government has put a number of policies and programmes in place to stabilize the economy with the economy continued to expand in 2019 as the first quarter GDP growth was estimated at 6.7%, compared with 5.4% in the same period of last year.

Government has also put in place incentives and policies to attract more investments. Some of these include Tax holidays, Locational incentives, and Investment guarantees. The Ghana Investment Promotion Centre (GIPC) and Ghana Free Zones Board (GFZB) are also avenues where various degrees of assistance are provided to foreign investors. The GIPC ought to act as the first port of call for investors. The operation of the GIPC is governed by the 2013 Ghana Investment Promotion Centre Act 865 which was enacted as an instrument to show government's commitment to encouraging foreign investment in its economy, including the renewable energy sector.



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

4.2.2 Existing Competition

Currently, there are about 20 private companies and research institutes who are actively involved in the design and construction of both domestic and institutional size biogas plants across the country. A few are purely focused on biogas or sanitation but most of them also have other business areas they are actively involved in. The latter is due to the slow market for biogas digesters. To date, Biogas Technologies Africa Limited (BTAL), now BTAL is one of the largely recognized biogas companies in the installation of fixed-dome digesters in Ghana. This company have been responsible for the construction of at least 400 biogas systems in institutions, hotels, government buildings and homes. Our market research revealed that most of the companies are engineering companies. Some of the companies also collaborate with foreigners in the installation of large-scale digesters. The Ghanaian biogas market will be well suited for biogas implementation due to rising electricity costs and need for alternative energy sources. The good news is that most of the companies do not have the capacity to construct large-scale digesters. Large scale digesters are usually installed by foreign companies. Additionally, most biogas companies are ready to improve their technical capacity and in search for technology that will suit the Ghanaian context. The only competition might come from BTAL who is well established in the African continent with several large-scale digesters installed in

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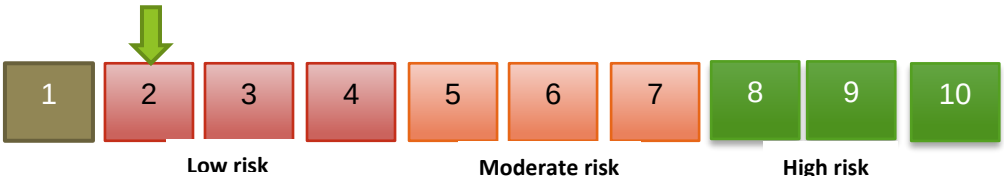
various African countries funded by UN organizations. Table 17 shown below lists several biogas companies affiliated with the Biogas Association of Ghana.

Table 17: List of organisations active in the design and construction of biogas sanitation systems in Ghana

Company	Year of entablement	Type of digester
Abu Biogas Construction Limited (ABCL), Obuasi	1998	Fixed Dome + Floating Drum
Apana solutions ltd, Accra	2012	Fixed dome
Beta Construction Engineers Ltd (BCEL), Accra	2006	Puxin
Biogas Engineering Limited (BEL), Kumasi	2002	Fixed dome
Biogas Technologies Ltd (BTAL) previously Biogas Technology West Africa Ltd, Accra	1994	Fixed dome
Biosanitation Company Ltd (BCL), Obuasi	1998	Fixed Dome + Floating Drum
Centre for Energy, Environment and Sustainable Development (CEESD), Kumasi	2013	Fixed Dome + Floating Drum
Environmental Impact Ltd, Obuasi	2005	Fixed dome
Environmental Impact Technology Ltd, Obuasi	2002	Fixed dome
Global Renewable Energy Services	1996	Fixed dome
CSIR-Institute for Industrial Research (IIR), Accra	1986	Fixed dome
Koajay Company Limited, Accra	2010	Fixed dome
Renewable Energy and Environmental Systems	2002	Fixed dome
RESDEM	1996	Bio-latrine
Unireco	2001	Fixed dome



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

4.2.3 Institutional and Market Factors

The successful implementation of biogas projects relies on a few factors with feedstock collection as one of the main identified factors that might hinder the implementation process in Ghana. Irregular amounts and irregular quality of feedstock is problematic. The collection of small volumes will create traffic movement and enormous costs. Other factors that are critical for biogas projects in Ghana include:

- ***Market size:*** The size of the market for a particular renewable energy technology is usually a driving force for the transfer of technology and hence could also become a barrier. The larger the market size, the more willing entrepreneurs are to exploit the possibility of acquiring the technology, adapting, and disseminating it. Likewise, the smaller the market size, the less likelihood that an entrepreneur will invest in technology

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transfer. In the case of Ghana, it is difficult to classify the size of the market as a potential barrier for some renewable energy technologies. Some renewable energy technologies with larger market size have not seen massive deployment, as is the case in other places. Domestic biogas for instance has a market potential of about 278,000 units for dung fed systems, however, less than 2004 units have been constructed nationwide so far (Bensah, 2015).

- ***High capital cost:*** Some potential clients such as food processors may have difficulties to finance the high initial investment that renewable energy projects i.e. biogas require as a result of challenging market situations and intermediate weak financial situations. The major waste management company in the country has shown concern with regards to the 1 MW electricity generation capacity.
- ***Access to finance and long-term capital:*** Financing biogas projects in Ghana becomes often uneconomical due to astronomically high interest rates and the lack of long-term loans. Even though financial mechanisms such as equity finance, venture capital fund, debt financing and crowd financing among others are available to entrepreneurs, some of them are not fully developed in Ghana. For instance, crowd financing is not fully developed in Ghana and hence inaccessible to entrepreneurs. Equity finance is also not very popular in Ghana thus the only financial mechanism available to Ghanaian entrepreneurs is perhaps debt finance. The current base rates of most banks are above 30% making the cost of borrowing very expensive in Ghana. In effect, access to long term financing has been identified as one of the major barriers to the successful implementation of biogas (Daniel et al., 2014).

  In 2019, the Agence Française De Développement (AFD) and Energy Commission (EC) of Ghana signed a Technical Assistance Facility (TAF) to support local banks and other key stakeholders towards the development of Energy Efficiency (EE) and Renewable Energy (RE) projects under the Sustainable Use of Natural Resources and Energy Finance programme (SUNREF) in Ghana. This has led to the establishment of unit/desk in some commercial banks such as Fidelity Bank, Cal Bank and Ecobank to specifically finance private sector investments in renewable energy project development in Ghana. The financial institutions will provide green credit loans to finance renewable energy and energy efficiency projects in Ghana (Energy Commission of Ghana, 2019).
- ***Unfamiliarity with biogas technology:*** Potential clients are generally unfamiliar with renewables and have institutional barriers to develop renewable energy concepts. Technical managers of food processors are focusing on their key competence – the production process itself. In terms of energy, managers are likely to concentrate on low-cost solutions and are not aware how renewable resources could fit into their systems. Only few environmental managers may consider pollution associated with their electricity demand.
- ***Lack of technical know-how:*** Workers must be trained to install, operate, and maintain renewable technologies. Biogas plants need special operating experience; the biological process needs to be controlled and monitored regularly to secure stable biogas generation. Education, training, and instructions to local managers, engineers and technicians are required and will also have a positive effect on the attitude to new technology in the long-term.

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- ***Lack of maintenance practice:*** Lack of knowledge and skills as well as awareness to maintain technology regularly and properly is considered to be a major risk in Ghana and will cause additional costs and funding for rehabilitation.
- ***Guaranteed price for energy services (feed-in-tariffs):*** The unavailability of feed-in-tariffs for electricity generation from renewable energy sources is a major obstacle for the adoption of large-scale biogas projects in Ghana. Safi Sana, who owns one of the largest biogas plants in Ghana has been struggling to meet their investment cost due to government inability to pay the approved feed-in-tariff to the company. The Public Utility Regulatory Commission in accordance with the provisions of the Renewable Energy Act 2011, Act 823 sets Renewable Energy Feed-in Tariffs (REFIT). The Guarantee period of the Power Purchase Agreement (PPA) has been a subject of concern for most project developers. Ghana's feed-in tariffs (FIT) guarantee period of 10 years is seen as a disincentive for project developers. The reason is the high risk of uncertainty after the 10-year period. Other countries using the FIT to drive the market have a guarantee period of 15 – 20 years. A shorter guarantee period scares banks away because of the high risk of uncertainty beyond the 10-year guarantee period.
- ***Lack of successful reference projects and failed experience:*** Successful reference projects serve to boost confidence in biogas technology leading to acceptability of the technology among end users. It also serves as a very powerful marketing tool for sceptics. Unfortunately, transfer technologies are perceived to be unreliable by end users even though that may not be the case. Failed demonstration projects re-enforce the perception of an immature technology that cannot be relied upon. This is evident in several renewable energy technologies solutions piloted in the past. For example, the failed Apolonia biogas project in 1986 with the support from the Chinese government due lack of operation and maintenance. Again, the absence of successful reference projects reinforces the perception of either an immature technology or a failed technology. Further, project financiers may consider renewable energy technologies too risky for the lack of visible projects. The interesting thing is that European companies and products will enjoy high reputation in Ghana due to their experience and innovation in the biogas field with evidence of most large-scale digesters installed by European companies.
- ***Controlled market in favour of conventional systems:*** The Government of Ghana used to subsidize transportation fuel leaving out market forces to determine the true price of the commodity even when the price of crude oil increased on the international market. However, in 2015, Government put in place a deregulation policy that allowed marketers and importers of petroleum products to set directly their own prices based on import parity costs, taxes and margins. Nonetheless, no subsidies have ever been announced for bioenergy products. Producers of electricity from renewable energy projects do not even have any means of selling their products to potential users since there are no dispensing mechanisms for fuel derived from renewable energy sources.

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Table 18: Feed-in Tariffs for utility-scale renewable energy technologies[73]

Electricity Generated from Renewable Energy Technologies/Sources	FIT (GHp/KWh)	Maximum Capacity (MW)
Wind with grid stability systems	55.7369	300 MW
Wind without grid stability systems	51.4334	
Solar PV with grid stability systems/storage systems	64.4109	150 MW
Solar PV without grid stability systems/storage system	58.3629	
Hydro ≤10MW	53.6223	No limit
Hydro (10 MW >≤100MW)	53.8884	No limit
Biomass	56.0075	No limit
Biomass (Enhanced Technology)	59.0330	No limit
Biomass (plantations as feedstock)	63.2891	No limit

4.2.4 Bargaining Power of Buyers/Customers

In Ghana, the technology is well known for its sanitation purpose. However, there is still lack of information with regards to the utilization of the technology for energy purpose. Additionally, there is limited information on the potential clients for investments into biogas systems in Ghana. The benefit of the technology to the customer is more of environmental solution than creating additional income for organisations. An example is the plant installed by Sewerage System Ghana Limited, where an anaerobic system is used to treat human waste without harnessing the gas for usage. The following are the most likely categories of potential clients for biogas installations in Ghana:

- Food processors that have a need to find cost-effective solutions to bio-degradable waste disposal. They may, or may not, take in other feedstock either to assist the biological processes or simply to increase income.
- Landowners/farmers who wish to treat their farm waste and add value to it. The waste coming from their farms can form a basic load for the plant. They may or may not take in material or waste products (e.g. source-segregated food waste) from other farmers or sources.

[73] Public Utilities Regulatory Commission of Ghana: PURC Gazetted Tariffs http://www.purc.com.gh/purc/node/178

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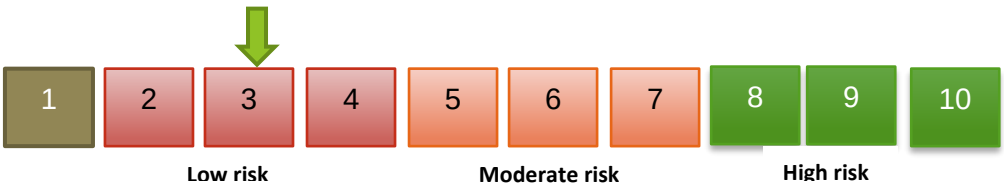
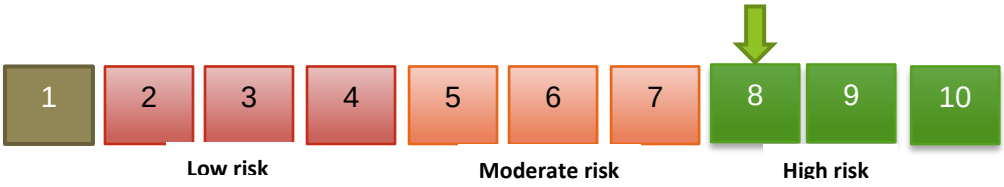
- Waste management companies that could install biogas plants close to landfill sites if the bio-degradable waste is separated and pre-treated before final disposal.



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

4.2.5 Buyer cost

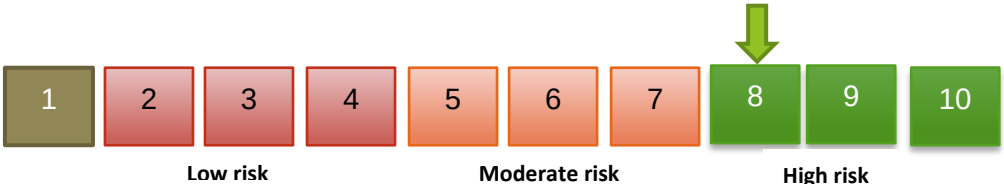
One of the major hindrances to adoption of biogas technology as identified by industries that need the technology is the high initial cost. A typical biogas projects with a capacity of 1.5 – 4 MW electricity generation ranges between 1.5 – 2.5 million Euros (Africa Business Communities, 2012). The lack of coordinated agency responsible for biogas projects in Ghana usually prolongs the project implementation period particularly in the acquisition of permit and licensing.



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

4.2.6 Suppliers (Bargaining Power of Suppliers)

No biogas equipment can be sourced locally. They are usually contracted to foreign companies. A prominent company in the biogas sector indicated that they normally source their supplies from Germany including biogas storage facilities and CHP equipment. However, there might be competition of products from China due to pricing as most Ghanaian companies prefer to acquire their products from China. The biogas technology is dominated by local companies installing small-scale digesters with the large-scale digesters constructed by foreign companies, usually from Europe. The fluctuation of the local currency has cascading impact on supply of biogas products to the Ghanaian market with suppliers opting for Chinese products due to the high exchange rate with other foreign currencies like the USD dollar and Euro.



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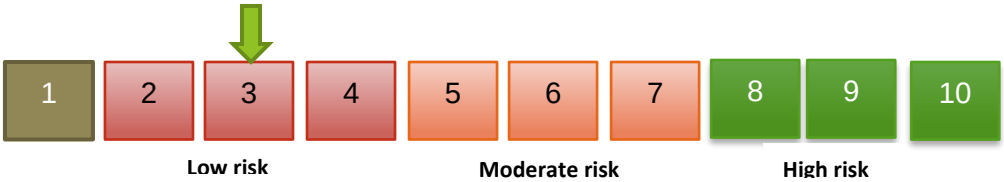
4.2.7 Threat of New Entrants/ Strategic Stakes

Government has put in place the necessary framework and policies to drive the renewable energy development in Ghana. An example is the Renewable energy Act 831 which was passed in 2011 with the aim of achieving 10% renewable energy penetration into the energy mix of the country by 2020. However, due to lack of investment in the sector, government has extended the current target to 2030. In Ghana, the government seems to be more focused on solar PV with little policy direction in the biogas sector as the current Bioenergy policy document is still in its draft stage since 2010. Most of the investment in the biogas sector has been driven by the private sector and donor funded projects specially to deal with waste management. The argument from the industries that are currently employing biogas technology to treat their waste is to comply with the standards sets by Environmental Protection Agency (EPA) in the discharge of waste into the environment. Government policy is to drive biogas technology as a solution to sanitation challenges at the household level in urban communities and for energy generation for off-grid communities in Ghana.



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

4.3 Market Policies and Incentives

Biogas is a renewable energy technology that is starting to grow commercially in the Ghanaian market. Due to the country´s economic growth and development of the regulatory environment, the Ghanaian renewable energy sector is attractive for foreign companies. As a result of the present-day energy situation, characterized by grid instabilities and increasing power prices, commercial and industrial producers from the agricultural and other service industries look for alternative solutions to secure constant energy supply to avoid production loss and to reduce energy costs. The installation of biogas plants on production sites is one of the most attractive solutions. It enables producers to dispose of waste in an environmentally friendly manner, generate electricity for self-consumption, use residues as fertilizer and feed-in energetic surpluses to the grid at the same time.

The structure of this section will follow these basic guidelines:

a. Policies and Programs that provides incentives for biogas development in Ghana will be used in determining the levels of incentives for adoption of biogas in Ghana.
b. Mandates of the various ministries, department, and agencies whose activities provide incentives for biogas development will be analyzed.

The scope of incentives in Ghana is largely structured around governmental legislations and policies. The Government's objective is to create an enabling environment for private investments in renewable energy (RE) projects. As a result, the Ghanaian Government has outlined several policies that provide the incentives for renewable energy development in Ghana including the development of biogas.

1. Ghana Energy Policy

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2. National Energy Policy
3. Sustainable Energy for All Action Plan (2012)
4. Renewable Energy Master Plan
5. Draft Bioenergy Policy (2010)
6. Scaling-Up Renewable Energy Program in Ghana (SREP) Investment Plan (2015)
7. Strategic National Energy Plan (2006-2020)
8. Energy Sector Strategy and Development plan
9. Ghana National Determined Contributions to Climate Change
10. Technology Transfer Regulations (L.I. 1547)
11. Environmental Sanitation Policy (2010)
12. Local Government Act, 462 (1993)
13. National Urban Policy (2012)
14. Ghana National Constitution (1992)

Table 19: Key Policy Framework for the energy sector in Ghana

Policy	Key issues related to RE, Environment and Industry
Constitution of Ghana, 1992	Parliament to pass all laws on the environment State to promote the development of agriculture and industry Citizens to protect and safeguard the environment
Local Government Act, 462, 1993	Places waste management under MMDA responsibility Encourages private sector involvement in waste management MMDAs to ensure drainage and sanitation in buildings
National Water Policy, 2007	Seeks to minimize the pollution of water sources from poor environmental sanitation services Ensures the provision of water and sanitation services
Environmental Sanitation Policy, 2010	Promote waste reduction, re-use, recycling, and recovery Ensure that sites for treatment and disposal of waste (landfills, composting facilities, waste stabilization ponds, trickling filters, septage treatment plants, etc.) are safe and hygienic and uses appropriate
National Urban Policy, 2012	Recognizes poor sanitation in poor neighborhoods Acknowledges that environmental deterioration which arises from unsatisfactory waste collection, disposal, and treatment
National Energy Policy	Encourages investments in renewable energy Bioenergy policy calls for recycling of waste to energy
RE Master Plan + SE4ALL Strategy	Prioritized investments in biogas, cookstoves and bioenergy solutions

Beside these, there are other relevant institutions whose mandate provides them with the responsibility to facilitate the development of renewable energy projects in Ghana. The roles, and policies of these institutions include:

- Ministry of Energy (MoE)

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- Energy Commission
- Ministry of Environment, Science, Technology, and Innovation (MESTI)
- Environmental Protection Agency (EPA)
- Ministry of Sanitation and Water Resources
- Ministry of Works and Housing
- Ministry of Local Government and Rural Development
- Ministry of Finance
- Ministry of Presidential Special Initiatives
- Ministry of Trade and Industry
- National Development Planning Commission
- Public Utility Regulatory Commission (PURC)

All these institutions have mandates and regulations that may serve as incentives or assistance to stakeholders in the biogas sector in Ghana. Besides the above-mentioned ministries/agencies, there are additional ministries and agencies whose activities and mandates also serve an important role for biogas development. However, specific ventures such as municipal waste-to-energy also require approval from the local Metropolitan, Municipal and District Assemblies (MMDAs).

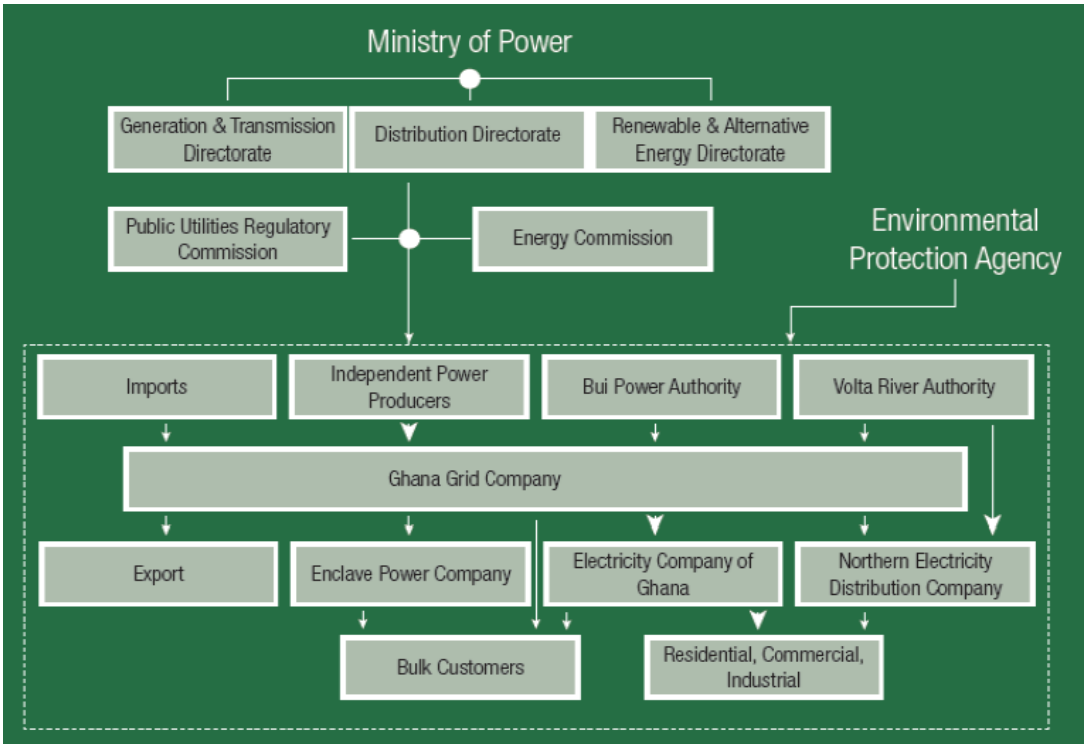

Figure 22: Key national institutions in Ghana's energy sector (Hagan, 2015).

4.3.1 Key Issues related to Renewable Energy, Environment and Industry within the National Regulations

There is no ongoing large-scale national biogas programme in Ghana yet. The Sustainable Energy for All (SE4ALL) Action Plan (2012) is the only national policy document that sets a target for the implementation of nationwide biogas system in Ghana. The target stipulated by

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SE4ALL focuses on conducting a feasibility study for the installation of 200 institutional biogas systems for selected boarding schools, hospitals, and prisons by 2019. However, government is yet to secure the necessary funds to see the realisation of this project.

Several policies and public initiatives are relevant for institutional biogas and its implementation. The Strategic National Energy Policy proposes to increase the use of renewable energy sources to 10% of the national energy mix by 2020. The plan recognizes the fact that establishment of a feed-in tariff regime that brings advantages for renewable energy and backed by regulatory framework is necessary to accelerate the development of renewable energy for electricity generation.

The Public Utility Regulatory Commission (PURC) in 2013 published the feed-in tariffs for renewable energy sources that was reviewed in 2014. Also, the Ministry of Energy through the National Energy Policy provides direction on how to reverse the decline in the fuel wood resource base of the country and further sustain its production and use by improving the efficiency of production and use. The plan suggests that, government should "Promote the production and use of improved and more efficient biomass utilization technologies and the use of modern biomass energy resources through creation of favourable regulatory and fiscal regimes and attractive pricing incentives".

The Draft Bioenergy Policy (2010) document also seeks to maximize the benefits of bioenergy on a sustainable basis. The policy targets, objectives, and strategies which the development of institutional biogas could facilitate include:

- Use of municipal wastes for energy purposes;
- Promotion of private sector participation in the bioenergy industry;
- Provision of an avenue to reduce poverty and wealth creation through employment generation, and;
- Reduce carbon dioxide (CO_2) emissions.

Within the Draft Bioenergy Policy, biogas is mentioned specifically, targeting the sanitation problems in the country. In promoting renewable energy in general, the government of Ghana has demonstrated its commitment in meeting these targets by passing the Renewable Energy Law (ACT 832) in 2011 which is expected to create a favourable platform for development of green energy and low carbon options. The RE Act 832 also provides the legal backing to establish a renewable energy fund which could be utilized to promote the development of renewable energy in Ghana.

Also, promotion of small and medium-sized enterprise (SMEs) participation in institutional biogas technology penetration has been identified as one of the five key priority energy related Nationally Appropriate Mitigation Actions (NAMAs) in Ghana. This is in line with the country's pursuit for low carbon development options which is identified in the National Climate Change Policy (2014) as well as the sustainable development objectives articulated in the Ghana Shared Growth and Development Agenda (GSGDA). The waste-to-energy policy objective as stipulated in the GSGDA is to convert most of the wastes generated in municipal, urban, rural, industrial, and agricultural activities to energy with the strategy of maximizing energy production from waste.

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Furthermore, sanitation and development policies in Ghana recognize the significance of improved sanitation and have thus outlined similar strategies in the GSGDA I, which are re-emphasized in GSGDA II. Strategies aimed at improving environmental sanitation include the following:

- Promoting the construction and use of appropriate and affordable domestic latrines;
- Support public-private partnerships in solid and liquid waste management;
- Promote cost-effective and innovative technologies for waste management; and
- Develop disability-friendly sanitation facilities.

Though the various developmental interventions such as the Ghana Poverty Reduction Strategy II (GPRS II), GSGDA I and GSGDA II do not directly mention biogas as a means of enhancing sanitation, some of the policy strategies provide a platform for the development of sanitary biogas systems to promote good sanitation. For instance, biogas systems can be used to improve household and institutional sanitation as outlined in the strategy.

Other policies and initiatives

According to Environmental Protection Agency (EPA) officials, EPA has acts in place stating that new public buildings will not receive a building permit when utilizing septic tank sanitation systems. Also, the EPA has a role in monitoring the efficiency of biogas systems and the quality of the effluent of biogas systems. The costs associated with this monitoring and the unavailability of a sufficient budget obstructs a proper execution of these tasks by EPA.

In 2012, the governments of Korea and Ghana started a cooperation project “Supporting green industrial development in Ghana: biogas technology and business for sustainable growth”, supported by United Nations Industrial Development Organization (UNIDO). This project was focused on industrial application of biogas systems, which in turn would also has an impact on large scale sanitation biogas systems by utilising a combination of industrial and/or agricultural feedstock.

In September 2014, the United Nations Development Programme (UNDP) and its partners launched an initiative to consolidate the partnership between the Government of Ghana, UNDP, and Governments of China and Denmark on Renewable Energy Technology Transfer. The initiative aims to facilitate the development and transfer of renewable energy technologies from China to Ghana along with the support required to make the technologies work on the ground.

4.3.2 Details of selected policies and regulations related to Biogas incentivization

NB: It is important to note that legislation and policy surrounding AD in Ghana is still under development

Renewable Energy Act, 2011 (Act 832)

The first legal framework condition for renewable energies has been established when the Parliament of Ghana enacted the Renewable Energy Act in December 2011. The goal is to increase the share of renewable energy technologies in the total energy mix and achieve 10% contribution in electricity generation by 2020. However, due to lack of investment in the sector, government has extended its target to 2030 with more strategic investment plans put in place.

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The objective of the Act is to support the participation of the private sector in the electricity sub-sector and to allow independent power producers (IPPs) access to the grid.

1.1. Key Provisions in Renewable Energy Act, 2011 (Act 832)

1. Renewable Energy Licensing

This regime gives the guidelines for the procurement of licenses for commercial service providers in the renewable energy industry. According to the Renewable Energy Act 832, 2011, any person or organization that wishes to engage in commercial activity in the renewable energy industry must obtain a license from the Energy Commission before doing so. For production and supply of electricity, Wholesale Electricity Supply License would be granted for 20 years. For installation and maintenance, Installation and Maintenance license would be granted for 10 years. Licenses are only granted to a citizen of Ghana or a body incorporated and registered under the company code 1963 (Act 179) or under any other law of Ghana or a partnership registered under the Incorporated Private Partnership Act, 1962 (Act 152). The acquisition of a License for the wholesale supply of Electricity undergoes three (3) main stages. First stage is the acquisition of provisional license, second is the acquisition of siting clearance and the acquisition of construction work permit, and the third stage is the acquisition of operational license.

To qualify for stage one, the applicant must submit feasibility reports and a financially sound business plan. Stage two requires an environmental assessment permit to be granted by Ghana's EPA and an approved Feed-in Tariff from PURC as well as a signed Power Purchase Agreement (PPA) with one of the electricity distribution utilities or a bulk customer (Ghana Energy Commission, 2012).

2. The Renewable Energy Feed-in-Tariff Scheme (RE FiT)

This scheme is to provide a guaranteed price for electricity generated from renewable energy sources. The Public Utility Regulatory Commission in accordance with the provisions of the Renewable Energy Act 2011, Act 823 sets Renewable Energy Feed-in Tariffs (REFIT).

3. Renewable Energy Purchase Obligation (RPO)

Under this provision, power distribution utilities and bulk electricity consumers are required to procure a specified percentage of their total purchase of electricity from renewable energy sources.

4. Net Metering (distributed generation)

Under this facility, renewable energy generation facility owners are credited for electricity the facility supplies to the grid, and this credit is set off against electricity purchased from the distribution utility. "Net metering is designed for applications where the renewable energy generation is not being used as a back-up to the main source of power supply. Instead, the excess energy is supplied to the distribution utility, on the assumption that the amount of energy supplied to the grid will not exceed the amount purchased over an annual tracking period".

5. Off-grid electrification for isolated communities

This provision promotes mini-grid and standalone off-grid renewable power systems for remote areas and islands.

6. Promotion of wood fuels and biofuels

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The Act provides for the efficient production and utilization of wood fuels and biofuels internally: and for exports where applicable

7. Research and Development (R&D)

This section elaborates the scientific, technological, and innovative research into renewable energy, as well as research into the establishment of standards for their utilization. The government has promised to increase funding for R&D to 2.5% of GDP from the current 0.25% in the long term to boost research programs including renewable energy projects. According to the Renewable Energy Master Plan, a Renewable Energy Demonstration Centre would be established to serve as a link between government and research institutions to promote and drive research that is targeted at national development priorities and bridge the gap between researchers, private sector and government. The Centre is expected to coordinate research dissemination, working closely with the existing universities and research centres. Government would also ensure to strengthen individual and institutional research capabilities, increase cost sharing in financing proposals, and upgrade equipment and instrumentation, and guides the Establishment of Renewable Energy Fund (RE Fund). Under this provision, a renewable energy fund has been established for the development, promotion, and utilization of renewable energy resources in Ghana such as financial incentives, feed-in-tariffs, capital subsidies, production-based subsidies, and equity participation. The Renewable Energy fund is sourced by funds approved from parliament, premiums payable by bulk consumers who fail to meet RPOs, donations, grants and gifts received for renewable energy activities, and funds approved by the board of the Energy Fund, and money generated by the Energy Commission from the provision of services for renewable energy activities. **Acquired money from the funds are to be used to promote activities such as:**

- innovative approaches, including new business models for developing and utilising sources of renewable energy.
- scientific, technological, and innovative research for renewable energy
- designing and implementing standards for the utilisation renewable energy
- manufacturing equipment for developing and utilising renewable energy
- programmes to adopt international best practices
- development of infrastructure for renewable energy
- capacity building for renewable energy development

8. Establishment of a Renewable Energy Authority (RE Authority)

The RE Authority oversees the implementation of renewable energy projects and activities in the country, execute projects initiated by the state and manage assets in the renewable energy sector on behalf of the state.

