Inland Norway University of Applied Sciences

Faculty of Applied Ecology, Agricultural Sciences and Biotechnology

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# Master Thesis

# Fighting climate change with biogas

Master's Degree in Applied and Commercial Biotechnology

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# Abbreviations

**AGCO** Allis-Gleaner Corporation,

**LPG** Liquefied Petroleum Gas

**AD** Anaerobic Digester

**GHG** Greenhouse Gas

**R&D** Research and development

**SNC** Supplier Network Collaboration

**USD** U.S Dollar

**RIO** Return on Investment

**PVC** Polyvinyl Chloride

**N/A** Not applicable

**PP** Polypropylene

**PE** polyethylene

**GDP** Gross Domestic Product

**NGO** Non-Governmental Organization

**IP** Intellectual property

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# Abstract

Micro biogas digesters are innovative systems that efficiently convert organic waste into biogas, offering sustainable energy solutions, especially in rural areas. Generating free cooking gas and biofertilizers, they effectively reduce carbon footprints, contributing to the fight against climate change. The case study assesses the environmental benefits of implementing micro biogas digesters on a small scale, targeting livestock farmers – especially cattle farmers – and those engaged in both cattle and crop growth in South America, who depend on traditional cooking methods. The scenario involves me as a master's student who undertook an internship with the task of evaluating micro biogas digesters as a potential new product line for a theoretical company that manufactures and distributes agricultural equipment. Based on my research for this case study, I conceptualized Allis-Gleaner Corporation (AGCO), an agricultural company, as a potential distributor model, and Flexi Biogas as a potential supplier model of micro-biogas digesters. AGCO and Flexi Biogas were considered as companies collaborating to distribute tubular micro biogas digesters in the South American region. According to this research, Brazil is the optimal location for introducing tubular micro biogas digesters. Moreover, this thesis describes the processes and methodologies utilized throughout this journey, from the initial stages of ideation and technology evaluation to the phases of market identification, as well as project planning. The emphasis remains on delivering value to customers and generating profits for the company, thereby facilitating a gradual expansion of its market share in Brazil.

**Keywords:** Micro biogas digesters, Rural farmers, Climate change, Market analysis, South America, Brazil.

# 1. Introduction

South America, with an extensive population of approximately 441 million people, accommodates around 122 million households residing in rural areas. However, it remains concerning that about 64 million rural households in South America do not access electricity (*Worldmeter.com*, *WorldBank.com*, *OurWorldinData.com*). This significant number indicates that a considerable portion of households in these regions depend on firewood and liquefied petroleum gas (LPG), for cooking. The excessive utilization of fossil-based energy sources leads to environmental pollution and contributes to the increase of climate change through the emission of greenhouse gases (GHGs). Traditional methods of cooking have negative consequences for both the environment and human health (Garfí et al., 2016a). Also, managing livestock waste is a challenge for rural farmers, and it often contributes to the emission of GHGs. With a growing concern for climate change, there is a pressing need for environmentally friendly solutions in the agricultural sector. Considering this situation, renewable and sustainable energy sources like biogas can play a vital role in transitioning towards clean energy and contributing to environmentally friendly progress. Biogas, a methane-rich gas, is produced through the anaerobic digestion of organic waste in the absence of oxygen, such as animal manure and crop residues. It has the potential to provide clean energy for cooking in rural areas while also reducing the release of GHGs into the atmosphere (Ahmed et al., 2022). Micro biogas digesters are a developing technology designed to meet the specific needs of rural farmers, with various sizes available for both small and mid-size livestock and crop farmers (Bond & Templeton, 2011). Micro biogas digesters offer multiple benefits, including improved sanitation and ecological conditions, increased energy availability, and the potential to generate income for small to midsize rural farmers. This is made possible through the generation of biofertilizers, which significantly impacts crop quality and yield (Laramee & Davis, 2013), (Möller & Müller, 2012), (Castro et al., 2017). The thesis presents a case study that evaluates the hypothesis and the potential for collaboration between two companies. Flexi Biogas Company, as a supplier, and AGCO Company, as a distributor. The central objective of this thesis is to evaluate the commercial viability and potential implementation of a small-scale biogas system, providing an alternative to conventional cooking methods like LPG and firewood. This initiative is directed towards rural areas across South America, with the overarching goal of generating economic and environmental benefits for local communities. The research not only

thoroughly examines the technical foundations of these digesters and their critical role in addressing climate change, but also involves assessing their feasibility and market demand. Additionally, it includes understanding customer segmentation and preferences, developing a comprehensive business plan, and carefully evaluating the competitive and alternative landscape. Importantly, preliminary market research has revealed that the optimal starting point for the distribution of tubular micro biogas digester is in Mato Grosso, Brazil. This business plan proposal not only facilitates AGCO Company in achieving profits but also positions them to gradually expand their market share over time.

## 1.1 Context

**Scenario:** As a master's student, I have been assigned a simulation role as a summer intern in the research and development department of an international company that produces and distributes agricultural equipment. I have identified and modeled this thesis on AGCO (Gleaner-Allis Corporation), a publicly listed company based in the United States. This assignment is independent and purely for academic purposes, and AGCO has no knowledge of or involvement in it.

AGCO, a major producer of agricultural equipment, aims to diversify its product portfolio with environmentally friendly products to address climate change. The company manufactures and distributes a wide range of farm machinery and equipment across North and South America, including tractors, planters, harvesters, diesel generators, and water pumps. AGCO also provides financial services, such as agricultural loans and machinery leases, to support farmers. In this master’s thesis simulation, the marketing team at AGCO has identified micro biogas digesters as a potential addition to AGCO’s product line. These digesters, utilizing the anaerobic digestion of organic waste, can reduce GHG emissions while expanding the company's product offering. To evaluate the feasibility of this product, the company's CEO has assigned the research and development (R&D) team to assess two options: developing and producing their line of micro biogas digesters or collaborating with an existing supplier and serving as a distributor. In this simulation, my role is that of a summer intern within AGCO's R&D department. My responsibilities include conducting independent research and analysis, guided by an experienced advisor who acts as a middle manager within AGCO. My objective is to provide valuable insights and assist the company

in making an informed decision regarding the distribution of micro biogas digesters in rural areas of South America.

## 1.2 Company Profile

AGCO is a global leader in designing, manufacturing, and distributing agricultural equipment. They operate in many countries, serving both small-scale farmers and large agricultural enterprises. Their product range includes tractors, harvesters, planters, and precision farming technologies, all focused on enhancing productivity, efficiency, and sustainability in farming. The company is well known for its high-quality and performance-oriented brands. Alongside equipment manufacturing, they provide financial services like agricultural loans, leasing options, and insurance programs to support farmers and improve their operations. They actively promote sustainable agriculture practices and address environmental challenges. The company aims to support farmers globally by providing them with reliable and advanced equipment to meet the increasing need for food production, while also minimizing harm to the environment.

### 1.2.1 Customers

AGCO Corporation serves a varied customer base in the agricultural sector, including crop farmers, livestock farmers, commercial farmers, and agricultural cooperatives. The company offers a wide range of advanced machinery, such as tractors, harvesters, and application equipment, which enhance productivity and efficiency. They introduce cutting-edge technologies and advanced agriculture solutions to support customers in farming more efficiently and with increased environmental awareness.

### 1.2.2 Competitors

AGCO has strong competitors in the agricultural machinery industry, such as John Deere, Kubota Corporation, and New Holland Agriculture. These companies specialize in manufacturing and distributing agricultural machinery and equipment. They have a strong market presence and offer a wide range of products to address the needs of farmers and agricultural businesses in North and South America. AGCO must continuously innovate and differentiate itself to stay competitive in the market against these companies that serve the requirements of the agriculture industry.

### 1.2.3 Collaborators

1) Collaboration with Suppliers: AGCO collaborates with Supplier Network Collaboration (SNC) to enhance its supply chain operations. SNC assists AGCO in optimizing material spending across its facilities, reducing complexity, and enhancing overall performance.
2) Collaboration with Academic Institutions: This partnership reflects AGCO's dedication to utilizing technology for improved efficiency in delivering high-quality agricultural machinery. AGCO collaborated with the University of Georgia to advance animal welfare in the poultry industry. The partnership focused on developing Smart Broiler buildings, using animal sensing systems to monitor bird behavior and improve animal welfare conditions. AGCO provided funding for a research building and two partial-scale broiler buildings to test new concepts and enhance product performance. This collaboration reflects AGCO's commitment to innovative and animal-centric research.

## 1.3 Aim of the Study

As a master's student interning at AGCO's R&D department, my goal was to assess the feasibility of distributing a line of micro-biogas digesters in South America and examining how this technology contributes to combating climate change. The analysis encompassed all stages of the product development lifecycle, from ideation to the final phase of commercialization. The aim was to help the company in making an informed decision regarding whether to produce their digesters or serve as a distributor for an existing producer.

### 1.3.1 Scope

The scope of this research covers an extensive investigation into diverse micro biogas digester technologies, combined with an examination of their environmental impact, with a specific emphasis on their contribution to reducing GHG emissions. The focus of this thesis centers on the distinctive tubular micro biogas digester model, recognized for its capacity to provide a significant three-hour supply of free cooking fuel, while simultaneously generating valuable biogas fertilizer. Furthermore, a critical aspect of this research involves assessing the feasibility of distributing micro biogas digesters by collaborating with a supplier company in the context of South America. This includes conducting a comprehensive

examination of the farmer population and the percentage utilizing traditional cooking methods, coupled with an in-depth analysis of customer needs. This evaluation predominantly centers on the rural landscapes of Mato Grosso, Brazil, catering to the requirements of both cattle farmers and those engaged in both cattle and crop cultivation. The research involves assessing substitutes and competitors for micro biogas digesters, aligning their technology with local agricultural activities, conducting a thorough assessment of the potential market demand in the region, and performing a detailed financial analysis. Simultaneously, the research explored an examination of the regulatory frameworks and policies that could play a role in influencing the distribution of micro biogas digesters in the Brazilian market.

### 1.3.2 Objectives

The thesis has several objectives, which include:

- Product line: To understand the technology behind micro biogas digesters and evaluate the feasibility of its implementation in South America.
- Environmental: To study the environmental impact of micro biogas digesters and understand how their use can contribute to combating climate change and reducing gas emissions
- Social: To identify the potential benefits for rural farmers, including improving their standard of living, promoting sustainable farming activities, achieving energy savings, increasing crop yields through fertilization, and generating income via selling biofertilizers.
- Economic: To determine the product's profitability, assess if it meets an unfulfilled need or opportunity for AGCO's existing customers, evaluate its potential to attract new customers, and analyze its contribution to expanding the market share of AGCO in Brazil.

### 1.3.3 Evaluation Criteria

The selection of criteria can vary depending on the goals and objectives of different types of projects. In the context of the Master's thesis, two different sets of criteria need consideration: one from an academic standpoint and the other related to the business aspect.

- Academic Perspective: The academic perspective outlined by Inland Norway University of Applied Sciences highlights the student's proficiency in knowledge and

skills in the domain of biotechnology commercialization. The thesis is expected to contribute significantly by addressing both practical and theoretical challenges, potentially integrating real-world applications.

