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Biomethane Market and Future Prospects

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Abstracts

The global market for biogas and biomethane has been on a growth path growing rapidly being driven by its growing role as a substitute for natural gas in many applications like electricity generation, transport and industry. There still remains significant untapped potential of biogas and biomethane but market expansion will depend on supportive policies, continuous investment, and technological progress aimed at increasing efficiency and cost reduction. Other challenges facing the biogas and biomethane market to be overcome are the competition with fossil fuels in the market, competing applications for feedstock and high initial costs. The biomethane market is projected to expand from an estimated $10.3 billion in 2023 to over $60 billion by 2030, being driven by growing applications as a renewable energy source for power generation, cooking and heating. The future for biogas and biomethane is bright, with potential to reach 150 bcm-eq by 2050 and has a crucial role to play in the energy transition and decarbonizing the energy sector through injection into natural gas grids and furl for vehicles. The pace of technological progress and innovation, enabling policies and evolving market dynamics will influence the possible futures for global energy and rate of growth.

Keywords
Biogas production; biogas upgrading; biogas uses; biomethane applications; biomethane market; biogas market growth

1. Introduction
Biogas is renewable g= energy resource as produced through anaerobic digestion of organic matter. Biogas is basically contains mix of methane and carbon dioxide, but raw biogas contains impurities (M. J. B. Kabeyi & O. A. Olanrewaju, 2022a; Kabeyi & Oludolapo Akanni, 2024), which hinder applications and reduce the heating value of raw biogas making it necessary to clean and for some applications upgrade it to biomethane. Biomethane is therefore a pure version of biogas that has the carbon dioxide in raw biogas and other impurities removed, Upgrading biogas makes it chemically similar to natural gas and can therefore be used. Interchangeably with natural gas, including injection into the gas grid or use as a vehicle fuel, On the other hand, biogas is ideal for on-site combined heat and power generation (Kabeyi & Olanrewaju, 2023a; Barasa & Oludolapo, 2023).

In an attempt to meet the global emissions and climate targets within the next decade, energy systems globally are undergoing a fundamental shift towards carbon-neutral sources. Key to this transformation is expanding the use of renewable energies and improving in energy efficiency of existing and future systems (Francisco López et al., 2024; Yang & Li, 2014).Biogas and biomethane are produced from organic residues and their sustainability is based on converting what is regarded as waste into a valuable resource. Biogas and biomethane can provide a means for developing more sustainable agriculture and environment, as well as providing clean, renewable energy resources. This enables bio-waste and residue management, while also improving soil quality (Kabeyi, 2024a; Kabeyi & Olanrewaju, 2022a, 2022d).

A healthier ecosystem provides carbon sinks, controls, and minimizes methane emissions from livestock (M. J. B. Kabeyi & O. A. Olanrewaju, 2022b, 2023b). Biomethane still has some limited environmental impacts based on its life cycle from products such as CO_2, CH_4 and N_2O, which vary in proportion to the technology applied, type, or origin of biogas, and feedstock along the supply chain. Biodegradation and gasification used to produce biogas and syngas for upgrading to biomethane help to keep the environment clean and healthy, while the direct use of biomethane reduces the pollution potential and negative environmental impacts of substituted fossil fuels (Bhardwaj & Das, 2017; Li et al., 2012; Mathur & Verma, 1988).

The global market for biogas and biomethane has realized significant growth, with the main driver for the growth being environmental concerns, growing need for energy security needs, global conflicts like the war in Ukraine and growing support by governments including shift towards decentralized generation. Globally production potential for biogases (biogas and biomethane) is huge substantial, and is estimated at 1,000 billion cubic meters of methane equivalent (bcme) today, and is projected to increase to around 1,400 bcme by 2050(Kabeyi & Olanrewaju, 2025; M. J. B. Kabeyi & O. A. Olanrewaju, 2023a; Moses Jeremiah Barasa & Oludolapo, 2023). .

2. Market Status and Growth

The market for biogases has witnessed significant growth, in a process characterized by global growth in the demand for renewable energy and decarbonization efforts in line with global commitments to the 2015 Paris Agreement and the Sustainable development Goals (SDG) targets set by the world community. The market projections project growth from about $8.19 billion in 2024 to over $29 billion by 2034, based on a compound annual growth rate (CAGR) 13.55%. with Europe currently leading the market, and strong growth in North America, Brazil, China, and India targeting applications in transport, and power production, mainly based on anaerobic digestion pathway (M. J. B. Kabeyi & O. A. Olanrewaju, 2022c; Kabeyi & Oludolapo Akanni, 2024; Nwala et al., 2025).