1.2. Progress since Implementing the Renewable Energy Act in 2011

1. Renewable Energy Licensing

The Energy Commission (EC) has developed the licensing framework, Grid Code, and manual for RE investment. It has also issued 66 provisional licenses; 17 sitting and 2 construction permits as at now. The provincial licenses categorised by technologies are as follows:

- Solar: 44
- Wind: 7

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- Biomass/Waste-to-Energy: 11
- Hydro: 3
- Tidal wave: 1

2. **The Public Utilities Regulatory Commission (PURC) in accordance with the RE Act has reviewed the RE Fit scheme on three occasions since 2013.** The first RE Fit scheme was set in September 2013. The second was reviewed and gazetted in October 2014, while the last review was gazetted in August 2016. The 2014 guideline introduced the integration of utility scale variable renewable energy technologies (i.e. solar PV and wind) with capacity limit indicated below. It was limited to an initial 10 years and made provision for grid stabilization and storage. The main principles of the 2014 guidelines are as follows:

    - The total nationwide capacity for solar PV and wind plants without grid stability/storage systems are limited to 150MW and 300MW respectively;
    - A maximum of 10MWp (Megawatts peak) per solar PV plant without grid stability/storage systems is allowed to be connected to the distribution system at any generation site;
    - A maximum of 20MWp per solar PV plant without grid stability/storage systems is allowed to be connected to the national transmission system (161 kV or 330kV) at any generation site (PURC, n.d.).

3. **Renewable Energy Purchasing Obligation (REPO)**

Under this scheme, the RE Act obliges all electricity distribution utilities and bulk consumers to purchase a percentage (%) of their electricity from renewable energy sources. Ghana currently has three distribution utilities 32 bulk consumers. The three distribution utilities include The Ghana Grid Company (GRIDCo), the Electricity Company of Ghana (ECG) and the Northern Electricity Distribution Company (NEDCo). On the percentage (%) required, the PURC is yet to establish the percentages of these consumers. However, German development partner, GIZ is offering technical support and capacity building for PURC to establish the required percentage and the mode of implementation.

There are also requests being considered by ECG from other renewable energy developers to sign PPAs. These developers are however seeking for government guarantees due to the troubling financials of ECG. These are presented in Table 20 and Table 21 below.

Table 20: Expressions of Interest (EOI) from Renewable Energy Developers (2015)

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RE Technology	No. of EOI	Proposed Capacity (MW)	Percentage Share
Solar	12	1,140	52%
Wind	4	175	8%
Hydropower	2	557	26%
Waste -to-energy	1	100	5%
Biomass	2	200	9%
Total	**21**	**2,172**	**100%**

Table 21: Wholesale Electricity Supply Licenses issued to Renewable Energy Developers (Energy Commission, 2015)

Category	No. of Wholesale Electricity Supply Licences Issued (as at 2015)			Total Proposed Capacity (MW)	Percentage Share
	Provisional Licenses	Siting Permits	Construction Permits		
Solar	55	16	1	2,742	58%
Wind	9	1	-	951	20%
Hydropower	4	-	-	201	4%
Biomass	2	1	-	68	1%
Waste -to-energy	10	1	-	764.61	16%
Wave	11	1	1	20	0.4%
Total	**81**	**20**	**2**	**4,746.61**	**100%**

4. Renewable Energy Net Metering Scheme

200,000 Solar Roof Top Programme has been initiated by the Energy Commission under this scheme. The government is giving a capital subsidy of 500W panel per installation.

5. Mini-grid Renewable Energy Electrification Programme

Five hybrid mini grids have been developed in island communities on the Volta Lake to cater for the electrical needs of more than 6,000 people

6. Off-grid Stand Alone Electrification Programme

Solar streetlights have been installed in remote off-grid communities, clinics, schools and security points. Energy centers have also been established in remote communities for charging mobile phones and batteries.

7. Kerosene Lantern Replacement Programme

70,000 solar lanterns with 70% subsidy have been deployed to replace kerosene lanterns. The target is 2 million solar lanterns by 2030.

8. Sustainable Energy for cooking and Productive Use

- Monitored cookstove initiatives (total improved woodstoves disseminated by private sector – 22,856 as June 30, 2016).

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- 32 Institutional Stoves constructed in 5 Districts for Gari Processors through a 50% grant facility from SNV/GIZ
- Rehabilitation works of Appolonia Renewable Energy Center has commenced - 30% work done to date.
- Completed market assessment for solar pumps for irrigation

9. Scaling-up Renewable Energy Program (SREP) in Ghana Investment Plan

In 2015, the Ministry of Energy (MoE) developed the Scaling-up Renewable Energy Program in Ghana Investment Plan (SREP-Ghana IP) to help facilitate and support Government's plan to access financial opportunities to develop a robust and sustainable renewable sub-energy sector. With targets for 2020, the program had four investment projects:

- Renewable energy mini-grids and stand-alone solar PV systems
- Solar PV based net metering with battery storage
- Utility-scale solar PV/wind power generation
- Technical assistance

Government has developed and obtained approval for $230m Ghana SREP Investment Plan. The 4 projects under SREP are:

- 55 Mini-Grid & 38,000 Solar Home Systems (SHS)
- 15,000 Net-metering
- 20-30MW utility scale solar/wind projects
- Technical Assistance
- Biomass waste to energy projects
- Sustainable energy for cooking.
- Medium-small hydro projects

The program will secure $40m financing from the Climate Investment Fund (CIF), of which $30m is granted to finance the above 4 projects. Additional $1.5m project preparation grant has been approved by CIF to develop the above projects. Table 22 presents the targets set by the Ministry of Energy on the renewable energy projects in 2020, under the Scaling-up Renewable Energy Program in Ghana Investment Plan.

Table 22: Targets on Renewable Energy Projects by 2020 – (Ministry of Energy, 2015)

Potential Renewable Energy Projects	Target	Required Investment US$ million
Development of utility type wind farms	50-150 MW	300-550
Development of grid-connected solar parks	N.A.	400-700
Solar lantern promotion	2 million units	150-200
Medium – small hydro	150-300 MW	450-900
Modern biomass /waste to energy	20-50 MW	60-150
Development of mini grid	30-42 units	21 - 38.5
Off-grid renewable energy project	30,000 units	10-25
Sustainable energy for cooking	2.0 million units	10-50
Total Investments		**1.4 - 2.6 billion**

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4.3.3 License Procedure under Energy Commission

By the provisions of the RE Act, any individual that wishes to engage in a commercial activity in the renewable energy industry must obtain a license from the Energy Commission before doing so. The Act defines the activities that require acquisition of a license, among others:

- The production and supply of electricity from renewable energy sources for supply to distribution utilities and bulk customers - Wholesale Electricity Supply License granted for 20 years
- The installation and maintenance of renewable energy systems – Installation and Maintenance License granted for 10 years.

A license may only be granted to a citizen of Ghana; or a body corporate registered under the Companies Code, 1963 (Act 179) or under any other law of Ghana; or a partnership registered under the Incorporated Private Partnership Act, 1962 (Act 152). The different manuals for licenses and application forms and license fees shall be available at the Energy Commission's website[74].

The acquisition of the Wholesale Electricity Supply License consists of three stages:

Table 23: Stages for the acquisition of the Wholesale Electricity Supply License

Stage 1:	Acquisition of Provisional License
Stage 2 A:	Acquisition of Siting Clearance (Siting Permit)
Stage 2 B:	Acquisition of Construction Work Permit (Authorisation to Construct)
Stage 3:	Acquisition of Operational License (Authorisation to Operate)

- At stage 1 the applicant has to submit the Feasibility Report and a Business Plan to demonstrate its financial capability as well as its operational experience and expertise.
- During Stage 2A an Environmental Assessment permit or certificate granted by EPA will have to be submitted.
- EPA has set guidelines for preparing of Environmental Impact Assessment for new energy investments as well as guidelines for preparing Environmental Management Plan for existing energy companies and general guidelines for monitoring environmental performance and indicators and de-commissioning of all energy investments.
- During Stage 2 B an approved FiT from PURC has to be provided as well as a signed Power Purchase Agreement (PPA) with an electricity distribution utility or a bulk consumer. ECG has developed a procedure for engaging IPPs. A template for a standardized form of a PPA is currently developed by EC and will soon be available.

4.3.4 Financing mechanisms and donor programs

A major barrier to rapid development of renewable energy projects is the lack of adequate financing mechanisms in Ghana. Although there is a strong interest by international and local financial institutions to promote RE projects, in Ghana, the financing becomes uneconomical

[74] Ghana Energy Commission website, can be accessed in: www.energycom.gov.gh

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due to astronomically high interest rates and a shortage of long-term loans. However, financing is one of the key elements in order to ensure project viability. Low interest long-term loans are the most suitable means for financing the renewable energy projects. This type of loan should meet the demands for long maturity, low interest, and low initial installments. Some local and international financial institutions have identified this lack and are in the process to develop instruments to make financing for renewable energy projects available under reasonable conditions.

- Establishment of Renewable Energy Desks by local banks to offer mainly micro to medium scale financing (i.e. by Fidelity Bank).
- Raising of Renewable Investment funds (i.e. by JCS Investment) to provide small to medium scale financing (GHS 500,000 to 3 million). The limited access to financing is also derived from lack of knowledge about suitable national and international available financing mechanisms and programs. Here just to name two special funds that could be suitable for certain biogas projects:
  (1) UNEP Renewable Energy Enterprise Development (REED) is providing seed capital to small and medium enterprises operating in the clean energy sector in certain developing countries, among others in Ghana.
  (2) Ghanaian Export Development and Investment Fund (EDIF): Under this scheme, companies with export programs can borrow up to $500,000 over a five-year period at a subsidized cedi interest rate of 15%.
- However, financing institutions or investors lack experience and knowledge in the sector. They are unfamiliar with the evaluation and calculation of biogas projects and only show interest in short payback period and high return on investment.

4.3.5 Investment conditions

The new Ghana Investment Promotions Centre (GIPC) Act 2013 (Act 865), which repeals the GIPC Act 1994 (Act 478), is introducing changes to the country's investment laws and institutions and contains provisions that may curtail foreign direct investment into Ghana. The Act requires Ghanaian citizens who partner with foreign investors to have at least 10% equity participation in the joint enterprise and capital requirements of the foreign investors of not less than US$50,000 in cash or goods relevant to the investment or a combination of both by way of equity capital. In the case of an enterprise that is fully controlled by a foreign investor, the capital requirement is not less thanUS$200,000. The Act also expands the investment activities reserved for Ghanaians and Ghanaian owned enterprises: Trading enterprise that is principally engaged in the purchase or sale of goods shall not be wholly owned by non-Ghanaian but shall operate by way of a joint venture with a Ghanaian partner. The capital requirement for the foreign investor is not less than US$1,000,000 and such joint ventures employ at least ten skilled Ghanaians.

4.3.6 Policy Gap and Barriers in the Renewable Sub-Sector

Regardless of the successes chalked since implementing the RE Act, there are still barriers that militate against the industry. Some of the barriers identified in this report are:

Challenges with license acquisition for RE projects and cumbersome licensing procedures:

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- Renewable energy developers experience difficulties in accessing license for projects because of the cumbersome processes involved. For a renewable energy IPP to enter the market, it has to interact with a host of regulators in the industry to facilitate license approvals, clearances and incentives where necessary.
- Some of these regulators and service providers include Energy Commission, Ghana Investment Promotion Centre (GIPC), Public Utilities Regulatory Commission (PURC), Environmental Protection Agency (EPA), Ministry of Energy, etc. The procedures involved here can be lengthy and complex with significant administrative and transaction costs. This can easily discourage potential investors and renewable energy project developers from conducting business in Ghana. Figure 23 below shows the licensing processes and procedures that IPPs must go through upon entering the RE industry.

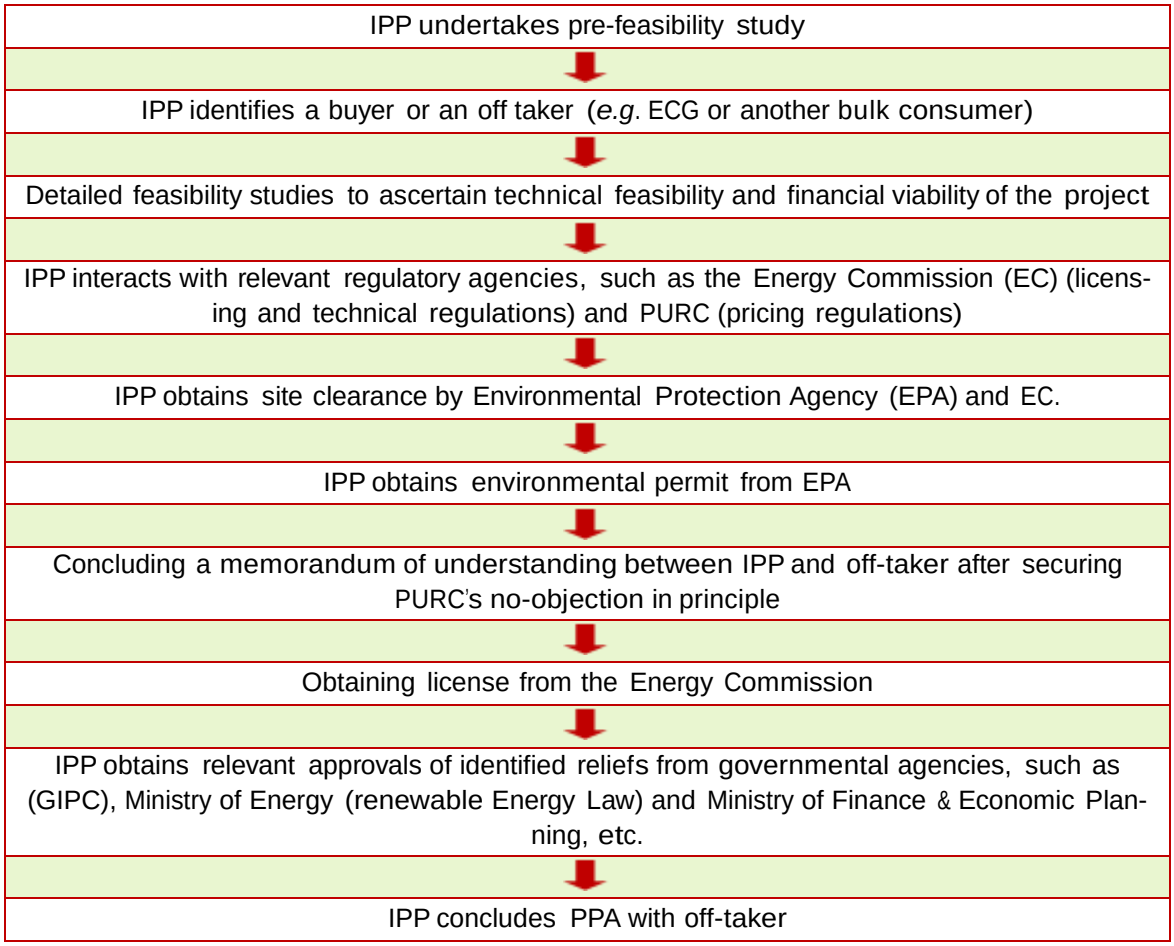

Figure 23: Procedures for Entry into the Electricity Market as Renewables (IRENA, 2015)

Poor financial investment mechanisms and lack of guarantees for IPPs

- Firstly, the Energy Commission has received a lot of applications for licenses from IPPs to develop RE projects. However, due to the financial state of ECG, the EC is cautious about granting these licenses. The utility provider is saddled with so much debt thus the question about whether it will be able to pay the RE project developers arises. Even if they turn to other financial service providers, financial closure for projects still becomes an issue because of the lack of government guarantees for payment, in the event of ECG defaulting in paying the RE companies.

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- Also, most RE developers are struggling to develop projects that are bankable to attract financial investment. There is also a general difficulty in accessing finance and long-term capital for RE projects in Ghana. This is because most financial mechanisms like crowd funding, venture capital funding, equity and debt financing are still underdeveloped in Ghana. Financial professionals from financial institutions also lack a good knowledge of the RE technology so they are unable to evaluate proposals for RE financing.

Lack of sufficient incentives in the RE industry

- One major challenge is the lack of adequate tax rebates and incentives in the industry. The high cost of RE technologies and its sheer market size means that incentives are important to ensure its full development and market development. In 2017, government put in place an import duty and a value added tax exemption for solar PV and wind generation systems.
- However, other RE technologies have not been catered for. Even though most of them are imported, they do not enjoy tax rebates and exemptions. These include some components of biogas systems such as de-sulphurisers, biogas storage balloons, pipes, and valves. Solar water heater components, large biogas systems, small hydro plants and improved cookstoves also do not enjoy these exemptions.

Lack of enforcement of key actions in the RE Act

- Firstly, the RE Act mentions the setting up of a renewable energy authority to oversee the implementation of renewable energy projects and activities in the country, execute projects initiated by the State and manage assets in the renewable energy sector on behalf of the State. However, this has not yet been established.
- Secondly, it also makes a provision for the establishment of a renewable energy fund to support the industry. This has also not been implemented. Thirdly, the Renewable Energy Purchase Obligation (RPO) in the provision obliges all electricity distribution utilities and bulk consumers to purchase a percentage (%) of their electricity from renewable energy sources. However, the PURC is yet to define and establish this percentage.
- Lastly, the Renewable Energy Master Plan that will set clear targets for the various RE technologies and the strategies to achieve the targets has also been fully developed and prepared.

Lack of adequate Research, Development, Demonstration and Deployment (R&DDD) into RE technologies

- R&DDD in Ghana to support the industry is either lacking or very low. One reason for this is the lack of a clear government policy direction for the process. Another is the lack of adequate funding to conduct R&DDD in the various RE technologies. Compounding these reasons is the lack of a clear strategic framework by the government on RE that will attract investors and funders to support R&DDD in Ghana. Universities and the industry can bridge this gap but lack of coordination and inadequate synergies; partnerships and weak linkage between them is also a problem.

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Lack of public awareness on Renewable Energy

- There is a general lack of awareness of RE technologies in Ghana. Though the solar technology (PV) has enjoyed considerable promotion in recent times, the public and consumers are generally lacking good understanding of the technologies to use them. Consumers believe RE technologies are overly expensive to acquire. They also lack access to information about the benefits of the RE technologies. therefore, creating a major barrier for renewable energy technology providers.

4.4 Resources

Agriculture continues to be the major contributor to Ghana's economy with 52% of the country's labour force engaged in agriculture. The five major subsectors of agriculture include food crops (59.9 %), livestock (7.1%), fisheries (7.6 %), cocoa (14.3 %) and forestry (11.1%). Despite the discovery of oil in commercial quantities in 2007, agriculture still contributes to 54% of the country's GDP, and accounts for 40% of export earnings[75]. The agrarian nature of the country is an indication of the nature of waste generated, with estimated 50-60% of the waste component being organic[76]. The availability of these feedstock particularly, agro-industrial residues, animal and agricultural residues presents a huge potential for biogas generation. Based on this, there are two main categories of feedstock for biogas production in Ghana. The first category includes farm-based products such as animal manure, agricultural by-products and farm-based wastes whereas the second category consists of a broad range of suitable organic wastes from the food and feed industries with municipal solid waste as the most dominant. The present report focuses on food processing waste, abattoirs and slaughterhouses and municipal solid and liquid waste. Despite the abundant availability of feedstock for biogas generations in Ghana, biogas as a sustainable renewable energy is at the introduction phase of market development in Ghana. With government effort to mitigate climate, biogas technology has been identified as a priority technology to be implemented as part of the Sustainable Energy for ALL (SE4ALL) Country action plan for Ghana, with the aim to improve access to modern energy for productive uses.

4.4.1 Food processing

Ghana's food processing industry includes the fruit processing, breweries, oil palm processing, cocoa, and cashew processing. However, the fruit processing and breweries industries are the focus of this study due to existing biogas plants in oil palm processing companies and the technical challenges in dealing with cocoa and cashew processing waste i.e. pre-treatment.

Ghana is a major producer of fruit and vegetables. Fruits such as mango, pineapple, papaya, and oranges are usually unprocessed and exported. Most of these agricultural products, fruit and vegetables are mainly cultivated by private small-scale farmers with the major commercial production areas located in the southern part of the country where close proximity to the ports enhances the export trade. At the coastal areas, commercial activities are concentrated in the

[75] http://agricinghana.com/wp-content/uploads/2017/07/AGRICULTURE-IN-GHANA-Facts-and-Figures-2015.pdf
[76] Agyenim et al. (2020) Powering communities using hybrid solar biogas in Ghana, a feasibility study. Environmental Technology & Innovation 19:100837

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Accra Plains and southern Central Region. Though most Ghanaian fruit is exported unprocessed, there are equally some companies that process mango, pineapple, papaya, or oranges locally. This sector is an important avenue for employment and private sector initiative.

The main different product groups are:

- Fresh fruit
- Fresh cut fruits
- Dried slices or fruit chips
- Fruit concentrates or juices

Even though most of the fruits and vegetables produced in Ghana are exported, there are few large fruit-processing companies that process the raw material for local consumption. These processing industries generate significant quantities of waste. The organic waste generated decomposes producing bad odour as one of the decomposition byproducts. Consequently, the decomposable material needs proper treatment with anaerobic digestion as an appropriate technology to generate energy and organic fertilizer as well. Table 24 below shows the capacity of the large fruit-processing companies in Ghana.

Table 24: Energy potential from biogas of selected fruit processing companies[77]

Companies	Products	Fruit residues (Mt/year)	Electric capacity (kW)
Peelco Ltd	45,000 Mt of tropical fruits	2,000 Mt of fresh cut residues	68
Fruittiland Ltd	Juice and concentrate for export from pineapples and oranges	45,000 Mt of fruit waste	1,249
Pinora Ltd	Juice concentrate for export from pineapples and oranges	40,000 Mt of fruit waste	1,110
HPW Fresh and Dry	Fresh, dried and fruit snacks for export from pineapple, mango, coconut, banana, and papaya	2,000 Mt	50
Blue Skies Ghana Ltd	Fresh cut-products for export and juice for the local market	8,000 Mt of fresh cut residues and fruit waste from juice production	298

4.4.2 Brewing

There are a number of companies in Ghana producing different alcoholic and non-alcoholic drinks. However, **Guinness Ghana Breweries Limited (GGBL) and Accra Brewery Limited are the largest breweries in Ghana.** The company has two branches. One in Kassi (Kumasi) and the other in Achimota (Accra). It is estimated that GGBL produces about 1.7 million hl beverages from the two breweries[78]. Accra Brewery Ltd (ABL) is the oldest brewing company in West Africa, a member of the Anheuser-Busch (AB) InBev family. ABL produces both alcoholic and non-alcoholic beverages with a total production capacity of 1,872 million hl.

Brewery wastes contain spent grains, yeast biomass but also liquid waste/ effluents. The company produces 6 hl of wastewater per every hectolitre of beer produced. Fortunately, GGBL

[77] https://energypedia.info/images/2/24/Biogas_in_Ghana_Sector_-_Analysis_of_Potential_and_Framework_Conditions_2014.pdf
[78] https://energypedia.info/images/2/24/Biogas_in_Ghana_Sector_-_Analysis_of_Potential_and_Framework_Conditions_2014.pdf

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has wastewater treatment facilities installed in Kumasi and Accra facilities and is generating biogas already producing biogas from its processes.

The following table gives an indication on the waste volume streams of a typical brewing process of one of the local breweries and their corresponding biogas potential:

Table 25: Energy potential from biogas of brewery in Ghana[79]

Type of residue	Volume [m³/year]	Electric capacity (kW)
Wastewater /effluent	300,000 m3	312
Sludge from wastewater treatment	4,000 m³	54
Spent grains	1,500 t	29
Spent yeast	120 t	Unknown

4.4.3 Abattoirs and slaughterhouses

The livestock sector is the third largest contributor to agricultural GDP of Ghana after crops and forestry. The major types of livestock production in Ghana include cattle, poultry, pigs, goats, and sheep. Among these, 50% of the livestock slaughtered in Ghana is cattle[80]. Each region in Ghana has a slaughterhouse. However, Accra and Kumasi abattoirs are the largest in Ghana and have been equipped with modern facilities. Both slaughterhouses are supposed to have a maximum capacity to slaughter 450-480 cattle per day, 450-480 sheep and goats per day and 200 pigs per day. Apart from these two large facilities in Kumasi and Accra, there are also small to medium scale slaughterhouses or slabs in Ghana with low number of animals slaughtered usually less than 200 large animals (cattle) per month or less than 1000 goats and sheep per month.

The livestock operations are prone to serious environmental impacts, such as GHG emissions, odour; water and land contamination; resulting from storage and disposal of animal waste. Slaughterhouses produce large quantities of solid waste such as rumens, darn, animal fats, bones, hooves, horn, meat scrap, animal dung and other kind of solid waste. These quantities of waste pose health and environmental hazards to the communities located near the slaughterhouses; largely affecting agricultural land. Unfortunately, majority of slaughterhouses in Ghana dispose of highly polluted wastewater and organic residues into the sewerage system and landfill without prior treatment resulting in environmental and ecological problems; and clogging wastewater drainage systems. One major environmental and health concern in most slaughterhouses in Ghana is the burning of rubber tyres for singeing the fur of the animals. However, by using biogas technology as an environmentally friendly alternative to generate energy from the organic component of the waste, we could also help discourage the use of car tyres which is considered unhealthy for meat consumers. Slaughtering of animals in various abattoirs is done daily in Ghana, indicating the consistent availability of biomass resource throughout the year with peaks on holidays.

Interestingly, slaughterhouse effluent has high Chemical Oxygen Demand (COD), high Biological Oxygen Demand (BOD) and high moisture content, which makes it well-suited to anaerobic

[79]https://energypedia.info/images/2/24/Biogas_in_Ghana_Sector_-_Analysis_of_Potential_and_Framework_Conditions_2014.pdf

[80] http://agricinghana.com/wp-content/uploads/2017/07/AGRICULTURE-IN-GHANA-Facts-and-Figures-2015.pdf

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digestion process. Slaughterhouse wastewater also contains high concentrations of suspended organic solids including pieces of fat, grease, hair, feathers, manure, grit, and undigested feed which will contribute to the slowing of the process of biodegrading organic matter. The biogas potential of slaughterhouse waste is higher than animal manure and reported to be in the range of 120–160 m^3 biogas per ton of wastes.

Table 26: Energy potential from biogas at abattoirs in Kumasi and Accra[81]

City	Type of live-stock	Average/month	Content per animal		Electric capacity (kW)
			Paunch (kg)	Blood (kg)	
Kumasi	Cattle	7,000	12	15.8	33
	Sheep	1,600	1.6	2.1	1
	Goat	1,900	1.6	2.1	1.2
	Pig	475	4.4	5.8	0.8
Accra	Cattle	1,900	12	15.8	8.8
	Sheep	275	2.1	2.1	0.2
	Goat	475	1.6	2.1	0.3

4.4.4 Municipal Solid and Liquid Waste

Solid waste management remains a major challenge for government and local authorities in Ghana, especially in the peri-urban and urban areas. The population of Ghana is currently estimated at about 30 million with a growth rate of about 2.5% p.a. (NPC, 2016). Each person is estimated to generate about 0.47 kg of solid waste daily. This translates to more than 12,000 tons daily of household solid waste generated in Ghana. Currently, apart from Kumasi, Tamale, and Takoradi, which have engineered landfill sites in place, the remaining towns, and cities, including the capital city Accra, do not have engineered landfills. As a result, more than 80% of the generated waste is either dumped in open fields or drains. Only about 10% (1200 tons/day) is collected and dumped. The remaining 10% is burnt or buried (Miezah, 2015). The uncollected waste and waste dumped in open fields and drains pose a huge environmental and health risk. Organic material forms the largest constituent of municipal solid waste streams in Ghana with household waste stream consisting of about 60-70% organic component. In rural areas, the percentage of the organic component increases to about 77-80%. Another major challenge confronting government and local authorities is the indiscriminate discharge of raw faecal and sewage sludge into oceans and landfills despite the advancement of anaerobic technology for the treatment of organic waste to generate energy. As shown in Table 27, there is huge potential for energy generation from municipal and solid waste generated in Ghana via anaerobic generation. However, most of the biogas plants installed in Ghana are usually for household which are used to produce cooking fuel or to power domestic lighting with few large-scale digesters installed by multinational companies operating in the food processing industry.

[81] https://energypedia.info/images/2/24/Biogas_in_Ghana_Sector_-_Analysis_of_Potential_and_Framework_Conditions_2014.pdf

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Table 27: Solid and liquid waste from various Metropolitan and Municipal capitals

Regional Capitals	Solid Waste/month (tons)	Liquid Waste per month (m^3)
Kumasi	45,000	6,500
Tema	41,600	3,281
Cape Coast	3,195	341
Accra	60,000	24,000
Sekondi-Takoradi	4,792	1,638
Sunyani	3,600	165
Wa	2,636	117
Koforidua	4,500	690
Bolgatanga	2,819	880
Ho	850	3,236
Tamale	5,600	5,504

4.4.5 Human Resource

Due to lack of legislative framework in the biogas sector in Ghana, there is no specific standard developed curriculum for training biogas practitioners in the country. However, there are several public and private institutions that carry out periodic training for practitioners, mainly brick layers. The lack of coordinated and formalized training has resulted in several unqualified experts who referred themselves as experts of biogas digester installers. Currently, the executives of the Biogas Association of Ghana (BAG) has been instructed by the Environmental Protection Agency (EPA) with funding from GIZ-Ghana to develop a standard curriculum for training of personnel in the value chain of the biogas sector. Many biogas projects have failed because of the lack of technical skills to operate and maintain the systems. This has been identified as the major obstacle to the development of the technology in Ghana.

Currently there are few training centres in the country mainly located in the two major cities in the country, Accra, and Kumasi. Unfortunately, most of these training centres are mainly focused on solar PV systems design, installation, and maintenance. However, the Institute of Industrial Research of the Council of Scientific and Industrial Research (CSIR) (public/research institution) and The Energy Centre (academic institution) have been involved in training of experts in biogas installation and maintenance in the past years.

4.4.6 Infrastructure and Support Industry

The supply of materials to construction sites depends to a large extent on the availability of infrastructure like roads and electricity. Manufactures of industrial biogas systems depend on power. Other technologies like domestic biogas plants may not require the availability of power but rather good roads to convey materials to site. The unavailability of good access roads to communities outside the urban centres thus has a negative effect on the manufacturing and dissemination of biogas technology. Additionally, the unavailability of spare parts like biogas storage system and other materials on the market are major impediment to mass production. The lack of supply of materials also affects the inability of biogas service producers to carry out periodic maintenance of biogas facilities which significantly affects the confidence end users have in the system.

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Conclusion

The passing into law of the Renewable Energy Act 832 in 2011 with the goal to scale-up Ghana's renewable energy capacity indicates the government of Ghana´s policy commitment towards renewable energy to support its development and deployment. In addition, some key regulatory and policy instruments including the Scaling-Up Renewable Energy Program (SREP) Investment Plan, Strategic National Energy Plan, and Renewable Energy Master Plan have also been established to facilitate the implementation of the Law. However, actual investments in the renewable energy sub-sector particularly in the biogas sector have been limited. Solar PV technology has seen some investment over the years with no specific investment earmarked in the bioenergy sector. Both private sector and government see biogas technology as a solution to waste management problems in the country rather than as an energy generation facility. Despite the abundance of biomass resources for biogas generation, most of the resources are either yet to be exploited or are not fully exploited. The analysis presented here identified food processing, municipal solid and liquid waste as well as brewery processing waste as the major feedstocks for DiBiCoo demo case projects in Ghana. The report presents a strong case for municipal solid and liquid waste in spite of the feedstock collection problem posed by this feedstock. The major impediment to the successful implementation of DiBiCoo lies on the project target of 1MW electricity generation capacity facility. Most of the potential companies/organizations approached and engaged during the compilation of this report were skeptical of the 1MW target due to unreliable availability of feedstock. Nonetheless, the good news is that there is a huge opportunity for large scale digester installers as the market is still untapped. The report further revealed less competition for large scale biogas installer companies as most of the local installers mainly focus on small scale/household digesters. Furthermore, the local companies may lack the capacity to operate in the commercial biogas installation sector.

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5 Republic of Indonesia

5.1 PESTLE or Macro Analysis

Introduction

In Indonesia, there is a total of 1,779 palm oil companies (Statistics Indonesia, 2017, p. ix) that deals with either planting or processing. 608 of those are designated Palm Oil Mills (POMs); 38 of which are equipped with methane-capture facilities (Winrock International, 2015b), and the remaining 569 are still operating a series of open lagoon. 10 of these POMs have Palm Oil Mill Effluent (POME)-to-electricity projects (Moriarty et. al., 2013, p. xiii) and only one is connected to the national power grid (MCA-Indonesia, 2014, p.2).

POME-based biogas industry faces political, economic, social, technological, and environmental challenges. The related issues are broad, cross-sectoral, and involving a wide array of actors. Given the particularities of Indonesian renewable policies and strategies, identifying stakeholders is required to correctly mitigate risks (Yudha & Tjahjono, 2019).

