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# VALUE-ADDED BIOGAS PRODUCTION AND ITS EFFECT ON ETHIOPIA'S RURAL ENERGY SECURITY

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**Abstract:**
Ethiopia has access to a variety of renewable energy sources. Agricultural waste, forest products, and other biological resources are used to make bioenergy. Bioenergy production's value and importance to Ethiopia's energy security are rarely studied. Therefore, the purpose of this study is to evaluate the gross value added in the production of bioenergy and how it affects energy security. Data from multiple sources was descriptively examined. The findings estimated the gross value added at all levels of the value chain for biogas generation from installed biodigesters at ETB 175.619 million (USD 6.23 million), or 0.0074 percent of the nation's GDP in 2018. Currently, only a few regions of the country use household-level biogas that provides benefits to 180,000 rural residents. In Ethiopia, there are approximately 1.1 million homes that might adopt dung-based bio-digesters. It is crucial to use this biogas feedstock for cooking, but it would also be crucial to provide the grid with the energy. By doing this, the sector's contribution to the nation's GDP and the gross value added from the production of biogas would significantly grow. Therefore, significant assistance for biogas-based power generation is required within the framework of sectoral policies at the federal level.

**Keywords:** Bioenergy, Energy saving, Gross domestic product, Gross value-added, Mega Jules

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## INTRODUCTION

Many of the economic and environmental issues we face today are caused by energy, which serves as both an engine of progress and growth (Mungwe & Colombo, 2015). According to FAO, a sustainable society requires clean and inexpensive energy services to reduce poverty (Kaoma & Gheewala, 2021). Studies have demonstrated that energy has an impact on all facets of development, including social, economic, political, and environmental factors, such as access to health care, clean water, agricultural and industrial productivity, education, and other essential services that enhance the quality of life (Berhe et al., 2017). Energy typically comes from two types of sources: renewable and non-renewable. A growing interest in renewable energy has been seen in recent years due to the depletion of non-renewable fossil fuel sources (Lemma et al., 2020).

Ethiopia is blessed with various renewable energy sources, including hydroelectric power, solar power, geothermal energy, solid biomass energy (charcoal, firewood, etc.), and bioenergy (Khan & Singh, 2017). However, despite the enormous potential of renewable energy sources, it continues to have a serious domestic energy crisis (Lemma et al., 2020). Over 80% of Ethiopia's energy needs are met by bioenergy, a significant and clean source of energy in the country (Elias & Shabbir, 2019). Despite being a significant energy source for homes, bioenergy is currently produced, transformed, and used inefficiently (Duvenage et al., 2012). It is made from agricultural waste, forest products (such as firewood and charcoal), crop waste, energy crops, animal manures, leftovers from

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various agro-industrial and food processing steps, and other biological resources (Kaoma & Gheewala, 2021). These resources can be used directly to meet basic energy requirements or converted into various renewable energies, such as biogas, biofuel, and bioelectricity, that can be used in homes and other settings (Dawit and Börner, 2015).

For Ethiopian families, biogas is a promising renewable energy source that is affordable, environmentally friendly, and clean (Elias & Shabbir, 2019; Tale et al., 2021). If it is properly managed and used, the use of biogas energy as an alternative source of energy has the ability to meet the energy needs of the rural community (Kelebe et al., 2017). The usage of biogas has the potential to replace conventional fuels like wood, manure, and charcoal. It would help to support the movement of nutrients within farms, reduce indoor smoke, and ease pressure on nearby forests (Schober et al., 2021). Additionally, it provides energy, fertilizer, enhances working conditions and hygiene, and safeguards the environment (Gaddisa, 2011; World Bank. 2019). Ethiopia's biogas industry is still developing and has yet to be fully utilized (Kamp & Forn, 2016). It is still in its early stages, and barely 20,000 or fewer families use it nationwide (Wassie & Adaramola, 2020). According to various research, urban households in Ethiopia use a wider variety of fuels than rural households do, although even in metropolitan areas, more than 80% of households still rely on biomass fuels (Lemlem, 2016; Mwirigi et al., 2018; SNV, 2018).