2.1. Current status

Biomethane or renewable natural gas represents a renewable energy resource produced from a wide variety of substrates including agricultural residues, wastewater, and municipal solid waste. Being a renewable and versatile resource leads its wide applications in various fields like transport, industrial operations, domestic energy use, electricity production, hence a very important resource for the energy transition.. The global market for biomethane is currently expanding remarkably and reached a value of USD 89,040 million in 2022 with projection showing it will reach close to USD 111,400 million by 2030 (Hidalgo et al., 2025). In 2023, the global biomethane market was valued at USD 10.3 billion and expected to grow at compound annual growth rate of approximately 28.7%. The global biomethane market is entering a consolidation phase being driven by the commercial maturity of a number of biogas upgrading technologies like membrane separation, water scrubbing, and pressure swing adsorption whose deployment in multiple regions sows scalability of biomethane production and end use diversification in applications like gas grid injection to liquefaction for transport fuels. (Hidalgo et al., 2025; Lincoln et al., 2023). The Combined global biomethane and biogas production capacity grew by approximately 17% from 2017, reach over 1.6 ExaJoules in 2022., with close to 50% of this capacity being based in Europe, then 21% in China, the US accounted for (12%) and India (9%). The global biomethane production potential is more than 1.9 billion m^3/yr, with many installations in Germany. Biomethane production is expected to grow and reach approximately 18 billion m^3/yr by 2030, with the improvement of already developed biomethane plants encouraged by the global energy transition and increased use of feedstock such as municipal solid waste (MSW). This projected potential is close to 10% of natural demand for the year 2030(M. Kabeyi & O. Olanrewaju, 2022; Prussi et al., 2019). Biogas upgrading accounts for approximately 90% of total biomethane globally. Upgrading technologies exploit the different properties of the various gases in biogas to separate them. Different methods are used for upgrading, however water scrubbing and membrane separation account for approximately 60% of biomethane production globally (M. J. B. Kabeyi & O. A. Olanrewaju, 2022a; Kabeyi & Oludolapo Akanni, 2024; Sher et al., 2024).

Biogas plants and upgrading installations have been growing with the value of global bio methane market in 2017 at USD 0.62 billion increasing at annual growth of 26%, with the value of biomethane market expected to be about be $4.96 billion in 2026. Several countries have set targets to replace natural gas with bio methane for domestic applications and bio methane is expected to be a significant source of cleaner renewable energy in future e.g. Sweden has set a target of 100% transportation fuel by 2028 (Khan et al., 2021). The biomethane market is experiencing continuous growth because of the advantages offered by biogas and biomethane. Market prospects are enhanced by increasing possibilities for storage, and transport of liquid biomethane, as well as policy incentives being offered by several countries that promote the development of biogas production and upgrading for various applications over fossil fuels and nonrenewable process feedstock. It is estimated that the global biomethane market growth at a CAGR of 6.9% from 2021 to 2031, to reach close to US$4 billion by 2031(Moses Jeremiah Barasa & Oludolapo, 2023).

Water scrubbing technology is the most widely used upgrading technology, although it has higher water requirements. The use of tertiary effluent and recycling of water can reduce water consumption and related costs. Membrane separation technology is also growing rapidly, with the number of plants increasing from 92 in 2015 to 173 in 2019. The advantages of membrane separation technology include modular design, fewer moving parts, robust design, and smaller footprints, while its performance has been continuously improving owing to developments in material science and engineering. In addition to water scrubbing and membrane separation, other commercially deployed upgrading technologies include pressure swing adsorption, chemical scrubbing, organic physical scrubbing, and cryogenic separation, all of which have fewer plants(Khan et al., 2021).

The production of biogas has been growing globally especially with the biogas and biomethane markets being Europe, North America, and Asia-Pacific. The market growth in these countries is driven by supportive policies and existence of high growth potential. Europe leads the world in terms of the highest number of operational plants and ambitious targets for biomethane production, with Germany and France taking leadership. North America is led by the US as major market having strong growth driven by government incentives. The Asia-Pacific is a significant and rapidly growing market having significant number of projects in China and India. So far, the dominant method for biomethane production is biogas upgrading. By April 2023, Europe had 1322 biomethane-producing facilities(Marzia et al., 2014). Figure 1 shows the growth in the number of biomethane plants in Europe between 2013 and 2022.