5.1.1 Political aspects

1. National targets and strategies

The development of biogas technology in Indonesia is inextricably tied to the nation's aspirations towards energy security. The revised National Energy Policy (*Kebijakan Energi Nasional* – "KEN"), signed through Government Regulation 79/2014, is a policy revolving energy mix diversification, independence, and a push towards renewable energy (RE) sources including biogas.

Another policy also exists as renewable energy target in Indonesia. The General Electric Generation Plan (*Rencana Umum Pembangkitan Tenaga Listrik*/RUPTL), promulgated in 2019, is essentially a business plan of the State Electricity Company (*Perusahaan Listrik Negara*/PLN). However, since they are the sole distributor of power in Indonesia, this plan can also serve as indicator of governmental interest in the sector in a moderate-to-long term. RUPTL also indicates the extent of guaranteed support PLN will give to RE development, as it shows their allotted budget and capacity to RE generation as shown in Figure 24.

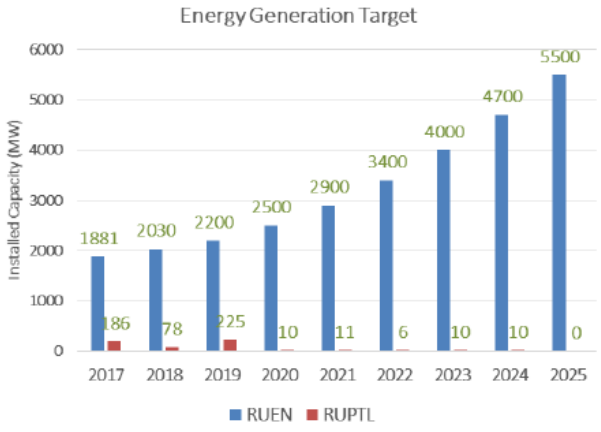

Figure 24: Energy generation target from 2017-2025, as written in the latest RUPTL (2019).

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2. Fossil Fuel Dominance

Indonesia's purported enthusiasm for the broader promotion of renewables in its recent energy policies falls flat through its lack of a clear strategy and implementation. The Indonesian government continues to contradict its clean energy goals with heavy investments towards new coal-fired power plants development. The attraction to coal usage within Indonesia lies in its reliability, low price, as well as its central role in the country's revenue stream to counterbalance oil and gas deficits (Arinaldo and Adiatma, 2019). Fossil fuels have historically been, and continue to be, a major player in Indonesia's energy sector.

3. Lack of Prioritization on Biogas and POME

Within the renewable sector, the Indonesian government has largely prioritized biofuel over biogas in its broader bioenergy strategy. Although Indonesia has achieved its 2018 bioenergy investment targets, this has little implication for the biogas industry and for POME-based biogas, as a significant portion of this figure is for biodiesel development (DITJEN EBTKE, 2019: p. 38). The long-term trends for general bioenergy are also concerning. Despite ramping up investments in general renewables, the 2018 bioenergy investment target is a drastic drop from 2017's $0.749 to $0.073 (in billion USD) (DITJEN EBTKE, 2019). Based on previous bioenergy trends, it would be safe to assume this would manifest as a decreased focus in biogas in lieu of biofuel development.

In terms of energy production and supply capacity, biogas makes up an alarmingly small amount of the potential domestic energy supply source (DITJEN EBTKE, 2019, p.39). Of this small figure, there have been further difficulties in increasing biogas energy supplies, as indicated by the DITJEN EBTKE 2018 Performance Report. There are also concerns regarding a sudden absence of POME-based biogas information, compared to previous reports between 2013-2017. This is concerning for two reasons. First, it reflects a larger trend of irregularity in government data and reports. It also signals a false shift of interest – private actors who read these reports will likely assume POME usage is no longer relevant for national government policies, incentivizing transition to cheaper non-biogas bioenergy. Proper planning and execution of risk management is important to RE development, since the sector is still relatively young. Financiers are wary of the monetary risks, Engineering-Procurement-Construction firms (EPCs) are still dependent on policy stability, and benefits for site owners are largely passive.

4. Governance

The project risks arising from the intersection of political, economic, institutional, and social characteristics should be taken into account when considering new biogas projects. Research by Aipassa, Kristiningrum and Tarukan (2018) on the potential of POME-to-energy programs in East Kalimantan demonstrates the need for intricate, multi-stakeholder cooperation in mitigating risks for new projects.

These projects span multiple levels of government, ranging from regency, provincial government, and district governments. This complex decentralization is further complicated by the additional need to coordinate with the private sector, such as the palm oil mills supplying feedstock, as well as other financing bodies supporting the program. The lack of administrative body for biogas development in Indonesia poses an issue for both Indonesia's aspirations towards energy security and disparity reduction. The Indonesian government lacks proactiveness in establishing, implementing, or promoting biogas projects in a tangible form. The current

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form of leadership provided by the government is hindered by overlapping priorities and jurisdictions, which slows the decision-making process.

Large-scale palm oil plantations have been incentivized to introduce POME-to-energy projects out of corporate social responsibility, ethical or public relations purposes instead of through government initiation (Winrock International 2015; Budiman 2019). However, this is not feasible for smallholder plantations, who may be more restricted in terms of capital and are deterred by higher risk factors and could benefit more from stricter biogas governance. Problems of governance are inextricably tied to previous issues of coal dominance and lack of focus on biogas, further made complicated by the lack of regulatory and administrative support by those who have the most influence (IISD 2018). Government decentralization also seeps into the problem of regulatory uncertainty, where the private sector is demoralized due to a lack of transparency on government support (Taylor et al, 2019).

5.1.2 Economic Aspects

1. Feed-in Tariffs

Feed-in tariffs (FITs) is the major policy support scheme for biogas development in Indonesia. They guarantee a fixed purchase price of renewable generation from power producers and aims to cover the costs of RE development, while providing reasonable rates of return to investors and reduce investor risks from RE projects financing (Bohringer et al 2012). The application of the feed-in-tariff scheme is commonplace for governments seeking to implement RE. In Southeast Asia alone, a majority of the developing countries already have applied FITs, as seen in Table 28. Indonesia is a bit late in joining in, only having FITs implemented after the creation of the General Energy Plan (RUEN) in 2017. The rates in which FITs are implemented in Indonesia are also biased towards the government's rates for fossil electricity generation – unlike other countries who provide greater FITs to encourage RE transition. To some extent this is also evident in Vietnam, but their recent achievements in RE generation prove that lower FITs do not always translate to underdevelopment.

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Table 28: (Solar) FIT implementation in major South East Asian countries (IRENA, 2018).[82]

FiT (USD cents/kWh)							
	Thailand[a]		Philippines[b]	Malaysia**[c]		Indonesia***[d]	Viet Nam
2012			23.11/kWh with 0.6% degression yearly after the first year	4–72 kW	39–40		
				72 kW–1 MW	37.6		
				1–10 MW	31		
				10–30 MW	28		
2013	Rooftop 0–10 kW	21.5	No change	4–72 kW	30–36		
	Rooftop 10–250 kW	20.2		72 kW–1 MW	32		
	Rooftop 250 kW–1 MW	19		1–10 MW	24.3		
	Solar farm > 1 MW	21*		10–30 MW	21.8		
2014	No change		19.58/kWh with 0.6% degression yearly after the first year	4–72 kW	22.9–31.5		
				72 kW–1 MW	22.1		
				1–10 MW	18.4		
				10–30 MW	16.5		
2015	Rooftop 0–10 kW	19	19.08/kWh	<4 kW	25.67		
	Rooftop 10–250 kW	17.78		4–72 kW	21.42–25.04		
	Rooftop 250 kW–1 MW	16.69					
	Solar farm > 1 MW	15.73					
2016				<4 kW	19.92	14.5–25	
				4–72 kW	14.83–19.44		
2017				<4 kW	17.22		9.35 (solar rooftop)
				4–72 kW	12.1–16.8		

There are two key actors associated with the current FIT program. The Indonesian government, through the state-owned enterprise State Electricity Company (PLN), is the major player in determining investments by independent power producers (IPPs). PLN regulates all current tariff regimes. Each tariff is benchmarked against PLN's average electricity generation. If local Levelized Cost of Energy (LCOE) is higher than national rates, PLN will only pay a certain percentage of it (never 100% FIT). If local LCOE is lower than national rates, the developer has rights to negotiate with PLN (>100% FIT is possible but very unlikely). This showcases a preferential treatment to existing generation systems.

Tariffs and pricing are sensitive issues within the Indonesian renewables and biogas regulatory framework. Although it purports greater flexibility and higher incentives for the development of Indonesia's outer provinces, the governmental level regulation (No 50/2017) has been heavily criticized for its non-investor friendly design and selective prioritisation of governmental pro-

[82] Full document can be accessed in: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_Market_Southeast_Asia_2018.pdf

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jects. Through this regulation, PLN has power over tariff negotiations through their direct selection mechanism, providing an incentive to sign PPAs suitable with PLN's mandates, while excluding those that have failed to do so.

Once selected, IPP projects are obligated to complete construction of the power plants in accordance with the PPA, where sanctions and penalties are imposed on those that fail to finish projects (PWC 2018a). Investors have criticized these low power purchase prices, claiming high risk implications and a "roadblock" that keeps developers from recovering investment and generating reasonable profit from projects (IISD, 2018).

2. Investment Types

Investments for biogas development can be sourced from both public and private sector. Public funding are commonly grants derived from the national budget. Private funding is provided from a wide range of non-government; we will mainly focus on commercial bank loans.

That aside, a lot of investment is needed to achieve the government's target of 5.5 GW renewable energy by 2025 (stipulated in RUEN, promulgated in 2017), as shown in Figure 25.[83] Around 13.5 Billion USD to be exact – and this is 2017 rates. That capital is to be distributed across 1.300 projects with a 2MW to 7.5MW generation scale.

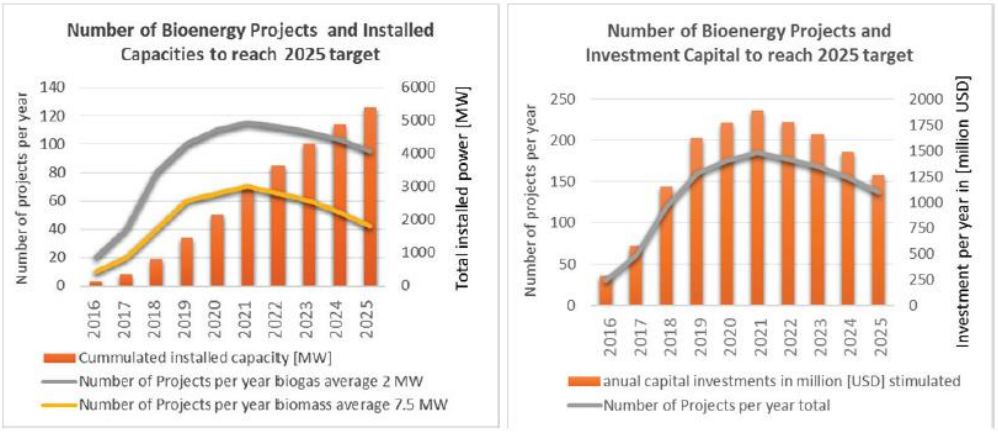

Figure 25: Estimation of investments required to achieve 2025 targets.

In addition to the Indonesia's FIT mechanism, biogas development is also, to a smaller extent, supported by other government-mandated mechanisms and incentives. This support scheme varies from a national, regional, and local level. However, implementation and execution are concentrated in the regional and local levels. These come in the form of disparity reduction programs (national targets on achieving 100% electrification to reduce energy supply disparity) and are supported by direct government subsidies. Non-governmental organisations, however, have panned the fully subsidized approach to biogas development by the Indonesian government as it contradicts the market-based sector development approach utilized by various international donor agencies (Greenpeace, 2019; IESR, 2018)

A. Commercial Banks

[83] The General Plan of National Energy can be accessed in: https://www.esdm.go.id/assets/media/content/content-rencana-umum-energi-nasional-ruen.pdf. (In Bahasa).

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The significance of banks within the Indonesian financial system should not be understated. Although Indonesia's financial market is small, with its financial sector assets representing 72% of the country's GDP, banks hold approximately three quarters of all financial sector assets (IMF 2017; ADB 2018). However, the financial sector's lack of experience with renewable energy led to risk averseness that impacts financing costs, capital availability and project viability (CPI 2018). There is also the issue of equity and debt balance. Biogas projects are costly in the earlier stages. Neither project owners nor EPCs are able (or willing) to set aside a large amount of asset as equity, but investors cannot be expected to just cover it all with debt.

Table 29: Commercial finances that are available in Indonesia. 2nd and 3rd are most common (GIZ LCORE-INDO and MEMR, 2017).

Investor	Project Phase	Duration	Return Expectation	Investment Size (Million USD)
Private Equity Fund [5]	Development Construction Operation	Short – medium	More than 20%	Minimum 100
Infrastructure Fund	Operation	Long	10 – 20%	50-100
Industrial Investors	Construction Operation	Short - long	15 – 20%	1 - 100

The novelty of biogas, let alone POME-to-energy project, further complicates financing schemes as lenders lack information from past projects, affecting their confidence in assessing future ones, leading to a conservative stance. This unfamiliarity with RE has resulted in the rarity of project finance implementation by local banks (CPI, 2018). Biogas programs ended up having to deal with equity or corporate financing (essentially 2nd option in Table 29 above).

As briefly summarised in Table 29, infrastructure funding done via corporate structure does not have favorable terms and rates for renewable energy development. It is created to finance well-established infrastructures (like roads) which already have a set development pattern and minimal, spread risks. RE development, in contrary, needs a lot of support even in earlier stages and significantly larger capital upfront. The latter is currently unsolvable, since the central financial authority has yet to legalize loan structures that allow large upfront investments. Blending financial sources is essentially required.

As an alternative, biogas programs have relied on international philanthropic donor-funded programs (Winrock International, 2015; IESR, 2019; APEC, 2017). This alternative is not without caveats. Donor program funding period are often limited to the length specified in a proposal, rendering post-project operations unpaid for. Combined for the philanthropic nature of donors, business viability is rarely in the equation in such funding schemes.

5.1.3 Technological Aspects

Anaerobic digesters (AD) are now being used as primary treatment for POME at Indonesia Palm Oil Mills (POMs) because aeration processes don´t need to be accommodated here, hence reducing cost and technical complexity effectively. Biogas from anaerobic processes, irrespective of the involved technology, can be utilized for other purposes such as producing

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electricity. This process will also produce sludge that can be reprocessed as fertilizer for agricultural applications (Abdurahman, et. al., 2013).

A. Covered Lagoon

Covered Lagoon is mostly used by Palm Oil Mill to treat POME in Indonesia (Eastern Research Group, Inc. and Winrock International, 2015). Covered lagoon is an improved version from the open lagoon method, covering a waste reservoir with floating plastic membranes. The operational simplicity and low investment cost of covered lagoons support and enable more installations of the covered lagoon compared to other AD technologies in POME treatment in Indonesia (Rajani A., et. al., 2019). However, the covered lagoon infrastructure requires large physical space and will still leave a sizable carbon footprint.

B. Continuous Stirred Tank Reactor (CSTR)

According to Eastern Research Group, Inc. and Winrock International (2015), there are only three POMs using the tank system to treat POME in Indonesia. A continuous stirred tank reactor (CSTR) is similar to a cylindrical closed tank reactor but it uses an agitator to increase contact between biomass and waste. Due to the agitation, CSTR can produce more biogas than closed tank. This reactor should be operated at steady state with continuous feed flow. There are several assumptions used in CSTR such as uniform composition throughout the reactor and uniform composition between exit stream and in the reactor.

5.1.4 Environmental Aspects

The Government of Indonesia has implemented the Program for Pollution Control, Evaluation, and Rating (PROPER) to promote “clean technology” back in 1995. PROPER is a national-level public environmental initiative created under the umbrella of the Environmental Impact Control Council (*Badan Pengendalian Dampak Lingkungan* - BAPEDAL). PROPER was created due to the BAPEDAL’s limited capacity to monitor the pollution caused by business expansions in the agricultural sector.

This mechanism helps enforce the industry to adopt “clean technology” practices by rating each company’s performance based on the regulatory standard. The rating of PROPER ranges from gold as the highest category to black as the lowest. Actual implementation, however, is rather lacking at this stage.

Sanctions exist for those who violate regulations related to PROPER; varying from administrative sanctions (written reprimand, revocation of operational permit, etc.) to punishment in jail as short as a year up to 15 years, as covered in Indonesian Law (UU) *Perlindungan dan Pengelolaan Lingkungan Hidup*, 2009. Perpetrators would also be fined 500 million IDR up to 15 billion IDR, depending on the severity of the case.

5.2 Market Characterization and Definition

Biogas project development in Indonesia will is best focused on turning palm oil effluent (POME) into electricity. This is the case due to several reasons: the palm industry is the only sector with the ability to produce constant feedstock, with regional localization that ease logistics, and with a clear track record of waste-to-energy practices. All these factors contribute to a decent potential for the palm oil sector to become a dependable power supplier.

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Commercial power purchase in Indonesia is only done at the national level, as mandated by law. Therefore, market assessment in this report will be conducted on the nationwide 'electricity market'.

5.2.1 Electricity Market Form

The Indonesian electricity market, like many developing nations, is state-controlled. The state-owned utility solely controls the national power distribution and is enabled by several laws to also control the generation side through the Build, Own, Operate, Transfer (BOOT) scheme. The State Electricity Company (PLN) operations are divided into regional branches – each with their own territorial reach but still compliant to the Central PLN. Non-governmental entities can also enter the power generation business, but on-grid supply will ultimately be done through the PLN infrastructure.

This topology divides the larger Indonesian market into multiple regional segments. The Java-Bali region of PLN is the largest power producer and consumer across the national grid, region also highly concentrated with power stations (several reaching Gigawatt-level capacity) and industrial facilities (especially in East Java).

The existence of PLN creates a balance between power producers and the general power consumers by supporting national-level management. However, this condition has resulted to difficult non-governmental development of renewable energy, especially in the upstream market. PLN, a state-owned enterprise benefits from governmental leverage through national regulations and bureaucratic structure enables and supports PLN operations (subsidies, project development process, electricity sale rates, etc.).

Indonesia's industrial scale of biogas generation market is very concentrated and developed due to stable supply of feedstock. For POME-based biogas, this means close proximity of biogas installation locations to palm plantations. By far, POME-based biogas installations are very prevalent in Sumatera and Kalimantan well-known regional hubs of Palm Oil Cultivation and Processing. Essentially, every province in these islands hosts large-scale biogas facilities. However, it is also important to note that majority of these facilities operate solely to support internal primary needs without having to sell excess power to PLN's national grid. Biogas technology owners end up using the electricity to fill gaps in their power deficit.

The financial and administrative labour intensive process deters biogas owners in exploring opportunities to sell excess power to PLN's national grid. In addition, Indonesian Palm Oil Association claims that palm mills only use 0.5 to 0.7 MW from biogas and therefore there is really no incentive to invest in biogas tech larger than 1MW. At least, until PLN decides to adjust the requirement for power purchase agreements.

5.2.2 Electricity Market Size

PLN is guided by governmental policy targets in planning the infrastructural and capacity development/expansions. This approach is useful in maintaining market equilibrium, maintaining energy demand forecasts and preventing excessive energy supply—this can be seen in how Indonesia's energy reserve is higher than average load, but not to the point of development being wasteful.

As we can see in the illustration in Figure 26, net capacity is consistently higher than peak load across all the regions shown below:

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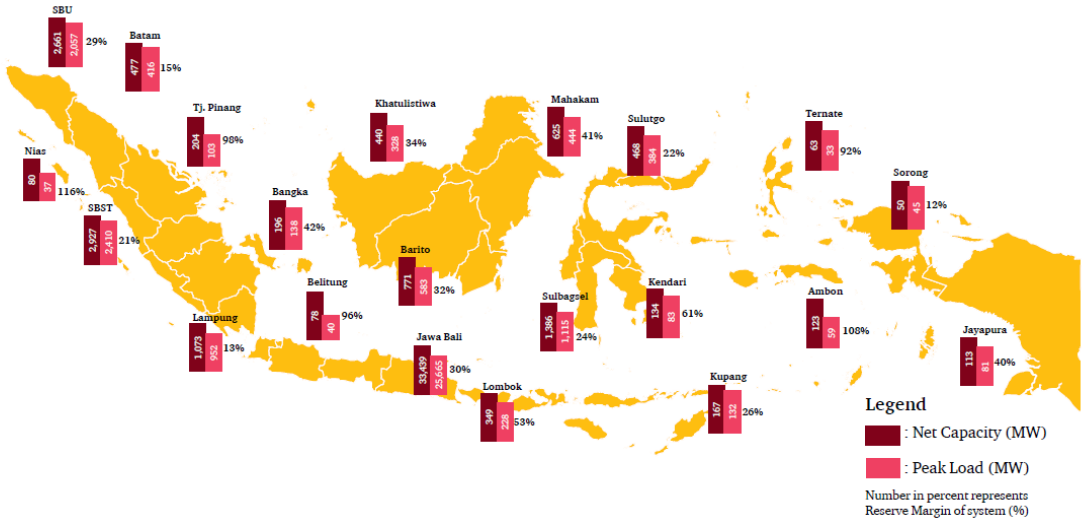

Figure 26: Governmental Targets for Electricity Expansion (Pricewaterhouse Cooper, 2018)

All regions within Indonesia have no shortage of power—if calculated by demand. Although not every regional demand is representative of its populace. If we attempt to compare regions purely on the basis of demand and observe the 25 GW demand of Java-Bali, other regions become relatively insignificant in terms of energy demand. In reality, many regions outside Java-Bali still need additional power. Unfortunately, the national grid (and by extension, PLN operations) cannot reach regions. Therefore, the lack of access to the national grid has birth off-grid power producers' market.

Biogas is rarely considered as a feasible power source in Indonesia and no demand can be directly traced to it. This negatively affects the size of biogas as a 'commodity'. The Ministry of Energy can only trace household usage of biogas, which is around 167 Barrels of Oil Equivalent (BOE) in the entirety of 2018 (MEMR, 2017). This is somewhat inconsistent with the PLN 2018 General Electricity Plan that listed around 39.4 MW worth of active biogas plants across Sumatra and Kalimantan excluding t biogas plants that are currently under construction.

In a more detailed rendition of the General Electricity Supply Plan (RUEN), PLN declared that Indonesia has an overall biogas potential of 94.2 MW (out of the total renewable energy goal of 2.1GW). This data was quite unclear, as the 2.1 GW goal was written as a 'national' projection which includes both industrial and household implementation. Therefore, this amount might not be representative for the actual growth.

We assume this means biogas demand is very exclusive, i.e. only considered by stakeholders that are related to the feedstock. Even then, the way Indonesian government perceives bioenergy favors biomass and biofuel implementation more than biogas.

Biogas is barely utilized for electricity generation in Indonesia. The government prefers other renewable sources such as hydro and geothermal. Biogas utilization ended up being focused to gaseous forms of energy, such as combustible for households or methane upgrading for industries. Even for bioenergy in general, POME and biogas usage as a source is rarely considered as the government prefers using solid palm hulls or straight up Municipal Solid Waste (MSW) via Biomass processes. Recent policy even shifts palm waste usage (both POME and the solid hulls) to Biofuel synthesizing for the national B30 initiative—a policy that intends to gradually replace conventional diesel fuel to biodiesel, with the national oil & gas company

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(Pertamina) serving as guaranteed buyer. Such measures further reduce the benefits of attempting a Biogas development project.

The private sector, especially owners of palm plantations, perceive the value of Biogas technology differently. Most of them utilize Anaerobic Digestion technology to provide electricity for internal use. By doing this, they can save operational costs while improving waste management (which further grants them certain environmental certifications) practice at the same time.

5.2.3 Electricity Market Growth

Stabilisation of demand can already be felt in several regions, especially those with higher count of electrification/had access to power early on. Java-Bali, Sumatera, and Kalimantan demands are stabilising. PLN acknowledged that the largest sum of electricity demand comes from annual household connections (PLN, 2018). Demand growth gets slower every year since electrification is indeed getting better, despite questions around '99% electrification rate' declared by the government.

Note that the Indonesian market is just stabilizing, i.e. it will no longer benefit from the large influx of new customers. Both PLN and private sectors believe that the uptrend will persist due to the developing nature of domestic economy. Energy demand increases with the growing industrial and financial sector.

If we follow PLN's methodology and take 2018's national economic growth rate and assume the same condition will persist for the following years, we can see (see Figure 27) that power demand will still rise despite the aforementioned stagnating household demand. Existing capacity will not be able to accommodate the growth rate.

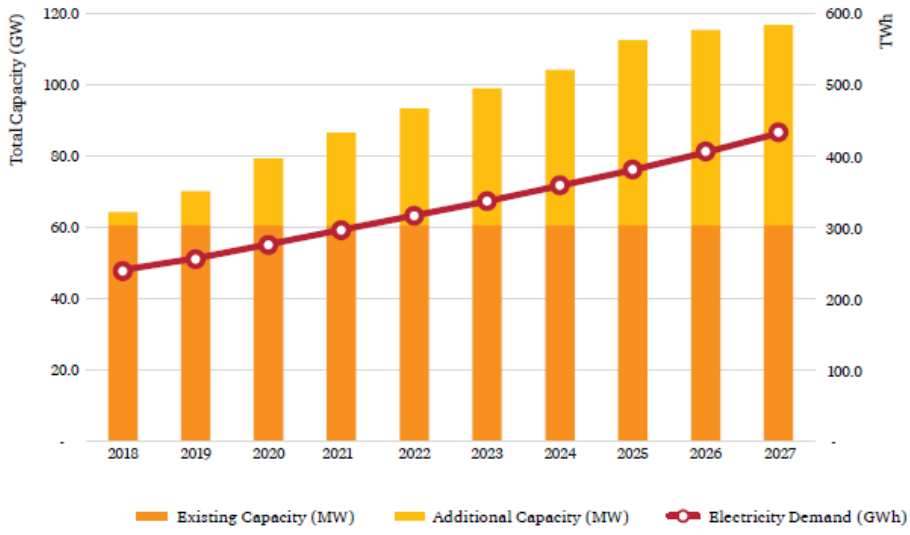

Figure 27: Electricity Demand (2018-2027) (Pricewaterhouse Cooper, 2018)

Demand will only surpass current generation capacity at around 2021-2022. Table 30 shows the development targets of the generation capacity of power plants.

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Table 30: Generation Capacity of Power Plants (PLT) (PLN, 2018)

No	Pembangkit - EBT	Kapasitas	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Jumlah
1	PLTP	MW	190	151	147	455	245	415	2,759	45	145	55	4,607
2	PLTA	MW	154	326	755	-	182	1,484	3,047	129	466	1,467	8,009
3	PLTM	MW	140	238	479	200	168	232	27	20	20	10	1,534
4	PLT Surya	MWp	63	78	219	129	160	4	250	-	2	2	908
5	PLT Bayu	MW	-	-	30	360	260	50	150	-	-	5	855
6	PLT Biomass/ Sampah	MW	12	139	60	357	50	103	19	5	15	35	794
7	PLT Kelautan	MW	-	-	7	-	-	-	-	-	-	-	7
8	PLT Bio-Fuel	Ribu Kilo Liter	520	487	291	167	151	146	154	159	166	175	2,415
Jumlah		**MW**	**560**	**933**	**1,697**	**1,501**	**1,065**	**2,287**	**6,251**	**199**	**648**	**1,574**	**16,714**

We can see that PLN is considering these estimates and is planning a massive expansion in 2021, to secure a total of 1,607MW additional supply in preparation of the projected demand increase. In addition, it must be highlighted that biogas is not explicitly mentioned in the table – but the biofuel target may serve as an entry point.

5.2.4 Electricity Market Share

In 2018, electricity became quite a large energy use in Indonesia. Indonesia consumed 156.95 Million BOE of its energy supply as electricity (industry, commerce, and household combined), making up 18.07% of the total energy consumption (National Energy Council of Indonesia, 2018).[84] This number is only surpassed by fuel use, which made up 38.79%.

The commonly discussed renewable energy target is 23%. The current administration hopes for renewable energy to contribute that amount to the national energy mix by 2025 – which would be around 560MW. This represents renewable energy's expected share in a larger energy market. Which is unrealistic when we consider the very minimal amount of renewable energy contribution was 4-5% in 2017. In the document (RUPTL 2018-2027)[85] itself biogas is only expected to contribute 5MW energy output (MEMR, 2018). That can also be understood as less than 1% of total renewable energy generation by 2025, likely because the government only expected heat energy out of Biogas.

[84] Full report by the National Energy Council of Indonesia: "2018 Energy Outlook for Indonesia" can be accessed in: https://www.esdm.go.id/assets/media/content/content-outlook-energi-indonesia-2018-bahasa-indonesia.pdf (In Bahasa)

[85] The full RUPTL document can be accessed in: https://web.pln.co.id/statics/uploads/2018/04/RUPTL-PLN-2018-2027.pdf (in Bahasa)

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Jenis Pembangkit	Kapasitas
PLTA	154
PLTBg	5
PLTBm	5
PLTM	140
PLTP	190
PLTS	58
PLTS/H	6
PLTSa	2
Total	560

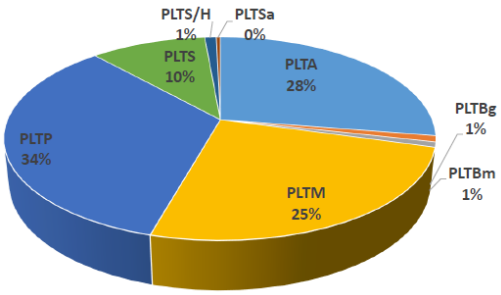

Figure 28: Detailed breakdown of Indonesia's 2025 renewable targets. (PLN, 2018).

National supply wise, the majority of electricity is generated by PLN (~74%) while the rest is generated by IPPs (~22%) and off-grid producers.

The BOOT scheme might contribute further to increasing PLN's numbers. IPP developers in contract with PLN were once obliged to hand over all assets after around 10 years of operations. IPP numbers were essentially transitional. This is changed in the latest iteration of the energy law (Energy and Mineral Resources Ministerial Law 4/2020 Article 27B), where IPPs are no longer required to hand over all infrastructure assets. But changes were so recent that no projects are made under these favorable terms yet.

Currently, the government is mainly focused on short term objectives such as improving electricity supply to the productive sector (i.e. industrial and financial sector), transitioning to renewable energy sources and solving waste issues. Therefore, we can infer that technological advancement and sustainability of business would not immediately be considered.

For example, this can be seen in one of the larger renewable energy initiatives of the current administration, where MSW-based bioenergy is to be developed in 12 major cities in Indonesia. The technology promoted is thermal biomass, which means burning via incinerator. The initiative also has a significant energy potential, but the primary goal is waste management. If this trend is to persist, bioenergy (and biogas alongside it) would stay a minimal contributor to the overall energy share.

5.3 Customers and Clients

There are 2 types of stakeholders that can be understood as customers. The definition will be based on our previous stakeholder mapping categorization which includes the technical role, clientele, input/process/output, and external issues;

Palm oil companies (both plantation and mills due to interdependency between them)

- Their technical role in a larger supply chain is the periodic cultivation and initial processing of palm into oils of varying quality;
- Clients of Palm Oil Companies operating in other industrial sectors; either domestic or international;
- Input: land use granted by the government, capital sourced via financing is required to reform land to palm standard and manage climate risk and operational cost via income, seeds are not in constant supply, because a tree can be productive for around a decade.
  There is a notable side impact to a developing market economy via employment (but on the other side an analogue process will limit productivity).

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- Process in a mill starts by sterilization – which applies for all mills, and the point where POME is created. Fruit bunches can also be taken from this point for biomass energy. Another POME-creating stage is the extraction.
- Outputs are crude palm oil (CPO) or Palm Kernel Oil (PKO) plus derivatives; these markets are generally in uptrend due to a sustained demand of consumer goods – several of which using palm oil to manufacture. Another recent trend is biofuel, also for domestic and foreign market consumption (but is subject to different sustainability certifications). Palm outputs are essentially products sold in large amount i.e. a commodity; (price very elastic to demand, closely related to policy making). There's an ongoing issue about productivity due to the slow replanting cycle. Indonesia's weaker currency value also makes international trading difficult and somewhat seasonal.
- General issues of palm mill/plantation include: a high dependency on the international market for sales, a product / commodity value that is very susceptible to market fluctuations, and important components for expanding value chain are almost never available in domestic markets.

