Biogas typically refers to a (biofuel) gas produced by the anaerobic digestion or fermentation of organic matter including manure, sewage sludge, municipal solid waste, biodegradable waste or any other biodegradable feedstock, under anaerobic conditions. Biogas is comprised primarily of methane and carbon dioxide.

Depending on where it is produced, biogas is also called:

- **swamp gas**
- **marsh gas**
- **landfill gas**
- **digester gas**

Biogas can be used as a vehicle fuel or for generating electricity. It can also be burned directly for cooking, heating, lighting, process heat and absorption refrigeration.

Biogas and anaerobic digestion

Main article: anaerobic digestion

Biogas production by anaerobic digestion is popular for treating biodegradable waste because valuable fuel can be produced while destroying disease-causing pathogens and reducing the volume of disposed waste products. The methane in biogas combusts more cleanly than coal, and produces more energy with less emissions of carbon dioxide. The harvesting of biogas is an important role of waste management because methane is a greenhouse gas with a greater global warming potential than carbon dioxide. The carbon in biogas was generally recently extracted from the atmosphere by photosynthetic plants, so releasing it back into the atmosphere adds less total atmospheric carbon than the burning of fossil fuels.

Recently, developed countries have been making increasing use of biogas generated from both wastewater and landfill sites or produced by mechanical biological treatment systems for municipal waste. High energy prices and increases in subsidies for electricity generated from renewable energy (such as renewables obligation certificates) and drivers such as the EU Landfill Directive have led to much higher utilisation of biogas sources.

Biogas typical composition range

The composition of biogas varies depending upon the origin of the anaerobic digestion process. Landfill gas typically has methane concentrations around 50%. Advanced waste treatment technologies can produce biogas with 55-75%CH_4 [1].

Biogas composition[2]

Matter	%
Methane, CH_4	50-75
Carbon dioxide, CO_2	25-50

Nitrogen, N_2	0-10*
Hydrogen, H_2	0-1
Hydrogen sulphide, H_2S	0-3
Oxygen, O_2	0-2*

- often 5 % of air is introduced for microbiological desulphurisation

Anaerobic digestion (AD) is the harnessed and contained, naturally occurring process of anaerobic decomposition.[1][2] An **anaerobic digester** is an industrial system that harnesses these natural process to treat waste, produce biogas that can be used to power electricity generators, provide heat and produce soil improving material.[3]

Anaerobic digesters have been around for a long time and they are commonly used for sewage treatment or for managing animal waste. Increasing environmental pressures on waste disposal have increased the use of AD as a process for reducing waste volumes and generating useful byproducts. It is a fairly simple process that can greatly reduce the amount of organic matter which might otherwise end up in landfills or waste incinerators.

Almost any organic material can be processed in this manner. This includes biodegradable waste materials such as waste paper, grass clippings, leftover food, sewage and animal waste. Anaerobic digesters can also be fed with specially grown energy crops to boost biodegradable content and hence increase biogas production. After sorting or screening to remove inorganic or hazardous materials such as metals and plastics, the material to be processed is often shredded, minced, or hydrocrushed [4] to increase the surface area available to microbes in the digesters and hence increase the speed of digestion. The material is then fed into an airtight digester where the anaerobic treatment takes place.

Stages of anaerobic digestion

There are two conventional operational temperature levels:

- *Mesophilic* which takes place optimally around 37°-41°C or at ambient temperatures between 20°-45°C with mesophile bacteria
- *Thermophilic* which takes place optimally around 50°-52° at elevated temperatures up to 70°C with thermophile bacteria

The residence time in a digester varies with the amount of feed material, type of material and the temperature. In the case of mesophilic digestion, residence time may be between 15 and 30 days. In the case of mesophilic UASB digestion hydraulic residence times (1hour-1day) and solid retention times (<90 days) are separated. In the thermophilic phase the process can be faster, requiring only about two weeks to complete. Thermophilic digestion is more expensive, requires more energy and is less stable than the mesophilic process. Therefore, the mesophilic process is still widely in use.

Many continuous digesters have mechanical or hydraulic devices to mix the contents and to allow excess material to be continuously extracted to maintain a reasonably constant volume.