According to Dawit and Börner (2015), Ethiopian biogas technology involves gasifying biomass resources via anaerobic digestion/fermentation based on animal waste. It provides a potentially economical and sustainable way for rural householders to meet their energy needs because it can be created from locally accessible raw materials (Kaifa & Wilson, 2019). As a renewable energy source and a country with a large potential for livestock ownership, Ethiopia, the biogas produced from animal waste can be sustainable (Dawit & Börner, 2015; Gemechu et al., 2019). The bioenergy sector could significantly ensure Ethiopia's energy security if it receives the attention it needs. Energy security is the ongoing accessibility of energy in various forms, in sufficient amounts, and for a fair price (Fang et al., 2018). It includes a stable supply, acceptable sources, costs, and prices, continued or enhanced accessibility, and reducing risks to the environment and public health or safety (Dawit & Börner, 2015). Several fundamental factors fuel improvements in energy security in developing nations like Ethiopia. Energy security is a critical challenge due to the susceptibility of national energy sectors to numerous risks related to supply and demand (Dawit and Börner, 2015; Kruyt et al., 2009).

According to studies, the primary energy problems in Ethiopia are a widening gap between the supply and demand for biomass fuels, the negative health and environmental effects of household energy use, the rising percentage of income spent on energy for cooking, especially in urban areas, the lack of awareness of the connection between household energy use and health, and ineffective coordination between the health and energy sectors (Beyene et al., 2018). It demonstrated the necessity of developing renewable energy to guarantee energy security in the nation. However, sustainable energy has several security and access challenges (Anteneh, 2019). According to findings from various studies, the main obstacles to using clean energy in Ethiopia are the low availability and dependability of energy resources, the weak purchasing power of poor rural communities, a lack of knowledge about clean fuel options and technologies, a lack of knowledge about the safety of clean energy, a developing market, and the electricity pricing structure (Beyene et al., 2018; Anteneh Belay. 2019; Nakamya et al., 2020).

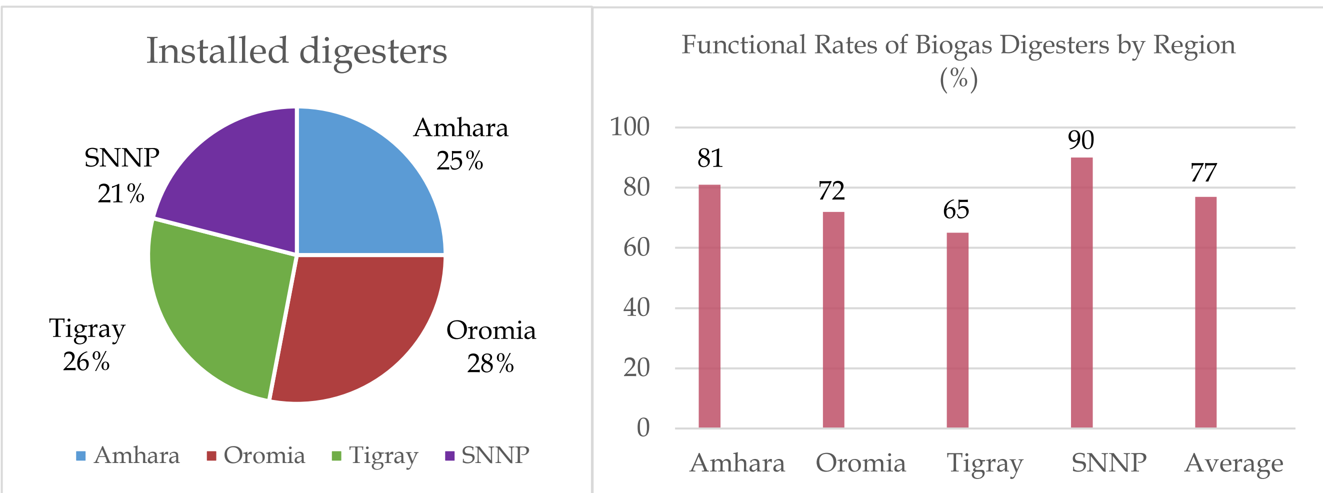
With many benefits for guaranteeing Ethiopia's energy security, bioenergy is one of the country's rising sustainable energy sources (Kaoma & Gheewala, 2021). Despite several advantages, few studies demonstrate the value added to bioenergy production and its impact on Ethiopia's energy security. Therefore, the purpose of this study is to evaluate the gross value added in bioenergy production and how it affects Ethiopia's energy security.