Engineering, Procurement, and Construction (EPC) firms that work in biogas projects:

- EPC technical role is the installation of various biogas infrastructure, ranging from digesters, gas engines and methane upgrading; They have a limited role in sourcing these technologies pre-project, and maintaining it after the construction project has finished.
- Clients of EPC firms are companies with a stable access to feedstock – either through own processes (palm companies) or waste collection (municipal landfill). Most Indonesian EPCs prefer engaging with one larger institution rather than several smaller ones, presumably to reduce operational and development risk;
- Input is mostly capital used for purchasing technology which can be sourced in several ways – own capital and repaid later, client's capital, or corporate financed by banks. This is dependent on the project structure and partners involved;
- Project development in Indonesia requires extensive coordination with related line ministries and the PLN. A project design relies heavily on ministries' and PLN approval, before proceeding to financing. There is also rigid tendering process for national projects. There is a limited number of projects approved within a period and contractors need to be pre-approved by the government. Thereafter, project developers are required to secure capital funding within a short period of time, before applying for construction approval;
- Output is generally turnkey projects, where the EPC source technology and installs it for the project owner to own (completely or partially) after completion/agreed date (the BOOT scheme practiced by PLN). Latest reviews of the law have removed this clause; Technically, AD processing yields gases that can be further used to provide CHP or upgraded to excrete methane component, while gasification (a derived process of bioenergy) is a way to produce syngas which has high industrial value and has a clear demand in Indonesia;
- General Issues for EPCs revolve around the difficulty in accessing the commercial money market, reactive governance (in policy and structure alike), difficulty in sourcing reliable inputs, unclear demand for biogas, and how RE implementation is rarely prioritized by the government and potential clients.

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As an attempt to mitigate the innate risks of palm companies and EPC profiles, we decided to set targets on state-owned enterprises. They represent a good balance between privatized business operations and governmental leverage. State enterprises are exempt from many bureaucratic processes a regular company would have to deal with. A three-year long development cycle can be reduced to one and a half by this status. They also have the benefit of subsidization, which theoretically allows them to take more business risks. State enterprises also synergize well with other state enterprises, which can benefit cross-sectoral biogas projects.

5.4 Competitive Analysis through the Porter's 5 Forces

In Indonesia, EPCs usually have an external supplier for technology while also being capable of planning a development project. The difference is that EPCs offer a wider range of services which usually include construction maintenance etc.

- Relevant because these EPCs indirectly provide all of the components – usually sourced from the US, Germany, or China. Service-wise these EPCs (ones picked as benchmark) compete on a national level – most have extensive project portfolio.
- Indonesian EPCs are required by law to piece together projects (indirect government role)

The competitive analysis included in this report will therefore be conducted from the perspective of POME-based Biogas EPCs. Implementation scale will be industrial due to project requirements, as household implementation will significantly limit target achievement and evaluation. Market scope will be national since many of the sample EPCs are based in Jakarta but targeting Sumatra and Kalimantan palm industries that normally focus on export.

Each force indicator will be analyzed, and later scored with these following specifications:

1. is absolute zero risk
2. is low risk with straightforward operational solution
3. is low risk which require strategic adjustment
4. is persisting low risk attributed to business model
5. is moderate risk with straightforward operational solution
6. is moderate risk which require strategic adjustment
7. is persisting moderate risk attributed to market responses
8. is high risk with straightforward operational solution
9. is high risk which require strategic adjustment
10. is high risk that is not solvable with available capital

5.4.1 Rivalry among Existing Competitors

- **Sectoral Growth** is not significant. It is negatively affected by 7-or-more years before actual returns. Profit margins from a project are not very different from other EPC jobs. One-time project owners rarely want to commit additional development.

  Scored 7. Even if not stagnating or negative, the long return period slows activity in the market.

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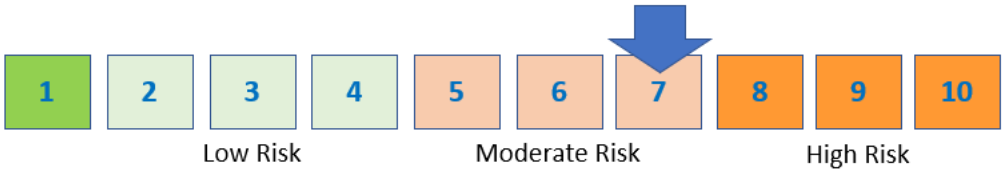

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- **Capital Costs** are high. During a bioenergy event conducted on 25 February 2020, one project owner stated that the total project cost can reach around 1 million in USD which is a lot for Indonesia. In a joint report with the Indonesian Financial Services Authority (2016), USAID also found that 30 to 40 % of that cost is incurred by Biogas technology such as digester, engines, auxiliary components. And that is only the fixed costs. Risks associated with developing biogas incur due to a lot of variable costs. Switching costs are a bit tricky, since customers are free to pick contractors before the project starts (essentially for free).

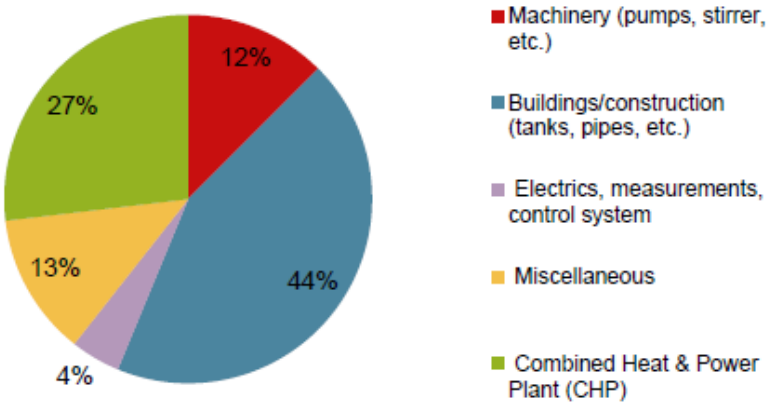
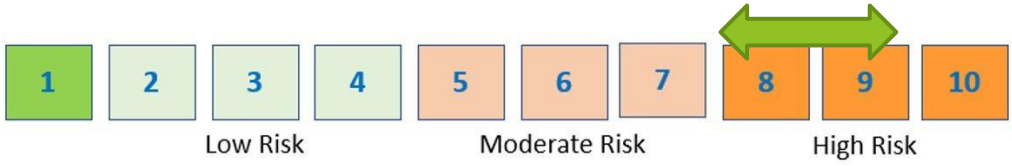


Figure 29: Detailed composition of investment in a biogas project.

Scored 8-9 depending on project. Starting a project costs a lot, and most of that cost cannot be adjusted because it is incurred by the technology. Unclear switching costs in between projects force competitors to be more active in engaging the market.



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5.4.2 Customers (Bargaining power of Buyers)

- **Effect on Industrial Processes** is limited for the time being. A vast majority of customers only utilize biogas for electricity generation – be it internal or to be bought by PLN. Benefits of biogas implementation tends to be a 'saving' than creating additional income, which is a lost opportunity for companies. But there is a side benefit for plantations who utilize biogas in the form of certifications, since a biogas process intersects on a lot of points with several environmental certifications e.g. Indonesian Sustainable

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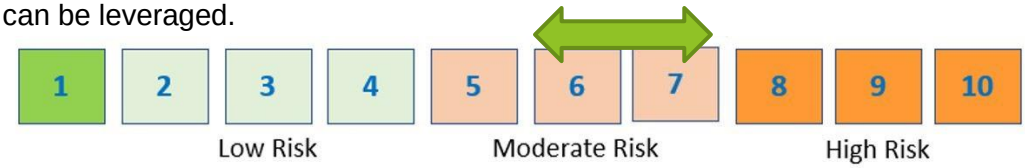
Palm Oil Certification System (ISPO) or Roundtable of Sustainable Palm Oil (RSPO). Owning these sustainability certificates opens additional markets for plantations – especially international.

Scored 6-7 depending on the buyer. The benefit of installing biogas into existing business is still limited. However, the role of biogas in achieving sustainable certifications can be leveraged.



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- **Buyer Costs** are numerous. In the project stage costs will be incurred by many things aside from the technology price – installation, logistics (customs included, almost every piece of critical technology is imported), land clearing, feasibility studies, etc. After everything is done the customer will still have to set aside some funds for maintenance and repair operations.

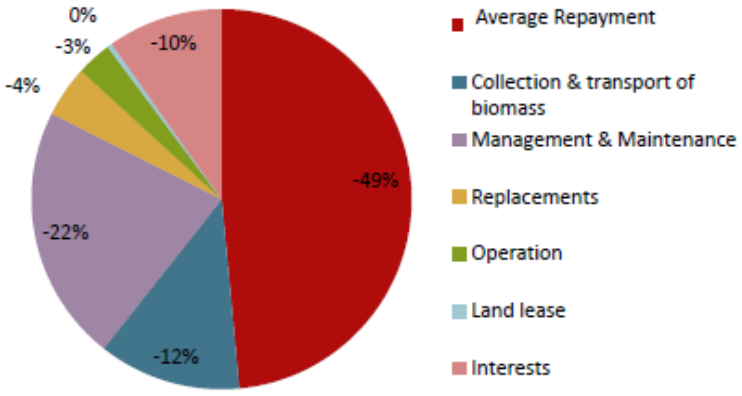
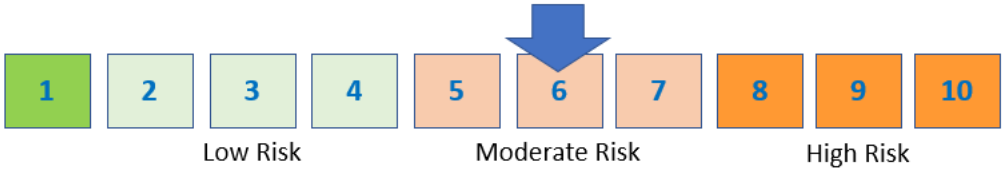


Figure 30: Costs incurred by operations. (USAID and OJK, 2016)

Scored 6. In a plantation context, a lot of additional costs will be involved in biogas development. Workaround is difficult since the law forbids POME to be moved out of the premises of a mill, and these palm mills are typically quite far from urban areas. Paying and arranging these additional services will be a hassle, but the effect to cost structure is actually not significant.



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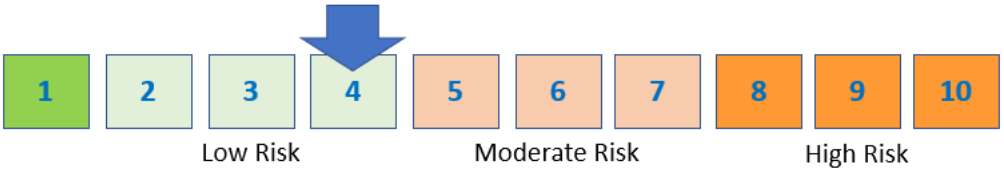
5.4.3 Suppliers (Bargaining Power of Suppliers)

To facilitate a comprehensive analysis, auxiliary component manufacturer or general exporting logistics will also be accounted as 'service provider'/supplier equivalent.

- **Substitutes** are only valid before a project starts. Once a project is initiated technology can rarely be replaced. But before projects substitute biogas technologies are provided by other EPCs (bundled with their own services) or by pure tech supplier/reseller.

  Scored 4. There are a number of EPCs in Indonesia that can supply a project with technology, so pre-project decisions can be made with a degree of flexibility. But it's kind of a choice illusion when we remember that the technology available in Indonesian EPCs are imported from foreign tech manufacturer anyways.



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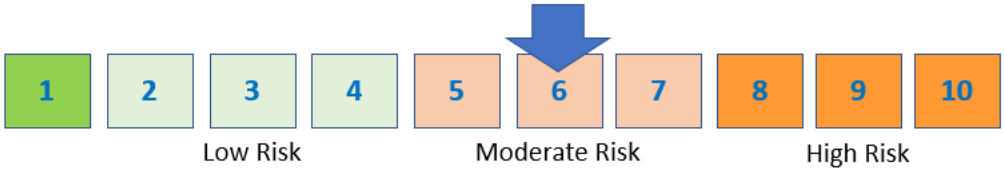
- **Supplier Concentration:** Concentrations of major international manufacturer (whose products are used in Indonesia) are all foreign – US, Europe, China. This will inevitably cause additional cost and time.

  Scored 6. Biogas technology is almost exclusively imported. This adds inevitable cost and time for EPCs or suppliers to stock up (or start a project). Trade routes are also prone to disputes, taxation, and exchange loss from dealing with a foreign currency. Fortunately, it appears that technology exporters also found value in the Indonesian market as no EPCs or suppliers have experienced a debilitating shortage of technology.



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5.4.4 Threat of New Entrants

Threat value becomes high when the market structure allows for easier participation from would-be competitors.

- **Scalability** is theoretically achievable for industrial-scale implementation. Biogas infrastructure of this level starts as small as 1MW generating power per 30 ton of waste. Increasing feedstock input (in this case, POME) yields greater power with an increase of 0.3MW per 15 ton of waste. Same thing with cost scalability. Larger biogas projects

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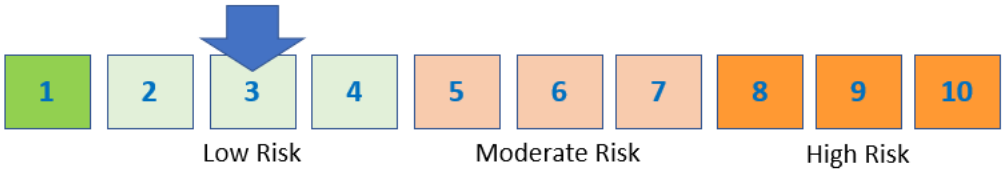
benefit from relatively stable design and construction cost (i.e. at least physical dimension not radically changing per MW upscale).

Scored 3. Economics of scale applies in implementing POME biogas in plantations. This is especially the case for industrial-scale implementation, which gives old players with established revenue stream and anyone who has additional capital an advantage over newcomers. Will be a bit problematic for smaller-scale attempts.



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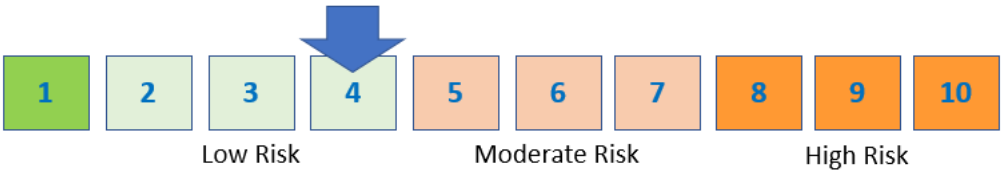
- **Capital Requirements** are high as mentioned before. New entrants who do not have previous industrial/engineering/chemical industry background (and assets) will have a hard time trying to participate in the market. Implied necessity of a Special Purpose Vehicle (SPV) establishment doubles this notion. On the flipside – larger companies from adjacent sectors (especially fossil energy) who transition into biogas development will be able to retain their network, assets, and reusable capacities effectively.

  Scored 4. Big initial capital is required to develop biogas projects. While theoretically this can become a barrier for newcomers similar to the 'Scalability' aspect, existence of financial institutions can bypass this.



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- **Government Policies** can act as barrier. Although no policy explicitly denies entry to the biogas market, there are policies who disincentives the intent. For example; low FIT prices when selling biogas electricity to PLN grid, mandatory transfer of assets after PPA term expires, minimum local content requirement (where development needs imported technology – happened in other industries as well). The whitelist previously mentioned also limits new entries.

  Scored 2. This is more or less the main determinant for someone to transition into renewable energy in the Indonesian market. While the government subsidizes energy, the same is not true for renewables. At the moment they only regulate, and the regulations are not exactly business friendly – even for the old players. This is clearly not encouraging.

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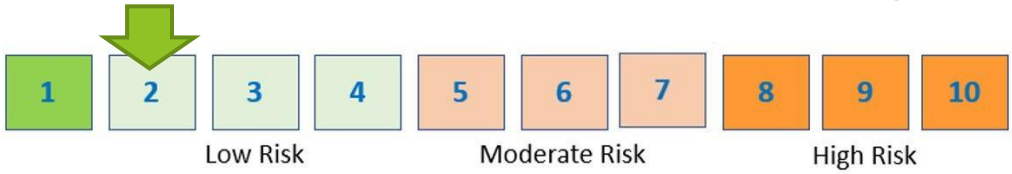

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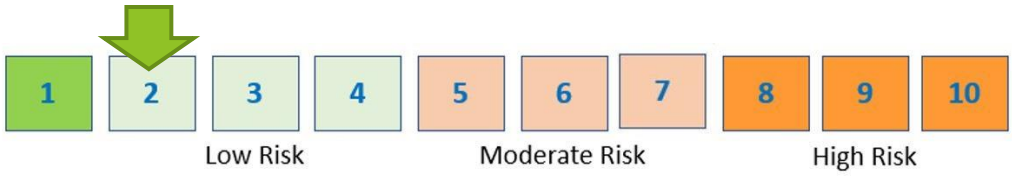
- **Incumbency** is somewhat perpetuated in the culture (thanks to the market as well). Project owners, either government or private, strongly prefer working with known EPCs. Project development portfolio is also a point of consideration. This gives old players a massive advantage. Biogas stakeholders also know one another, and this network of connections enables Business-to-business (B2B) marketing, a clear Human Resource (HR) pipeline, project opportunities, and several other benefits.

  Scored 2. The poor quality of information management in Indonesia does not give benefit from late movement. Not to mention the limited amount of biogas development projects available to tender in each given period. EPCs who move fast will get the project, and EPCs who get said project will be known across the market – easing future projects and collaborations.



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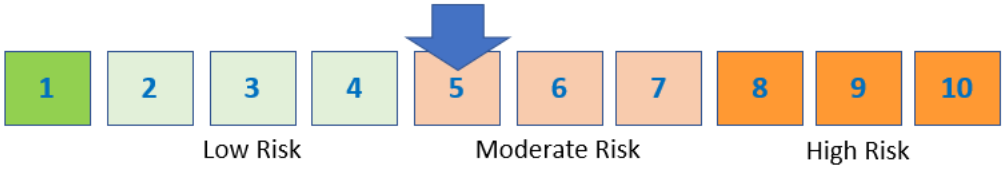
- **Project Stream** is also limited for government and private alike. The government approaches contractors via the whitelist, because state fund allocation for renewables is getting cut every year – and biogas is not prioritized in the list. Private sector is hesitant to participate because they are not yet sure about the financial feasibility and value of implementing biogas into their existing business processes.

  Scored 5. While government and private sector projects are communicated to the market most of the time, actually accessing the tender process is difficult. The government has its limitations, and actors from the private sector rarely do so. Not to mention direct contracts which depends on the extent of someone's network.



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5.4.5 Substitute Sector

- **Price Gap** exists between biogas and biomass development, but the yield-to-cost ratio is actually in favor to biogas. In Indonesia biogas is 1:1, biomass incinerators 1:2, and

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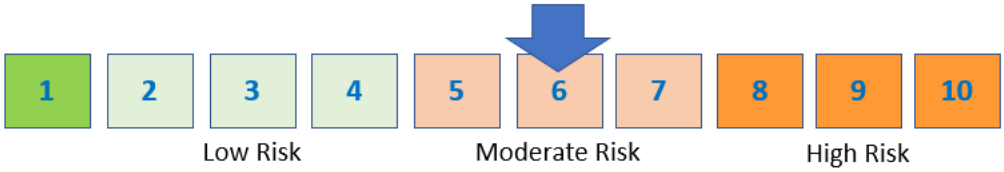
MSW landfill gas 1:4. The ratio mentioned is also based on Covered Lagoon technology, which is generally subpar in everything but price. CSTR biogas exists in Indonesia, but information on its development and associated costs are very limited.

The price gap is indirect for biofuel development. Unlike biomass technology (where the implementation excludes the use of biogas because a site rarely has both), biofuel enters a palm mill process from a different point. They purchase mill CPOs directly, not engaging with waste. In this sense, a buyer will not need to invest on tech infrastructures but still participating to renewable energy production BUT they will not be able to internally control savings or income rates.

Scored 6. Biogas is stuck in an unusual condition where the commonly used technology is actually cheaper, but it is neither endorsed explicitly by the government nor does it have clear offtake for yields. EPCs ended up preferring the more expensive substitute for the clarity of benefits. Biofuel, while supported by governmental uptake, is beyond private stakeholders' control.



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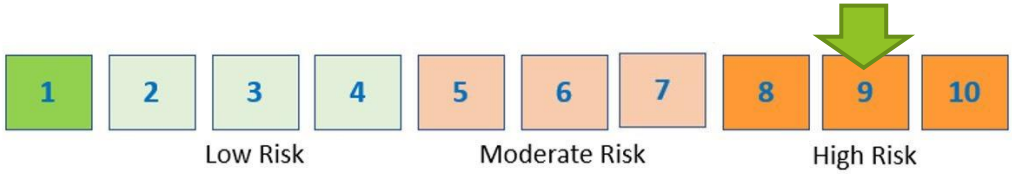
- **<u>Buyer Sensitivity</u>** is very apparent in the biogas market. Clients are wary of a market that is still non-commercial, since there aren't many other cases that can be used as a benchmark. The plantation sector (as primary client segment) is also dealing with a naturally fluctuating business. Investing in a technology that currently has limited use *and* is risky to develop is not a good decision.

  In this manner biofuel is more threatening. The current governmental purchasing scheme addresses buyer sensitivity to price flux directly by buying their products at a fixed rate. While the scheme does not necessarily buy all of a mill's output, the fact that they will be able to sell a guaranteed amount per period sets a price floor and ceiling for their core business (CPO).

  Scored 9. Buyers are considering every financial component of renewable energy projects due to the massive time and money investment required. Development costs cannot be modified in a meaningful way since it consists of fixed costs, and financial benefit is still limited and uncertain.



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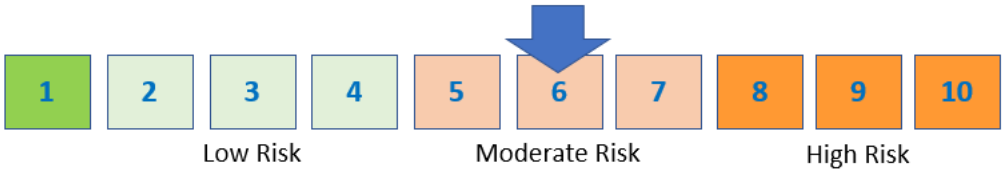
- **Product Performance** – within the context of palm plantations as clients, biomass plants will be using fruit bunches. Biomass plants have two clear uses for its yields: electricity from heat-based generators and ash that can be sold as fertilizers. Biogas, on the other hand, requires additional processing and technology to utilize maximized yield (since biogas is effectively manufacturing material as well). Both will require a long time before return of investment occurs. Relative simplicity can also ease local development.
  Biofuel performance does not matter, since the current scheme is limited to raw purchase of CPO.

  Scored 6. The rates in which these technologies produce power is similar. The difference lies in the process. Biomass seemingly offers higher performance because the process is more straightforward than biogas (and the full potential of biogas is not yet realized in the market).



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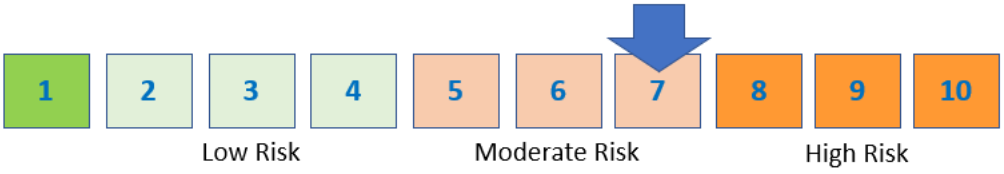
- **Sub-Sector Trends** are positive in large part thanks to the government. Earlier, we mentioned how renewables development in Indonesia is largely dependent on governmental policy and decisions. And the government is quite supportive of biomass recently. For example, Presidential Order No.35/2018 mandated the development of biomass in 12 Indonesian major cities to solve municipal waste problems. Even if the target is not power generation, orders like these are still beneficial for the substitute sector. Biomass development became a government target, with quite a clear guideline as well.

  The same applies to biofuel, to a greater extent. A Presidential Mandate regarding national biofuel use is in effect, with clear milestones and asset mobilization. Having governmental support increases confidence in the biofuel segment, and it seems that the trend will persist at least until the cabinet changes in the next period.

  Scored 7. Biomass sectoral performance is not affected by the current trend, as technology research and development are generally progressing slowly in Indonesia. However, increased adoption that is enforced by the government continually improves financial access and EPCs efficiency in implementing – essentially reducing the risk of additional costs.



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5.4.6 Competition

Competition for new biogas project developers will come from those who provide access to biogas technologies to the market. The role is primarily fulfilled by EPCs who are either in standing agreement with certain suppliers, or by a tech manufacturer's subsidiary organization. When the industrial scale of >1MW of biogas power plant is taken into context, identification parameters are:

- Operational Region is important because it is related to palm variety, soil characteristics, related stakeholders, and governmental idiosyncrasy.
- Primary Digester Technology (and yield) will show us the most relevant type and size of technology that typically leads into a successful project.
- Organizational Status ranges from local EPCs that are made from scratch to palm mills that are starting to transition into renewable energy development.

Accounting for tech suppliers is also important, but it is rarely mentioned by the companies or the news pertaining their activities. Any notable responses to approach will also be detailed – whether these stakeholders are taking a competitive or cooperative stance. Names listed below are taken due to their close relation to GIZ Indonesia's current efforts at improving Bioenergy commercial viability, i.e. they are well-known as veteran players, or have achieved a milestone, or have a tendency to actively participate in market-building events.

1. GREE New Energy became notable for its development of a large cassava-based covered lagoon in Lampung with 3MW yield, which was successfully connected to the national grid. It is also notable how they are explicitly setting a GHG reduction target of 65KT per year. GREE is an independent EPC which also offers operational services (post-construction, taking a role similar to SPVs) and project feasibility checking.

2. Ecody Agro Energy is one of the most prolific EPCs in Indonesia, with 11 Biogas plants spread across Sumatra and Kalimantan. They usually deal with covered lagoon technology ranging from 500KW to 3MW in size. Ecody also offers a wide range of services, essentially becoming a one-stop shop for Biogas development. This extensive capacity, coupled with a constant stream of governmental and private contracts, left them in an advantageous market position. We perceive them as market leader in commercial Biogas development.

3. Pasadena Engineering Indonesia is one of the early players in Indonesian renewables development. Initiated in 2006 as an EPC and continually adapting to the market, Pasadena is adept at capitalizing off market trends. Their covered lagoons are located across Sumatera and Kalimantan, yielding 1-2MW in average. They are currently chasing the prospect of Biofuels, shown by the establishment of Pasadena Biofuels Mandiri, a subsidiary that exclusively deals in Biofuel processing. Both of these companies were cooperative and are willing to provide information and resources in later stages of the project.

4. Austindo Aufwind New Energy (AANE) is a special purpose vehicle (SPV), created via joint venture between Austindo Nusantara Jaya plantation and Germany-based Aufwind Schmack Asia Holding (GmbH). Austindo originally deals with operating plantations that yield consumable crops, one of which being oil palm. Wastes of internal

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processes are then handled by AANE to generate energy. Their covered lagoon in Belitung currently generates 1.8MW, with technology directly supplied by their German counterpart.

5. Taat Inti Energy is a relatively new participant in the Indonesian Biogas community but has the privilege of association with Pasadena. This allows them access to a number of ongoing Biogas tenders, which unfortunately cannot be disclosed in detail. Taat Inti's earlier ventures as EPC are based in Sumatera, implementing covered lagoons around the 1-2MW range. They are also testing the waters on gasification and CNG upgrading in Kalimantan.

6. Asian Agri is one of the larger palm plantations in Sumatera (and Indonesia, and even Asia), boasting around 100.000 Hectares of cultivated land in cooperation with plasma and smallholder farmers. Their venture to Biogas was very recent. In 2018, they developed 5 CSTR plants (yielding around 2MW each, imported from Japan) in some of their sites with the assistance of BPPT (the National Agency of Technology Implementation). The usage of CSTR is still rare in Indonesia, as most companies prefer to use the cheaper lagoon method.

5.5 Market Policies and Incentives

The scope of incentives in Indonesia is largely limited to governmental legislations. The current cabinet has directed line ministries, along with their regional branches and other national-level agencies, to take measures in developing an environment that is beneficial for the entire biogas development process. This is evident in the policy incentives available in Indonesia.

Several ministries have begun legislating laws that may serve as incentives or assistance to stakeholders in the Indonesian biogas sector. In addition, several governmental agencies also serve an important role for biogas development, such as the Financial Services Authority. The current cabinet may also be involved directly in governing the biogas sector.

In the following section, analysis on incentives will be structured in accordance to the regulated process of biogas development, divided into phases of project development: **initiation**, **feasibility study**, **power purchase agreement**, **financial closure**, **construction**, **commercial operation date**, **operations and maintenance**.

Structure of writing in the following sections will follow these basic guidelines:

a) General principles of law will be used in determining relevant legislations – specific laws over general laws, newer laws over older ones.
b) Explicit differentiation will be made between incentives and directives. The former hastens growth, while the latter stabilize the scene in order to sustain it.

Initiation phase revolves around project conceptualization and planning. *For Indonesia, this phase explicitly requires a clear policy directive, which can significantly affect project Segment Target Position (STP).* Policies help project owners by specifying market segments and giving quantifiable targets. The following regulations are relevant with project initiation phase:

Presidential Directive No.61/2011 on Greenhouse Gas Emission Reduction

➔ Highlights the governmental commitment in reducing national greenhouse gas emission by 26% (independently, 41% if accounting foreign assistance) by 2020. Sectoral

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focus put on farming, forestry, energy, transportation, industrial manufacturing, and waste management sectors (including other related sectors).

➔ Gives private developers a quantifiable target and points at specific sectors to target (allowing developers to correctly focus their resources).

Legislative Act No.30/2007 on Energy

➔ Prioritizes local energy sources for renewable energy generation, and mandates local governments to allocate funds into electrical development of rural areas—which are typically stuck with low income, lagging in development, and geographically remote.

➔ Essentially incentivizes regional governments to invest on renewable power, legally obliging them to be a potential client for private developers.

Legislative Act No.30/2009 on Electricity

➔ Reinforcing the prioritization of 30/2007 regarding local renewables, and explicitly allowing the private sector to operate their own renewable infrastructures and sell energy to the PLN.

➔ Allows the implementation of a more profitable long-term business model. By operating and selling rather than hired for construction, the private sector is able to create a new income source and actually have asset investments. The democratization of power generation also helped stabilize power pricing.

Ministry of Energy Regulation No.35/2013 on Power Provider License Requirements

➔ Defines and provides procedural guidance for power generation businesses – for public purposes, for company internal use, or for support businesses.

➔ Helps private developers to further define the most profitable positioning in the market and ensures administrative compliance for a project.

Feasibility Studies cover benchmarking of project design to situations in the field OR existing technology. *This phase needs clear methodology from the EPCs/developers/contractors and data consistency from the project owner.* Benefits of standardization incentivize project owners to start (and standardization details provide a foundational framework of assessment), while utilization directives ensure that renewable yields will have a degree of guaranteed offtake. The following regulations are relevant in the Feasibility Study phase:

Ministry of Environment Decree No.28/2003 on Technical Guidelines regarding Wastewater Utilization in the Palm Oil Industry

➔ The government will grant utilization of wastewater based on the results of certain assessments;
a. Analysis on Environmental Impact (AMDAL);
b. Environmental Management Intent (UKL) and Environmental Control Intent (UPL) standards;
c. Studies on Environmental Impact Evaluation (SEMDAL);
d. Environmental Control Strategy (DPL).

➔ Despite clarifying administrative needs of waste utilization, the multiple layers of required documentation add complexity in checking a project's feasibility.

Ministry of Farms and Plantations Regulation No. 19/2011 on the Indonesian Sustainable Palm Oil Certification

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- ➔ Subjects all palm mills and plantations to Indonesian Sustainable Palm Oil Certification System (ISPO) assessment per December 31st of 2013.
- ➔ Indirectly benefits palm oil producers that practice sustainability standards since ISPO-certified products will have an easier time being distributed into the market. Incentivizes mills and plantations to (at least) comply with ISPO sustainability standards for the sake of strategic advantage.
- ➔ Waste-to-biogas may become an alternative for mill owners to comply towards sustainability standards while generating insubstantial profits.