- ❖ Business Perspective: In the distribution of micro biogas digesters, various factors are significant, as outlined below:
- ➢ **Time/Schedule:** A well-defined timeline for market research, micro biogas digester product development, and distribution logistics ensures a successful product launch while considering market trends and competitors' actions. This timeline can be visually represented through a Gantt chart, illustrating the duration of each phase.
- ➢ **Cost:** Effective cost management is crucial for offering the micro biogas digester at a competitive price point, especially considering that farmers frequently depend on LPG as an alternative.
- ➢ **Quality:** Using high-quality semi-final components and polyvinyl chloride (PVC) bags leads to the company's reputation and boosts customer satisfaction. This commitment involves delivering superior products that excel beyond competitors, ultimately increasing the overall values.
- ➢ **Safety and Environmental Impact**: Assessing the biodigester's environmental benefits in terms of reduced GHG emissions, meeting the demand for sustainability. Strict safety measures and comprehensive training ensure secure digester operation, effectively mitigating potential risks.
- ➢ **Customer Satisfaction**: Enhance customer satisfaction by tailoring products to meet the needs of rural farmers through customer needs analysis and feedback, and offer exceptional support during installation, usage, and maintenance.
- ➢ **Market share (Market demand):** Evaluating market share not only provides insights into the company's competitive position but also measures its potential to capture a significant portion of market demand. Additionally, comprehending the landscape of substitutes enables the company to effectively position itself within the market.
- ➢ **Profitability Considerations:** When it comes to finances, each phase has its own set of costs. Analyzing sales revenue and distribution process expenses is crucial. Analyzing factors such as farm size, income levels, market demand, and other success criteria significantly influences profit attainment.
- ➢ **Strategic goals:** The objective of AGCO is to serve as a distributor of micro biogas digesters in Brazil. If this product proves to be profitable for the company, they may

consider starting their product line while simultaneously expanding their operations across South America.

- **Return on Investment:** Evaluate the company's revenue potential and optimize resource allocation for the distribution of micro biogas digesters, directing resources to activities that generate more profit and help the company grow steadily. This underscores the significance of Return on Investment (ROI) as a crucial tool for determining the success of distributing micro biogas digesters.

### 1.3.4 Research Questions

The research questions aimed to gain a comprehensive understanding of micro biogas technology, its potential impact on combating climate change, and its feasibility for distribution in South America. The research sought to analyze the market demand, profitability, risks, and customer preferences related to micro biogas digesters. Additionally, the research aimed to explore the competitive landscape and possible substitute products available to farmers and evaluate whether the green business plan of distributing micro biogas digesters was a viable and valuable idea. The research questions were designed to provide valuable insights and guidance for AGCO and other stakeholders in making informed decisions about distributing micro biogas digesters in South America. The following questions were explored in this study:

- What is the technology of micro biogas digesters, and how can it significantly contribute to addressing climate change?
- What is the market demand for micro biogas digesters in South America and Brazil, and is there a feasible market for their distribution?
- What is the ROI and profitability of introducing micro biogas digesters in the region?
- Who are the target customer segments, and how can micro-biogas digesters be effectively marketed, sold, and serviced to these customers?
- What are the requirements and preferences of potential customers?
- Who are the main competitors in the market, and how do they affect AGCO's planned green business strategy?
- What are the main substitutes, and what is the positioning of the micro biogas digester in the markets of South America and Brazil?
- What are the risks and opportunities related to implementing this green business plan?

# 2. Material and Methods

In this thesis, the research methodology primarily revolved around desk research, which included gathering data from various secondary sources such as academic publications, research papers, reports, case studies, and relevant documents. This approach was chosen to conduct a comprehensive exploration of the subject matter by analyzing pre-existing knowledge and insights. To gather a wide range of relevant literature, a systematic strategy was employed. The Oria search engine within the database of the Inland Norway University of Applied Sciences provided access to academic collections containing scholarly articles, books, and reports. Additionally, web-based search engines like Google, Google Scholar, and ScienceDirect were utilized to ensure comprehensive coverage of available literature. The selection of search terms and keywords was approached to yield outcomes closely aligned with the thesis goals.

Several frameworks and methodologies were employed. Market estimation helped in understanding the market size and demand for the products. Customer segmentation and needs analysis provided insights into the target customers and their requirements. An analysis of competitors and substitutes showed where the micro biogas digester stands in the South American market. Furthermore, a financial analysis was conducted to determine the final cost of the biogas digester and its profitability. SWOT analysis helped identify the strengths, weaknesses, opportunities, and threats of the company concerning the distribution of micro biogas digesters in South America. The PESTEL analysis method was used to evaluate external factors influencing the biogas digester market in Brazil. The Business Model Canvas was employed to assess all aspects of the business, making planning more effective. The study also included industry reviews, considerations of intellectual property rights (IPR), risk assessments, and evaluations of the value and supply chain to thoroughly understand the project's feasibility and impacts.

# 3. Result & Discussion

## 3.1 Product Identification (Ideation Stage)

### 3.1.1 Biogas digester technology

Biogas is a mixture of methane and carbon dioxide, along with a small number of other gases such as hydrogen sulphide (McKendry, 2002). Methane, the valuable component of biogas, is a colourless gas that burns with a blue flame. It is commonly used for cooking, heating, and lighting purposes (Itodo et al., 2007). Being environmentally friendly, efficient, and sustainable, biogas serves as an alternative energy source to conventional fuels (Yu et al., 2008). Anaerobic digestion (AD) is a process that occurs in the absence of oxygen. It involves the breakdown of complex organic waste into smaller molecules. The residue or slurry obtained from the digester contains high levels of ammonium and other valuable nutrients that can be utilized as an organic fertilizer. Considering that biofertilizer is generated from the biodigester, it leads to significant improvements in crop yields (R. B. Singh, 1972, Rajendran et al., 2012a). Biogas digesters positively impact the environment by reducing GHG emissions and addressing public health concerns related to indoor air pollution (Kinyua et al., 2016a). AD can be implemented on various scales, from small-scale applications to larger setups in both urban and rural areas. Currently, three types of biogas digesters are prevalent: fixed dome, floating drum, and plastic tubular digesters (Obaideen et al., 2022).

### 3.1.2 The process of Operation of Micro Biogas Digester

Anaerobic digestion involves four steps: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. During the hydrolysis stage, complex carbohydrates, fats (lipids), and proteins are broken down into sugars, amino acids, and fatty acids (glucose, glycerol, purines, and pyridines). In the acidogenesis phase, these simpler components break down into alcohols, carbonic acids, and VFAs (volatile fatty acids). During acetogenesis, the short-chain acids transform into acetate, hydrogen, and carbon dioxide. Ultimately, methanogens convert these intermediates into methane and carbon dioxide. Importantly, approximately one-third of methane formation results from the reduction of carbon dioxide by hydrogen (Al

Seadi, 2008), (Deublein & Steinhauser, 2011). The reaction scheme is illustrated as equation 1 below:

*Equation 1 biogas composition*

$$C_6H_{12}O_{\ 6} \rightarrow 3CO_2 + 3CH_4 \quad (1)$$

Moreover, Figure 1 demonstrates the elements present at each stage of the AD process.

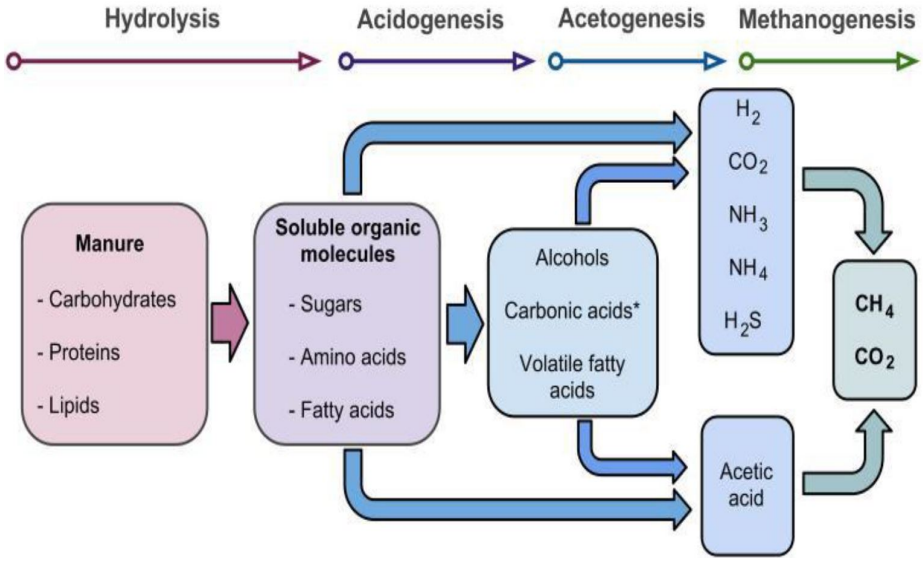


*Figure 1 Anaerobic digester process diagram (Girarrd, 2013).*

When conducting a comparison between biogas digester and alternative fuels like LPG, it becomes crucial to assess how biogas influences energy content and combustion characteristics. Biogas mainly consists of $CH_4$ and $CO_2$, with fewer hydrocarbons, leading to reduced emissions of GHGs during combustion. Similar to natural gas, biogas can be pressurized for efficient transportation and resale due to its $CH_4$ and $CO_2$ composition. The final components of the biogas are listed in Table 1 below:

*Table 1 Presents the composition of biogas from bio-waste (Eawage, et al., 2014).*

| Components | Symbol | Concentration (vol/ %) |
|---|---|---|
| Methane | $CH_4$ | 55-70 |

| | | |
|---|---|---|
| Carbon dioxide | $CO_2$ | 35-40 |
| Water | $H_2O$ | 2(20˚C)-7(40˚C) |
| Hydrogen sulphide | $H_2S$ | 20-20 000 ppm (2%) |
| Nitrogen | $N_2$ | <2 |
| Oxygen | $O_2$ | <2 |
| Hydrogen sulphide | $H_2$ | <1 |
| Ammonia | $NH_3$ | <0.05 |

## 3.1.3 Technology-Alternatives

### *3.1.3.1 Fixed Dome Digester*

The fixed dome digester, pioneered in China, is a popular choice in developing countries. It consists of a cylindrical chamber with a feedstock intake, outlet, and storage tank. The construction of a fixed dome digester typically involves the use of concrete, brick, cement, and sand as y materials for an underground structure. The size of micro biogas digesters ranges from 4 to 20 $m^3$ (Uche et al., 2020), (Rajendran et al., 2012). Biogas collects in the upper chamber. The difference in levels between the slurry inside the digester and the chamber creates pressure in the gas. As the pressure of biogas increases, it pushes some of the substrate into the tank. The biogas is transported through a pipeline from the digester to gas storage, where it is stored and subsequently utilized for cooking (Garfí et al., 2016b). The main drawback of fixed dome digesters is their reliance on skilled labor during construction. Furthermore, fluctuations in liquid volume, methane production, and temperature can impact the gas pressure within the fixed dome, potentially leading to operational issues with the burner and raising safety concerns (Schoeber et al., 2021), (Kinyua et al., 2016b). The Figure 2 simply demonstrates the fixed dome digester:

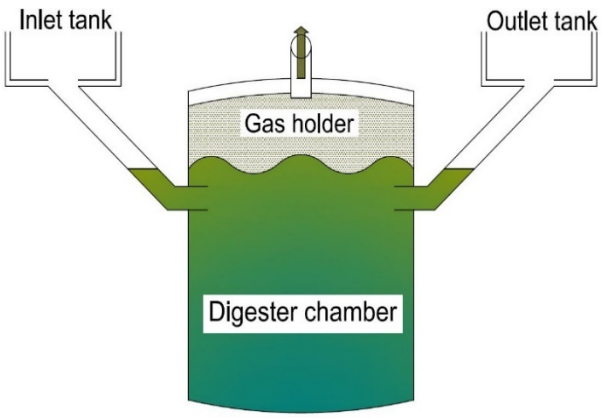


*Figure 2 Fixed Dome Digester*

### *3.1.3.2 Floating Drum Digester*

India commonly adopts the floating drum digester design for biogas systems. This digester features an underground structure, which can be either cylindrical or dome-shaped, along with a mobile gas holder. It is constructed from concrete and steel underground, and the floating drum, typically made from steel or polyvinyl chloride (PVC), is positioned on top of the digester. The floating drum serves as a storage container for the gas. The pressure needed for gas to flow in the pipeline is generated by the weight of the floating drum, which is pulled down by gravity. Floating drum digesters vary in size, ranging from 1.6 $m^3$ to larger ones of 10 $m^3$, effectively serving multiple households with biogas. While the processes are easy to build, they require consistent maintenance to avoid corrosion, particularly in tropical climates (Rajendran et al., 2012b), K. J. Singh & Sooch, 2004). The Figure 3 simply demonstrates the fixed dome digester:

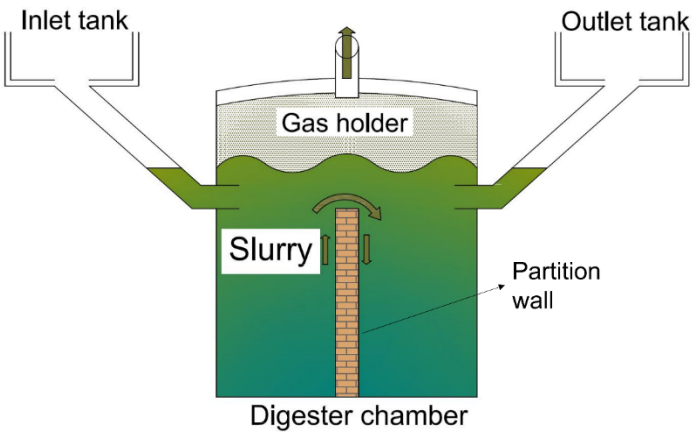


*Figure 3 Floating Drum Digester*

### *3.1.3.3 Plastic Tubular Digester*

The plastic tubular biogas digester has become popular for its affordability and convenience. It does not require advanced skilled labour for installation. Its simple construction, utilization of easily accessible materials, and adaptable design have led to its widespread adoption. The first tubular biogas digesters were set up in Colombia and Ethiopia during the 1980s by Botero and Preston. This led to the development of a polyethylene (PE) tube and PVC pipe-based tubular digester by a Vietnamese group. This design was discovered to be more cost-effective than using plastic bags and is currently known as the Taiwanese model (Kinyua et al., 2016a). In the horizontal model of a tubular digester, a long and narrow tank is utilized, with manure added to one side. As digestion occurs, it naturally moves other material away from the opposite side. Typically, these models have a capacity ranging from 2.4 $m^3$ to 12 $m^3$, with about 75% of the volume filled with liquid during operation (Martí-Herrero, 2011), (Rajendran et al., 2012b). Tubular micro biogas digesters are commonly constructed using materials like PVC, polypropylene (PP), and PE. These choices were made to address the challenges faced by farmers who encounter difficulties when using concrete materials because concrete domes tend to crack, which emits methane and reduces biogas output to burners (Cheng et al., 2014). The Figure 4 simply demonstrates the plastic tubular digester:

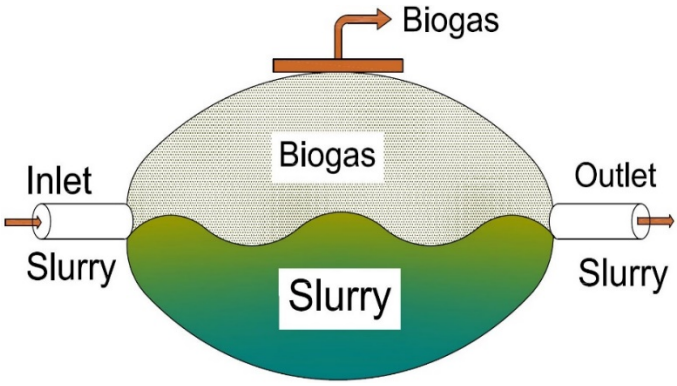


*Figure 4 Plastic Tubular Digester*

Different materials are used for constructing tubular digester bags, each with its benefits and drawbacks, which are provided in Table 2 below:

*Table 2 Different types of materials used for tubular micro gas digesters.*

| Materials | Advantages | Disadvantages | References |
|---|---|---|---|
| **PVC** | **.** Lightweight<br>**.** Resistant to corrosion<br>**.** Inexpensive | **.** Sensitive to high temperatures<br>**.** Durability (low life span)<br>**.** Not biodegradable | **.** (Anaswara, 2015)<br>**.** (Lansing et al., 2008)<br>**.** (Lansing et al., 2010) |
| **PP** | **.** Lightweight<br>**.** Resistance to extreme heat<br>**.** Non-toxic materials | **.** Expensive<br>**.** Not biodegradable<br>**.** Not durable | **.** (Rajendran et al., 2012b) |
| **PE** | **.** Durable<br>**.** Work in various temperature<br>**.** Resistance to UV rays | **.** Expensive<br>**.** Not biodegradable<br>**.** Not Flexible | **.** (Ferrer et al., 2009) |

#### *3.1.3.4 Micro Biogas Digester Technology Selection*

Fixed-dome digesters are highly popular in South Asia (Ghimire, 2013) , India (Bond & Templeton, 2011), and China (Chen et al., 2012), with more than 45 million units installed. Similarly, floating drum digesters share many features with fixed domes. They are renowned for their extended lifespan, over 20 years. However, this technology requires materials such as bricks, cement, and skilled labours, making it more expensive and less suitable for both urban and rural regions. The innovation of low-cost household tubular digesters by Preston and colleagues offered an affordable alternative to other types of micro biogas digesters. Several Latin American countries have adopted this technology. In contrast to fixed-dome and floating drum digesters, tubular digester designs come with lower material and labour costs, making them a cost-effective option at half the price. Tubular digesters bring logistical advantages, particularly easier and more economical material transport, highly beneficial for financially constrained farmers in remote rural areas (Castro et al., 2017).

Table 3 provides an extensive comparison of different biogas digesters, highlighting crucial aspects to factor in while selecting a micro biogas digester. Evaluation criteria are rated on a scale of 1 to 5, with 1 indicating very low and 5 indicating high rate.

*Table 3 Comparing different types of biodigesters*

| Criteria \ Products | Fixed Dome | Floating Drum | Tubular Digester |
|---|---|---|---|
| **Long-lasting performance** | 5 | 5 | 4 |
| **Easy installation & Maintenance** | 3 | 4 | 5 |
| **Affordability for rural farmers** | 3 | 4 | 5 |
| **Effective operation** | 3 | 3 | 5 |
| **Farmer interest** | 3 | 4 | 4 |
| **Safe to use** | 3 | 4 | 4 |
| **Positive environmental impact** | 4 | 4 | 4 |
| **Total score** | 24 | 28 | 31 |

### 3.1.4 Customer Needs Analysis

When developing an effective micro biogas digester solution for rural farmers in South America, it's important to understand the specific challenges and needs they face. These farmers have three primary tasks and needs:

1. Cooking and Fuel Efficiency: The primary need of farmers is daily cooking. Farmers rely on traditional methods for cooking such as LPG and firewood. They require a solution that offers economic efficiency, safety, and time-saving benefits for their cooking needs.
2. Waste Management and Addressing Challenges: Farmers face challenges when dealing with managing cattle waste. They require an effective waste management solution that not only improves hygiene but also enhances the overall waste management process.
3. Farming and Crop Yield: The target customers depend on farming as their primary occupation. They are actively seeking cost-effective fertilizers to improve crop yield and quality. Bio-fertilizers provide a promising solution without any cost, as they

convert waste into valuable fertilizer that is environmentally friendly and easily accessible to them. Table 4 presented below offers a clearer depiction of both customer requirements and our capability to fulfill them.

*Table 4 Customers need analysis*

| Jobs | Minimum Farmer Specifications | Target specifications for product capabilities |
|---|---|---|
| **Cooking** | Minimum 3 hours of cooking time | Provides a minimum of 5 hours of cooking time |
| **Waste management (manure processing)** | Efficient cattle manure waste management for at least 1 cow | Efficient cattle manure waste management for at least 3 cows |
| **Improving crop yields (fertilizer production)** | Ensure consistent weekly fertilizer supply for crops | Sufficient daily fertilizer supply for crops. |

If rural farmers are considering purchasing the tubular micro biogas digester, their requirements as buyers cover the following:

1. Ease of Use and Reliability: Given the busy schedules of rural farmers and their potentially limited technical skills, these customers prioritize solutions that are simple to operate and maintain. They are concerned about complexity and factors that discourage them from considering the product.
2. Product Support: Customers need product assistance, including guidance for setting up and help with troubleshooting.
3. Health and Environmental Considerations: Farmers express worry about health risks connected to traditional cooking methods, especially indoor air pollution. Their preference leans towards eco-friendly solutions.
4. Affordability: Farmers are actively seeking a micro biogas digester that offers the right balance between cost and value for their investment.

### 3.1.5 Substitutes

- **Substitutes for Cooking**

➢ LPG is a convenient and easy-to-use cooking substitute for rural areas, as it saves time and can be delivered to remote locations. However, it can be unsafe due to its flammability, and when burned, it emits $CO_2$, a GHG leading to air pollution and potential respiratory issues (Schilmann et al., 2021, Bond & Templeton, 2011).

- Firewood is generally easily accessible, inexpensive, and self-sufficient. However, it's not highly efficient and can lead to indoor air pollution, deforestation, and respiratory problems (Bond & Templeton, 2011).
- Charcoal is produced by burning wood with limited oxygen, resulting in a fuel that produces less smoke than firewood. However, its production can contribute to environmental impacts and respiratory risks.
- Consider the environmental impact of dung and crop residues, as their burning leads to indoor air pollution, and respiratory problems.

- **Substitute for Biofertilizer**

Synthetic fertilizers can be used as substitutes for biofertilizers to improve and enhance crop yields. Synthetic fertilizers provide specific formulations with higher nutrient content, effectively boosting crop productivity. However, the production of synthetic fertilizers has a significant carbon footprint. This footprint arises from activities, energy-intensive ammonium production (often using fossil fuels), and fertilizer transportation to customers, which can lead farmers to turn to biofertilizers. Biofertilizers, as a safe and eco-friendly alternative, aim to minimize ecological harm. Their outputs consist of natural and organic components, free from pollutants, and they are proven to be more cost-effective for farmers (Möller & Müller, 2012).