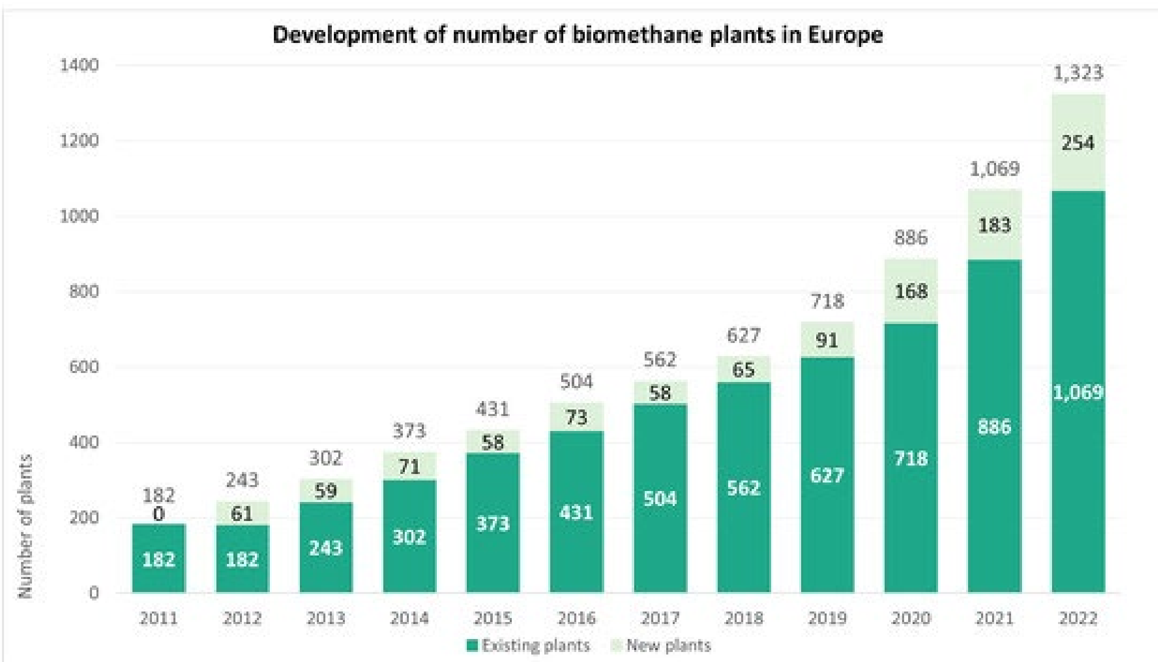

Figure 1. Development of number of biomethane plants in Europe.

Figure 1 shows the number of biomethane plants in Europe between 2011 and 2022. The number grew from 182 plants in 2011 to 1323 in 2022.

In terms of energy value, combined biogas and biomethane reached 196 TWh in and 2020 with biomethane production reaching 31 TWh in Europe which. Increased to 37 TWh in 2021, which about 20% growth. Biomethane production doubled from 2018 to 2022 with the fastest growing markets being Italy, France, Denmark, and the UK (Francisco López et al., 2024). Figure 2 shows the growth in biomethane energy value between 2011 and 2022 for Europe.