Ministry of Farms and Plantations Regulation No.11/OT 140/2015 on ISPO Certification Targets

- ➔ Article 2 (1) declares that the implementation of the Indonesian Sustainable Palm Oil Certification System (ISPO) will be conducted both mandatorily and voluntarily.
  1. Mandatory ISPO will be applied for:
     a. Plantations that conduct land cultivation along with industrial processing;
     b. Plantations that focus on conducting land cultivation; Plantations that focus on industrial processing.
  2. Voluntary ISPO will be available for:
     a. Plasma plantations (which land is granted by the government, owned by plantations, are community fields, or privately owned) that are associated to a plantation in developing their land;
     b. Smallholders that develops/owns land entirely on their own capital;
     c. Standard-compliant plantations that are producing palm oil with the specific intent of generating renewable energy.
  3. Can be utilized as a selling point for companies to better market their products. Newer standard-compliant plantations with limited interest in maintaining sustainability can be persuaded to instead develop Biogas to exempt them from mandatory ISPO audits.

Power Purchase Agreement (PPA) is somewhat exclusive to Indonesia since we have PLN as the sole monopolistic distributor. *A deal needs to be made with PLN for pricing and ownership of renewable-based power generating infrastructure. This is particularly important if the Biogas plant is going to generate electricity, since it determines pricing and stakeholder coordination.* At the bare minimum, PPA regulations set a uniform procedure for all renewable energy projects. The following regulations are relevant with the PPA Phase:

Ministry of Energy and Mineral Resources Regulation No.31/2009 on PLN Renewable Power Purchasing

- ➔ Mandates PLN to purchase surplus renewable energies in a fixed price, from producers that yield less than 10MW. Priced at 656 Rupiah per KWh (medium voltage) and 1.004 Rupiah per KWh (high voltage), not accounting regional variabilities.

Ministry of Energy and Mineral Resources Regulation No.4/2012 Revising No.31/2009

- ➔ Changing the mandate in No.31/2009, increasing the fixed price. It became around 975 to 1.725 Rupiah per KWh, dependent on technology and voltage, not accounting regional variabilities.

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Ministry of Mineral and Energy Resources Regulation No.27/2014 on PLN Power Purchase from Biomass and Biogas Power Plants

- ➔ Further changing the mandate in No.4/2012, increasing the fixed price again. It became around 1.050 to 2.400 Rupiah per KWh, dependent on technology and voltage, not accounting regional variabilities (now expressed in a 1.0 to 1.6 price multiplier). This iteration also implemented a load follower scheme for Bioenergy plants.
- ➔ Allowing Bioenergy plants to become load follower rather than full-fledged producer makes investing to Biogas more feasible for stakeholders with limited capital. Load following plants only need to produce at peak demand – removing the need to use large generating infrastructures.

Ministry of Energy and Mineral Resources Regulation No.21/2016 on PLN Power Purchase from Biogas Power Plants

- ➔ Directs PLN to specifically purchase electricity from Biomass or Biogas power plants run by certified private producers.
- ➔ Even if the government *de facto* prefers solar, wind, and hydro renewables, the existence of this legislation can be invoked in a PPA deal.

Ministry of Energy and Mineral Resources Regulation No.10/2017 on Power Purchase Agreement (PPA) Principals

- ➔ This law details all non-price elements of PPA such as risk management in the face of force majeure, supply chain structuring, and a sort of minimum service requirement. A most notable result of this law would be the application of a mandatory ownership transfer in all PPA (after 10-20 years).
- ➔ To some degree, this law helps project owners or developers to determine project direction and business strategy in the future by creating quantifiable standards for all aspects in a PPA. Unfortunately, parts of it are either risk-inducing or restricting for private stakeholders.

Ministry of Energy and Mineral Resources Regulation No.50/2017 on Renewable Power Generation

- ➔ Reiterates the Indonesian Feed-in-Tariff rates. Percentage of local cost of energy is used to determine purchase prices if renewable cost is higher than existing cost (which is most likely the case). Biomass and Biogas FIT is capped at 85%, while MSW-based Bioenergy is negotiable.
- ➔ Actually, this is more of a disincentive for project owners and developers alike. The law overwrites older iterations of FIT which are able to support commercial operations. The current percentage-based FIT makes commercial operations very difficult on financial balance.

Ministry of Energy and Mineral Resources Regulation No.4/2020

- ➔ Declaring the removal of mandatory asset transfer to government agencies post-PPA.

Financial Closure marks the point where the project's finances gets covered by corporate financing of commercial banks, grant from donor organizations, internal funds – or a mix of all. *One important factor is the accessibility of these funds to renewable energy development.*

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Even if a country's money market is alive, they rarely focus on renewables. Investment legislations created by the Ministry of Finance and any related stakeholders do not affect developers directly, but it will push commercial banks or other financial institutions to invest in renewables. The following regulations are relevant in the project's financial closure phase:

Financial Service Authority Regulation No.18/POJK 03/2016 on Risk Management for Commercial Banks

- ➔ Mandates the implementation of risk management strategies for commercial banking operations. This includes credit risk assessment, market analysis, asset liquidity, operational management, legal compliance, and some more.

Financial Service Authority Regulation No.51/POJK 03/2017 on Sustainable Financing by Financial Institutions

- ➔ Mandates the implementation of sustainable financing principles for financial service providers and companies who underwent public offering via stocks or bonds. Aspects that have to be implemented as baseline are:
  a. Development and launch of sustainable credits, green investments, or similar projects;
  b. Internal development of sustainable finance divisions;
  c. Organizational strategy adjustment to facilitate sustainable finance practice.

  Implementation of these measures will be rewarded by the government.
- ➔ This law is beneficial for the Biogas sector, by pushing financial institutions to start funneling capital into sustainability – and by extension, renewables. Unfortunately, this law is still general in coverage with weak incentives for financial institutions.

Ministry of Energy and Mineral Resources Regulation No.21/2016 on PLN Power Purchase from Biogas Power Plants

- ➔ Article 10 (2) set a deadline of 12-month gap between PPA agreement and financial close. If developers were unable to source adequate amount of funds within this timeframe, their awarded Biomass or Biogas development rights may be rescinded.
- ➔ Article 12 (1) states that proof of successful financing will have to be presented to the government, specifically the Ministry of Energy and Mineral Resources, via Renewables and Energy Conservation Division.
- ➔ Article 13 (1) mandates that developers who have achieved financial close for their development projects must immediately apply for the Electricity Generation Business License.
- ➔ This regulation is more of a directive than incentive. This stage of a project shows that achieving complete financial close is important for continuation. However, from stakeholder experience, 12 months can sometimes be difficult since renewable energy developments are still assessed as corporate projects.

Construction is where EPCs/developers/contractors are given green light to begin the physical building of the Biogas plant. Logistics and administration occur at this phase as well. Usually this is accompanied by some form of monitoring to ensure design and regulatory compliance. *Regulations or policies that can circumvent additional processes can be utilized to cut time and costs from this phase.* Construction standards reduce project owners' risk by enforcing EPC conduct and (sometimes even further by) providing quantifiable, technical baseline.

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Tax and administrative waivers for particular sectors direct stakeholders to focus on a particular segment.

Ministry of Finance Regulation No.176/PMK.011/2009 on Import Tax Waiver of Industrial Machineries and Components Necessary for Industrial Development

➔ Machinery importing taxes that are usually imposed on companies can be waived if:
   a. Machineries are not yet manufactured domestically;
   b. Already manufactured domestically but not up to par with necessary specifications;
   c. Already manufactured domestically but not able to fulfil demand.

Ministry of Finance Regulation No.66/PMK.010/2015 on Import Tax Waiver of Electricity Generation Infrastructures

➔ Is basically a specified extension of the preceding law. All companies with an Electricity Generation Business License can apply to the National Agency of Investment Coordination and Ministry of Finance for this waiver.

Standards also play a part in directing construction. There may be more standards that are available and practiced internationally, but the Indonesian market has a tendency to apply lenient domestic standards instead, or just straight up ignoring standardization.

- Indonesian Standard (SNI) 7826:2012 on Biogas Manufacturing Units with Fixed Dome Digesters
- Indonesian Standard (SNI) 7926:2013 on the Workings of a Biomass Boiler
- Indonesian Standard (SNI) 7929:2013 on the Grid Requirements for a Biogas Unit

Commercial Operation Date (COD) is when the Biogas plant actually starts supplying power. Depending on the project participants, this may come as soon as the operation starts, or set to a later date to make room for testing (the latter being more common). The following regulations are relevant with the commercial opening date of the project:

Ministry of Energy and Mineral Resources Regulation No.21/2016 on PLN Power Purchase from Biogas Power Plants

➔ Article 5 of the regulation states that a PPA will last for up to 20 years after COD and it can be prolonged.

➔ Article 11 mandates for developers to report upon their construction, per 6 months, up to COD. This report is to be delivered to both Ministry of Energy and Mineral Resources and PLN.

➔ Article 14 (1) Limits COD start of Biomass and Biogas projects to 36 months after PPA signing.
   (2) Failure to achieve COD within 36 months will subject developers to reduced power purchase prices, differentiated according to how late it is finally completed:
   a. 3 months or less will be subject to 3% reduction
   b. 3-6 months will be subject to 5% reduction
   c. 6-12 months will be subject to 8% reduction

Operations and Maintenance will occur indefinitely. Can either be conducted by the EPCs/developers/contractors themselves or handled by the project owner on their own/via SPVs.

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5.6 Resources

5.6.1 Natural Resources

Indonesia is the world's largest palm oil producer, with 29,344,500 tonnes worth of annual production. Indonesia contributes 50% share of global production (OECD, 2017) with its main exports are directed towards China, Singapore, Malaysia, India, Pakistan, Bangladesh, Sri Lanka, Egypt, Netherlands, and Germany. Thus, it was not surprising when the palm oil sector became one of Indonesia's strategic focuses. Despite the country current focus on hydro and geothermal power, the government has also shown keen interest in the by-products of palm oil as it presents an opportunity for renewable energy. Considering the waste management needs of the palm oil sector, biogas can actually be a good investment for palm producing regions, such as South Sumatra.

South Sumatra is considered relevant to biogas project development for four reasons:

- The province's palm industry is quite large and concentrated in certain regions, which allows for a reliable feedstock supply.
- Development in the province is growing at a quick pace, improving accessibility to important infrastructures that may aid construction.
- Governance and bureaucracy in medium-scale cities (Palembang) in developing provinces (South Sumatra) are usually less complex.
- Existence of other industries and energy distribution channels are able to support biogas offtake in the future.

As a country with a strong agricultural background, Indonesia is also producing several other commodities that are also relevant for biogas generation as listed in table 31.

Table 31: Commodities Relevant for Biogas Generation (MEMR, 2016)

Commodity	Waste forms	Potential electricity generation (MWe)
Palm oil	Fibre, shell, empty fruit bunch, fronds, POME	12,654
Sugar cane	Bagasse, leaves and shoots	1,295
Cassava	Effluent	271
Plywood	Sawdust, offcuts, bark	380
Rice	Husks and straw	9,808
Total		24,408

Past biogas developments projects have also explored these potentials – especially rice and cassava. Rice husks are often used in community-level, while cassava feedstock for industrial-level generation is a relatively recent breakthrough that is currently being explored.

5.6.2 Human Resources

Out of all 8.4 million inhabitants of South Sumatera, approximately 4 million is actively employed, with 1.8 million specifically by the agricultural sector. Labor concentrations exist in the

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Palembang Municipality, plus Ogan Komering and Banyuasin Regencies. The latter is expected, as these regencies house most (if not all) of South Sumatera's palm plantations. No less than 150.000 agricultural workers reside in each of these regencies.

A large amount of the agricultural labor force has not completed basic education (1.1 million of them) while only 25.336 *across the entire province* are known to complete college. This is rather problematic as a bulk of the labor demand requires General High School-level expertise, followed by University-level expertise (BPS, 2019).

Palm oil plantations require intensive labor, which implies availability of human capital in regions that depend on palm as a main income. This is also true for South Sumatra. Agricultural sector's growth and production keeps increasing and small and plasma holders of palm exist alongside larger plantations. This emphasizes the availability of human resources. A lot of these human resources are blue-collar. Most of the employment created by the palm sector is for tending the plants and collecting fruit bunches, characterized by purely physical labor.

Plantations and mills usually require 3 types of workforce: planters, factory workers, and administrative staff.

- Planters tend and cultivate palm tree in the field (including harvesting and transportation) and require more practical experience than education. Planter demand covers the bulk of workforce absorption by the sector. Small or plasma holders associated with a company can be put into this category.
- Factory workers in the palm sector used to be mid-tier workers, i.e. one's education will be expected, but specific knowledge was not mandatory. This was when the industrial process of palm was strictly mechanical. Nowadays, the bioenergy trend introduced biochemical processes into a mill. This calls for workers with such specific knowledge.
- Administrative staff are necessary for proper operations and management of a plantation or a mill. These types of workforce usually require a degree of education – varied according to role and rank. A purely operational desk worker can pass with high school credentials when managerial roles will demand higher education or more experience.

Labor's importance in the business can be estimated through costs that represent 60% of total operational expense. Paying wages is the highest cost share for plantations. The numbers, however, might not be representative for the entirety of the labor force. Fruit haulers and mill operators are both plantation labor – but their wage rates are surely different.

Minimum wages for plantation workers are calculated per hour or per fresh fruit bunches harvested. National minimum agricultural wage in plantation regencies is also very low – a mere 1.7 million IDR (provincial average) which is around half or third of the Capital's 4.7 million minimum wage. Premium wages are usually applied when individual harvest exceed 600 kg of fresh fruit bunches/worker/day.

The income of small or plasma holders who are not directly employed by a company still comes from selling fresh fruit bunches as revenue or payment from companies. Depending on whom (state companies, multinational companies, group of individuals, or other smallholders) one deals with, profits will vary with price as low as 700-950 IDR/kg when the normal commodity price is 1,300 IDR/kg (November 2015).

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5.6.3 Infrastructure and support industry

Palm oil is a commodity that significantly contributes to the economy of South Sumatra and Indonesia in general. Support industries exist throughout the product stream to improve value.

The increasing growth of the agricultural sector is not accompanied by adequate infrastructure development in many important areas. While Sumatera is subject to rapid modernization in its urban areas, palm plantations are far from population centers. Limited infrastructures make access difficult for vehicles and power grid alike.

According to a study conducted by the Indonesian Palm Oil Association (IPOA) in 2016, major supporting sectors of the Indonesian palm oil sector include:

- National and International Traders as primary customers of the palm oil sector. Larger mills usually sell their products themselves, with some of the smaller mills also selling to them. Alternatively, smaller mills can sell their products locally instead.
- Banking and Insurance provides capital input and risk management facilities. Many commercial banks involve themselves with the palm sector, but via regular corporate financing. While this allows investment into the palm sector, it is not very suitable for renewable development.
- Transportation, Logistics, and Seaports allow distribution. Larger mills usually have their own logistic infrastructure set up – a fleet of trucks or tanker vessels. Smaller mills with limited capital can instead 'rent' these infrastructures to extend distribution chain.
- Research and Development can improve efficiency and increase value in the long run.
- All palm companies conduct R&D (according to their available resources) in order to achieve more value. This can be done by improving efficiency, creating a new palm strain, or implementing proprietary technology. Governmental agencies e.g. the Oil Palm Plantation Fund Management Agency (BPDP-KS) for palm-specific tech, or BPPT for renewables in general) can also assist.
- Technical Education is important to have workers with adequate skills. This is especially evident for the technical workforce demand, which requires graduate or vocational education. Several universities across Indonesia have noticed this trend and have started to integrate palm sector skills into their curriculum. There is even a new polytechnic institution (Citra Widya Palm, in Bekasi) recently created for this purpose.
- Fiscal and Monetary Legislators create laws that affect price, cost, and budgeting. This role is fulfilled by the Ministry of Finance (fiscal regulations on the national level) and the Financial Services Authority (regulating bank operations).
- Land Use Legislators create laws that affect long-term strategies. The Ministry of Farms and Plantations is responsible for the legislation, implementation, and assessment of these laws.
- Commodity Associations promote and facilitate product uptake in the market. The prime example would be the Indonesia Palm Oil Association (IPOA). IPOA advocates for palm oil trading and use, while also conducting some degree of research and networking events.

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6 Republic of South Africa

6.1 Market overview

The South African biogas sector is still in a nascent state, due to a historically slow rate of uptake as a result of the poor track record for implementing projects with the local context. This means that there is general inexperience in designing, constructing and operating of biogas projects. Increased uptake of biogas technology in conjunction with development of local expertise is therefore expected to assist the industry in maturing to a level where biogas technology and the industry is commercially sustainable.

Some of the complexities faced by the biogas sector in the Republic of South Africa (RSA) include optimisation of multiple revenue streams and the need for feedstock security, while several market barriers such as cost of digestate management and low landfill gate fees hamper growth. Biogas stakeholders need to understand the current viable project models in RSA[86], and follow a comprehensive project development methodology to assist in the development of bankable and successfully implemented projects.

Development of the South African biogas industry over the next five to ten years is therefore expected to be driven by the increasingly stringent environmental regulations seeking to minimise impacts of environmental degradation and climate change; social factors addressing access to services; and legislative factors that simplify the regulatory complexity in the sector all of which increase economic viability of projects.

6.2 PESTLE or Macro Analysis

A PESTLE analysis was carried out to outline the macro-environmental factors that may impact the success of the DiBiCoo project in RSA. In terms of the six aspects of the PESTLE analysis, the key factors that will have a significant effect on the DiBiCoo project in the RSA are economic and environmental. With the lack of clarity on funding of larger projects as well as stringent/rigid environmental frameworks, project development is faced with substantially prolonged processes, generally in excess of three years at best. However, the legislative and policy landscape is in the process of changing to more favourable conditions. Positive developments include bans for all organic and liquid waste from landfill (Department of Environmental Affairs, 2013) and Integrated Resource Plan (IRP) (Department of Energy, 2019) for development of biogas projects.

6.2.1 Political and legal

RSA has enjoyed a prolonged period of relatively stable government, with the constitution of the different levels of government showing limited shifts since 1994. However, the ongoing inquiry into allegations into state capture[87] highlights a few negatives that include increase in corruption and lack of accountability. In recent years, this has led to the growth of opposition parties. A positive effect, as this allows more accountability within governance bodies.

[86] See Table 32: Current viable biogas project models (UNIDO, 2018)

[87] Website of the Commission of Inquiry Into Allegations of State Capture can be accessed in: https://sastatecapture.org.za/

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Over the last 10 years, there has been a stronger focus on correcting the injustices of the past, including a strong focus on developing local enterprises and small, medium and micro-sized enterprises (SMMEs), particularly from previously disadvantaged groups. This has also led to legislative policies supportive towards growing the participation of local businesses in the country. As such, one of the routes for an exporting partner is to identify and work with a local partner within the ambits of the law and working on supporting the aims of transformation.

With increased interest in investing in both basic infrastructures (such as source separation, improvement in transfer stations and waste disposal sites) for waste management, the associated increase in regulation and policy has led to a need for good understanding of the policy and legislation that has been recently promulgated, as well as that in the process of promulgation. The bulk of the legislation and policy that has been recently developed focuses on environmental protection, and in recent years there have been many issues identified (such as outdated legislation, lack of understanding of emerging technologies amongst regulators) in the green economy sectors with suitability of legislation, understanding of legislation and implication thereof. As such this is still a strongly developmental area, with one of the biggest positives being the engagement with both private and public stakeholders across different sectors in order to ensure better promulgation and implementation.

These implications include understanding the recently promulgated liquid and organic waste to landfill bans and Carbon Tax Act (CTA) (2019). In addition, increased expertise in implementing and improvement of existing Acts, in the form of operations and understanding the potential for public private partnerships (PPP), can help existing wastewater treatment works (WWTWs), both in the private and public sectors, can assist in achieving wastewater discharge standards being met as per National Water Act (NWA) (1998). These are considered key drivers as they impact the costing and time taken for a project developer to complete the environmental impact considerations, licensing and permits required.

The developments with the renewable energy sector impact the potential of the off-take markets for the products produced by a biogas plant. GreenCape's 2020 Energy Services Market Intelligence report highlights these developments which include the amendment of Schedule 2 of the Electricity Regulation Act 4 of 2006 on 10 November 2017. Certain power generation facilities of less than 1 MW in size are now exempted from having a generation license provided an installation meets the criteria as stipulated in the amended schedule. Another development is the Integrated Resource Plan (IRP) 20191 which was promulgated in October 2019. The updated document allocates 500 MW per annum for distributed generation for own use of between 1 MW and 10 MW, starting in 2020.

6.2.2 Economic

RSA has a highly developed economy, primarily built on extraction of natural resources such as gold, platinum and coal. In addition to being one of the world's largest exporters of gold and platinum, the country's economy is characterised by a wide range of industries producing goods for both local and export markets. However, there is room to expand the current economic sectors further, whilst also focusing on the development of additional sectors and industries.

As a super-exporter, top 1% of the country's exporters produce 80 products, which account for 75% of South Africa's export market (Trade and Investment Promotion Agency, 2014). The

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export power is however almost evenly balanced with the import needs. During 2018, the country imported and exported goods worth US$92.6 billion and US$93.6 billion respectively (WITS, 2020).

As a growing economy, RSA is focusing on reducing the import bill, and growing the export income, and as such has seen strong growth in foreign direct investment (FDI). Within sub-Saharan Africa, 16.5% of the US$32 billion that was invested in the 46 sub-Saharan countries in 2018 was invested in RSA. In addition to being a prime destination for FDI, investment in RSA increased by 165% between 2017 and 2018 (from US$2 billion to US$5.3 billion) (United Nations Conference on Trade and Development, 2019). This is testament to the potential for growth of the economy, with businesses, institutions, and regulatory landscape in RSA geared to use the opportunity.

Economic growth in RSA has not been without challenges. In addition to the global economic crisis of 2008, challenges in power (electricity) production has dampened growth significantly over the last 10 years. However, some of the challenges are being addressed - with the World Economic Forum (WEF) reporting that RSA's competitiveness has regained momentum after the recent political landscape shift. This has seen the country moving up 7 places to 60th in WEF's 2019 Global Competitiveness Report (World Economic Forum, 2019).

As an economy geared towards accelerated growth, with increased demand for energy in order to both grow industry and increase access to (cheap) power sources, RSA is therefore a good prospect for the development of renewable and sustainable energy sources in its growth towards a more resilient and sustainable economy. That, and the challenges in provision of electricity due to ageing power stations therefore make a good case for the expansion of alternative (renewable) energy solutions, including energy from biogas.

Other indicators indicated in WEF's 2019 Global Competitiveness Report that are of interest and are indicative of growth potential of the economy include:

- well-developed equity, insurance, and credit markets, placing RSA as a regional financial hub (score of 83.2, 19th place);
- advanced transport infrastructure (score of 58.7, 45th place) and is among the top countries in Africa for market size (score of 68.6, 35th place);
- improved institutional quality (+3.3 points, 55th). Some aspects of this category have achieved remarkable progress, including restored balance of powers across different state entities (+7.7 points, 16th), enhanced administrative efficiency of the public sector (+6.3, 39th) and corporate governance (+3.3, 26th).

In contrast, there are other aspects that show deficiency within WEF's 2019 Global Competitiveness Report, and although possibly a worry for development, they provide additional streams for development. These include:

- security (42.7, 135th) remains one of the main restraints to South Africa's competitiveness;
- transparency (43.0, 62nd) and government adaptability to change (39.6, 100th), although there is continuous work at addressing these, particularly in terms of public sector governance;
- relatively low business dynamism (61.9, 60th), which is inhibited by insolvency regulation and administrative burdens to initiate a business;

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- limited labour market flexibility (52.1, 111th). For instance, flexibility of wage determination is limited (41.1, 134th) and hiring foreign labour is difficult (40.6, 123rd), the latter often leading to delays where specialised skills are not available locally;
- dependence on export of mineral resources places a heavy dependence on global market prices, often affecting the country's economic outlook and making unemployment reduction efforts challenging.

6.2.3 Social

As a developing economy, South Africa has shown improvement in a number of social indicators, including increasing life expectancy (Figure 31), decreasing mortality rate (Figure 32), increasing per capita income and increasing average disposable income. Although these are all positive, inadequate planning to accommodate these changes inadvertently puts a significant strain on provision of services.

In addition, increasing immigration from other African countries coupled with increasing rural-to-urban migration has also put a significant burden on service provision in urban areas. In terms of waste management specifically, the higher per capita income, increasing average disposable income, changes in lifestyles as access leads to changes in buying behaviour will lead to increasing amount of waste generation per capita in the short-medium term.

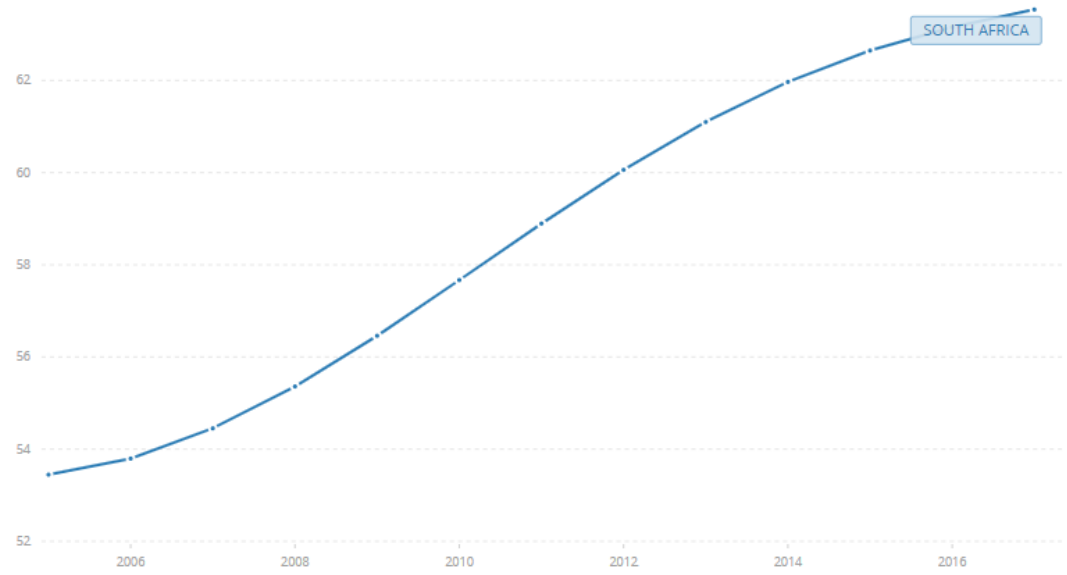

Figure 31: Life expectancy in South Africa (Wolrd Bank, 2020)

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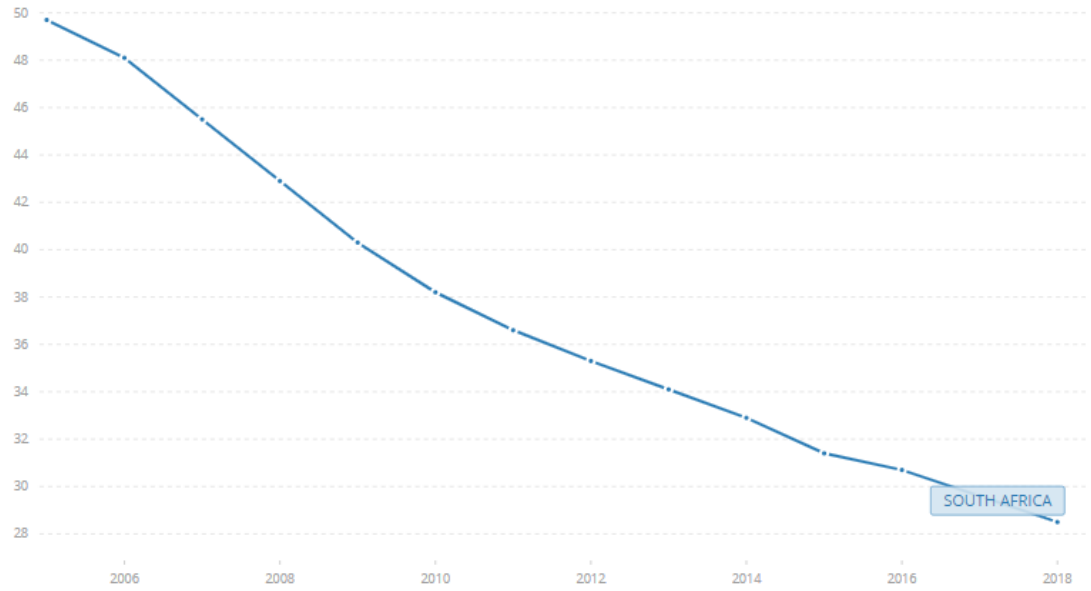

Figure 32: Mortality rate per 1000 live births in South Africa (World Bank, 2020)

Although landfill is still perceived as the cheapest option for waste management, there are a number of factors that are positive for the biogas market in RSA, viz. the need for diversification of energy mix due to deficiencies from Eskom (RSA's primary energy provider); and the general perception around sustainable waste management practices leading job creation. In a country grappling with an unemployment rate of 29% (Statistics South Africa, 2020), the job creation potential associated with the i.e. development and implementation of waste diversion practices makes this a priority area for government support.);

Hence AD is a good technology for implementation in addressing a number of the social issues which RSA is currently facing.

6.2.4 Technological

The development of biogas projects may be designed to meet one or a combination of three pressing needs:

- Energy provision;
- Waste management;
- Sanitation.

In RSA, abundance of lower cost energy sources (primarily coal for electricity) and low cost of landfill have for the most part limited the development of biogas technology as means for energy provision and waste management respectively. In addition, biogas generated as a by-product from sanitation within wastewater treatment works (WWTW) has in most cases not been captured and used further.

The technology itself has been tried and tested more recently in various environments within RSA and has exhibited good outcomes in areas with homogeneous solid based feedstock - primarily in farm/agriculture settings. Many of the installations are under 10 years old and with the exception of one with an installed capacity of 5.5MW, most fall under 1MW (typically 250 – 600kW installed capacity).

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Wastewater treatment works are a second and much larger sector that has historically had the AD installed, but many of the plants are now defunct or operating inefficiently. Due to the age of installations at WWTW, most of them were designed to treat sewerage and flare off the gas, with no energy production.

Research & development activities exist and are growing at tertiary education level institutions and research institutions such as Council for Scientific and Industrial Research (CSIR) and South African National Energy Development Institute (SANEDI). The National Research Foundation (NRF) has funded several postgraduate projects related to various application of biogas technologies, such as at schools, households, industrial wastewater treatment and sites in the agriculture sector. The local knowledge developed in RSA does enhance the prospect of biogas potential.

The technological gaps identified from existing projects currently exist with feedstock preparation particularly within municipal waste. These gaps showed issues that include:

- Poor or lack of source separation;
- And limited skills to design, build and operate within the public sector (most biogas projects in the public sector have outsourced the technology design, construction and in some cases the operation).

6.2.5 Environmental

With increasing awareness of the environmental and climate change impact of coal-based electricity and fossil-fuels, demand for environmentally friendly technologies is increasing. At a higher level, RSA has committed to contributing and achieving the SDGs which the flexibility of biogas technologies allows it to be implemented in energy, water and waste sectors.

A review into the country's development history would provide such insight – focusing on sustainable development. In the early 1990s, RSA's transition came with policies and plans that aimed to realign the governance of matters influencing the environment, the economy and society. To illustrate this new intent, new legislative acts focusing on resource management, conservation and preservation were promulgated (e.g. National Water Act (NWA) (1998) and the National Environmental Management Act (NEMA) (2008)). There is increasing legislation supporting both environmental protection as well as sustainable waste management practices.

Therefore, anaerobic digestion (AD) does mitigate both provision of energy demand and lack of efficient waste management and sanitation by addressing issues such as poor quality effluent entering water bodies and poor air quality as a result of coal fired power plants.

6.3 Market Characterization and Definition

The South African biogas industry is in an infant state, as insights gained from established projects demonstrated that there is a low rate of uptake and general inexperience in designing, constructing and operating of biogas facilities. The drivers that support and assist the South African biogas industry in maturing include economic, environmental, social and legislative factors. The key drivers of increased biogas technology uptake include more the increasing costs of organic waste disposal, both solid and liquid forms, and the demand for energy security and diverse energy mix (GreenCape, 2017).

GreenCape's market intelligence gained through stakeholder engagements showed that there is a large potential and opportunity for biogas project implementation. Much of the research to

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date to understand the viability of biogas in South Africa has been focused on the technical models used to develop biogas projects. However, due to the lack of commercial success a number of biogas projects that have been implemented, site owner and investors' confidence for biogas projects are considered to be low (UNIDO, 2018).