### 3.1.6 Customer Segmentation

Market segmentation is a crucial step in identifying and targeting specific customers for the introduction of tubular micro biogas digesters in South America, including Brazil (the beachhead market is discussed in the market estimate part). The evaluation criteria for selecting target customer segments include factors such as types of farmers, market size, and income level of farmers. In South America, the agricultural landscape is varied, with farmers ranging from livestock farmers, and those engaged in both cattle and crop growth, to large-scale commercial producers. Among those who raise livestock, distinctions regarding target customers are made based on the scale of their operations and the specific livestock they care for. This differentiation is detailed in Figure 5, which illustrates the number of livestock in Brazil for the year 2021.

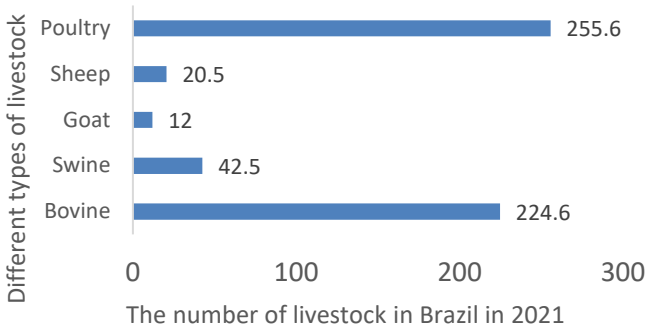


*Figure 5 Data was provided by IBGE.com*

The target customers are bovine farmers, driven by the significant number of bovine animals indicated in Figure 5 and the higher volume of slurry generated by bovine, making it an ideal feedstock for micro biogas digesters capable of consistent cooking gas production and biofertilizer.

Bovine farmers are categorized into three primary types: beef cattle farmers who do not collect manure, dairy farmers who utilize manure collection systems, and dual-purpose farmers engaged in both crop-cattle farming. Target customers primarily consist of dairy farmers and dual-purpose farmers, with varying farm sizes. For dairy farmers, differentiation is made between small operations (those with fewer than 20 cows), mid-sized ones (ranging from 20 to 40 cows), and large-scale enterprises (having more than 40 cattle). The target customer base primarily comprises small to mid-sized operations that have the financial capacity to invest in micro biogas digesters (to find income data for the target customers, it's advisable for a consultant to visit rural areas in Brazil to gather more information).

### 3.1.7 Competitors

To conduct an effective competitor analysis, it's crucial to gather and analyze data on companies and organizations involved in the manufacturing or distributing tubular micro biogas digesters in South America, particularly in Brazil. This process involves identifying both local and international markets. Furthermore, it's essential to assess competitors' digester technology, sales, and marketing strategies. By summarizing these findings, identifying gaps, and opportunities, and evaluating potential demand, the company can make informed decisions about selling, marketing, and distributing micro biogas digesters in suitable beachhead regions. Table 5 shows some information about competitors that produce or distribute tubular micro biogas digesters for farmers (Home Biogas and Sistema are

currently operating and distributing their products in Brazil. However, it is assumed that NIDECO could potentially emerge as a competitor in the Brazilian market).

*Table 5 Compares competitors according to different criteria*

| Company / Criteria | Location | Size | Price | Operation & Maintenance | Performance |
|---|---|---|---|---|---|
| **Home biogas** | USA | 3x1.5x1.3 m 83x45x52 in | $1375 | 75 L/ 20 gallons of slurry | 3 h/D cooking |
| **NIDECO** | Norway | Gasholder 1 m3 for Rural Biogas Digester 10m3 | $ 417 | N/A | N/A |
| **Sistema.bio** | Mexico | Small model | N/A | 45 manure L/D (2cows) | 3.3 h/D cooking |

### 3.1.8 SWOT Analysis of Product

The SWOT analysis is a widely utilized strategic tool in business and management. It involves assessing the strengths, weaknesses, opportunities, and threats linked with a company, product, or project. By examining internal strengths and weaknesses, as well as external opportunities and threats, organizations can identify their advantages, areas needing improvement, potential pathways for growth, and possible risks (Pickton & Wright, 1998). To gain a clearer understanding of the strategy for distributing tubular micro biogas digesters to rural cattle farmers and cattle-crop farmers in Brazil, analyzing the SWOT of micro biogas digester as a product line is crucial.

**Strengths:**

1. A Sustainable Product: The tubular micro biogas digester relies on non-renewable energy sources promotes environmental sustainability and reduce greenhouse gas emission.
2. Time-saving and Cost-saving: By reducing dependence on expensive energy sources like LPG, the digester offers significant cost savings. Additionally, it saves time by eliminating the need for firewood collection or traditional cooking preparations.

3. Efficient Waste Management: Addresses waste management challenges by converting organic waste into biogas for cooking, thus improving hygiene in farming areas.
4. Fertilizer Production: The digesters produce fertilizers that enhance soil fertility, boost crop yields, and reduce the need for synthetic fertilizers.
5. Compact Design: Suits small-scale farms with limited available space.
6. Easy Installation & Low Maintenance: The digester features a straightforward installation process, suitable even for farmers with limited technical expertise.
7. Durability: With a minimum 10-year lifespan, it provides long-term value and enhances sustainability by reducing the need for frequent replacements.
8. Health Benefits: Customers are protected from indoor pollution, reducing the risk of respiratory problems, particularly among children and women.

**Weakness:**

1. Technical Expertise: Limited technical expertise in rural areas presents challenges for farmers to address technical issues or perform necessary repairs.
2. Safety Concerns: Farmers may have worries about potential biogas leakage and the proper handling of slurry, as improper handling can lead to infections and illnesses.
3. Reliability and Performance: These concerns arise when the amount of slurry generated is insufficient for everyday cooking needs because the product provides 3 hours of cooking per day.

**Opportunity:**

1. Potential for Growth: Gain more market share in Brazil through the distribution of tubular micro biogas digesters aligns with the increasing demand for sustainable energy solutions among rural farmers.
2. Collaboration with Environmental Programs: Partnering with government and non-government organizations (NGOs) can create a favorable environment for promoting and adopting products, potentially leading to support and incentives.
3. Raise Awareness: Opportunity to inform and educate rural farmers about the benefits of sustainable products.

4. Environmental Impact: Emphasizing the positive impacts on the environment, including maintaining cleanliness and green surroundings for rural farmers, can appeal to those who prioritize sustainability.

**Threats:**

1. Substitutes: LPG's dominance in the market and the widespread use of LPG and firewood present challenges in convincing farmers to adopt biogas digesters.
2. Competitive Challenges: Rival manufacturers of tubular micro biogas digesters can present a challenge by offering alternative solutions to potential customers, impacting market share.
3. Access to Remote Areas: Difficulties in reaching remote rural areas with limited infrastructure and rough terrain can lead to customers not receiving the product on time.
4. Technical Issues: If farmers encounter operational difficulties or face problems with the biodigesters, they may be discouraged from using the technology.
5. Cultural Obstacles: Cultural preferences and traditional cooking methods may hinder the acceptance of new technologies like biodigesters.

## 3.2 Product Prototyping

### 3.2.1 Product Description

The tubular micro biogas digester, produced by Flexi Biogas in Kenya, offers an above-ground, versatile solution that is both cost-effective to build and operate. This innovative system eliminates the need for manual stirring, utilizing a unique design—a 6m x 3m PVC tarpaulin bag—instead of a sealed tank for the digester. With an estimated daily production of 15 to 30 kg of dung from a single cow, the Flexi Biogas setup can generate approximately 1,000 liters of cooking gas from 20 kg of fresh cow dung. This quantity is sufficient to meet the cooking needs of a family comprising at least five to seven members for a minimum of 3 hours. Figure 6 illustrates the prototype of a tubular micro biogas digester for rural areas.

*Figure 6 The prototype of a tubular micro biogas digester*

### 3.2.2 Operation of the Flexi Biogas System

As per the information provided by Flexi Biogas company, the Flexi Biogas system stands out as a highly adaptable and easily transportable solution, boasting a shorter breakdown time for organic materials compared to other micro biogas digester systems. This innovative approach involves a plastic digester bag housed within a greenhouse tunnel, resembling an open-ended pillowcase. The tunnel acts as insulation, maintaining temperatures between 25 and 36 degrees Celsius, enhancing gas production, and decreasing the time it takes for gas to be retained. This ensures efficient fermentation and gas creation. As microbes digest the organic material, biogas is produced and inflates the plastic bag. The system heats up in the sun, rapidly generating methane gas, which is then channeled through a PVC tube for use in appliances like gas stoves.

### 3.2.3 Installation Process

The installation process of the tubular micro biogas digester is designed to be simple for a wide range of users, including those with limited technical knowledge. The installation process begins with the selection of a proper location. The second step involves preparing a flat surface. Subsequently, the assembly of the digester components takes place, utilizing the lightweight nature of the PVC bag (which weighs around 10 kg). Adding a green, thin, and long pipe on top to make the PVC bag more stable and a shade-net cover follows. Farmers receive training to comprehend each stage, from assembling the parts to preparing the biogas. The entire installation process takes approximately 8 hours, resulting in the

establishment of a fully operational biogas system. Figure 7 below shows the complete process of installing a tubular micro biogas digester in a rural area for customers.

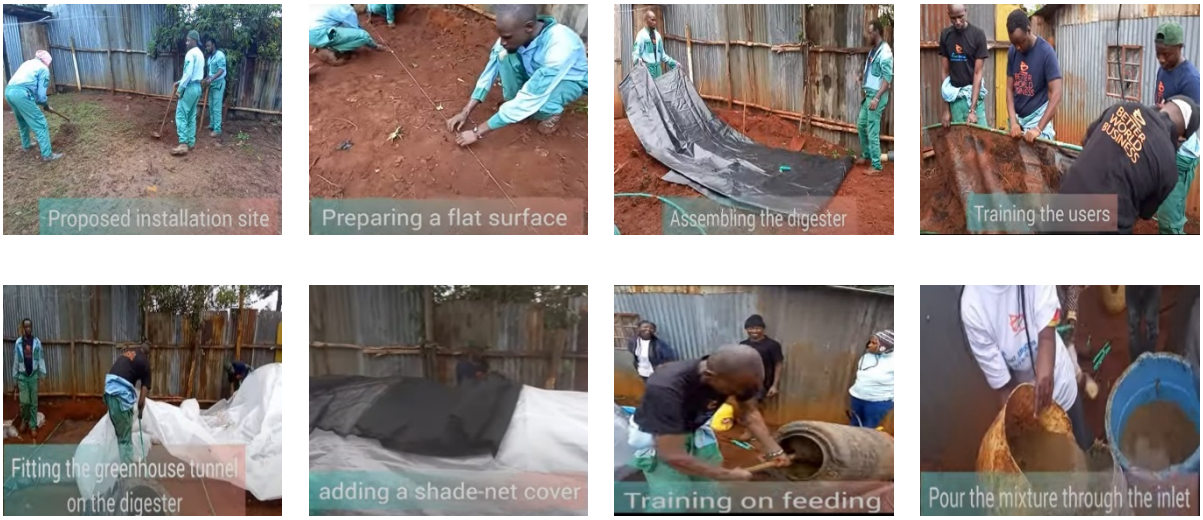


*Figure 7 The complete process of installing a micro biogas digester*

### 3.2.4 Target Customer Profiles

The target customers are small to mid-sized cattle and crop farmers in rural Brazil, particularly in the rural areas of Mato Grosso. They rely on conventional cooking methods. While their daily routines mainly involve cooking, cattle raising, waste management, and crop fertilization, they face several challenges. To gain deeper insights into our customers, it's crucial to have market experts who can directly interact with our target customers. These experts will conduct assessments of customer preferences and provide us with comprehensive reports. Additionally, the marketing team can actively engage rural farmers through surveys, interviews, and focus group sessions, further enhancing understanding of customer characteristics and needs. Table 6 below provides an overview of customer profiles within the target market segments. It's important to note that this table is based on research and represents a theoretical template.