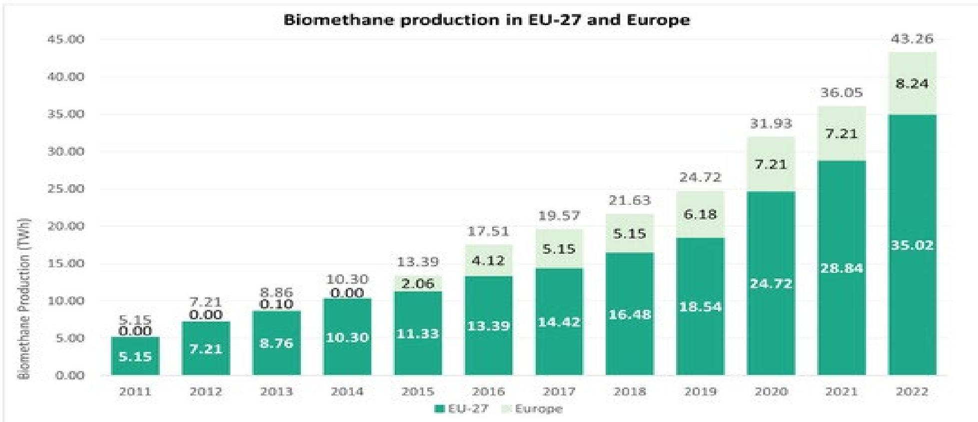

Figure 2. European biomethane production in EU-27 and Europe

From Figure 2, it is noted that the energy potential of biomethane in the European market has been on growth trajectory growing from 5.15 TWh in 2011 to 43.26 TWh in 2022. The annual consumption of both biogas and biomethene is expected to increase to between 628 TWh and 836 TWh in 2050 up from 198 TWh in 2017. However the global potential of biomethene production by biogas upgrading higher than the current production., and if the full potential is utilized biogas and biomethane can meet 20% of the current global gas demand(Francisco López et al., 2024).. With the current conflict driven energy crisis especially in Europe, the soaring prices, and energy dependence, biomethane has emerged as an essential and sustainable renewable energy source whose rapid expansion indicates its importance globally emphasizing the of biogas enhancement technologies (Francisco López et al., 2024; M. J. B. Kabeyi & A. O. Olanrewaju, 2023b).

2.2. Global Growth Prospects

There is significant differences in the production levels of biogas and biomethane, globally influenced by resource availability, access to technologies, and policy frameworks with Europe emerging as the most important producer, with the second-largest biomethane market share in 2022. The markets are expected to grow further driven by the growing demand for renewable energy anaerobic fermentation. Germany alone has close to two-thirds of the operating plants, followed by the Netherlands, France, and Denmark, which consolidates as a global leader in the market. Figure 3 shows the regional share of global biomethane demand.

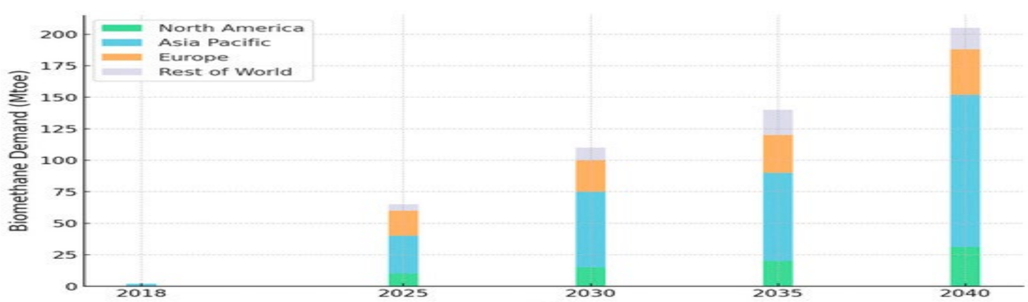

Figure 3. Projected biomethane demand by geographical region.

From Figure 3, it is observed that Asia, China has strongly promoted biomethane and biogas as part of its strategy for renewable energy and clean cooking solutions. For China, the national plan of 2019 reinforced upgrading technologies to increase the share of biomethane in transport sector. .

Biomethane production in the US is associated with associated with landfill gas, while the future perspectives point at livestock waste integration, with the primary application in transportation fuel, being backed by federal incentives. For the African continent the main challenge for biomethane market, is access to clean cooking fuels: especially for rural households still rely on solid bio-based fuels such as firewood, charcoal, or dung, with serious health and environmental impacts. The Sub-Saharan Africa accounts for one-third of the global population with no access to clean newest clean cooking access, and has five out of six people that have no access to alternatives e.g. in India there is heavy dependence on polluting stoves. Additionally initiatives like subsidies to promote biogas and biomethane investments, are largely missing in many developing countries (Lincoln et al., 2023).

The global panorama of biogas and biomethane development is a reflection of a complex interaction between technological, geographical, policy and regulatory aspects to influence the adoption biogas and biomethane in the energy mix with contracts and agreements being expected to enable market actors in the near future and ensure continuous growth of biogas and biomethane market(Hidalgo et al., 2025).

3. Applications for Biogas and Biomethane

Biomethane or its natural blend can be used in powering vehicles, leading to a significant reduction in fossil fuel pollution compared with the use of gasoline- and diesel-powered engines, as well as biodiesel and bioethanol. Biomethane thus offers an ideal transportation pathway that reduces emissions in cities, currently accounting for approximately 400,000 premature deaths per annum in Europe, besides contributing towards a circular economy. Digestate from anaerobic digestion is also a valuable organic product used as an organic fertilizer that can replace millions of tons of carbon-intensive mineral fertilizer (BIOSURF, 2017).