Recent research has focused on understanding the conditions for bankable biogas projects and the factors that will enable appropriate markets to develop biogas projects. Currently, bankable biogas projects with the private sector are site specific and only strong under certain conditions. These include situations where large volumes of feedstock of good quality are available, waste management costs are high, and there are high energy requirements (electric or heat) on-site or in a close and viable proximity (GreenCape, 2017).

The South African biogas industry is small compared to many other countries. It is estimated that there are currently around 500 digesters in RSA, 200 of which are at wastewater treatment works (GreenCape, 2017). However, of the remaining 300 digesters, the majority are small-scale domestic digesters and very few biogas projects within the commercial and industrial (C&I) sector. Most existing C&I biogas projects are embedded within a site for their own usage and, are initiated and driven by the private sector.

6.3.1 Market form

The South African biogas market, in common with other developing countries, is a growing market. There have been some "innovators" and possibly "early adopters" within the biogas market within RSA. The South African biogas market has reached a "tipping point", as shown in Figure 33, where the industry will grow and mature by unlocking the opportunities and barriers that improve the business case viability for biogas projects.

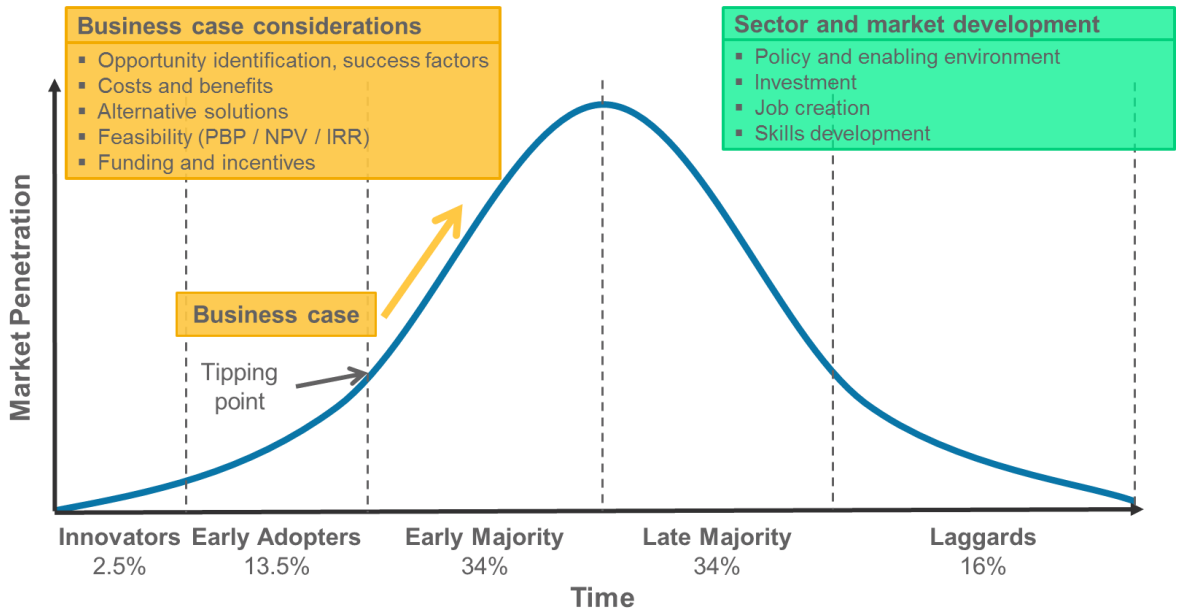

Figure 33: Roger's diffusion of innovation model showing key elements for consideration to build a business case and for market and sector development (GreenCape, 2017)

This market is in its infancy compared to most European markets. Existing barriers are strong financial business case except for very large-scale projects, low cost of competing energy

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sources, until recently no grid access, not permitted to generated above 1MW for own consumption until recently, long-term security in feedstock supply, and significant regulatory hurdles. Despite these challenges, several projects have still been commercialized in RSA.

The drivers for the uptake of biogas in RSA have mainly originated within the private sector. These drivers include several economic and environmental factors (GreenCape, 2017):

- **Waste disposal costs –** These costs are relatively low in RSA but becoming higher for particular types of organic waste such as abattoir and liquid waste which is no longer allowed to be disposed of at landfills.
- **Electricity price increases** – As Eskom continues to struggle to meet the energy demand, electricity prices have consistently increased above inflation, with over a 300% increase since 2004.
- **Increased energy security –** As a result of on-going load shedding, there is an increased need to produce and utilise energy on-site, and biogas (with its ability to be stored) can meet this demand.
- **Lower carbon footprint -** Potentially beneficial for agricultural exports to regions with increasingly environmentally conscious consumers and government policies, such as the European Union[88]. In addition, implementation would reduce pressure from regulators with regards to current environmental legislation violations such as water discharge standards and landfill bans.

6.3.2 Market size and growth

Typically, within RSA, the biogas market is defined within three sub sections, viz. small-scale sector, private sector and public sector. The small-scale sector includes residential and domestic biogas digesters which usually have a power supply capacity of less than 25kW (cooking, lighting and sanitation). The private sector is often referred to as C&I sector and has digesters with a typically capacity ranging between 25kW – 5MW (heating and electricity generation)[89]. GreenCape (2019) indicated ZAR14 billion was spent on municipal water & sanitation services in RSA in 2018. The public (or municipal) sector refers to mainly WWTW and solid waste facilities that incorporate AD technologies. GreenCape (2019) reported that RSA's largest water market is the municipal sector and that ZAR30 billion per annum was invested in water & sanitation infrastructure budget in 2017.

Biogas has the potential to tackle the energy shortage crisis at base load and the consumption of organic waste to produce either bio methane (electricity, heating and cooling, transport fuel) and digestate (liquid & solid). As such, the market for biogas is therefore defined by energy demand as RSA has a significant energy supply shortage. However, with competing energy sources with lower cost, the main driver for biogas has be shown to be waste treatment (solid organic and liquid organic).

[88] Note that a full life cycle analysis (LCA) would need to be done to confirm that the biogas system has a lower carbon footprint to business as usual or a system to which it is to be compared.
[89] Mutungwazi, A., Mukumba, P., & Makaka, G. (2018). Biogas digester types installed in South Africa: A review. Renewable and Sustainable Energy Reviews, 81(October 2017), 172–180. https://doi.org/10.1016/j.rser.2017.07.051

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GreenCape's[90] research indicates that South Africa has 28 C&I biogas projects and five landfill gas (LFG) projects, one of which is part of the Renewable Energy Independent Power Producers Procurement (REIPPP) programme. The 28 C&I biogas projects energy equivalent sizes range from 12.5 kW to 5.5 MW with various feedstock being used. The feedstock breakdown for these projects include five energy crop farms, eight livestock farms, four abattoirs, four water and/or wastewater treatment sites, and seven food and general waste generating sites. All of these 28 C&I projects are private sector projects and either generate electricity and heat on-site usage or use the biogas as a fuel replacement.

The current South African biogas market is considered in a very slow growth phase due to the factors that impact the business case for the projects being project-specific (such as of site requirements, on-site energy demand, financial structuring). UNIDO's waste-to-energy project identified success conditions for bankable biogas projects within RSA as of 31 March 2018. These success conditions were determined through market research and stakeholder engagements. The resulting viable models for biogas projects are summarised in Table 32.

[90] BIOGAS IN SOUTH AFRICA: LESSONS LEARNT, GreenCape Presentation 2020, Yaseen Salie & Tawanda Sango

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Table 32: Current viable biogas project models (UNIDO, 2018)

Size	Small	Medium
Type	Private	Project finance or SPV
ZAR value	***R2 - R20 million	***R20 - R400 million
Typical project size	< 500kW	> 500kW
Key component	****Site/developer collateral	Off-take guarantee (gas and or electricity), Wheeling agreement, Feedstock security with alternatives sources
ZAR/kWh	***R1.4- R1.5/kWh	****R1.4-1.5/kWh; R145-R180/GJ of CNG
Site conditions	Feedstock on-site Offtake on-site Digestate zero cost to project	Portion of feedstock or offtake on-site Need digestate management process (net zero financial impact)
Site options	Abattoir, feedlots, chicken farms, malls, piggeries, food processing, fruit, and vegetable processing	Mega farm (single supply), centralised farm (multiple feedstock supply)
Revenue model	Electricity and heat and /or gas and offset disposal fees	Premium on electricity sales (banking on green energy premium or Eskom rising above fixed escalation), Gas sales - CNG projects > 1.5MW, Combination of on-site use, offset disposal fees and heat use
Financing	D:E - 60:40 IRR - 18-25% Debt tenor - 7- 10 years Rate - 10.5- 12% Fund 5 years with options to refinance residual value (Debt requires min tail of 3 years) DSCR - 1.3	D:E - 70:30 IRR - 18-25% Debt tenor - 12 years Debt requires tail of 3 years DSCR - 1.3, Debt reserve account 6 months (interest and capital)
Cover	Site owner/developer balance sheet strength (different revenue stream options), land collateral	• Cession rights, buy back options • Independent assessment for feedstock/design • PR guarantees of plant • Continuous feedstock analysis (visual or test) • Insurance options
Key considerations	No revenue considered during the first 6-12-month commissioning	No revenue considered during 6- 12-month commissioning 50% buffer on feedstock supply 1 main feedstock supplier with 2 secondary options

***An indicative CAPEX cost for a biogas plant is R40 million/MW, provided by industry experts.
****A developer could finance a biogas plant through their own balance sheet, secured through an offtake agreement with the site owner. This could be included as developer collateral.
*****An indicative value provided by industry experts.
NOTE: A project can still be financially viable if values above or below is quoted, but it requires a justification for the values quoted.
D:E – debt to equity ratio, IRR – internal rate of return, DSCR – debt service cover ratio,
PR – performance ratio

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In addition, a study conducted by EcoMetrix Africa (Pty) Ltd in 2016[91] is conservative as they looked at the biogas potential from major feedstock. In the study they concluded that South Africa had biogas production potential around 3 million Nm^3 per day.

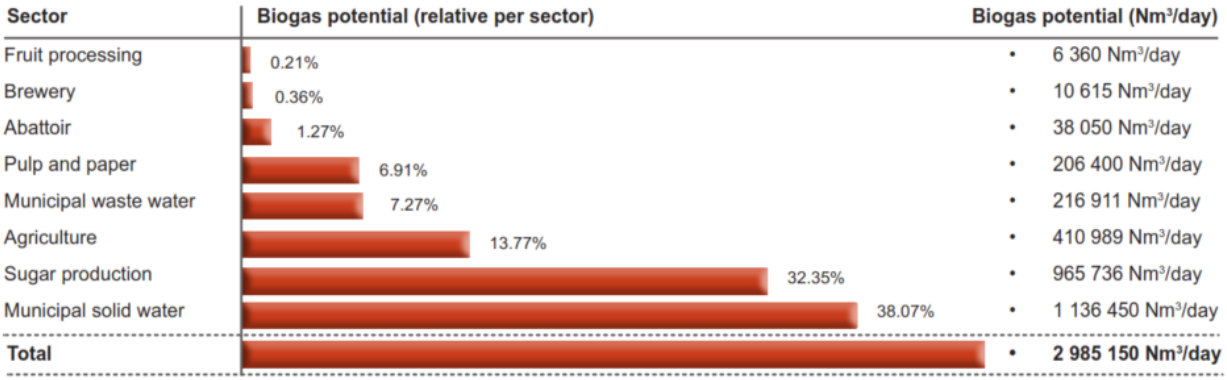

Figure 34: Biogas potential relative to sector (Ecometrix Africa, 2016)

Figure 34 suggests a potential for 700MW installed capacity (1.58% of existing installed capacity within RSA) using 1 Nm3 of biogas at 60% methane is 20 MJ or 5.6 kWh. However, through engaging with existing plant owners and developers, the market focus has been on agricultural and agri-processing residues due to the difficulties faced when engaging with municipalities with regards to municipal solid water and municipal wastewater. The sugar production sector has already invested in biofuel production from its residues.

Although the biogas market within RSA is considered growing (albeit slowly), there exist potential for the market increased growth and acceleration due to the current energy crisis, the limited landfill airspace within the metropolitan areas of RSA and liquid and organic waste bans due to resulting contamination of groundwater. RSA has begun planning waste diversion strategies on a national level through the Operation Waste Phakisa programme[92] and proactive provinces already promulgated organic waste landfill bans over the next 5-10 years. The president of RSA's recent state of nation address highlighted the country's plan for allowing municipalities and large energy users to purchase electricity from independent power producers (IPPs) within the next 12-18 months.

6.3.3 Market share

There is limited data with regards to the market which biogas holds within the waste treatment and energy mix markets due to the small and nascent nature of the biogas market. However, based on market intelligence gained through stakeholder engagements the total market size

[91] FACILITATION OF LARGE-SCALE UPTAKE OF ALTERNATIVE TRANSPORT FUELS IN SOUTH AFRICA – THE CASE FOR BIOGAS, commissioned by the Department of Environmental Affairs (DEA) in collaboration with the South African National Energy Development Institute (SANEDI) funded by the UK Department for International Development (DFID) through the Strategic Climate Policy Fund (SCPF) Programme

[92] Phakisa means "hurry up" in Sesotho. Operation Waste Phakisa is an initiative by national government to fast track the implementation of solutions on critical development issues under the National Development Plan (GreenCape, 2019).

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biogas projects previously identified is 43,800 kW of which 36.3% (15,886 kW) is in the C&I market.

At utility scale (i.e. above 10 MW), the REIPPPP has only awarded a single landfill gas project out of the 92 IPP projects awarded across the various technologies: solar PV (49%), oshore wind (37%), CSP (8%), hydro (3%), biomass (2%) and landfill gas (1%). ENER-G Systems was the project developer, owner, operate and installer of the country's first largest gas-to-power 18 MW project, spread across the five Johannesburg landfill gas sites as broken down in Table 33. The landfill sites are owned by the City Council of Johannesburg and share revenue with Eskom over the 20 years. Biogas market share growth and penetration has encountered barriers due to lower cost of electricity from other energy sources such as fossil fuels; lower efficiency of biogas compared to conventional fuels (Mukumba et al., 2016); lack of local technology providers introduces high capital cost implications for importing the technology and lack of awareness/skills from the sector.

Table 33: Landfill Gas-to-Energy project sites in Johannesburg

Landfill gas site	Expected waste (t/year)	Planned capacity (MW)
Robinson Deep	400 000	5.5
Marie Louise	530 000	6
Linbro Park	360 000	3.3
Ennerdale	90 000	0.5
Goud Koppies	270 000	3.3
		18

6.4 Customers and clients

The components for the biogas value chain within RSA can be seen depicted in Figure 35.

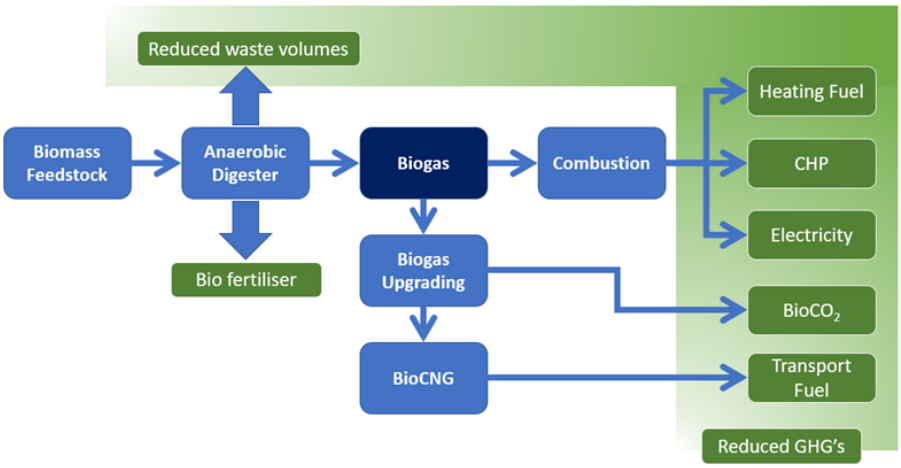

Figure 35: Components of biogas value chain[93]

[93] Overview of biogas site value chain depicted by Selectra (Pty) Ltd

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The customer and client value chain relationship for biogas projects and its components has been summarised in Table 34. The market segment dictates the feedstock generator and / or handlers (customers) as well as the potential client off takers with majority of proposed projects.[94]

Table 34: Biogas market segment and value chain (Customers and clients)

WASTE MANAGEMENT PHASES	Market Segment	Potential Feedstock	Potential Output
WASTE GENERATORS (CUSTOMERS)	1. Mining companies	Wastewater Treatment Works (WWTWs) sourced from their local communities	
	2. Metropolitan Municipalities/Local Municipalities	Municipal solid waste and WWTWs,	
	3. Fast Moving Consumer Goods, pharmaceutical companies	Organic solid waste, organic rich effluents	
	4. Agro-processors	Agricultural residues (also wastewater)	
WASTE HANDLERS (CUSTOMERS)	1. Private sector 2. Metropolitan Municipalities/Local Municipalities, WastePreneurs (small, micro, medium enterprises new to waste space) 3. Waste shredders	Organic waste from public and private sectors (dewatered sludge – considered liquid waste)	
UTILITY OFF-TAKERS (CLIENTS)	1. Local communities 2. Farmers 3. Mining companies 4. Manufacturing industries 5. Private sector 6. Transportation		Electricity, Heat, Bio-methane, compost (from processed sludge?)

6.4.1 Customer potential – Waste generators and handlers:

In 2017, South Africa generated approximately 108 million tons of solid waste, made up of 56 million tonnes of general waste and 52 million tonnes of hazardous waste. For general waste, 65.2% disposed to landfill, 34.5% was recycled and 0.1% treated.[95.] Disposal is the least fa-

[94] Based on stakeholder engagement with project developers
[95] Department of Environmental Affairs. (2018). South Africa State of Waste Report 2018 (Vol. 10, Issue 2)

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voured option within the waste management framework due to harmful effects to the environment and atmosphere. Domestic, commercial, business, and industrial waste in urban areas is disposed into landfill sites. Therefore, electricity generated from landfill sites can be distributed to neighbouring communities with minimal transmission losses.

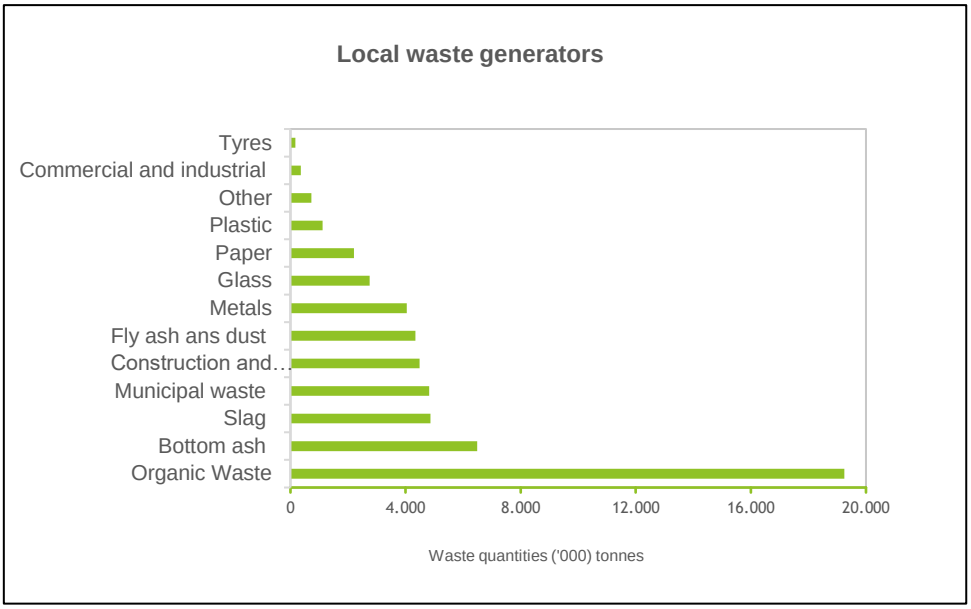

Figure 36: General waste generators (Department of Environmental Affairs, 2018)

An example of the customer potential within the LFG space can be seen in the LFG projects implemented in Gauteng. Gauteng's City of Johannesburg municipality initiated a carbon reduction project aimed at tackling excess methane emissions released from landfill sites; to control the air quality thresholds and convert the landfill gas to electricity for selling to Eskom through the REIPPPP. ENER-G Systems was rewarded the tender at an indexed 94 c/kWh to design, build, own and operate the five landfill sites. Three sites will be connected to the Eskom grid and two to the City Power's grid. ENER-G Systems is the only landfill developer with these REIPPPP projects.

City Power were prepared to purchase biogas electricity at a rate higher than the MEGAFLEX tariff, however ENER-G instead applied for REIPPP to sell power through the REIPPPP auction programme in which they received a better tariff. In order to fully assess the sector risks, we need to understand the tariff prices between Eskom, and the municipalities, and then municipalities to local consumers. The project indicators for the LFG to electricity project can be seen in Table 35.

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Table 35: Landfill Gas to Electricity project sites indicators

Projects Indicators	
Powered mid income households	25 000
Average output per MW installed	8 000 MWh/MW installed per year
Capacity factor	92%
Capital cost per MW installed	ZAR13.4 million
Operational cost per MW installed	ZAR 333/MW installed per month
Operational costs per MWh	ZAR 330 per MWh

6.4.2 Client potential – Energy off takers

Eskom, a state-owned electricity utility generates and sells over 90% of the electricity in South Africa; and supplies over 45% of the electricity used in Africa. The utility operates 16 power stations with total installed capacity of 44 172 MW, that generated 218 319 GWh during 2019 from the different sources of electricity (Eskom, 2019). Currently IPPs only sell electricity to Eskom.

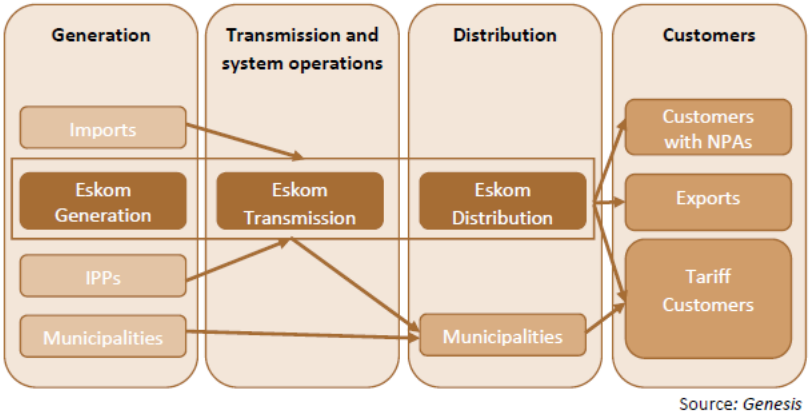

Figure 37: South Africa Electricity Supply Industry framework (Department of Public Enterprises, 2019)

Figure 37 shows the structure of the generation, distribution, and transmission units. It accurately illustrates the relationships among Eskom's units and other relevant parties such as customers with Negotiated Pricing Agreements (NPAs),[96] IPPs, municipalities, exports, and tariff customers. Additional electricity produced by stakeholders other than Eskom and the uptake thereof is guided by the Integrated Resource Plan and Renewable Energy Independent Power Procurement Producer Programme (REIPPPP).

6.4.2.1 Integrated Resource Plan

The Integrated Resource Plan (IRP) 2010 - 2030 is a long-term electricity generation plan that forecasts the country's electricity demand and procures energy sources to meet this demand

[96] Municipalities and businesses that have a high energy usage demand often negotiate a special pricing with energy supplier and/or regulators.

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based on the least cost tariff price. The plan allocates megawatts per technology and the implementation schedule that will supply and meet the country's forecasted energy demand. This process is promulgated by the Department of Mineral Resources and Energy (DMRE) and regulated by the National Energy Regulator of South Africa (NERSA) through Section 34(1)(a) of the Electricity Regulation Act, no 4 of 2006 (ERA).

6.4.2.2 Renewable Energy Independent Power Procurement Producer Programme

Renewable Energy Independent Power Procurement Producer Programme (REIPPPP) auction programme was created to support and achieve the country's target to generate 42% of its electricity from renewable energy technology sources by 2030 as variable source to supplement the baseload energy sources. In 2010, DMRE, National Treasury (NT) and Development Bank of Southern Africa (DBSA) established the Independent Power Producers Procurement Office (IPPPO) to delegate priority to the country's power generation capacity crisis. The IPPPO manages the REIPPPP auction programme where private sector independent power producers (IPPs) competitively bid to generate and source power from various renewable energy technologies such as solar PV, onshore wind, hydro, landfill gas and biomass.

An overview of the IPPPO procurement process and timelines can be seen in Figure 38 below.

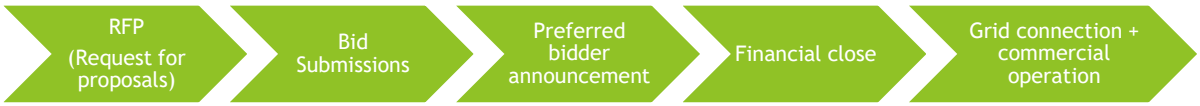

Figure 38: IPPO Procurement process with an average 1.8 years lead time

An overview of renewable energy technology investment costs and average tariff offered can be seen in Table 36 and Table 37. The biomass technology highlighted in Table 37 refers lignocellulosic biomass, i.e. woody material.

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Table 36: Renewable energy technology investment costs

Technology	Procured (MW)	Total project spend (ZAR billion)	Avg. investment per MW procured (Million ZAR/MW)
Onshore Wind	3 388	80.6	24.0
Solar PV	2 292	65.9	28.0
CSP	600	58.4	97.0
Landfill gas	13	0.3	21.0
Hydro	19	1.1	59.0
Biomass	42	3.4	66.0

Table 37: Average technology tariffs offered, REIPPPP projects

Average technology tariff	R/kWh
Onshore wind	1.13
Solar PV	2.15
CSP	2.96
Hydro	1.55
Biomass	1.28
Landfill	1.88

6.4.2.3 Government guarantees

The IPPs compete on price tariff (70%) to be charged to Eskom and economic development contributions (30%) to local communities within 50km radius from project location. Preferred bidders sell power to single buyer Eskom; the national power utility over the 20-year PPA. National Treasury, Department of Public Enterprises and NERSA are the co-signatories to the Government Support Framework Agreement (GSFA) that underpins the Implementation Agreement (IA) between Eskom and national government; should Eskom defaults on its PPA payments to the IPPs. The IRP 2019 provides a breakdown of government guarantees with regards to renewable energy technology provisions (Table 38).

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Table 38: IRP 2019 renewable energy technology provisions

Technology	IRP 2019 Provisions by 2030 (MW)
Coal	1 500
Nuclear	1 860
Hydro	2 500
Storage	0
PV	6 000
Wind	14 400
CSP	0
GAS/Diesel	3 000
Other[97]	4 000

6.4.3 Biogas technology components suppliers

Local biogas technology companies remanufacture used technology to meet the original manufacturer standards, because the technology undergoes degradation due to the corrosive nature of the landfill gases, quality of the gases (poor gases damage the infrastructure more rapidly) and abrasive post-combustion residue. Therefore, local companies will opt to provide service exchange units for energy efficiency and maintenance purposes. Some of the most commonly manufactured parts include the valve-train components, connecting rods, crankshafts and cylinder blocks[98].

We observed that local technology components providers are predominantly smaller subsidiaries / agents to companies headquartered in European countries. In addition, local biogas technology companies act as the sales driver and technology distributors for the internationally head quartered companies. Our observation leads us to conclude that the biogas industry in South Africa is very immature, and it only makes a feasible business case to coordinate sales locally, rather than launching an entire manufacturing facility to a market with passive appetite to biogas technology.

6.5 Industry attractiveness (Porter's 5 Forces analysis)

A Porter's 5 forces analysis was completed to determine industry attractiveness of the South African biogas market for foreign and local stakeholders within the value chain.

6.5.1 Threat of New Entrants

The factors considered a threat for new entrants, who may include DiBiCoo companies, with regards to market accessibility wishing to enter the local market are listed below.

6.5.1.1 Barriers to entry

[97] The other technology category includes distributed generation, cogeneration, biomass, and landfill gas

[98] Engineering, M. A. (2019). Local remanufacture of gas engine components saves time, money. Metric Automative Engineering. https://www.metricauto.co.a/local-remanufacture-of-gas-engine-components-saves-time-money/

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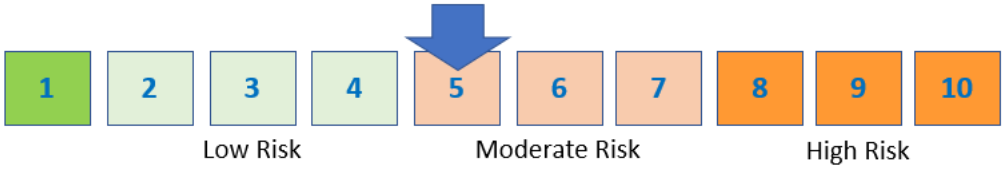
Economic & Political Outline

RSA is currently conducting an inquiry into allegations into state capture[99] as a means for dealing with and cleaning up a legacy of corruption and graft in both government and private sectors while Government's policies have not addressed the main structural problems such as high government debt at 59.9% of GDP with a debt service cost approaching 14% of revenues. Furthermore, public debt is expected to increase to 64.2% in 2020 and 67.9% in 2021. The ratings agencies have pictured South Africa in a downgrade cycle and South Africa could revert to junk status in upcoming rounds with political instability and associated unrest having created an unstable environment. External threats include arduous US trade policies and more recently the threat of the corona virus and the reduced local buying power with a declining Rand / Euro exchange rate will negatively impact imported goods.

In addition, the RSA renewable energy market already has high capital requirements and sunk costs related to market research, environmental impact assessments and non-refundable bid development costs estimated between R 10 to R30 million per bid. These costs have increased per bid window due to increased competitiveness observed through the programme's over-subscriptions in the bid window 3 to 4. The industry barriers encountered by new entrants are industry specific; however, exaggerated by the unsubstantiated regulatory delays enhanced the nascent renewable energy industry's perceived risk.



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

6.5.1.2 Institutional & Market Factors

These factors for South African biogas projects are summarised in Table 39.

[99] https://sastatecapture.org.za/

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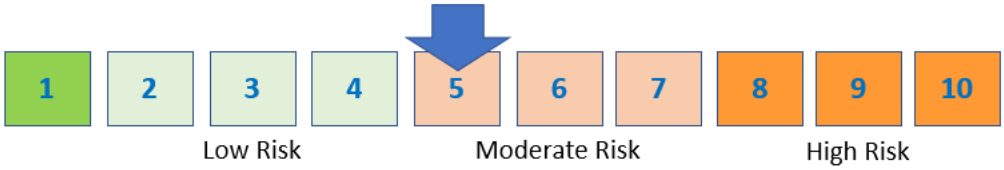
Table 39: Institutional and market factors identified

Factor	Remarks
Cheap Electricity	Current electricity supply is coal-based without costing in externalities. Competition from other renewables which yield lower cost electricity.
Limited subsidies & incentives	Initially a major factor in developing the European biogas industry.
Low-value waste	Government policy is to implement the "polluter pays principle" by increasing landfill gate fees, however fees will remain low to prevent illegal dumping. Current municipal tip fees range between free and R500 per tonne for general waste.
High capital cost	The cost of AD systems (including allied equipment) is beyond the reach of most farmers and small-medium companies.
High development cost	The cost of getting a project to Financial Close is between 12-18% of the total project. A large proportion of this cost is committed without any guarantees.
Long development time	Results in high holding costs and project fatigue.
Limited & high cost of funds	There are few local companies who readably finance biogas projects. Expected IRR's are in the 25-30% range.
Bureaucratic roadblocks	Including; - Legislative process not streamlined - local, municipal, and national legislation not aligned as is specific legislation such as The Waste Act, OSH Act, prescripts by the energy regulator (NERSA) and others. - The Municipal Finance Management Act – ordinarily municipalities cannot contract in excess of 3 years without specific treasury approval. - Working with municipalities – lack of skills and a culture of excellence including willingness of individuals to conduct straight deals.
History of failed or less than successful systems	We have many failed or less than successful projects as references. - Most of the digesters at municipal wastewater treatment plants are hardly working. - Commercial examples include; o Kanhym Piggery – technology & waste stream analysis o Riverside Piggeries – turbines not supported locally as agent emigrated o Elgin – initially did not operate as envisaged design capacity due to overstatement of waste yields & plant capability o New Horizons plant in Cape Town – the IDC has recently issued an RFP for a local empowered company to take over the project.