## METHODS

This analysis included both primary and secondary data. The secondary data came from information gathered by the National Biogas Program of Ethiopia and the Netherlands Development Organizations (SNV), Ethiopia, in several woredas across four regions (Tigray, Amhara, Oromia and Southern Nations, Nationalities and Peoples). In order to examine and enrich all of the available data, discussions with essential stakeholders and specialists in various involved institutions were conducted in addition to the secondary data. A review of essential documents, and various study reports, including those retrieved from the internet, project documents, periodicals, etc., were also employed. Institutions from which various sets of data were gathered and with which conversations were held include the Ministry of Mines, Petroleum and Natural Gas; the National Biogas Program for Ethiopia (NBPE); the Ethiopian Electric Power Corporation; the Ethiopian Central Statistical Agency (CSA); the Ethiopian Petroleum Supply Enterprise (EPSE); the Transport Division at the Ministry of Transport; the Ministry of Agriculture; the Universal Rural Electric Access Program; and the Ethiopian Rural Energization Program.

## RESULT AND DISCUSSION

Current status of biogas production in Ethiopia: - By the end of September 2018, Ethiopia had installed about 22,166 biodigesters. Only four states—Amhara, Oromia, Tigray, and the Southern Nation's Nationalities and People's (SNNP) region—have Biodigesters distributed regionally in Ethiopia. Ethiopia's regional biodigester share is 19% in the southern nation's nations and people's area, 25% in Oromia, 23% in Tigray, and 33% in Amhara (Figure1). Biodigesters were installed in other regional states of the nation in minuscule numbers (0.3%). (NBPE., 2018). Approximately 77 percent of biogas plants (biodigesters), with some variation between regions in Ethiopia, are operational, according to the results of the SNV study (Figure 1). (SNV, 2018).




Source: SNV, 2018

**Figure 1**. Distribution and Functionality rate of Biodigesters in Ethiopia

Because biogas is inexpensive in comparison to other energy sources, it presents an excellent chance for the rural population to rely on it (Berhe et al., 2017). It has been discovered that Ethiopian

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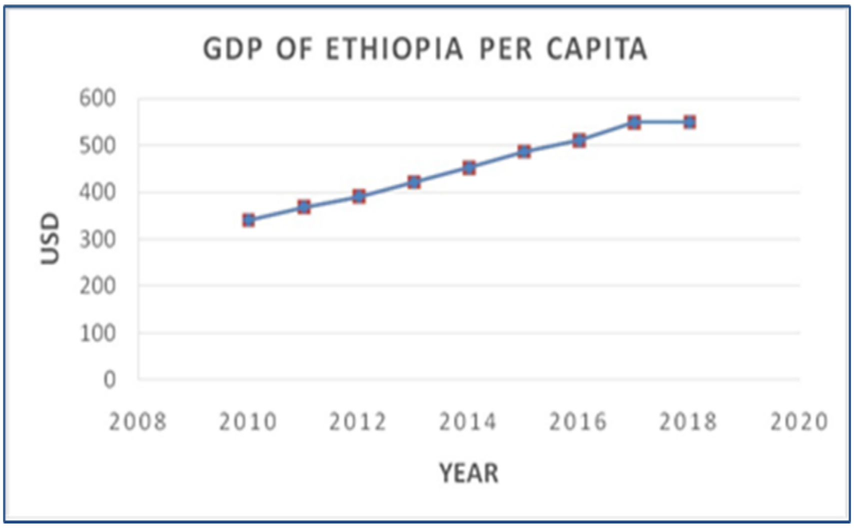
families with at least four cow heads can sustainably feed at least the minimum size of residential biodigester that is advised (4m3) (Desalegn, 2014; Mengistu, et al., 2016). Compared to other energy sources, the biogas digester is affordable.