Biomethane, also called renewable natural gas, is chemically similar to natural gas; hence, it is a substitute fuel for fossil fuels and can be fed into gas transport and distribution networks. Biomethane is used for domestic and industrial power and heat production and as a fuel for the transport sector.

Biogas and biomethane have direct applications in cooking, lighting, electricity generation, and transportation. Other applications include vehicle fuel, fuel cells, and injection into the public gas grid for domestic and industrial applications (Kabeyi, 2024b). As a process feedstock for value addition, biomethane is used in the Fischer-Tropsch (FT) process for the production of other fuels, including methanol fuel. Biomethane is also compressed and used as compressed biogas (CBG) and liquid biogas (LBG) for heat and power generation, which widens its application as a direct substitute for natural gas(Kabeyi, 2024b; M. J. B. Kabeyi & A. O. Olanrewaju, 2023b).

The use of biogas has many environmental benefits, with upgraded biogas exhibiting properties similar to those of natural gas. Biogas has thermal, electrical, and industrial applications (Kadam & Panwar, 2017). Biomethane applications, which are often similar to those of biogas, are summarized in Figure 4.

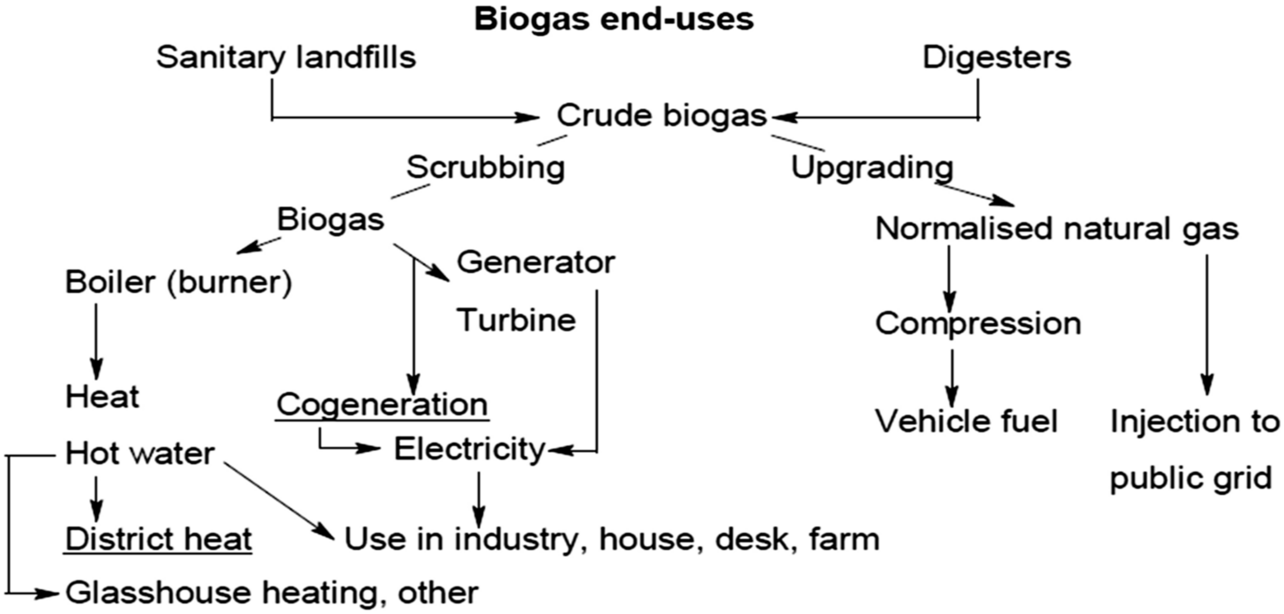

Figure 4. Summary of biomethane and biogas applications in the energy transition

The various applications and pathways for biogas and biomethane energy applications, as summarized in figure 4, include cleaning such as scrubbing for use in heat and power generation, district heating, greenhouse heating, and cooking. The other pathway is biogas upgrading by the removal of carbon dioxide for application as a substitute for natural gas, such as vehicle fuel and injection into the natural gas public grid.