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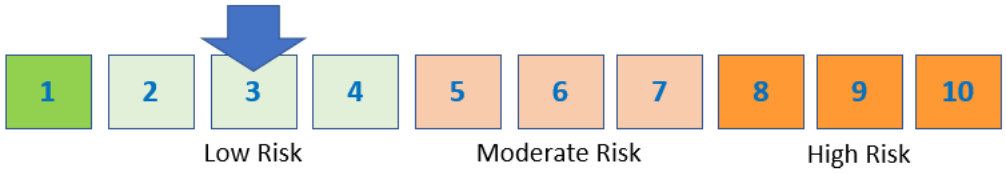
6.5.1.3 Economies of scale

Local project developers are attracted to the development of larger projects due to better ROIs and an insignificant development cost and time difference between small, medium and large projects. This has resulted in project developers focusing on niche markets in which their expertise allows them to excel. Examples of these can be seen in the abattoir, breweries and poultry sectors.

One project developer has developed several abattoir projects, which have allowed them to amortise market development costs and "school fees" for future projects thus giving them an advantage in the market. Similarly, another project developer has partnered with one of RSA's largest brewery businesses to supply a standard solution to all their breweries within South Africa.

Most industrial applications require bespoke solutions due to the high degree of concentration. For example, South Africa has only two large breweries and many small craft breweries. Installing imported biogas systems at the craft breweries may not be feasible and if feasible, the business case could be prohibitive.

The chicken broiler and layer industries are potential growth markets that could benefit from economies of scale, as the industry is served by many Independent contract farmers. However, a demonstration site will be necessary to develop this market segment.



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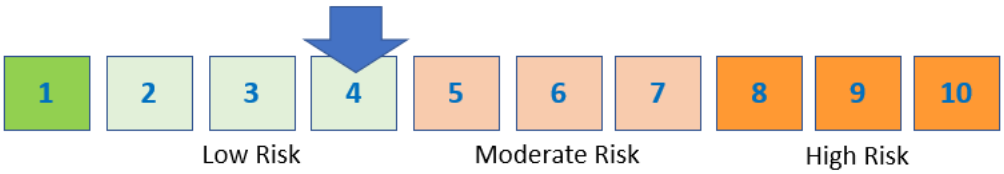
6.5.1.4 Brand loyalty

The local market is served by solution providers who have reference projects to use in marketing. However, in most cases, the local companies have international technology partners who support their market activities and underwrite their technology. New market entrants are unlikely to do well without the support of a reputable South African partner and finding these new partners may be difficult.



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6.5.1.5 Capital requirements

The long development lead time, high RSA Rand cost of equipment, and long project payback is a major deterrent for new market entrants. The ideal timeline for biogas project development in RSA is highlighted in Figure 39 and Table 40 below.

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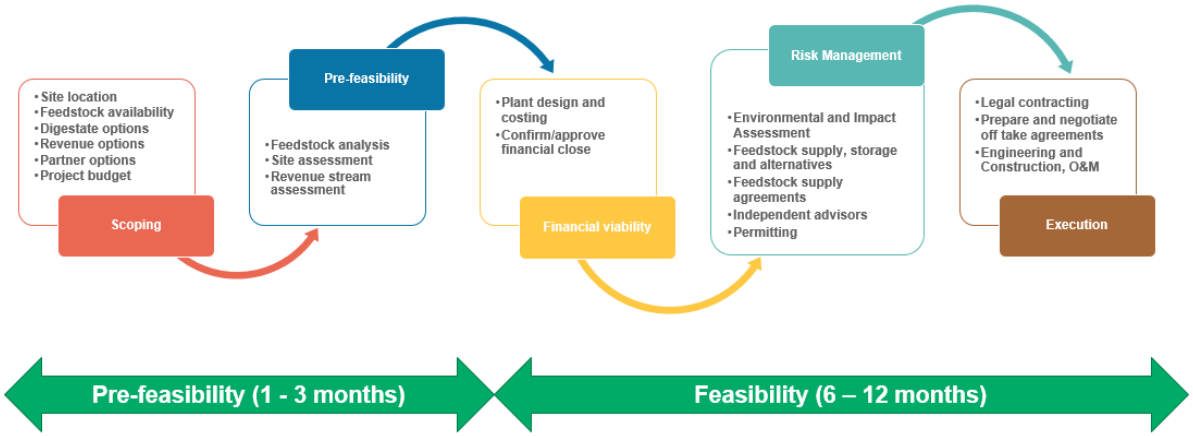

Figure 39: The overview feasibility of a biogas project development[100]

Figure 39 outlines the pre-feasibility and feasibility steps taken before a project can process to the project development phase as outlined in Table 40.

Table 40: Biogas project development guidelines[101]

Project development phase	Duration
Financial close	**1 - 6 months**
Commitment to capital and build	
Conclusion of contracts (offtake, EPC, feedstock, O&M, digestate, SPV)	
Construction	**6 - 12 months**
Lead contractor management	
Owners engineer, lenders technical advisor	
Commissioning	**6 -12 months**
6 - 12 months commissioning	
Operations and maintenance	**24 months**
Two-year EPC management and training – performance guarantee	

Typically, it can take 3-5 years to develop a biogas project, however existing projects that have been developed show that the development lead time are longer than the ideal timelines mostly as a result of environmental permitting and allied licensing (it takes 12-18 months to conduct an EIA). In addition, funding and structuring is challenging as working with institutions and development banks is time consuming.

The project development timeline for the Bronkhorstspruit Biogas Project, South Africa's first commercial AD project, is depicted below.

[100] GreenCape. (2018). Biogas project development life cycle.
[101] GreenCape. (2018). Biogas project development life cycle.

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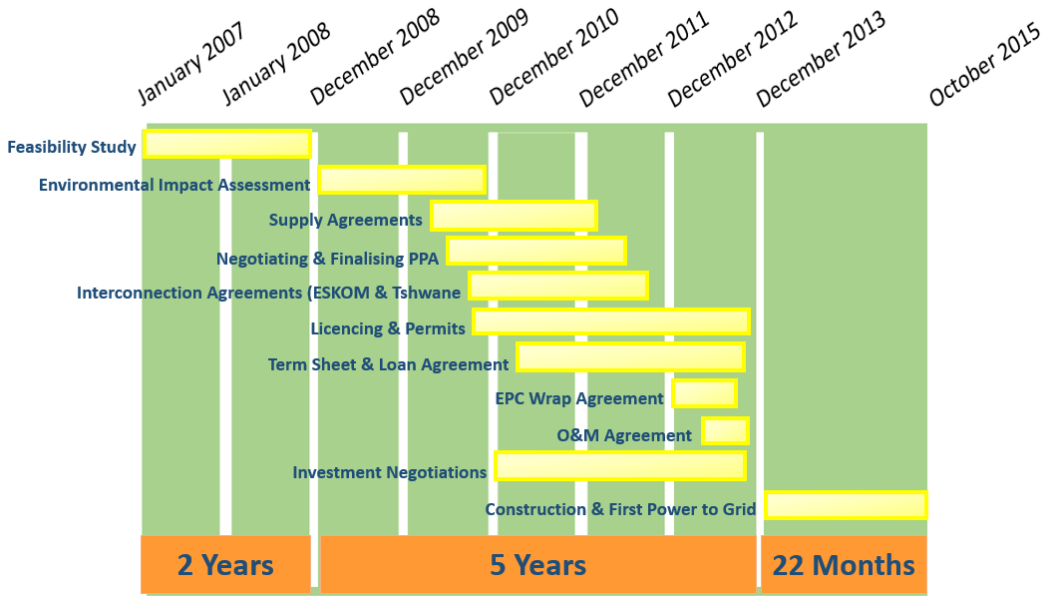

Figure 40: Bronkhorstspruit Biogas Project development timeline[102]

Bio2Watt's project development timeline has been reduced after gaining experience from doing the Bronkhorstspruit Biogas Project as shown below.

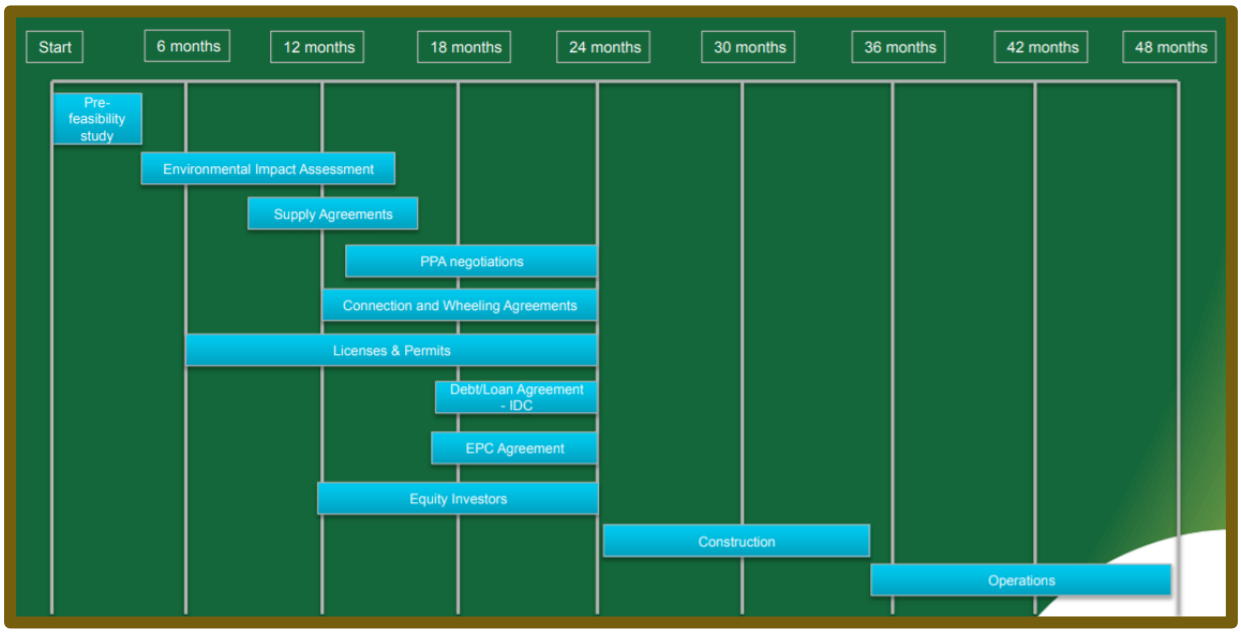

Figure 41: Updated biogas project development timeline[103]

The global biogas equipment suppliers commonly partner with local sales agents; for business development and cost-effective market entry purposes. These agents work for/with major foreign technology suppliers and this has massive cost implications and is affected by the foreign

[102] Adapted from Presentation IMPLEMENTING A BIOGAS PROJECT IN SOUTH AFRICA: LESSONS LEARNT, Bio2Watt, January 2014

[103] Presentation BIOGAS PROJECT: LARGE SCALE MIXED WASTE AD SYSTEM, Bio2Watt, February 2015

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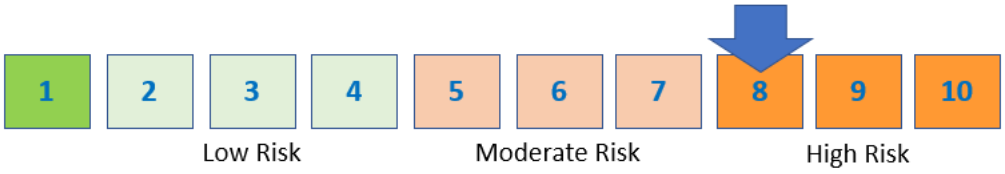
exchange fluctuations. The cost of the equipment is informed by the design of the digester, type of energy infrastructure and the size of the infrastructure and prone to foreign exchange.

The cost of large-size biogas plants is around Euro3.5m per MWe[104] or R70m at current exchange rate (€1 = R20). A rate of R1.25/kWh is required just to recover the capital cost over 15 years. This rate, which is significantly above the utility rate excludes OPEX and generation costs.

Typically, the biogas project payback period within the SA market ranges between 5 – 8 years. The payback period is the time taken for a project's net cash flows to recover project's initial investment. Commonly, biogas projects report payback period of 7.62 years deems the biogas project economically unviable. However, the discounted payback period where the cash flows are firstly discounted before the payback period is calculated, deems biogas project economically viable. Discounted payback period is superior to payback period; and subsequently we regard biogas project as suggested.



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

6.5.1.6 Government policies

Current government policies are viewed as a major barrier for new market entrants. AltGen Consulting of 105 list 29 policies, legislature and framework upholding the green economy in RSA.

The basic requirements to develop a biogas project[106] are listed in the columns below:

Table 41: Biogas project legislative requirements breakdown

1. Energy and Environmental Policies ○ Renewable energy policies ○ Climate change policies ○ Agriculture policies ○ Waste policies ○ Natural gas policies **2. Socio / Political** ○ Government procurement policies ○ Broad-Based Black Economic Empowerment (BBBEE) ○ Employment Equity	**3. Economic and Financial Policies** ○ Feed-in tariffs ○ Grants / soft loans ○ Exchange control **4. Research and Development** ○ Coordinated (large-scale) R&D programmes **5. Other Support Schemes** ○ Long-term government planning documents ○ Partnerships between the public and private sectors
6. National Environmental Management Act (NEMA) Act 107 of 1998	

[104] Based on aggregated pricing obtained through stakeholder engagements with existing project developers and owners.

[105] Biogas Industry In South Africa: An Assessment Of The Skills Need And Estimation Of The Job Potential, AltGen Consulting for Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and South African-German Energy Programme (SAGEN), https://www.sagen.org.za/publications/19-assessment-of-skills-needs-and-estimation-of-the-job-potential-for-the-biogas-industry-in-south-africa/file

[106] Eddie Cook, SABIA

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- Overarching environmental legislation which provides for Special Environmental Management Acts (SEMA's)
- Listed activities with thresholds which determine if authorisation is required
- Enabling legislation for EMPr, Audits, Appeals
- National Environmental Management Waste Act (NEM: WA) – Waste Management License
- National Environmental Management: Air Quality Act (NEM: AQA) – Atmospheric Emissions License (currently being relaxed)
- National Environmental Management: Biodiversity Act (NEM:BA) - Permit
- National Environmental Management: Protected Areas Act (NEM: PAA) – Environmental Authorisation

7. National Authority

- Waste Management License (hazardous waste)
- Environmental Authorisation for generation of electricity
- Water Use License (digestate, irrigation)
- Gas Registration
- Heritage

8. Provincial Authority

- Waste Management License (general waste)
- Environmental Authorisation
- Heritage
- Local Authority
- Air Emissions License (District Municipality)
- Planning permissions

9. Other legislation to comply with

- National Water Act
- National Heritage Resources Act
- Agriculture (SALA, CARA, Fertiliser Act)
- Planning (SPLUMA)
- Civil Aviation

10. Minimum Requirements

- National Gas Act
- Municipal planning laws
- Building regulations
- Engineering and design
- Site and zoning approvals
- Fire and safety approvals
- Environmental and waste approvals
- Installation and commissioning approvals
- Operational and trading approvals
- Recertification and periodic inspections

Progress has been made from government departments: Department of Mineral Resources and Energy (DMRE) and the Department of Environment, Forestry and Fisheries (DEFF) to support the industry. Within the government sector, DMRE is the largest most influential core stakeholder because they have direct authority over anything related to energy development. The DMRE is the primary authority for policy and legislation in the energy sector within South Africa. They have the authority to declare the conditions to generate, distribute and trade electricity. The sheer number of Acts and policies to comply with can act as a disincentive to new market entrants.

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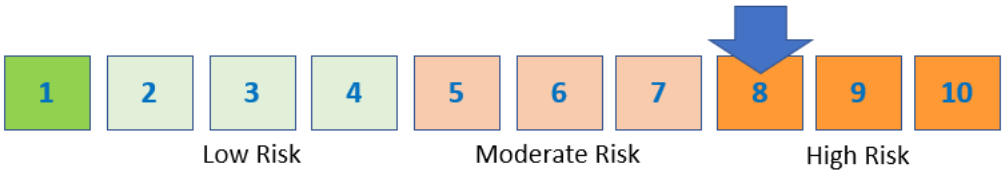

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6.5.2 Bargaining Power of Buyers

There is a large degree of specialisation amongst the biogas project developers within RSA. A non-exhausted list with a few examples of active stakeholders and the feedstock used within their projects developed within RSA can be found below:

- Agama – rural & household
- Bio2Watt – cattle manure
- Fountain Green Energy – landfill gas
- Green Create – poultry abattoir/processing
- Ibert - livestock abattoirs
- Talbot & Talbot – brewery applications
- Veolia – wastewater treatment

This demonstrates that there is broad spectrum of opportunities for biogas project development within RSA.

6.5.2.1 Number of customers

In the past there were a limited number of local companies developing a limited number of biogas projects. In Appendix 1 we list the major solution providers (developers & technology providers) and their projects. The list contains 19 solution providers across 46 projects / installations as shown in Table 42.

Table 42: Number of projects in relation to number of solution providers

Project Category (number of projects completed)	Solution Provider by Project Category	Total Projects
1	10	10
2	3	6
3	2	6
4	2	8
5+	2	10
	19 Solution Providers	46 Total Project Analysed

Agama and small biogas projects have been excluded in the above analysis as this category is unlikely to be a customer for DiBiCoo.

The above table shows that most solution providers have completed only one project – 10 projects by 10 solution providers. Three solution providers have each completed two projects; two solution providers have each completed three and four projects. The maximum number of projects completed by a solution provider is 10 projects.

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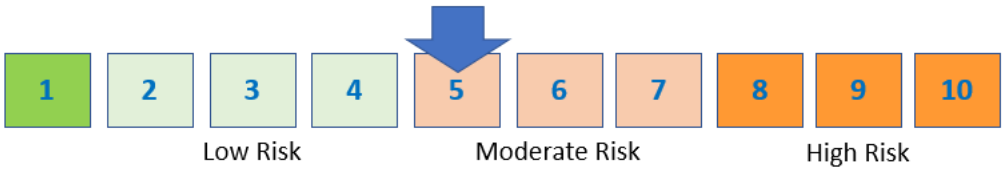
Our market research indicates that there are more than 45 companies in RSA promoting AD Biogas technologies within the country, most of which are project developers / engineering companies and specialist equipment suppliers.

6.5.2.2 Size of each customer order

Obtaining project costs and making comparisons is not easy and fraught with danger as developers do not readily share this information. We estimate the cost range for new builds sized between 12.5kW to 4,6MW to be ZAR40 million per MW. But this is highly dependent on the feedstock and other processing requirements. The following project costs (Table 43) have been disclosed through previous desktop studies conducted.

Table 43: Project costs breakdown

Project	Cost	Details
Zandam	R8.5m	500m^3, 75kWe, 105kWt
Uilenkraal	R11m	7,000m^3, 500kVA
New Horizons	R400m	760Nm^3/h BioCNG 18 t/d food grade CO2
Elgin	R20m	500kW



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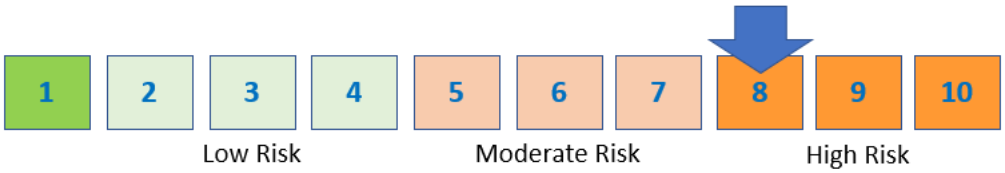
6.5.2.3 Buyers costs

It takes between 3-5 years to develop a biogas project from start of initial project scoping to financial close in RSA. The long lead time item is the Environmental Impact Assessment which takes between 12-18 months to complete. The total cost of developing a biogas project typically ranges between R2m to R7m with about half at risk if the project is not completed.



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6.5.3 Threat of Substitute Products

There are very definite applications where biogas has an opportunity to sustainable substitute other technologies / fuels.

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6.5.3.1 Number of substitute products

The substitute products are relative to the primary and secondary functions of the biogas system. A list of substitute products, product market competitors and motivation for biogas products can be seen in Table 44.

Table 44: Products which biogas projects may substitute

Product / Service	Market competitor	Motivation for biogas
Transportation fuel	petrol, diesel and lately electric	Lower cost green fuel, good for the environment.
Wastewater treatment	aerobic digestion vs anaerobic digestion	Aerobic digestion is energy intensive, while AD yields energy-rich biogas while reducing sludge volumes.
Electricity production	coal, diesel power generation	Reduction in GHG emissions, cheaper than diesel power generation.
Renewable electricity	wind, solar, hydrogen fuel cells and hydro	Only viable in special circumstances
Solid waste treatment	composting and thermal treatments	Sustainable way to treat organics

Current commodity prices are very supportive of using biogas in transport applications as market intelligence indicates that BioCNG can be sold for R140 – R180/GJ (UNIDO, 2018). At this price BioCNG is an economic substitute for paraffin, LPG, diesel and natural gas used in heating applications as shown in Table 45 and can be considered almost comparable with natural gas in terms of pricing.

Table 45: Commodity price comparison[107]

Commodity	Price	
Parafin	R233	R/GJ
LPG	R396	R/GJ
Electricity	R214	R/GJ
Natural gas	R160	R/GJ
Diesel	R349	R/GJ
Solid Fuel	R28	R/GJ
Charcoal	R120	R/GJ
Coal	R31	R/GJ

Electricity generated from biogas cannot compete on price only with regards to utility scale electricity produced from coal as well as other renewable energies. The cost of biogas electricity is in the region of R 1.40-R1.50 per kWh with free issue of feedstock. This is about twice the IPP tariff (Bid Window 4, expedited) for Solar PV (R 0.62) and Wind (R 0.62).

[107] Calculations completed and compiled by Selectra (Pty) Ltd

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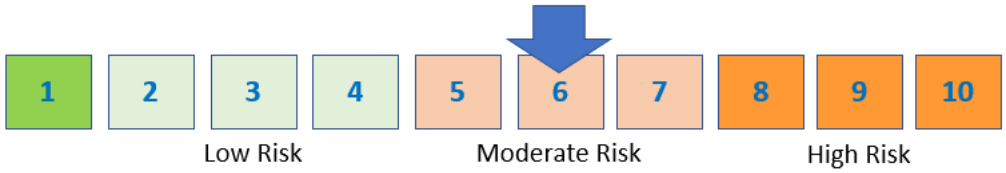

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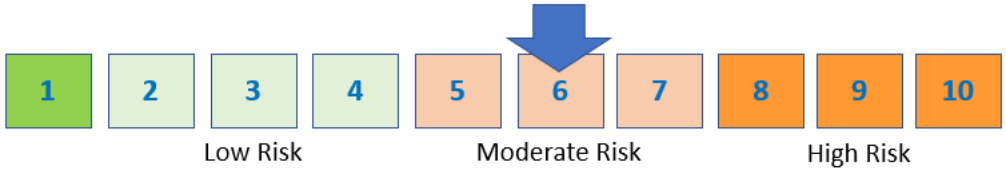
6.5.3.2 Buyer propensity to substitute

Buyers normally have a choice of technologies and suppliers of these technologies. However, there are several failed or underperforming biogas projects in RSA. Buyers are therefore less likely to shop around once a track record and strong relationship has been formed.

In addition, in the utility scale renewable energy landscape biogas is one of the under allocated clean energy sources within the national energy mix plan, IRP; with only 0.5% procured clean energy technology providers; as shown in Table 46. The renewable energy industry breakdown does not currently favour biogas. Therefore, lack of biogas regulatory framework to catalyse the growth of the industry significantly limits the possibility for technology buyers to substitute. In addition, this industry is highly specialised and biogas technology providers for specific end user are limited.

Table 46: The REIPPPP breakdown of the renewable energy sources

Pro-grammes	Large IPP			Small Scale IPP		
Technology	**Procured**	**Opera-tional**	**Deter-mined**	**Procured**	**Opera-tional**	**Determined**
Wind	3 357	1 980	6 360	9	0	400
Solar PV	2 292	1 474	6 225	80		
Concen-trated solar power	600	500	1 200	0		
Landfill gas	13	22	540	0		
Small hydro	19			0		
Biomass	42			10		
Total	**6 323**	**3 976**	**14 325**	**99**	**0**	**400**



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6.5.3.3 Relative price performance of substitute

In section 6.5.3.1, the relative fuel costs have been noted. CSIR demonstrates (Figure 42) that biogas electricity is on a par with mid-merit coal (a power plant that adjusts its power output as demand for electricity fluctuates throughout the day).

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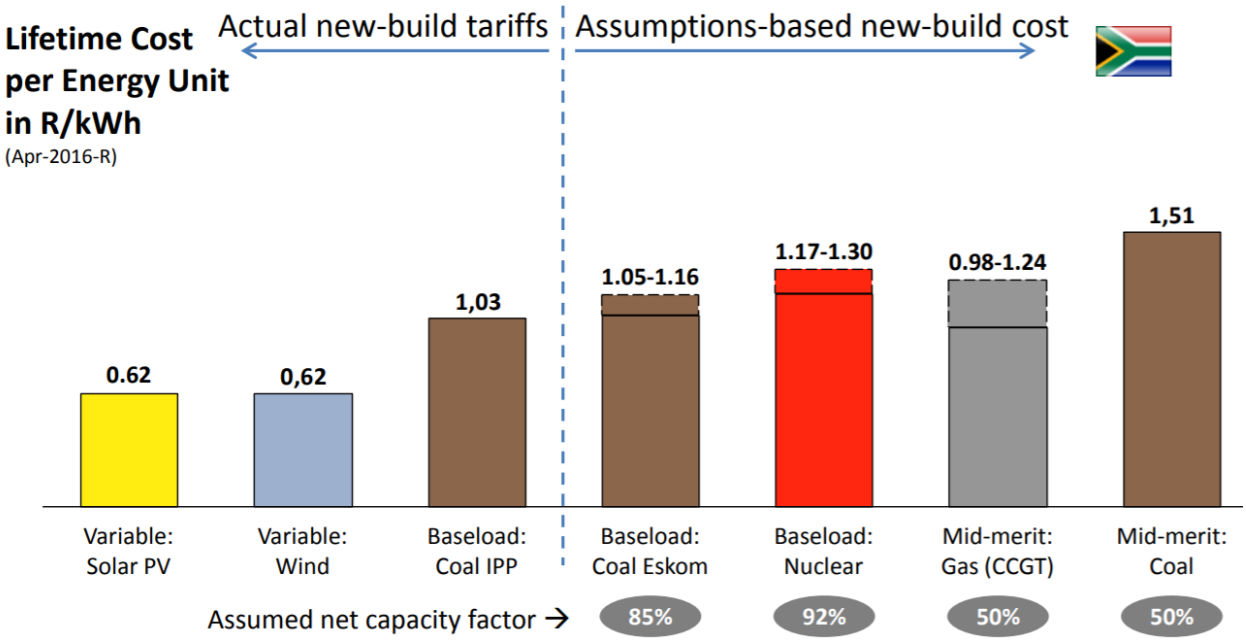
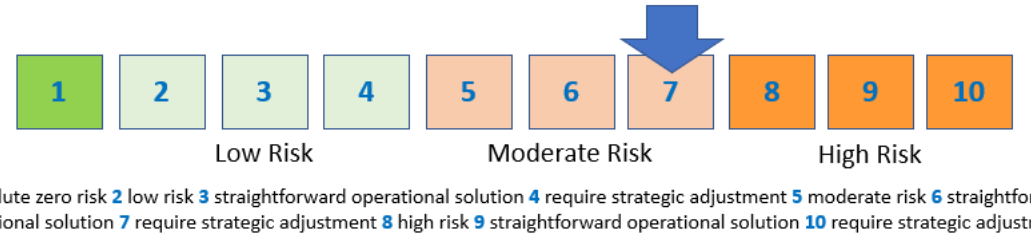


Figure 42: Lifetime cost per energy unit in R/kWh[108]

The CAPEX cost of a biogas electricity generating plant is four times that of an equivalent PV plant although a 100kW biogas will produce 2,250kWh/day compared to a 100kW solar plant that only produces 500kWh/day.



6.5.4 Bargaining Power of Suppliers

The local biogas market is small with probably less than 5 large projects per year.

6.5.4.1 Number and size of suppliers

Most of the local biogas technology and equipment providers are contracted to overseas suppliers which are predominantly European companies. New locally based market entrants will look to partnering with technology suppliers who are not active in the local market.

In section 6.5.2.1, it was noted that market research indicated more than 45 companies in RSA promoting AD Biogas technologies, most of which are project developers / engineering companies and specialist equipment suppliers.

Typically, these companies range from;

- Small company (less than 10 staff) offering small-scale solutions for households up to rural communities, the exception being Agama who is a medium sized company.

[108] CSIR Energy Centre presentation, 14 October 2016, https://www.csir.co.za/sites/default/files/Documents/WindAC_LCOE_bofinger.pdf

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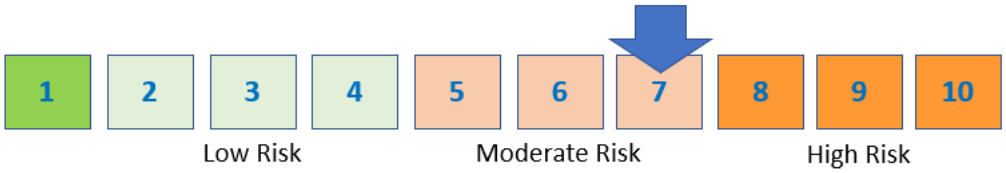
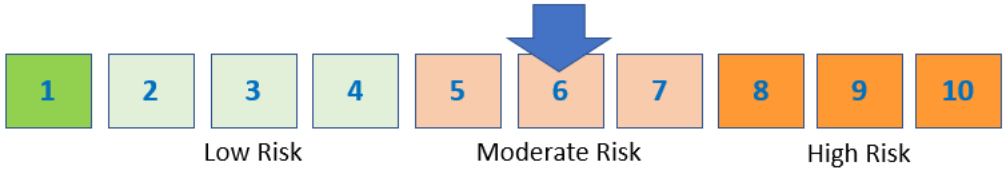
- Small/medium company doing medium sized projects up to 1MW.
- Large companies doing large projects – good examples are Veolia and Talbot & Talbot.



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

6.5.4.2 Uniqueness of each supplier's product

The biggest differentiation for the uniqueness in supplier product can be determined in the quality versus price relationship. In RSA, the perception is that European suppliers trade on superior technological solutions predominantly for mature markets with skilled personal whilst in contrast, suppliers from the East primarily tend to trade on price. This can be seen in the completed projects which suggest that the South African market is more quality conscious although less costly lower quality systems have found a foothold.

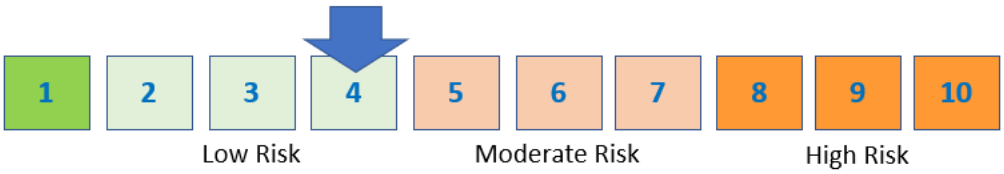


1 absolute zero risk **2** low risk **3** straightforward operational solution **4** require strategic adjustment **5** moderate risk **6** straightforward operational solution **7** require strategic adjustment **8** high risk **9** straightforward operational solution **10** require strategic adjustment

6.5.5 Rivalry Among Existing Competitors

The local market is very competitive, with a large number of project developers competing for a very small number of projects (fewer than 5 large projects reach financial closure per year). Projects have high capital cost coupled with long return of investment which results in customer scrutiny. Project developers who have reference sites have a distinct advantage as customers want to see proof of concept and successful local application. The credibility of visiting sites on other continents has been reduced due of past failures or underperforming systems unable to adapt to local conditions.

Competition is also expected from traditional air separation companies. Afrox (a member of the Linde Group) supported the New Horizon project in Cape Town by supplying and funding. The Linde built the world's largest plant for converting landfill gas into eco-friendly biogas.



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

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6.6 Competitive analysis

6.6.1 Competition overview

The European biogas systems and OEM markets may have reached maturity, however the South African biogas market, in common with other developing countries, is a growth market entering the Mainstream Market stage. RSA is moving past the innovation and early adopters' stages and hence qualitative differentiation and focused market/application strategies become important to insure continued growth and maturity as demonstrated in Figure 33 previously.