According to statistics from 2018, the average price of a biodigester is between ETB 13,888 (EUR 448) and ETB 21,719 (EUR 668) for sizes 4, 6, 8, and 10m3. The most popular size is 6m3, which has an average price of ETB 16,366. (EUR 528). 36 percent (ETB 5892) of the cost of the 6 m3 Biodigester was spent on construction materials, 23 percent (ETB 3764) on pipes, fittings, and other appliances, and 41 percent (ETB 6710) was spent on labor costs (NBPE., 2018). The operating costs are then added to the initial investment's amortization over 25 years at a rate of 12 percent, which results in a total operating and investment cost of Birr 1862 in the Tigray region (Berhe et al., 2017).

**Ethiopian gross domestic product (GDP):** - With a $783 per capita income, Ethiopia is one of the most underdeveloped nations in Africa. Official statistics data show that between 2003/04 and 2016/17, the nation's economy grew by an average of 10.5%. Real per capita income increased from $396 to $862 within the same time period, while real per capita GDP more than doubled from $32 billion in 2010–2011 to $81 billion in 2016–2017. The World Bank's development indicators, derived from officially recognized sources, show that Ethiopia's gross national income per person was $1,890 in 2017. From 30% in 2011 to 24% in 2016, a smaller percentage of people lived below the national poverty level. The youth unemployment rate is 7%, while 25% of young people between the ages of 15 and 29 are reportedly underemployed. Youth unemployment in metropolitan areas is around 29% (ECSA, 2014).




Source: Processed by World Bank, 2018

**Figure 1**. Ethiopian gross domestic product (GDP)

**The Gross value added of biogas and its contribution to Ethiopian GDP:** - Ethiopia now only produces biogas at the home level. In the country, there is no industry-scale production of biogas energy. This study concentrated on the gross value added of bioenergy produced at the home and national levels. Utilizing the information provided, the gross value added per unit of bioenergy at the household level in Ethiopia was calculated (Table 1).

According to the table below, an anaerobic digester (AD) with a volume of 6 m3 produced value added from fuel and fertilizer savings of ETB 10,290 on average (USD 365). In other words, the value added per MJ of biogas fuel produced in Ethiopia is ETB 0.76/MJ (USD 0.027/MJ), which means that for every MJ of biogas produced, Ethiopia earned ETB 0.76. Additionally, it was

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calculated that the 22,166 biodigesters now in use at the household level (or 77 percent of them) produced a total Gross Value Added of ETB 175.62 million (USD 6.23 million) in 2018. (Table 1). According to Statista, Ethiopia's GDP in the same year was approximately ETB 2366.30 billion (83.84 USD billion). As a result, in 2018, the gross value added of biogas generation accounted for around 0.0074 percent of the nation's GDP.

**Table 1.** The gross value added from Biogas production in Ethiopia in 2018

| Content | Unit | ETB | USD |
|---|---|---|---|
| Cost Savings Per AD/Year | ETB/USD | 11,850.00 | 420.00 |
| Saving Charcoal | ETB/USD | 3,600.00 | 128.00 |
| Saving Firewood | ETB/USD | 1,500.00 | 53.00 |
| Saving Kerosene | ETB/USD | 4,050.00 | 143.00 |
| Saving Electricity | ETB/USD | 2,400.00 | 85.00 |
| Selling organic fertilizer | ETB/USD | 300.00 | 11.00 |
| Benefit from increased crop yield | ETB/USD | 2,717.00 | 96.00 |
| Operation Cost of Biogas energy Per AD/Year | ETB/USD | 2,966.00 | 105.00 |
| Maintenance cost | ETB/USD | 1,311.00 | 46.00 |
| Gross Value Added Per AD | ETB/USD | 10,290.00 | 365.00 |
| Number of ADs in the Country | Number of plants | 17,067 | 17,067 |
| Gross Value Added of Biogas Produced | ETB/USD | 175,619,430.00 | 6,229,455.00 |
| Total Biogas Production at Household Level | MJ/year | 230,489,835 | 230,489,835 |
| Gross Value Added Per Unit of Biogas Produced | ETB/USD /MJ | 0.76 | 0.027 |