4. Findings and Discussion

Although clean raw biogas can supply energy for power generation, cooking, and heating needs, among other applications, biogas can be a reliable energy resource as a transport fuel, substitute for natural gas, feedstock for industrial and energy products, and provide energy storage, which significantly increases its utility and value. Although methane is the main component of biogas with energy value, raw biogas has impurities that may be undesirable for some specific applications, making biogas cleaning and upgrading an important process that creates the biomethane market. The biomethane technology market has become globally attractive because of many mature upgrading technologies, conversion technologies, and growing feasible applications for biomethane.

The main reason for the viability of biomethane is the abundance of cheap feedstock supplies for anaerobic digestion and biomass gasification. Biogas, which is a renewable and clean energy option, has the potential to address this challenge. Although biogas offers a reliable form of energy and multiple applications, including household fuel, vehicle systems, and electricity generation, raw biogas contains impurities or contaminants that can be removed to enhance its quality and energy content. This study comprehensively reviewed different biogas upgrading processes, including cryogenic separation, membrane technology, adsorption, and scrubbing, with technical, economic, environmental, and social indicators of energy sustainability. Chemical scrubbing is the most frequently employed method compared to other processes.

Biomethane has applications in heat and power generation and can be used to run prime movers such as gas turbine internal combustion engines, Stirling engines, and fuel cells, making it a key component in the hydrogen economy, energy sector, industry, and transport sectors as a feasible feedstock for the manufacture of transport fuels for onward application in direct heat and power generation (CHP). As a substitute for fossil natural gas, biomethane can be applied to CNG and LPG, reforming to preproduction of syngas, production of methanol and gasoline by partial oxidation and feedstock in the Fischer-Tropsch process, and hydrogen production, among other applications across many sectors. Therefore, biomethane is an important renewable energy resource for heat, chemical, industrial, and power generation as fuel and feedstock. The challenge facing biomethane production is the high process costs, while many promising processes are still under research and development.

This study demonstrated that biogas to biomethane conversion and use is currently technically feasible, although cost remains a challenge compared to natural gas, raising questions about overall sustainability. The study recommends a similar study for biomethane production from syngas produced by solid biomass gasification, a technology that can be used on hard-to-digest solid biomass such as lignin to obtain the overall feasibility of total biomass to biomethane via biogas and syngas. Additionally, since the production and use of biogas and biomethane from sources such as energy crops has a negative impact on agriculture, while residue digestion produces fertilizers that can improve local nutrient cycles, this study recommends a life cycle assessment of various biomethane and biogas production and use pathways for optimal production and use of biogas based on recommended sustainability criteria.

5. Conclusions

Raw biogas production and use is an established and mature technology, but recent trends and developments have opened up new horizons for the exploitation of biogas due to advances in technology, growing demand for green energy, and global commitment to energy transition and coupling various sectors to energy. Biogas plays an important role in the conversion of bio-waste and wastewater to renewable resources that reduce carbon emissions and contribute to cleaner air, healthier soil, and a healthier life for humanity in clean environments. Methane is the main energy component of biogas, followed by noncombustible carbon dioxide and impurities such as moisture, hydrogen sulfide carbon dioxide, siloxanes, siloxanes, hydrocarbons, oxygen, ammonia, oxygen, carbon monoxide, and nitrogen, most of which are undesirable as they reduce the calorific value of biogas and cause operational challenges such as corrosion and clogging, while others are poisonous. Hence, it is necessary to clean and upgrade biogas to biomethane.

Biogas can be used directly or upgraded to biomethane form an important component of the circular economy and renewable energy market. Biogas has multiple applications ranging from thermal/heat, automobile fuels, natural gas substitution in gas grids, manufacture of biochemical, and alcohols among others. Green hydrogen from biogas and biomethane can facilitate sustainable decentralized power generation and substitute natural gas in electrifying in remote and rural areas. Most of these applications require the cleaning and upgrading of biogas for methane purification and removal of harmful impurities which requires large-scale development of hydrogen (H_2) energy technology with biogas reforming promising to be an auspicious process for green hydrogen gas production as renewable energy source and feedstock providing a sustainable pathway for waste disposal and production of green energy and feedstock for various industrial processes. Overall, biogas production and applications provide a feasible pathway for reducing greenhouse gas emissions by reducing dependence on fossil fuels, providing a green solution to the management of waste disposal. This has created a growing market for biogas and biomethane globally.

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