Competition, to a large extent, from both the energy and waste management dictates and informs the existing and developing marketing programmes for biogas projects.

6.6.2 Direct competitors

A total of 39 stakeholders promoting biogas technologies were identified within the stakeholder mapping study for RSA. These 39 stakeholders include combination local technology suppliers, project developers, EPCs and owner's engineers. These local stakeholders represent the direct competition within the biogas market as they all compete for the available feedstock resources generated by the customers, viz. waste generators and handlers, highlighted in Section 6.4 and Table 34. The customer needs provide insight to technological requirements. Some of these needs are highlighted in the SWOT analysis of potential sites suitable for biogas projects in Table 47 below.

Table 47: SWOT analysis of potential sites

Customer sector	Strengths	Weaknesses	Opportunities	Threats
Sugar Estates	Produce large quantities of digestible material in waste stream Most? have sufficient space for a digester Ability to be a self-off taker	Worldwide over supply of sugar, industry in decline Combustion least cost way to extract value from straw & bagasse	Vinasse & filter cake have high potential for biogas Opportunity to produce high value vehicle fuel – convert transport fleet to duel fuel Industry looking for ways to reduce costs / increase sales Could be the future food & fuel farm	Government's land redistribution policy Largest local producer in severe financial difficulty – market and corporate malefice
Dairy farms	Well established dairy industry Eastern & Western Cape has large number of farms Industry has reference sites Farms already have open lagoons for low-tech conversion	Few TMR dairies, most cows not in barns resulting in reduced collectable manure volumes High production costs in relation to selling prices	Eastern Cape has high electricity costs and poor electricity supply from inept municipalities Energy required for heating & cooling	Government's land redistribution policy Located in prime areas High concentration of major dairy farms

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Piggeries	Large number of intensive farms with pigs in barns High biogas potential Open lagoons SOP Has successful reference sites	Cost of producing electricity from biogas Not big energy users unless have an on-farm abattoir as in the case of Riverside Piggery Has unsuccessful reference sites Heating lagoons during cold winters	Farms require upgraded waste treatment solution to meet current & future environmental standards	Government's land redistribution policy
Broiler farms	Large number of commercial farms with chickens in climate-controlled houses Commercial farm will have at least 4 x 6 houses with 30,000 broilers/house	Some bedding material not suitable for digestion[109] May need organic material to adjust C:N ratio Difficult to digest Houses cleaned out after 35 days Costly to replace coal heaters	Need to look at export customers as waste can produce 2-3 times farm's energy requirement Good way to reduce carbon footprint	Government's land redistribution policy Litter sold to feedlots (illegal) and fertilizer producers Biosecurity – need to remove litter from farm
Layer poultry farms	High production farms Litter normally removed daily No bedding material	May need organic material to adjust C:N ratio Difficult to digest Good fertiliser material	Opportunity to produce high value vehicle fuel – convert transport fleet to duel fuel Good way to reduce carbon footprint	Government's land redistribution policy Big move to "free range" Litter sold to feedlots (illegal) and fertilizer producers Biosecurity – need to remove litter from farm
WWTW	Continuous and consistent supply of organic waste Industry familiar with /acceptance of treatment method – not new	Low organic loading of wastewater Many sites not operating near capacity, if at all Shortage of skilled operational personnel	Produces energy-rich biogas Good way to reduce production costs while increasing capacity Government's support of PPP's for implementation	New high capacity, low sludge producing and low-energy wastewater treatment technologies

[109] Most bedding used consists of lignocellosic (woody) material not suitable for anaerobic digestors

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	Aerobic treatment is energy intensive Large volumes, and with population increase volumes will increase	Availability of land at the treatment works		

6.6.3 Indirect competitors

The indirect competition to the stakeholders that deliver and implement biogas projects can be divided into the following sectors, viz. waste, energy and water.

Within the waste sector the largest competitors for biogas are waste handlers and municipalities. Waste handlers include the 6 major waste management service companies within RSA. These waste management service companies provide services to both the C&I sector and municipalities. Municipalities are mandated by legislation to collect and dispose of waste from residential areas and expanded services to the C&I sector. The municipalities would often outsource these services to waste management companies. These indirect competitors can be converted into customers through collaboration.

The demand for energy within RSA provides insight to the indirect competitors to biogas and its clients highlighted in Table 34. A large portion of these competitors are found in the renewable energy technologies space, but it does not exclude Eskom. The current legislation and policies and the cost of biogas compared to other renewable energy technologies make it difficult for biogas to compete with other energy sources such as solar, wind and coal within RSA as has been highlighted in section 6.5.3.

6.6.4 Potential competitors

Other potential competitors include the following stakeholders/sectors:

- Composting – Compost manufacturers often compete directly for feedstock and provide a lower cost solution to feedstock generators.
- Black soldier fly farms – Similar to composting, this technology competes for the same feedstock to produce a raw feed protein alternative for animal feed.
- Water treatment – There are a number of alternative water treatment technologies such as membrane separation, chemical and mechanical treatments.
- Piggeries – Smaller pig farms would often compete for the same feedstock as biogas which they would use as a feed to their pigs.
- Electric vehicles – With the increase growth of the electric vehicle market, it provides competition to the development of biogas being used as an alternative fuel in RSA.
- Other renewable energy technologies – The growth of renewable energy technologies such as solar PV and wind in RSA has been more rapid as these projects have lower CAPEX and are not as complex thus carrying lower risk for investors.

6.7 Market policies and incentives

RSA has three tiers of government: National, Provincial and Local. Broadly speaking, National Government is responsible for drafting of legislation (and enforcement thereof); Provincial Government has the same responsibilities as National Government, but on a Provincial level, with

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local government having the primary role of implementers. This is illustrated in Figure 43 and Figure 44.

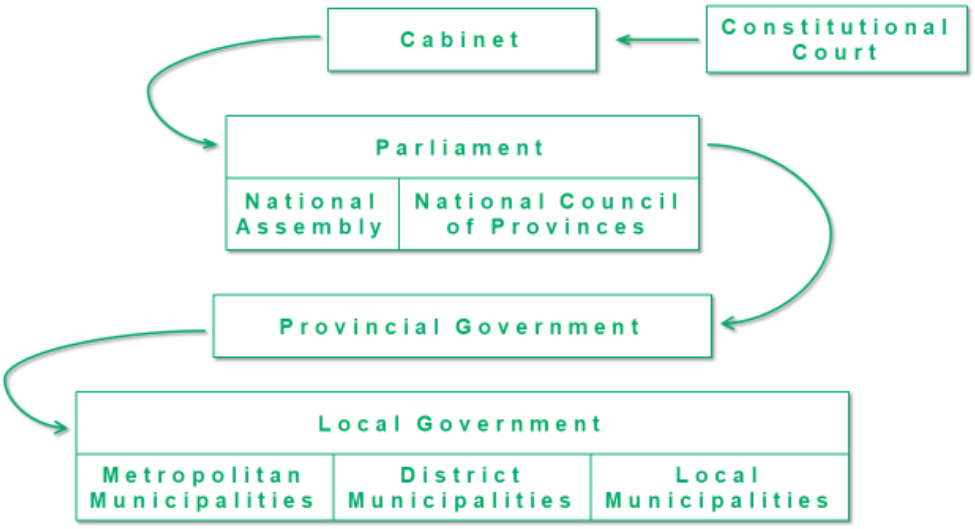

Figure 43: Tiers of government

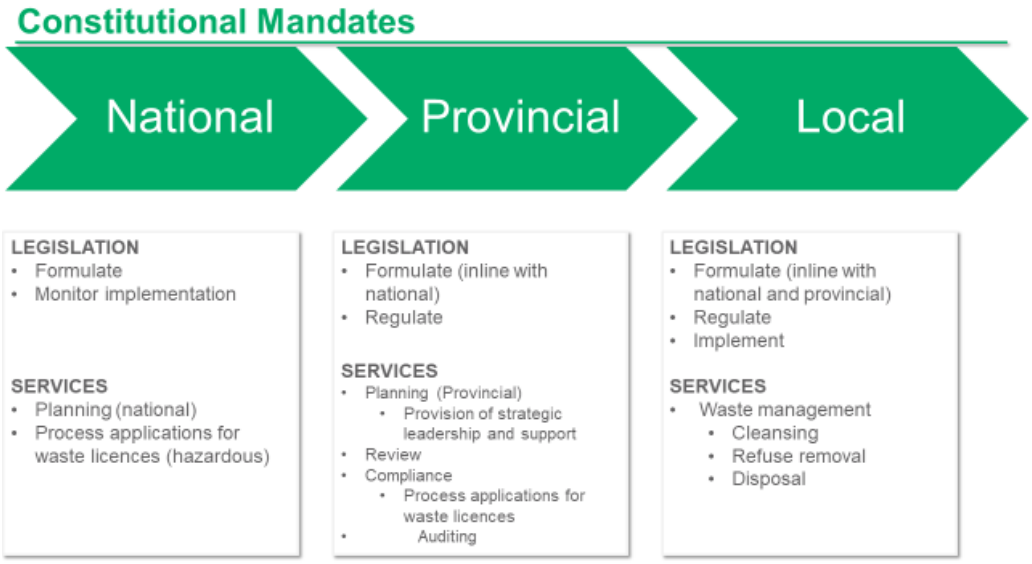

Figure 44: Constitutional mandates of branches of government

6.7.1 Government legislation and policies

The following legislation and considerations may be applicable to the development and implementation of a biogas project:

- National Environmental Management (NEM) Act - GN 983, 984 and 985
- National Environmental Management: Waste Act - GN921
- National Environmental Management: Air Quality Act - GN248
- Biodiversity consents (National Forest Act, NEM: Biodiversity Act, NEM: Protected Areas Act, Outeniqua Sensitive Coastal Areas, Integrated Coastal Management Act)
- National Water Act - Water Use License

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- National Heritage Resources Act
- Agricultural Consents & Regulations (Subdivision of Agricultural Land Act, Conservation of Agricultural Resources Act, Fertilisers, Farm Feeds, Agricultural Remedies and Stock Remedies Act)
- Land Use Planning – Rezoning or subdivision
- Civil Aviation Authority – Height of facility and location within the vicinity of an airfield, airport or aerodrome

The NEM acts highlight the requirements a project would need to address in terms of its environmental impacts. The biodiversity consents and National Heritage Resources Act ensure that a project has considered the impacts it may have on the local ecosystems and resources. The National Water Act considers the water usage and efficiency implications of the project. Agricultural consents and regulations may impact the feedstock and digestate of a project. The land use and civil aviation considers the logistical side on the project location and its implications. These considerations are applicable to all biogas projects. A breakdown of the basic requirements to develop a biogas project can be found in section 6.5.1.6.

6.7.2 Other incomes

Other incomes, incentives and policies that may not be considered as the primary focus for the business case for biogas projects but may make it more attractive include:

- Carbon Tax Act – A tax rate of 120 ZAR/tCO2e for direct emissions at large industrial emitters (annual increase of CPI plus 2%). This means that businesses are motivated to reduce their direct emissions.
- Small scale embedded generation (SSEG) feed in tariffs – Certain municipalities offer feed in tariffs to projects up to 1MW scale provided those projects are net users of the electricity generated.

6.8 Resources

It is important to identify the natural, human and proximity resources available within a region or country to understand the support mechanisms as well as risks that may influence the development of a biogas project. A number of research studies have been conducted to identify the available resources.

6.8.1 Natural resources

South Africa is rich in natural resources suitable for usage as feedstock within biogas plants. The Bio-Energy Atlas (Hugo, 2016) published by the Department of Science and Technology provide an overview of the potential of bioenergy materials across RSA which are suitable to be used as feedstock for biogas projects. Table 48 shows the available feedstock that could be used to feed a biogas plant.

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Table 48: Availability of feedstock for energy applications (Hugo, 2016)

Source	Potential (dry mass) Million Tonnes/yr.	Available now (dry mass) Million Tonnes/yr	Energy equivalent available now (GWh/yr)
Agricultural residues	36.22	5.80	16 097
Sugar cane bagasse	5.35	0.60	1 672
Pulp and paper mill residues	0.69	0.01	25
Organic solid waste component	6.47	5.82	16 175
Organic sewage sludge	2.53	2.28	6 325
Purposely cultivated crops	9.26	9.26	37 811
Total	60.52	23.77	78 105

For the agricultural residues highlighted in Table 48 above has a relaxed assumption that 50% more agricultural residues can be extracted above a conservative extraction rate of these residues. This safe assumption means that the availability of agricultural residues could be increased in practical implementation. All sugar cane bagasse and pulp and paper resources are currently used for low-efficiency energy generation. It would be possible to improve the efficiency of energy generation from 33% to 50% through capital investment in new technology, however both of these industries are currently in decline which may reduce the feedstock amounts available. Both the organic fraction of domestic solid waste and organic sewage sludge highlighted were reported as the total available, minus an estimated 10% that is currently used for composting, electricity generation or biogas manufacture. The purposely cultivated crops were highlighted for the best available options in respect of feedstock, however, may not be feasible to process on techno-economic grounds as the stated amount takes only subsistence farmland into account. However, RSA has limited arable land and legislation and policies dictate that this land must be used for food production. Therefore, purposely cultivated crops only hold potential for biogas if the crops are grown on land that needs to be rehabilitated.

Additional studies include GIZ (2016c) and GIZ (2016b) which estimated the distribution of the potential of biogas production for electricity generation from agro-waste sectors and WWTWs. Table 49 and Table 50 highlighted the estimated potential of livestock wastes as well as abattoir wastes.

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Table 49: Livestock manure quantities and methane production capacity potential (GIZ, 2016c)

Province	Total cattle solid manure production (Million tonnes/yr)	Expected methane production (m^3/yr)	Total cattle liquid manure production (Million tonnes/yr)	Expected methane production (m^3/yr)	Total pig manure production (Million tonnes/yr)	Expected methane production (m^3/yr)	Total poultry manure production (Million tonnes/yr)	Expected methane production (m^3/yr)
Eastern Cape	98,0	5 194 000	3 425,1	58 227 142	73,8	885 504	158,6	13 163 828
Free State	336,0	17 808 000	780,6	13 270 880	100,5	1 206 509	194,7	16 163 382
Gauteng	504,0	26 712 000	198,9	3 381 300	251,1	3 012 960	292,7	24 297 159
KwaZulu Natal	42,0	2 226 000	2 605,4	44 291 562	198,5	2 382 086	394,0	32 702 246
Limpopo	70,0	3 710 000	54,7	930 580	133,6	1 602 854	125,1	10 386 459
Mpumalanga	224,0	11 872 000	270,1	4 591 054	210,3	2 523 706	451,8	37 500 512
Northern Cape	308,0	16 324 000	18,1	307 496	33,2	398 477	4,2	349 055
North West Province	140,0	7 420 000	339,7	5 774 220	111,4	1 337 146	606,4	50 331 517
Western Cape	42,0	2 226 000	2 546,1	43 284 397	256,5	3 078 106	626,1	51 967 211
Total	**1 764**	**93 492 000**	**10 239**	**174 058 631**	**1 369**	**16 427 348**	**2 854**	**236 861 369**

Table 50: Livestock abattoir waste quantities and methane production capacity potential (GIZ, 2016c)

Province	Total cattle waste production (Million tonnes/yr.)	Expected methane production (m^3/yr.)	Total pig waste production (Million tonnes/yr.)	Expected methane production (m^3/yr.)	Total poultry waste production (Million tonnes/yr.)	Expected methane production (m^3/yr.)
Eastern Cape	22,721	1 192 396	2,894	165 949	N/A	N/A
Free State	15,148	794 931	3,444	197 452	37,610	2 135 551
Gauteng	106,033	5 564 514	18,261	1 047 055	53,310	3 027 028
KwaZulu Natal	30,295	1 589 861	6,277	359 933	46,515	2 641 165

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Limpopo	9,960	522 694	0,890	51 047	19,332	1 097 713
Mpumalanga	22,721	1 192 396	2,738	157 015	27,534	1 563 410
Northern Cape	7,574	397 465	1,366	78 313	N/A	N/A
North West Province	22,721	1 192 396	1,302	74 629	33,837	1 921 331
Western Cape	22,721	1 192 396	7,846	449 898	71,002	4 031 602
Total	**259,894**	**13 639 049**	**45,018**	**2 581 291**	**289,140**	**16 417 800**

GIZ (2016c) estimated the fruit processing waste potential with a focus on apples, apricots, pears, peaches, grapes, mangoes, guavas, pineapples, strawberries, plums, oranges, lemons/limes, grapefruits. The wastewater produced from these fruits is 3 513 144 m^3/yr with additional 1 034 330 m^3/yr of pomace produced. Table 51 provides the estimated distribution of potential methane production from these food processing waste across RSA.

Table 51: Estimated distribution of potential for methane production from food processing waste on a provincial level (GIZ, 2016c)

Province	Annual methane production pomace (m^3/yr.)	Annual electricity production (MWh/yr.)	Annual thermal energy production (MWh/yr.)
Eastern Cape	8 337 737	29 182	37 520
Gauteng	10 422 171	36 478	46 900
KwaZulu Natal	2 084 434	7 296	9 380
Limpopo	12 506 606	43 773	56 280
Mpumalanga	4 168 869	14 591	18 760
North West Province	2 084 434	7 296	9 380
Western Cape	14 591 040	51 069	65 660
Total	**54 195 291**	**189 685**	**243 880**

The sugar industry waste quantities and methane production capacity potential can be found in KwaZulu-Natal and Mpumalanga. The wastewater produced from this industry is 3 192 236 m^3/yr with an estimated annual methane production = 5 426 801 m^3/yr. In addition, press mud of 798,059 million tonnes/yr is produced which has an estimated annual methane production = 47 883 538 m^3/yr (GIZ, 2016c).

In RSA, breweries and wineries hold potential for biogas production through usage of the wastewater, spent grain and grape pomace produced. Table 52 and Table 53 highlights the estimated waste quantities and methane production potential for breweries and wineries.

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Table 52: Breweries waste quantities and methane production capacity potential (GIZ, 2016c)

Province	Clear Beer Breweries Wastewater production (m^3/yr.)	Expected methane production (m^3/yr.)	Clear Beer Breweries Spent grains produced (Million tonnes/yr.)	Expected methane production (m^3/yr.)	Opaque Beer Breweries Wastewater production (m^3/yr.)	Expected methane production (m^3/yr.)	Opaque Beer Breweries Spent grains produced (Million tonnes/yr.)	Expected methane production (m^3/yr.)
Eastern Cape	960 000	2 016 000	46,1	3 225 600	337 000,0	707 700	16,2	1 132 320
Gauteng	8 280 000	17 388 000	397,4	27 820 800	337 000,0	707 700	16,2	1 132 320
KwaZulu Natal	2 880 000	6 048 000	138,2	9 676 800	337 000,0	707 700	16,2	1 132 320
Limpopo	600 000	1 260 000	28,8	2 016 000	---	---	---	---
North West Province	---	---	---	---	337 000,0	707 700	16,2	1 132 320
Western Cape	1 800 000	3 780 000	86,4	6 048 000	---	---	---	---
Total	**14 520 000**	**30 492 000**	**697,0**	**48 787 200**	**1 348 000**	**2 830 800**	**64,7**	**4 529 280**

Table 53: Wineries waste quantities and methane production capacity potential (GIZ, 2016c)

Province	Wineries Wastewater production (m^3/yr)	Expected methane production (m^3/yr)	Grape pomace produced (Million tonnes/yr)	Expected methane production (m^3/yr)
Northern Cape	494 741	494 741	20,6	3 628 099
Western Cape	5 258 059	5 258 059	219,1	38 559 101
Total	**5 752 800**	**5 752 800**	**239,7**	**42 187 200**

RSA has 131 WWTW that was identified within the GIZ (2016b) study. The number of WWTW that were assessed to have biogas potential were 87 with only 39 identified with the potential of a feasible CHP project. Of the 39 WWTW, 22 are situated in Gauteng, 5 in the Western Cape, 5 in KwaZulu-Natal, 2 in North West Province, 2 in Eastern Cape, 2 in the Free State and 1 in Limpopo. A summary of the potential for electrical and thermal power produced from biogas for RSA can be found in Table 54.

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Table 54: Summary of the potential for WWTW (GIZ, 2016b)

	Total plant capacity Ml/d	Electrical power kWe	Thermal power kWt
Total "sewage" CHP potential (>10 Ml/d)	5 499	61 370	67 507
Total existing infrastructure CHP potential	4 453	33 369	36 706
Total feasible CHP potential	3 523	27 145	29 860

6.8.2 Human resources

Currently, no specific framework or training facility that focuses on the development of human resource required for the value chain of a biogas project exists. However, the GIZ (2016a) study highlighted and modelled the skills required and development of those skills within the existing framework for skills development within RSA. The framework of policies that dictate and guide skills development with RSA can be seen in Table 55.

Table 55: South African Frameworks and Policies associated with Skills Development (GIZ, 2016a)

Framework/ Policy	Function
National Qualifications Framework (NQF)	- Sets boundaries, principles, and guidelines to provide a base and structure for the qualifications system - The system allows for national recognition of learner achievements, and ease of understanding of learner qualifications and knowledge
Organising Framework for Occupations (OFO)	- Links occupations to specific skills and identifies training needs - Provides a skills-based classification system in the RSA context in terms of skill level and specialisation as attributes of a job - Allows a parallel to be found within the NQF
South African Qualifications Authority (SAQA)	- Oversees the development and implementation of the NQF, in terms of regulations specified in the National Qualifications Framework Act (No. 67 of 2008)
Quality Council for Trades and Occupations (QCTO)	- Develops occupational qualifications according to the OFO in order to meet industry needs - Figure 38 contains an excerpt from the QCTO application process that details the information required when applying for registration of a qualification
Energy and Water Services Sector Education and Training Authority (EWSETA)	- Responsible for coordinating, facilitating and providing quality assurance for sector reliant skills development programmes for stakeholders and managing skills through the National Skills Development Strategy (III), all associated with the water and energy sectors - Implements skills plans by establishing learning programmes, approving Working Skills Plans and Annual Training Reports - Allocation of grants to employers, education and training providers and workers as well as education monitoring and training in the sector falls under EWSETA - Facilitates learnerships with employers in terms of workplaces and supporting creators of material

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Using these defined framework and policies, the skill level, NQF and OFO major groupings can be compared to the Paterson grading within the Paterson table (Table 56).

Table 56: Expected skill level required for various Organising Framework for Occupations (OFO) groupings (GIZ, 2016a)

NQF	Skill level		Paterson Table	OFO Major Groupings
7-10	**Higher Education & Training** 1st degrees, second and tertiary education leading to higher qualifications	Highly skilled	E/F	Top/Senior Managers
			E/F	Professionals
6	**Higher Education & Training/ Further Education & Training** First stages of tertiary education	Skilled	C/D/E	Managers
			C/D/E	Technicians & Associate Professionals
3-5	**Further Education & Training** Secondary level of education	Semi-skilled	B	Clerical & Support Workers
			B	Services & Sales Workers
			B	Skilled agriculture, forestry, fisheries, craft & related trades
			B	Plant & machine operations & assemblers
1-2	**General/Basic Education & Training** Primary level of education	Un-skilled	A	Elementary workers

There are several institutes and programmes (Table 57) that can assist in skills development for biogas projects. These institutes also hold potential for the development and delivery of specific accredited skills development programmes that would be internationally recognised. The South African Renewable Energy Centre specifically has been successful in developing formal training programmes for solar PV and wind technologies and have the skills required to develop a formal training programme for biogas technologies.

Table 57: Institutes and programmes in South Africa in the renewable energy and biogas industries (GIZ, 2016a)

Framework/ Policy	University affiliation	Programmes offered	Link
South African Renewable Energy Technology Centre (SARETEC)	Cape Peninsula University of Technology	Short courses and formal training courses	http://www.saretec.co.za/
Sustainability Institute	University of Stellenbosch	Postgraduate programmes, short courses	http://www.sustainabilityinstitute.net/

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Centre for Renewable Energy and Sustainability Studies (CRSES)	University of Stellenbosch	Postgraduate programmes, short courses, workshops, lectures	https://www.crses.sun.ac.za/
Centre for Energy Research	Nelson Mandela Metropolitan University	Postgraduate programmes, short courses	http://energy.nmmu.ac.za/
Environmental and Process Systems Engineering	University of Cape Town	Postgraduate programmes	http://epse.uct.ac.za/
Energy Research Centre	University of Cape Town	Postgraduate programmes	http://www.erc.uct.ac.za/
Risk and Vulnerability Science Centre	University of Fort Hare	Postgraduate programmes	http://ufh.ac.za/centres/rvsc/introduction
Dicla Training Centre		Sustainable agriculture practices	http://www.diclatraining.com/training_courses/index.asp
InternationalEs Biogas und Bioenergie Kompetenzzentrum (IBBK)		Biogas Training Seminar and Study Tour	https://ibbk-biogas.com/training-courses/
National Cleaner Production Centre (NCPC)		2-day end user & 9-12-month expert biogas systems optimization courses offered	http://ncpc.co.za/biogas

The GIZ (2016a) study highlighted the full-time equivalent jobs from a jobs plot model for both existing biogas sites as well as potential job forecast up to 2030 (Table 58).

Table 58: Predicted FTE jobs from jobs plot study (GIZ, 2016a)

Jobs currently in operation phase of biogas industry	270 FTE
Conservative job forecast to 2030	59 000 FTE
Optimistic job forecast to 2030	88 000 FTE

Although biogas projects have a high potential for creating high skill jobs, as shown in Table 58, the lack of a biogas training framework means that South African biogas projects are required to upskill and training own operators. An established biogas training framework would reduce the risk for biogas projects in terms of commissioning time for improved operation and maintenance. However, the viability of establishing a biogas training framework would be dependent on the number of implemented projects within RSA.

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6.8.3 Infrastructure and support industry

An infrastructure and support evaluation for RSA was completed within the Bio-Energy Atlas (Hugo, 2016) to demonstrate if infrastructure is adequately placed to support bioenergy projects. The evaluation indicated that power stations and electrical transmission/distribution infrastructure are adequately placed in respect of economic activity, but less so in respect of population. New transmission infrastructure planned by Eskom in areas such as the rural Eastern Cape, the KwaZulu-Natal Midlands and western Limpopo which are considered areas that are poorly served. There is generally good infrastructure cover in areas where potential feedstock is produced (Figure 45).

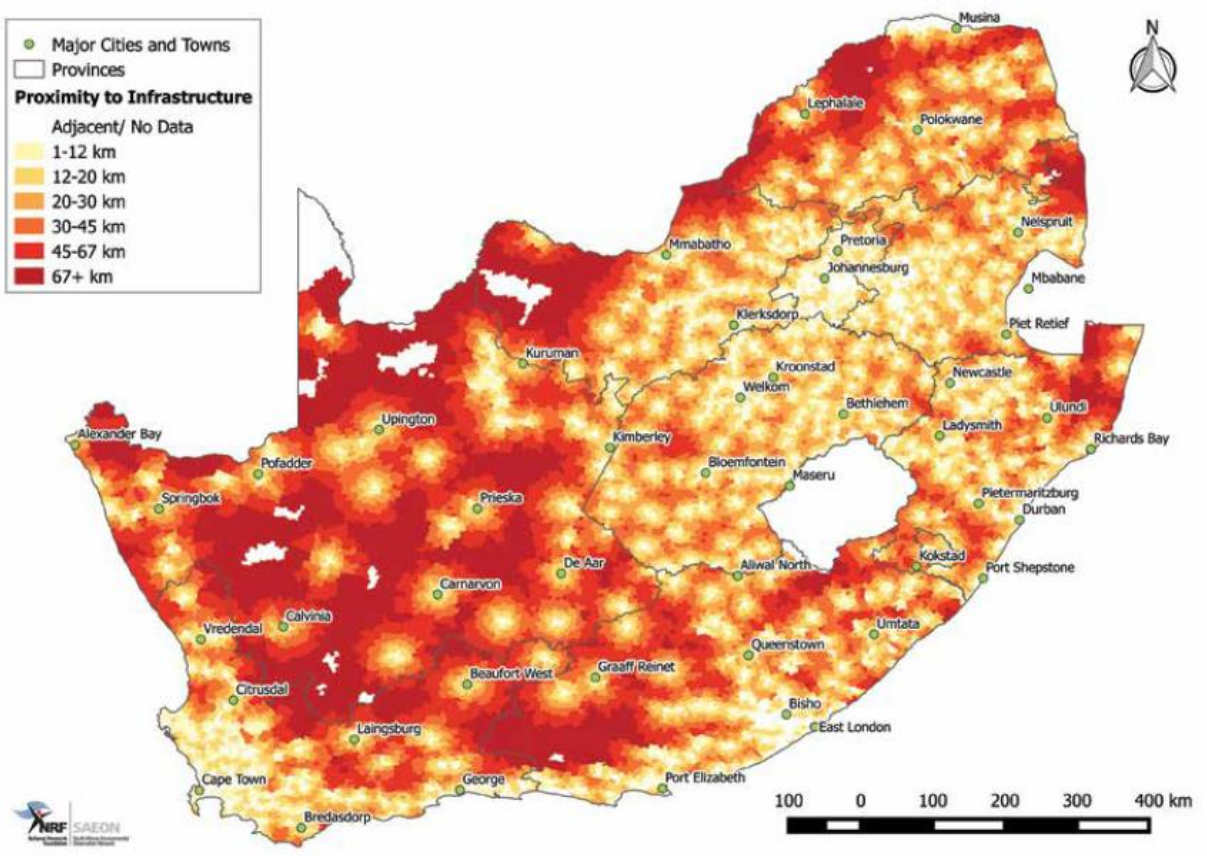

Figure 45: Proximity of the closest infrastructure (of all types) to each location in RSA (Hugo, 2016)

Figure 45 shows that RSA has good transport and logistical infrastructure in the eastern parts of the country and the Western Cape which makes accessibility to feedstock ideal. Projects that are established more than 20 km away from feedstock often have higher transportation costs.

The RE portfolio has been previously covered in Section 6.4.2 as part of the IRP and REIPPP. The current base load electricity infrastructure can be seen in Table 59.

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Table 59: Eskom's entire generation fleet

Type of Station	Source	Installed Capacity (MW)	Installed Capacity (%)	Capacity Generated (GWh)	Capacity Generated (%)
Base loads	Coal-fired stations	36 479	83%	200 210	91,45%
	Nuclear power	1 860	4%	11 580	5,29%
Mid merit/peaking stations	Pumped storage stations	2 724	6%	4 590	2,10%
	Hydro stations	600	1%	1 029	0,47%
	Open cycle gas turbines (OCGTs)	2 409	5%	329	0,15%
Self-dispatching	Sere Wind Farm	100	0%	1 202	0,55%

Typically, the base load plants generate all day electricity, mid-merit plants generate electricity before the morning and evening peak demand with a 10% to 40% capacity factor supplement the gaps during high peak demand; and the Sere Wind Farm is Eskom's own renewable energy plant. Base loads power stations operate continuously 24 hours a day to ensure there is always electricity available for different end users with different energy demand profiles.

There is an ongoing plan to decommission the coal fired stations approaching end of life, IRP 2019 has indicated a target to decommission 11 GW by 2030. Over the years, the plants have experienced declining generation capacity. In the recent IRP 2019 draft report, the coal decommissioning process is reported to kick off in 2019, decommissioning 2.7 GW of coal. This submission brings forward the decommissioning of Grootvlei, Komati and Hendrina[110]. Another factor driving coal decommission, is the Air quality regulations under the National Environmental Management Act that regulates coal plants under Eskom's fleet to meet the minimum emission standard (MES) by a certain time, otherwise the non-compliant plants would be illegally operated, if not shut down. Although the RSA is currently in an energy crisis, biogas projects have the potential to reduce the energy load demand particularly if implemented at WWTW and large energy demand agri-processing sites.

Local manufacturing of biogas project equipment and parts are limited in RSA. This is mainly a result of the small number of projects implemented per year. However, RSA does favour local manufacturing and the development of local manufacturing lines as can be seen in designation of a special economic zone in Atlantis, Western Cape. This is an opportunity for EU technology and equipment suppliers to collaborate with local stakeholders in establishing local manufacturing facilities as the local biogas market grows.

RSA has an existing infrastructure and potential for development that can currently support the uptake and implementation of biogas projects.

[110] Department of Energy (2019). Integrated Resource Plan 2019

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Review

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