*Table 6 The persona of target customers*

| Criteria / Customers | Customer 1 | Customer 2 | Customer 3 |
|---|---|---|---|
| Age | 30-35 | 40-50 | 50-60 |
| Gender | Male | Male | Male |
| Income (monthly) | $450 | $600 | $700 |
| Occupation | Small-scale cattle | Cattle and crop | Medium-scale cattle |

| | | | |
|---|---|---|---|
| | farmer | farmer | farmer |
| Material Status | Married | Married | Married |
| Family Size | 5-6 members | 6-7 members | 8-9 members |
| Education | High school | Secondary school | High school |
| Psychographics<br><br>Key Characteristics | Family-focused, self-sufficient, eco-conscious, tech curious | Hardworking, Traditionalist, self-sufficient, Family-focused | Realistic, Social, cost-conscious, Hardworking |
| Behavioral<br><br>Key Characteristics | Prefer buying in person, Guarantee of products, value-oriented | Prefer buying in person, Loyal to products, Guarantee of products, Buy simple products, value-oriented | Prefer buying in person, Loyal to products, Guarantee of products, Wholesale buying, value-oriented |
| Geographics/Climate & Language | South America, Brazil, Mato Grosso, Tropical, Portuguese | | |

### 3.2.5 Value Proposition

The value proposition consists of two key components: customer understanding through the customer profile and the value map that describes how value will be created for the customer. The goal is to achieve a fit between the customer profile and the value map, ensuring that the product or service meets the needs and preferences of the target customers (Kyhnau & Nielsen, 2015). Target customers include small to mid-sized cattle farmers and those engaged in cattle and crop farming. These farmers typically rely on traditional energy sources like LPG and firewood for cooking, methods that are not only time-consuming and costly; but also present health and environmental challenges. Our product introduces an economical and safer cooking alternative by replacing these conventional fuels. This not only saves time spent on gathering firewood but also reduces health risks. The tubular biogas digesters are specifically designed for ease of use and reliability, providing about 3 hours of cooking time each day. The value of the tubular micro biogas digester goes beyond, as it contributes to addressing climate change and curbing greenhouse gas emissions. By converting livestock waste into biogas, it effectively reduces methane release. Additionally, the micro biogas digester produces biofertilizer, which enhances both soil and crop health while reducing the farmers' dependency on synthetic fertilizers. Moreover, the company

offers after-sales service, including guidance during installation and help with troubleshooting, to ensure smooth and effective use of tubular micro biogas digester.

## 3.2.6 Price

### *3.2.6.1 Pricing and Sourcing Analysis*

The tubular micro biogas digester is priced based on the essential components required for its construction and operation. Table 7 demonstrates the pricing details for each component. The prices for each component are obtained from online websites in Brazil, and there are no wholesalers involved. This research is for assessing the purchase of components from Brazil instead of importing from Kenya by Flexi Biogas company.

*Table 7 The cost of components*

| Materials | Price | Description | Reference |
|---|---|---|---|
| PVC pipe (25cm d, 3m) | $40 | Two 1.5-meter PVC pipes, one serving as the inlet and the other as the outlet. | Olx.com.br |
| Corner PVC pipe (25cm) | $3 | 3 corner connectors attach the PVC pipes to the bag, and 2 additional corner connectors at the top of the PVC pipes. | Leroymerlin.com.br |
| PVC bag ($6m^3$) | $100 | It is a container designed to store and facilitate the anaerobic digestion of organic material for biogas production. | Alibaba.com |
| Gas pipe ($1m^2$) | $2 | Connects stove to biogas digester | Produto.mercadolivre.com.br |
| Stove- 2 burners | $20 | A cooking appliance equipped with two separate burners on its cooktop. | americanas.com.br |

Producing a tubular micro biogas digester involves additional costs for other components, including the shield cover (plastic cover, net shade cover, etc.), which amounts to a total of $15. All components are purchased in Brazil; only the PVC bag was imported from China. The total cost for the assembly of the tubular micro biogas digester is $180. If the Flexi biogas company imports PVC bags from Kenya the total cost is $240.

#### *3.2.6.2 Flexi Biogas Costs in Kenya*

According to the information provided by Flexi biogas company in Kenya, the high cost of quality plastic and rubber increased manufacturing expenses. Initially, the Flexi Biogas system utilized low-cost plastic digester bags, resulting in a total system price of US$180. However, these bags were prone to tearing during transportation and required replacement every two years due to damage. The systems now feature durable PVC tarpaulin bags with a minimum lifespan of 10 years. This, along with other improvements, has raised the cost of the smallest system to US$410 (Table 8), including installation. Further cost reduction is possible by manufacturing the systems in countries like China or India, where raw material prices are significantly lower than in Kenya. It should be mentioned that the company has posted a price of $800 on its website without providing additional information

*Table 8 Construction cost of a Flexi Biogas system*

| Item | Cost (US dollars) |
|---|---|
| Digester bag (PVC tarpaulin) | 160 |
| Greenhouse tunnel (polyethylene plastic) | 20 |
| Inlet/outlet pipes and 15m gas delivery pipe | 70 |
| Personnel (2 technicians) | 50 |
| Profit mark-up | 70 |
| Office overheads | 20 |
| Total US | US$410 |

### 3.2.7 Promotion

- Advertising: The marketing strategy focuses on creating customized Portuguese content for Brazilian customers. Utilize local media outlets such as radio channels, brochures, and newspapers. Additionally, use banner advertising in and around Mato Grosso to broaden the reach and engage the target customers.
- Participation in Local Events: Exhibitions and agricultural fairs, offers a valuable opportunity for face-to-face interaction with potential customers. It provides a platform to showcase the product's features and directly address any inquiries,

thereby educating farmers about the practical aspects of the product, its functioning, and the benefits it offers. Focus on these factors also in events:

- Success Stories: Sharing case studies from customers who have had positive experiences with the digester can be very influential.
- Special Offers: By providing initial discounts, benefits for recommending others, or flexible payment plans, the digester becomes more affordable for farmers. This could significantly encourage them to adopt the technology.
- Interview and Focus Group: Longside local events, interviews, and focus groups are conducted to directly engage potential customers. This provides deeper insights into their preferences and concerns, enabling the provision of products designed to meet their specific needs.

- Local Partnerships: Collaborating with local government agencies or NGOs can help gain the trust of the community, as these organizations already have established relationships with the farmers.

### 3.2.8 Placement

AGCO has an existing office in Brazil, but the website only mentions the address of the office in Brazil.

- Brick-and-Mortar Retail: Partnering with local rural stores or agricultural cooperatives provides an effective channel. Farmers are familiar with these stores, which are conveniently located in rural areas, offering an ideal platform for reaching target customers. The collaboration not only enhances product availability but also offers the opportunity for direct interactions, building trust, and fostering a strong connection with potential buyers.
- Sales Agents: Engaging well-connected sales agents with established local farming relationships offers a personalized distribution approach. These agents understand the community's needs, challenges, and preferences, allowing them to introduce the product personally.
- E-Commerce Platforms: A user-friendly online platform allows farmers to access product information, explore features, and even place orders from home. This digital presence offers convenience, allowing individuals to make informed decisions at their own pace.

### 3.2.9 Business Model

The business model canvas developed by Osterwalder and Pigneur in 2010 has become widely popular as a highly regarded tool for business modeling. It offers a versatile framework and a set of guiding principles to assist in the development and improvement of a business model (Van Der Pijl et al., 2016). In simple terms, a business model is a strategic representation of how a company creates and delivers value to customers while generating revenue. It has become a subject of great interest among academics and business professionals in recent years (Massa & Tucci, 2014). Table 9 presents the business model canvas for a tubular micro biogas digester.

*Table 9 Canvas business model of tubular micro biogas digester*

<table>
<tr>
<td rowspan="2">Key Partners:<br><br>.Suppliers of semi-final components<br>.Flexi biogas company<br>.Local partner (Government & NGO)<br>.Retailers<br>.Labours<br>.Sales agent<br>.Online platform</td>
<td>Key Activities:<br><br>.R&D<br>.Market research<br>.Sales & Marketing<br>.Assembling process<br>.Workforce education &Training<br>.Financial analysis<br>.Development supply chain<br>.Development value chain<br>.Quality control</td>
<td rowspan="2">Value Proposition:<br><br>.Green energy<br>.Time saving<br>.Cost-saving<br>.Reduced GHG emission<br>.Simple technology<br>.Managing waste<br>.Increasing hygiene<br>.A long life span<br>.Organic fertilizer<br>.ROI for farmers<br>.Reduce respiratory problems</td>
<td>Customer Relationship:<br><br>.Personalized customer support during events<br>.Effective communication during installation<br>.Online chat box<br>.After sale-service<br>.Regular updates</td>
<td rowspan="2">Customer Segments:<br><br>.Small to midsize farmers engaged in both cattle and crop growth</td>
</tr>
<tr>
<td>Key Resources:<br><br>.Semi-final components<br>.Assembling facilities<br>.Warehouse</td>
<td>Channels:<br><br>.Direct:Local events<br><br>.Indirect: E-commerce</td>
</tr>
</table>

| | | | | |
|---|---|---|---|---|
| | .Human resources<br>.Investment capital<br>.Agreement contract for collaboration<br>.Distribution network<br>.Timeline (Gantt chart)<br>.Regulatory authority certification | | platforms<br>.Sales Agent<br>.Retail stores<br>.Government and NGOs | |
| **Cost Structures:**<br>. Building expenses (Rent & Utilities)<br>. Semi-final components<br>. R&D<br>. Training labours<br>.wages<br>. Operational cost<br>. Shipping & import fees of PVC bag<br>. Vehicle (Deliver to customers)<br>. Regulatory fees<br>. Sale & Marketing<br>. Tax & Insurance<br>.Branding & Licensing | | **Revenue Streams:**<br>. One time payment (Sale biogas digester) | | |

## 3.3 Feasibility Study

### 3.3.1 Market Estimate

A market estimate for tubular micro biogas digesters involves quantitatively assessing the potential demand for these products in South America's rural farming communities. This estimation includes analyzing data on factors such as market size, agricultural activities, regional adoption rates, and substitution analysis to determine the market's overall size and growth potential. A well-conducted market estimate guides the company in understanding the feasibility and market opportunity for tubular micro biogas digesters, while also helping in making smart decisions and using resources wisely to enter the market successfully.

After analyzing the provided information, South America represents the total addressable market (TAM) with a population of 440 million in 2023 (*Worldometer.Com*). Among the countries in South America – Brazil, Argentina, and Colombia – Brazil stands out as a highly potential market for distributing these tubular micro biogas digesters. This preference is influenced by factors such as its large population, a significant number of cattle, high consumption and price of LPG, farmers' income, and the government's attention to sustainability. Brazil can be categorized as a serviceable available market with a population of 214 million (SAM) because of the high consumption of LPG in Brazil. Additionally, there is a high level of agricultural activity in Brazil. Agriculture significantly contributes to the release of GHGs. At the national level, Brazil's agricultural sector, which includes both livestock and crop production, is responsible for just over a third of the country's total GHG emissions (Freitas et al., 2019). Table 10 describes the criteria for choosing a beachhead market.