The difference between the high daily output (2.5MJ/M3) and low daily production (1.2MJ/M3) is used to compute the average daily production (1.85MJ/M3). * It is computed as follows: 230.49 million MJ/year = 22166 biodigesters x 0.77 in use x 1.85 m3 biogas per day x 20 MJ/m3. In addition to the results mentioned above, a survey by the Netherlands Development Organization (SNV, 2018) reveals that biogas users have cut their use of chemical fertilizers by 50%. The average national savings from fertilizer costs for farmers was 35 percent, even after accounting for the rise in the price of chemical fertilizer and the decrease in fertilizer use by biogas owners. Following the installation of a biogas digester, biogas users in Ethiopia have generally reported seeing a large drop in chemical fertilizer use due to the substitution of chemical fertilizer with bio-slurry. The average amount of fertilizer used nationally dropped from 146 kg to 60 kg, a 65 percent decrease (Anteneh, 2019; Nakamya et al., 2020; NBPE, 2018).

**The importance of using biogas to replace wood fuel and other energy sources**: - According to studies, wood produced 4.5 kWh of energy per kilogram. However, the energy produced by biogas was roughly 6-6.5 KWh/M3, which can be converted to the power of 1.30 kg of wood. One kilogram of firewood equals 0.2 meters of biogas, and one kilogram of charcoal equals 0.5 meters of biogas energy. It is how the comparable need for biogas is calculated. As a result, the 43.2 m3 of biogas that will be produced each day can supply 43 homes' daily needs for cooking energy. It shows that the substrate gathered from the seven houses is sufficient to provide the energy needed for cooking for a single household (Gaddisa, 2011).

According to studies, biogas technology decreased weekly energy usage per person by 75.1 Mega Jules (MJ) (Woubakal, 2018; Mengistu, 2016). The usage of biogas energy has partially replaced the reliance on home energy sources like wood and other fuels. The sample of houses using biogas consumed 6.5TJ of energy annually, of which biogas energy made up 1.2TJ (18.5 percent). Therefore, the opportunity cost of using this much biogas energy is the equivalent of 78.1 tons of fuelwood. It is the same as removing between 0.3 and 0.5 hectares of tropical forests each year to produce wood fuel (Mengistu, 2016). It indicated that bioenergy production has the double advantage of providing energy security through access to efficient and clean energy and conservation of forest resources. Besides, reducing the depletion of woody biomass through biogas technology contributes to carbon sequestration (Lansche & Müller, 2017). Studies indicated that reducing wood-fuel consumption by a single tone is equivalent to getting a roughly one-half tone of carbon sequestered in the woody biomass (Mengistu, 2016). According to this, humans must replace energy sources like firewood and charcoal since doing so prevents energy from being used inefficiently and is crucial in preventing climate change. The rural community can have sufficient access to energy, which will lead to energy security.

## CONCLUSION

The gross value contributed from the value chain across all stages of household biogas production in all biodigesters installed in Ethiopia was estimated to be ETB 175.619 million (USD 6.23 million), or around 0.0074 percent of the GDP of the nation in 2018. Only a tiny portion of the country currently uses the biogas produced at the household level, which benefits about 180,000 rural residents. Particularly at the agricultural level, biogas feedstock has a considerable surplus potential. In Ethiopia, 1.1 million homes may adopt dung-based bio-digesters. Cooking with this biogas feedstock is crucial, but providing the grid with the energy would also be essential. It would significantly raise the sector's GDP contribution and the gross value generated from biogas production. As a result, good sectoral policies at the national level must be developed to encourage biogas-based power generation.

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