

# Biogas: A Sustainable Solution for Energy Production and Environmental Protection

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## Abstract

As the global community accelerates its transition toward renewable energy systems in 2026, biogas has emerged as a critical component in the circular economy and climate change mitigation strategies. Produced through the anaerobic digestion of organic matter, biogas serves as a versatile energy source capable of generating electricity, heat, and transport fuel while simultaneously addressing waste management challenges. This article provides a comprehensive overview of biogas production technologies, applications, and its environmental and economic significance. It highlights recent data indicating that biogas systems can reduce methane emissions from agricultural waste by up to 90% and offset significant fossil fuel consumption. Furthermore, the economic analysis reveals substantial potential for job creation, with the U.S. market alone poised to support over 335,000 construction jobs through expanded infrastructure. Despite its benefits, biogas currently accounts for a small fraction of primary energy, necessitating robust policy frameworks to unlock its full potential as a decarbonization tool.

**Keyword:** Renewable energy, organic matter, biogas, fossil fuel, decarbonization.

## Introduction

Biogas is a special nexus of waste management, environmental responsibility, and energy security in the pursuit of sustainable energy solutions. Anaerobic digestion is the process by which microorganisms break down organic materials, including food scraps, animal dung, and sewage, in an oxygen-free environment to produce biogas, a renewable fuel. Methane (CH<sub>4</sub>), which usually makes up 50% to 70% of the resultant gas mixture, and carbon dioxide (CO<sub>2</sub>), which makes up 30% to 40%, are the main constituents, with trace amounts of other gases being present (Jameel et al., 2024). By 2026, biogas has developed into a sophisticated industrial energy source, having previously been utilized for basic lighting and warmth in rural regions. Biomethane, often known as renewable natural gas, can currently be produced using advanced upgrading technology. It can be put into existing grid infrastructure and is chemically identical to conventional natural gas (IEA, 2026). Biogas has become increasingly relevant as countries work to achieve net-zero goals because it provides a workable way to decarbonize hard-to-electrify sectors like industrial heating and heavy transportation.

## Biogas Production: Process and Technologies

Biogas is produced using a naturally occurring biological process that has been optimized for efficiency in regulated settings.

### The Anaerobic Digestion Process

In the biochemical process known as anaerobic digestion (AD), a group of bacteria break down complex organic molecules without the presence of oxygen. Hydrolysis, acidogenesis, acetogenesis, and methanogenesis are the four main phases of the process. Large organic polymers (fats, proteins, and carbohydrates) decompose into smaller molecules throughout these phases, ultimately producing carbon dioxide and methane. In addition to producing energy, this procedure stabilizes the waste and lowers infections and odors (EESI, 2017).

### Production Pathways and Technologies

There are three main technological approaches used in the manufacture of biogas nowadays:

**Biodigesters:** are covered lagoons or airtight tanks used to treat and dilute organic material. These range from large-scale industrial operations to little households in impoverished countries.

**Landfill Gas Recovery:** Over time, anaerobic breakdown of municipal solid waste (MSW) occurs in landfills. The produced methane, which would otherwise leak into the environment as a strong greenhouse gas, is captured by extraction wells and piping systems.

**Wastewater Treatment Plants (WWTP):** Anaerobic digesters are used to treat sewage sludge in order to recover energy and reduce volume. By 2026, more and more facilities will be using this biogas to power plant operations, leading to energy neutrality.

### Key Feedstocks

The broad variety of feedstock alternatives that biogas offers accounts for its adaptability. Among the primary sources are:

**Animal manure:** Untreated, is a major source of methane emissions. This potential energy is captured by AD systems on animal ranches.

**Crop residues:** are leftovers from agriculture, including husks, straw, and stalks.

**Biosolids:** The organic fraction of MSW includes yard trash and food waste, which make up a significant amount of municipal waste streams.

**Co-digestion**— In order to increase methane outputs, the process of combining many feedstocks, such as manure and food waste—is becoming more and more popular. According to research, process stability and gas output can be considerably increased by adjusting feedstock mixtures (Saboochi, 2025).

### Applications of Biogas

After been caught, biogas can be used in a variety of ways, providing flexibility that is unrivaled by intermittent renewable energy sources like solar or wind.

### Electricity and Heat Generation

Systems that combine heat and power (CHP) are the most widely used. In these systems, waste heat is recovered for on-site usage or district heating, and biogas powers a combustion engine to produce electricity. Efficiency rates of over 85% can be attained with this cogeneration strategy (IEA, 2026).