*Table 10 Selecting beachhead market based on key criteria (2022)*

| Country | Population (millions) | Number of Farmers (millions) | Annual LPG Consumption (million tonne) | Number of Cattle (millions) | Sustainability Ranking | Farmer's Annual Income | LPC'S Price $/kg |
|---|---|---|---|---|---|---|---|
| Brazil | 215 | 4.4 | 7.18 | 224.6 | 58.7 | $7,862 | $ 1.7 |
| Colombia | 51.5 | 2.7 | 0.513 | 24.7 | 65.3 | $4,656 | $ 0.6 |
| Argentina | 45.6 | 0.236 | 1.504 | 14.5 | 54.3 | $1,800 | $ 0.7 |

Focusing on specific regions within Brazil, the rural area of Mato Grosso shows significant potential as a Serviceable Obtainable Market (SOM) with a population of 3.441 million, due to its high agricultural activities ( *IBGE*.gov.br).

### 3.3.2 Beachhead Market

Mato Grosso state, situated in Brazil's central-west region, boasts a total population of 3.6 million people, with 552 thousand residing in rural areas. Mato Grosso exerts a significant impact on global agriculture due to its extensive land area, spanning over 900 thousand square kilometers. The state takes the lead as Brazil's primary contributor to soy, corn, cotton, and cattle production. People in Mato Grosso rely on LPG and firewood for cooking (*City Population.de*). In 2021, Mato Grosso's LPG consumption reached 203.468 million cubic meters per month, marking a significant increase from the previous usage of 186.008 million cubic meters per month. Additionally, the price of LPG for consumers has gradually risen over the years. The price stood at $0.61 in 2010 and reached $1.7 in 2022, reflecting a 175% increase over the span of a decade ( *CEIC Data.Com*). More detailed information is provided in Figure 8:

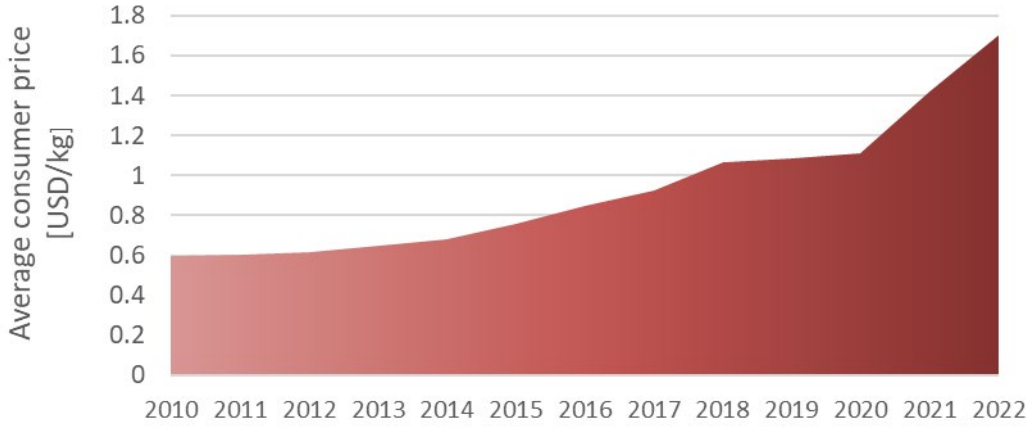


*Figure 8 Price of LPG for consumers (2010-2022): A decade of steady growth (*CEIC Data.Com*).*

There was a growth of 16% in the number of operational plants and a 10% rise in the amount of biogas generated in 2021 when compared to the previous year (*CEIC Data.Com*). However, there was not any clear information about the tubular micro biogas digester. But even without that detail, Figure 9 illustrates that Brazil has been quite active in setting up

these biogas-producing plants. Industrial biogas digesters are commonly found in commercial agriculture, wastewater treatment facilities, and industrial sectors. They are designed to efficiently process significant volumes of organic waste, resulting in substantial biogas production for energy purposes. These facilities are known for their extensive size, with a requirement for significant financial investment. They are essential components in waste management and the generation of sustainable energy for larger-scale operations and industries (Lu & Gao, 2021).

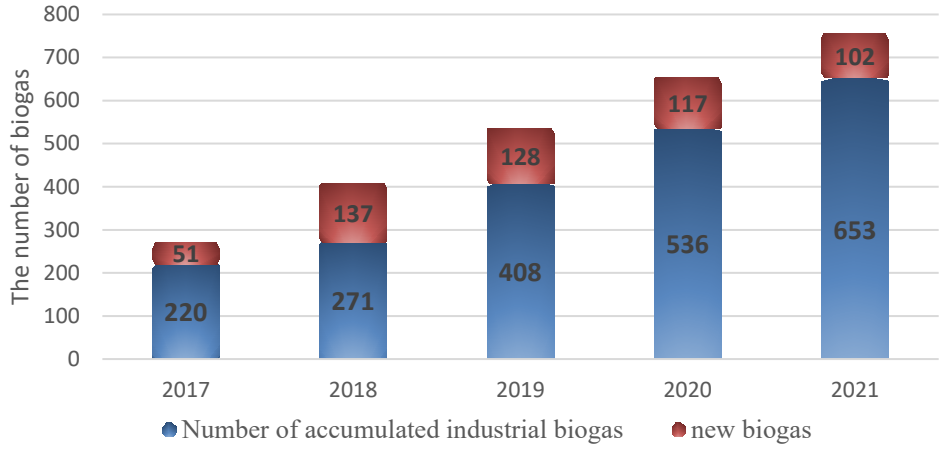


*Figure 9 The significant growth of the biogas sector over the past five years (CIBiogás.org).*

Figure 10 demonstrates where larger biogas plants for industries are being established in various cities across Brazil. This information reflects the level of demand present in Brazil for these biogas facilities (CIBiogás.org).

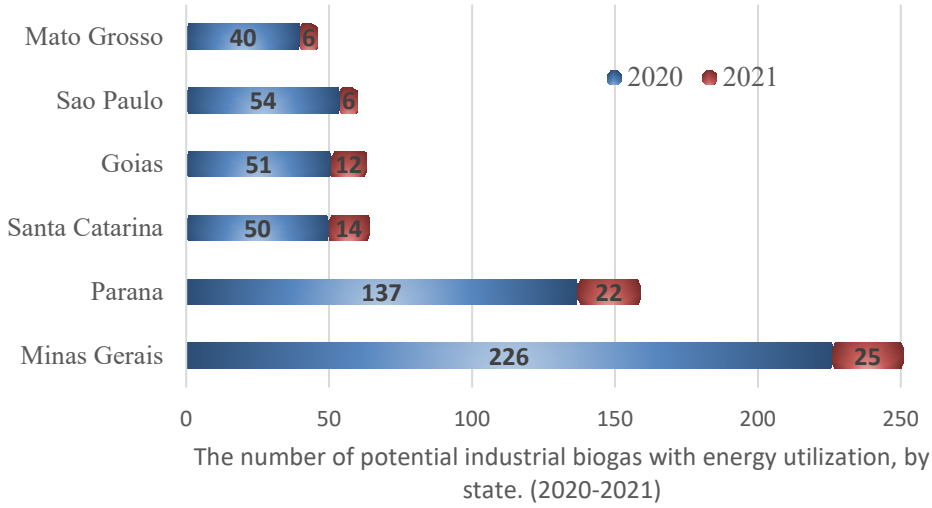


*Figure 10 Industrial biogas digester across five cities in Brazil (CIBiogás.org).*

### 3.3.3 PESTEL Analysis

The PESTEL analysis provides a structured framework to assess the external factors that could impact the distribution of tubular micro biogas digesters in a given region. By exploring Political, Economic, Social, Technological, Environmental, and Legal aspects. Table 11 breaks down each of these categories, highlighting key considerations and potential challenges that AGCO might face in its collaboration with Flexi Biogas for distribution in Mato Grosso, Brazil.

*Table 11 PESTEL analysis for distributing micro biogas digester in Brazil*

| | |
|---|---|
| **Political** | .Brazilian government supports biodigester .International policies concerning biogas .Local government policies in Mato Grosso .Trade relationships with Kenya .Tax rates |
| **Economic** | .GDP contribution from agricultural activities .Brazil's economic stability and inflation rates .Rural income levels in Mato Grosso |
| **Social** | .Demographic analysis of rural farmers .Increase awareness and educate farmers about biogas benefits .Cultural acceptance of biodigester |
| **Technological** | .Ensuring easy installation and maintenance while prioritizing the health and safety of farmers .Efficiency of the biogas output tailored to the farmers' needs |
| **Environmental** | .Local climate conditions and their impact on biodigester performance .Role of the biodigester in combating climate change and reducing GHG emissions |

| | |
|---|---|
| **Legal** | .IPR and patent associated with the technology .Regulations for importing PVC bags and distributing biodigester in Brazil .Rights of farmers as customers .Labour rights regulations .Required authorizations for sales and marketing operations in Brazil |

## 3.3.4 Financial Analysis

### *3.3.4.1 Fixed Costs & Variable Costs*

In the context of business financials, costs are broadly categorized into variable and fixed. Variable costs are expenses that vary in direct proportion to the activity or volume of the business, adjusting as production or sales volumes change. On the other hand, fixed costs stay constant regardless of the level of business operations or production, remaining stable within a specified time frame or production range. A deep understanding of these costs is required for businesses, guiding pricing decisions, budgeting, and overall financial planning, and knowing profit margins. Table 12 presents a list of costs associated with the introduction of micro biogas digesters. For a more detailed breakdown of the costs for each item, a dedicated team should be located in the Mato Grosso area of Brazil to gather data.

*Table 12 Clear distinction between the two cost types*

| **Fixed Costs** | **Variable Costs** |
|---|---|
| . Building expenses (rent& utilities)<br>. Salaries<br>. R&D<br>. Training labours<br>. Operational cost<br>. Regulatory fees<br>. Tax & Insurance<br>. Branding & Licensing | . Semi-final components<br>. Transportation<br>. Sales & Marketing<br>. Shipping & import fees |

In Brazil, the cost of LPG stands at $1.7. However, customers are required to pay $22 for a 13 kg LPG cylinder, which provides around 25 hours of usage. If the company offers the tubular micro biogas digester for $500, farmers have the option to invest in the digester for $500, receiving the equivalent of 22 units of 13 kg LPG, offering them approximately 550

hours of usage initially. Afterward, they would need to continue purchasing LPG, leading to escalating costs. On the other hand, they could opt to purchase the micro biogas digester, which costs $500. The company provides the convenience of a deferred payment option, allowing customers to spread the total cost over four months. By doing so, farmers not only secure the benefits of the digester's initial 550 hours of usage but also gain the advantage of long-term profitability over the continuous expense of LPG. With this flexible payment plan, the micro biogas digester emerges as a compelling and cost-effective solution. Also, by selling 1000 units annually at $500 each, the company would have a net profit of approximately $183,385 after accounting for all expenses and the 15% tax deduction.

Additional details can be found in Appendix 1.

## 3.3.5 Industry Analysis

#### *3.3.4.1 Barriers to Entry: Moderate*

- Familiarity with the concept of biogas digesters might vary among farmers in rural areas; The idea of transforming waste into energy could be unfamiliar and there may be some reluctance to change from traditional energy sources. Lack of awareness about the benefits of biogas could pose an obstacle. Moreover, the biogas digester provides a few hours of cooking gas per day, it might not meet all the energy needs of the farmers, who often work long days and might have higher energy demands.
- The lack of necessary infrastructure for product distribution and service can make it difficult to transport and install the biogas digesters on time. Additionally, if the digesters require regular maintenance or repairs, Delivering these services quickly can be challenging due to logistical constraints.

### *3.3.4.2 Competitive Rivalry: Moderate*

Selling tubular micro biogas digesters to Brazilian farmers involves a competitive landscape influenced by key factors. These include the number of competitors, product pricing and quality, customer service, and overall customer loyalty. The competition rivalry is not high for our product because the number of industrial biogas is more than household digesters, and most are located in the southern regions of the country.

#### *3.3.4.3 Bargaining Power: Low*

Entering the Mato Grosso market as a new distributor of tubular micro biogas digesters, the situation is one where farmers hold the upper hand in negotiations. Their pre-existing relationships with other suppliers present a challenge to the immediate establishment. Furthermore, LPG, as a substitute, holds a significant portion of the market share, as it is used by approximately 98% of Brazilians for cooking purposes, limiting bargaining power. To succeed in the Mato Grosso market, a careful approach that considers the farmers' specific needs, preferences, and price concerns while building trust and gradually increasing influence is necessary.

#### *3.3.4.5 Threat of Substitute Product: Moderate*

- **LPG:** Brazil is a major user of LPG, using it widely for cooking in both urban and rural areas. It serves as the primary cooking fuel for millions of households in the country. In 2021, Copa Energia emerged as the leading distributor of liquefied petroleum gas (LPG) in Brazil, capturing a substantial market share of 25.7 percent. Ultragaz secured the second position, accounting for 21.2 percent of the sales volume. Ultragaz, a part of the Ultrapar group, sold approximately 1.71 million metric tons of LPG that year (*Statista.com*). LPG is a strong alternative to micro biogas digesters in Brazil because it is widely available, familiar, and convenient. The country has a well-established distribution network for LPG, involving both state-owned companies and private distributors.
- **Fertilizer:** In Mato Grosso, synthetic fertilizers hold a dominant position. These fertilizers have earned trust over the years due to their effectiveness and rapid results. In contrast, bio-fertilizers from biogas systems, while environmentally friendly and sustainable, may not yield results as quickly as synthetic fertilizers. This gradual impact could make it less appealing for farmers seeking immediate outcomes.

### 3.3.6 Value Chain & Supply Chain Analysis

**Scenario:** AGCO, a well-known agricultural machinery company, is determined to introduce tubular micro biogas digesters to rural farmers in Mato Grosso. AGCO, a distributor, partnered with Flexi Biogas, a supplier, to establish a distribution agreement. The plan is for AGCO to establish a warehouse for assembling tubular micro biogas digesters in Mato

Grosso. Setting up a warehouse in Mato Grosso would result in cost savings by eliminating the need to import tubular micro biogas digesters from Kenya to Brazil, with only PVC bags imported from Kenya.

#### *3.3.5.1 Supply Chain*

Supply chain management focuses on meeting customer demands by efficiently coordinating the flow of goods from source to consumers. The goal is to optimize operations, reduce costs, and provide an excellent customer experience (Bowersox & Closs, 1996). The supply chain begins by sourcing semi-final components, as guided by Flexi Biogas, to procure high-quality components from Brazil, then importing the PVC bags from Kenya. Furthermore, by establishing a local warehouse in Mato Grosso, they can optimize logistics and reduce transportation expenses. This partnership also allows Flexi Biogas company experts and technicians to focus on training labours, while AGCO assumes responsibility for controlling and managing each step of the process. Once ready, the digesters are packaged, labeled, and stored locally for distribution to farmers directly or through local agricultural retailers. Ultimately, after-sales support process, offering farmers technical assistance and training. Figure 11 demonstrates the process of the supply chain


*Figure 11 Supply chain of distributing tubular micro biogas digester*

### *3.3.5.2 Value Chain*

The value chain involves companies working to enhance their positions by entering new markets, increasing value, and improving collaboration. Value added is created at different stages and depends on market characteristics and technological capabilities (Kaplinsky, 2000).

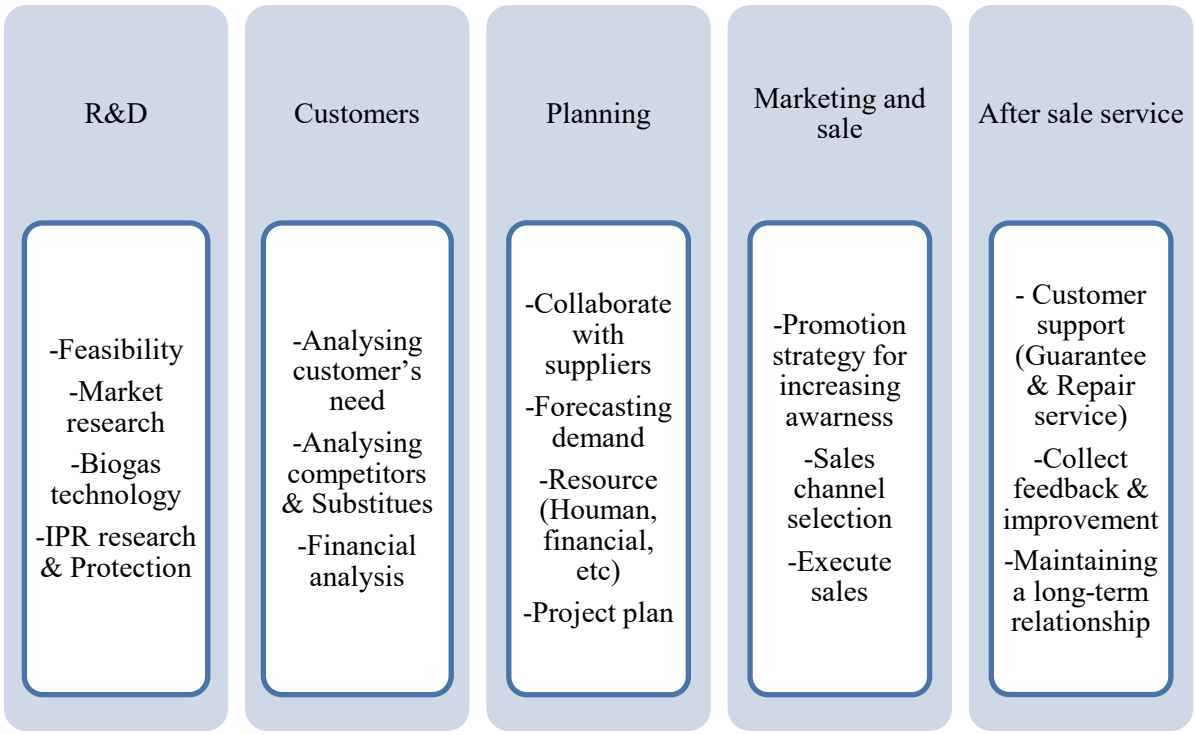


*Figure 12 Value chain of distributing tubular micro biogas digester*

#### *3.3.5.3 Market Maturity*

The increasing numbers of industrial and household biogas digesters, along with supportive governmental policies, indicate a maturing market for introducing biogas digesters. However, there are challenges, especially in rural areas like Mato Grosso, where infrastructure may be limited. For AGCO company, overcoming logistical challenges may involve collaborating with local transportation providers. Furthermore, considering that Portuguese is the dominant language in Brazil, the need for bilingual expertise in marketing and customer relations is crucial. Effectively overcoming these challenges helps AGCO to take advantage of the opportunities in Brazil's growing biogas sector.

### 3.3.7 Literature Search

Intellectual property refers to the original and creative works produced by individuals, giving them the right to govern the use of their creations. Intellectual property holders have the freedom to engage in diverse activities, including buying, selling, exchanging, or licensing their works to other individuals or organizations (Handa & Bhatt, 2015). IPR includes various rights like patents, copyrights, trademarks, industrial designs, geographical indications, and trade secrets (Stim, 2022):

- Patents: Exclusive rights for inventors to protect their inventions.
- Copyright: Legal protection for original works.
- Trademarks: Differentiate products or services.
- Design: Protect product appearances.
- Geographical indications: Identify origin-related qualities.
- Trade secrets: protect confidential information (design, devices, process) for competitive advantage.

### 3.3.8 Intellectual Property

The tubular biogas digester, as indicated by patent number US20150000357 on the Google Patents website (*Google Patents*.Com), is not associated with the Flexi Biogas company. However, certain factors should be considered to ensure operational freedom in Brazil.

1. Intellectual Property (IP) Landscape: An understanding of the existing patents, trademarks, and other intellectual property in Brazil's relevant market is essential.
2. Geographic Scope: Intellectual property rights, including patents, are territorial. It's vital to ensure that the product doesn't infringe on any local Brazilian patents or other IP rights.
3. License Agreements: Acquiring licenses from IP owners related to the product can provide the necessary freedom to operate.
4. Regulatory and Compliance Issues: Brazil might have particular regulations concerning biogas digesters. Following these regulations is crucial to sidestep potential legal issues.

There exists a licensing and distribution agreement between AGCO and Flexi Biogas company. Under this agreement, AGCO is authorized to market and distribute the biogas digesters in Brazil. Moreover, concerning branding, several strategies are available:

• Adopting AGCO's established brand, needing Flexi Biogas approval

• Using the Flexi Biogas name for its expertise

• Merging both brands

Both companies can decide which option is best for them regarding the condition of the agreement.

### 3.3.9 Quality Control

Flexi Biogas is responsible for providing PVC bags, evaluation of other components, and training labours, while AGCO takes charge of controlling quality, monitoring, and managing each step. AGCO examines semi-final components, manages orders from suppliers, oversees the assembly stages, and conducts comprehensive testing. Additionally, AGCO ensures punctual delivery to customers. Through collaborative efforts, AGCO and Flexi Biogas ensure that each product achieves the highest standard.

### 3.3.10 Environmental Impact and Risk Assessments

#### *3.3.10.1Health:*

- Exposure to pathogens and illness from contamination: During the collection of agricultural residues and cattle manure as feedstocks, rural farmers may be exposed to various harmful bacteria, viruses, and parasites. Exposure to these pathogens can result in a range of illnesses, from minor infections to severe diseases. This includes respiratory infections, skin infections, and more serious conditions that may require medical treatment and can lead to long-term health impacts.

#### *3.3.10.2 Safety*

- Explosion and fire risks: Methane is the main component of biogas and is highly flammable. To reduce these risks, it is important to follow appropriate safety protocols during installation and provide adequate training to handle, store, and prevent leaks effectively.
- Occupational Hazards: Working with biogas equipment may expose workers to physical risks like falls, or injuries from heavy equipment. Proper training, following safety protocols, and using the right safety equipment can minimize these risks, ensuring a safer work environment.