### Biomethane and Vehicle Fuel

Biogas is converted to biomethane using upgrading procedures (such membrane separation or water washing) that remove CO<sub>2</sub> and contaminants. Fossil natural gas and renewable natural gas (RNG) are completely interchangeable. It provides a low-carbon option for freight transportation and is being utilized more and more in heavy-duty vehicles as a replacement for compressed natural gas (CNG) or liquefied natural gas (LNG).

### Agricultural Applications

Digestate is a beneficial byproduct of anaerobic digestion that is rich in nutrients. Digest is a more plant-accessible version of the original feedstock's nitrogen, phosphorus, and potassium. By using it as a bio-fertilizer, agricultural systems can close the nutrient loop and become less dependent on synthetic fertilizers (Jameel et al., 2024).

### Environmental Benefits and Importance

The environmental case for biogas encompasses important ecological and climate benefits in addition to the provision of renewable energy.

### Climate Change Mitigation

Systems that use biogas are an effective way to reduce methane emissions. Methane has a 20-year warming potential that is 86 times greater than that of CO<sub>2</sub>, making it a short-lived climate pollutant. Biogas systems stop these emissions from entering the atmosphere by absorbing methane from organic waste that is breaking down. Research indicates that methane emissions from agricultural waste streams can be reduced by 70–90% with biogas systems (Akingba et al., 2026). Additionally, compared to petroleum gasoline, RNG can cut greenhouse gas emissions by up to 91% throughout

the course of its lifecycle when utilized as car fuel (EESI, 2017).

### Waste Management and Pollution Prevention

Waste liabilities can be turned into assets with biogas technology. It provides a sustainable way to get rid of the millions of tons of organic waste that are produced every year. Furthermore, AD processes greatly lower the pathogens in sewage and manure, preventing contamination of nearby water bodies and lowering the risk of waterborne illnesses (World Wildlife Fund, 2020).

### Economic Benefits and Global Industry Overview

The biogas sector is a developing economic engine that supports rural economic growth and employment generation.

### Job Creation and Market Growth

Building and running biogas facilities requires a lot of work. More than 335,000 temporary construction jobs and 23,000 permanent operating jobs might be created in the United States alone if more than 13,500 new biogas systems are fully developed (American Biogas Council, 2024). Increasing energy demand and environmental laws are driving the growth of the global biogas plant market, which is expected to reach \$6.5 billion by 2026.

### Global Production Landscape

Production is geographically concentrated but expanding:

**Europe:** Continues to dominate the world in biogas generation, especially in Germany, because to strict renewable energy regulations and early feed-in tariffs.

**China:** Has quickly increased capacity, concentrating on large-scale industrial waste treatment facilities and rural home digesters.

**United States:** With a heavy emphasis on landfill gas recovery and RNG for the transportation sector under the Renewable Fuel Standard (RFS), the industry is expanding.

### Challenges and Future Prospects

Despite its advantages, biogas and biomethane only account for around 0.3% of the world's primary energy demand at the moment (IEA, 2026). Widespread adoption is hampered by several obstacles.

### Barriers to Adoption

Long payback times and high initial capital expenses continue to be major obstacles for project developers. Project delays may also result from technical issues with the logistics of the feedstock supply chain and RNG grid connections. Due to subsidies or a lack of carbon pricing, fossil natural gas is still artificially cheap in many areas, making it challenging for biogas to compete without government backing.

**Outlook to 2030 and Beyond**

The potential for biogas to displace fossil fuels in difficult-to-abate industries is what holds its future. According to the International Energy Agency, 20% of the world's gas consumption may be fulfilled by sustainable biogas and biomethane. In the short run, many industrialized economies can realistically aim to replace 10% of their natural gas with biomethane by 2030. Growth is anticipated to be stimulated by ongoing technological innovation and supportive policies like the U.S. Inflation Reduction Act and the EU's RePowerEU plan.

**Conclusion**

Biogas is a tried-and-true, multipurpose, and vital technology for a sustainable future. It offers a unique solution to two of the most important issues facing the globe: the management of organic waste and the demand for clean, renewable energy. Biogas promotes a circular economy by turning waste streams into useful resources including heat, power, fuel, and fertilizer. Anaerobic digestion technology must be deployed more quickly in 2026 due to environmental requirements, even though infrastructural and cost issues still exist. Biogas is not just an alternative fuel; it is a key component of worldwide decarbonization initiatives due to its ability to significantly cut methane emissions and supply dependable baseload power. For biogas to reach its full potential in the ensuing 10 years, governments and stakeholders must give priority to legislative frameworks that recognize its many advantages.

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