#### *3.3.10.3 Environmental Impacts*

- Positive impacts: Improving waste management through the conversion of organic waste into biogas can lead to decreased contamination and improved hygiene.
- Negative impacts: Improper handling of waste materials or chemicals in the biogas process could lead to soil or water contamination, affecting both human health and

the local ecosystem. To prevent this, waste must be responsibly managed, and all activities must align with environmental regulations.

#### *3.3.10.4 Risk Assessment*

- Market demand: Rural farmers have a conservative attitude towards new technology, they may resist adapting to change. The adoption of micro biogas digesters by these farmers is influenced by the price of LPG. Convincing them to transition to a new and relatively unfamiliar technology can pose challenges.
- Technical and performance: The effectiveness of micro biogas digesters relies on their technical capabilities and efficiency in converting organic waste into biogas. Any technical issues may lead to dissatisfaction among farmers. To address this risk, it is essential to ensure that the digesters meet high-quality standards and undergo thorough testing at each step.
- Timely Delivery (Transportation): Ensuring consistent and punctual distribution of digesters can present challenges. Any interruptions or delays in the supply chain could potentially result in farmer dissatisfaction (Mittal et al., 2018).
- Competitors: As the market for sustainable energy solutions grows, other companies may offer similar or alternative products. This increased competition can lead to price competition and reduced profit margins.
- Substitutes: Farmers have easy access to alternative energy sources, such as LPG and firewood, which are substitutes for micro biogas digesters. Additionally, LPG has a great market in Brazil.

Table 13 is the risk assessment, showing scores for severity and probability, with each criterion rated on a scale of 1 to 5.

**.**Green: Acceptable **.**Yellow: Acceptable with Mitigation **.**Red: Unacceptable

*Table 13 Risk Assessment Scores - Severity and Probability (Rated on a Scale of 1 to 5)*

| Risk Probability | Risk Severity | | | | |
|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 |
| P5 | - | - | - | - | - |
| P4 | - | - | - | Substitutes | - |
| P3 | - | - | - | The demand of farmers for biodigester | Competitors |
| P2 | - | Not delivering the product on time | Occupational risks | Illness of farmers by collecting manure | Explosion of biodigester & Fire |
| P1 | - | Technical and performance issues | - | Soil and water contamination | - |

## 3.4 Project Plan

### 3.4.1 Project Description

- **Aims:** To evaluate the potential of introducing micro biogas digesters into the South American market, with the primary goals of boosting profitability for our company as a distributor, assessing the impact of micro biogas digesters on combating climate change, and improving the lives of rural farmers.
- **Scope:** The project's primary focus is on the distribution of tubular micro biogas digesters to rural farmers in South America, particularly in Brazil's rural areas, where traditional cooking methods are prevalent. This case study focuses on collaborating with suppliers to deliver an effective biogas digester solution to our target customers. Key activities for gaining an understanding of the South American market involve analyzing the demand for biodigesters and assessing our digester's position by studying competitors and potential substitutes. Establishing a distribution network for these digesters, and educating farmers about the advantages of biogas technology. Another aspect involves assessing the technology's contribution to combating climate change and developing sales and marketing strategies for the tubular micro biogas digester. However, the efforts will not extend to other renewable technologies, areas

outside of South America, or any changes to the existing digester design. The commitment is to the present digester design, without any plans for alterations.

- **Requirements:** The project plan has several key requirements:

  - AGCO company must obtain authorization for quality control at each step and be knowledgeable about the necessary rights and regulations for marketing and distributing biogas digesters in Brazil.
  - Researching the product's patent and intellectual property rights, Flexi Biogas company maintains primary ownership while AGCO company handles marketing and distribution.
  - On the branding side, choose one of these options: AGCO using its brand, using the Flexi Biogas name, or combining both.

- **Resources:**
  - AGCO representative oversees supply and value chain operations.
  - Flexi Biogas specialist manages workforce training.
  - A skilled team, proficient in Portuguese, is hired.
  - Semi-final digester component sourced from warehouse.
  - The finance department oversees budget and financial aspects.
  - Gantt chart used for monitoring and determining product launch dates.
  - Regulatory authority certification for distributing micro biogas digesters in Brazil

- **Constraints:** Navigating the project in Brazil comes with specific challenges. Financial limitations might limit the extent of digester distribution and the areas targeted. Timing is crucial; the unique agricultural cycles in Mato Grosso determine the best times for digester distribution and installation to enhance impact and encourage adoption by farmers. Furthermore, it's essential to be aware of potential legal issues. Existing regulations in Mato Grosso or throughout Brazil might have guidelines concerning the distribution or use of biogas digesters in rural areas. As a result, following local laws and regulations is essential.

### 3.4.2 Research and Development (R&D Phase)

This is the step where the real product development takes place.

- Materials Formulation: A comprehensive list of all semi-final components required for assembling the products and ordering information.
- Cost Calculations: Evaluate expenses across each phase, including components, quality control costs, and other factors.This comprehensive examination results in the ultimate financial cost, not accounting for any discounts.
- Production and Quality Control Procedures: As a distributor, receive comprehensive production procedures from the supplier, outlining a step-by-step guide for assembling the tubular micro biogas digester. AGCO oversees and validates these QC protocols, stepping in if any issues arise.
- Stability Assessments: This involves assessing how the digester's performance, efficiency, and structural integrity may evolve under different environmental conditions. The aim is to ensure that the micro biogas digester maintains its functionality and safety throughout its intended lifespan.
- IP, Health, and Risk Assessments: Conduct a comprehensive IP assessment to prevent patent issues. Moreover, ensures the following health standards. Assess risks, including potential dangers during customer usage, market dynamics such as competitors and substitutes, and financial risks.

### 3.4.3 Transfer Phase

A warehouse is established in Mato Grosso. Production and Quality Control procedures are defined and finalized through Standard Operating Procedures (SOPs). A semi-assembly approach is adopted, with the final assembly designated for the farmers' locations. They are subsequently trained in both the installation and usage of the micro biodigester. Cost calculations are comprehensively negotiated. Simultaneously, comprehensive documentation is undertaken.

### 3.4.4 Pre-Launch

This phase focuses on product marketing and the ways of distribution. A marketing strategy is developed, and collaboration has been coordinated with government entities and NGOs. Through collaborations with a diverse range of distributors, including brick-and-mortar retailers, and sales agencies, the micro biodigester becomes readily available to target customers. Moreover, training staff to offer enhanced customer service and obtaining required regulatory approvals ensures a smooth launch.

### 3.4.5 Commercial Launch

During the commercial launch of the micro biogas digester, the product is formally introduced to the market through press releases and major marketing campaigns. Various events to educate users about the product's benefits. During the event conducting interviews and focus groups to gather customer feedback about the micro biogas digester. It's crucial to monitor initial customer responses and sales, adjusting quickly to any challenges. A feedback system is set up for customers to share their experiences, allowing for prompt product enhancements.

### 3.4.6 Post Launch

After gathering reviews and feedback from customers, necessary modifications or improvements are made to the product or its associated services. Additionally, new markets or regions are identified and explored based on the product's initial performance. Loyalty programs encourage repeat purchases and expand the customer base through word of mouth. To maintain the connection, post-sales services like maintenance checks, workshops, or community engagement are offered, ensuring the user community remains engaged and satisfied.

# 4. Conclusion

In this case study, the scenario involving AGCO, an agricultural company intending to distribute tubular micro biogas digesters in South America, was investigated. Through research on the technology of micro biogas digesters, the tubular micro biogas digesters are identified as the proper product, offering 3 hours of cooking time and generating biofertilizer which contributes to the fight against climate change by reducing GHG emissions. The Flexi Biogas company, which provides our target product, collaborates with AGCO Company as a supplier. In the research for the feasibility of tubular micro biogas digesters in the South American market, Brazil, with a specific emphasis on rural areas in Mato Grosso, has emerged as the ideal location for the distribution of tubular micro biogas digesters. The target customers include small to mid-sized farmers engaged in cattle farming and those involved in both crop cultivation and cattle rearing. Through educating and raising awareness among customers about the benefits of tubular micro biogas digesters and conducting thorough data analysis regarding customer preferences, we can conclude that there is significant potential for distributing household biogas in rural areas of Mato Grosso. According to the projected financial report, AGCO anticipates a gradual increase in profitability and return on investment over the coming years. However, the company needs to conduct more detailed research. While the tubular micro biogas digester appears to be a viable option for our target market, it's crucial to note that this business plan does not provide a comprehensive review of every aspect of the model due to limited available data. Therefore, conducting further research on the performance of tubular micro biogas digesters, the state of biogas production in the Brazilian market, and understanding the needs of rural farmers will yield more precise insights into economic viability and feasibility.

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# 6. Appendix

Associated costs for selling 1000 units of biogas digester:

1. Labor Costs:

   8 workers × $268/worker = $2,144

2. Representative from the US Costs:

   2 months per year × $3,000/representation for each month = $6,000

3. Representative from Kenya Costs:

   1 month per year × $1,000 = $1,000

4. Warehouse and Utility Costs:

   12 months × $280/month = $3,360

5. Sales and Marketing Costs:

   12 months × $130/month = $1,560

6. Transportation Vehicle Costs:

   3 vehicles × $10,000/vehicle = $30,000

7. Registration Costs:

   $56

8. License Costs:

   $85

9. Certification Costs:

   $47

Total cost for the year:

$2,144 + $6,000 + $1,000 + $3,360 + $1,560 + $30,000 + $56 + $85 + $47 = $44,252.

Total cost per unit = $44,252 / 1,000 units = $44.252/unit.

Cost per unit including components and fabrication = $44.252 + $240 = $284.252/unit.

To determine the profit margin when selling each unit at $500:

$$Profit\ Margin\ \% = \left(\frac{Gross\ Profit\ per\ unit}{Selling\ price\ per\ unit}\right) \times 100$$

Given:

Total Cost Per Unit (from a previous calculation): $284.252

Selling Price per unit: $500

Gross Profit per unit = Selling Price - Total Cost =$500 - $284.252 = $215.748

Now, plug this into the profit margin formula:

$$Profit\ Margin\ \% = \left(\frac{215.748}{500}\right) \times 100 = 43.15\ \%$$

If selling each unit at $500, the profit margin would be approximately 43.15% without considering tax.

Given the 15% tax deduction on the gross profit, the calculation would change as follows:

Gross Profit Before Tax: $215.748 per unit.

Tax Amount: Gross Profit Before Tax × Tax Rate = $215.748 x 0.15 = $32.3622

Net Profit After Tax Deduction: Gross Profit Before Tax – Tax Amount

= $215.748 - $32.3622 = $183.3858

Profit Margin After Tax Deduction:

$$Profit\ Margin\ \% = \left(\frac{Net\ profit}{Selling\ price\ per\ unit}\right) \times 100$$

$$Profit\ Margin\ \% = \left(\frac{183.3858}{500}\right) \times 100 = 36.68\ \%$$

With the 15% tax deduction applied, the profit margin on each unit sold at $500 would be approximately 36.68%.

Company net profit:

Net Profit Per Unit = $183.3858 (as calculated above)

For 1000 units:

Total Net Profit = Net Profit Per Unit×1000 = $183,385.80

By selling 1000 units annually at $500 each, the company would have a net profit of approximately $183,385 after accounting for all expenses and the 15% tax deduction.