The digestion of the organic material involves a range of many different species of naturally occurring bacteria, all doing a different job at a different step in the digestion process. Maintaining suitable conditions in the digester is essential in maintaining a healthy bacterial population.

Four stages of anaerobic digestion have been recognised.

1. The first is hydrolysis, where complex organic molecules are broken down into simple sugars, amino acids, and fatty acids with the addition of hydroxyl groups.
2. The second stage is acidogenesis where a further breakdown into simpler molecules occurs, producing ammonia, carbon dioxide and hydrogen sulfide as byproducts.
3. The third stage is acetogenesis where the simple molecules from acidogenesis are further digested to produce carbon dioxide, hydrogen and mainly acetic acid, although higher-molecular-weight organic acids (e.g., propionic, butyric, valeric) are also produced.
4. The fourth stage is methanogenesis where methane, carbon dioxide and water are produced.

[edit] By-products of anaerobic digestion

There are three principal by-products of anaerobic digestion.

- Biogas, a gaseous mixture comprising mostly of methane and carbon dioxide, but also containing a small amount hydrogen and occasionally trace levels of hydrogen sulfide. Biogas can be burned to produce electricity, usually with a reciprocating engine or microturbine. The gas is often used in a cogeneration arrangement, to generate electricity and use waste heat to warm the digesters or to heat buildings. Excess electricity can be sold to electricity suppliers. Electricity produced by anaerobic digesters is considered to be green energy and may attract subsidies such as Renewables Obligation Certificates.

Since the gas is not released directly into the atmosphere and the carbon dioxide comes from an organic source with a short carbon cycle biogas does not contribute to increasing atmospheric carbon dioxide concentrations; because of this, it is considered to be an environmentally friendly energy source. The production of biogas is not a steady stream; it is highest during the middle of the reaction. In the early stages of the reaction, little gas is produced because the number of bacteria is still small in size. Toward the end of the reaction, only the hardest to digest materials remain, leading to a decrease in the amount of biogas produced.

Acidogenic anaerobic digestate

- The second by-product (acidogenic digestate) is a stable organic material comprised largely of lignin and chitin, but also of a variety of mineral components in a matrix of dead bacterial cells; some plastic may be present. This resembles domestic compost and can be used as compost or to make low grade building products such as fibreboard.

- The third by-product is a liquid (methanogenic digestate) that is rich in nutrients and can be an excellent fertilizer dependent on the quality of the material being digested. If the digested materials include low levels of toxic heavy metals or synthetic organic materials such as pesticides or PCBs, the effect of digestion is to significantly concentrate such materials in the digester liquor. In such cases further treatment will be required in order to dispose of this liquid properly. In extreme cases, the disposal costs and the environmental risks posed by such materials can offset any environmental gains provided by the use of biogas. This is a significant risk when treating sewage from industrialised catchments.

Nearly all digestion plants have ancillary processes to treat and manage all of the by-products. The gas stream is dried and sometimes sweetened before storage and use. The sludge liquor mixture has to be separated by one of a variety of ways, the most common of which is filtration. Excess water is also sometimes treated in sequencing batch reactors (SBR) for discharge into sewers or for irrigation.

Digestion can be either *wet* or *dry*. Dry digestion refers to mixtures which have a solid content of 30% or greater, whereas wet digestion refers to mixtures of 15% or less.

anaerobic digestion (AD) has the potential to:

- reduce odour and pathogen levels in manure
- reduce greenhouse gas production from a farmstead
- allow the incorporation of off-farm sourced organics
- produce renewable energy and

- improve the immediate fertilizer value of the manure.

Effect of metals on biogas production

Presence of some metals also influences the biogas production.

addition of calcium (5 mM), cobalt (50 µg g^{-1} TS), iron (50 mM), magnesium (7.5 mM), molybdenum (10–20 mM), nickel (10 µg g^{-1} TS) individually as well as in combination enhanced the biogas production and attributed this to the increased methanogenic population in the digesters.

addition of nickel at 2.5 ppm increased the biogas production from digesters fed with water hyacinth and cattle-waste blend and attributed this to higher activity of nickel-dependent metalo-enzymes involved in biogas production.

Addition of Cd and Ni at 600 and 400 µg g^{-1} of dry matter, respectively, increased the biogas production and methane content.

But further addition of iron or manganese at 1100 µg g^{-1} of dry matter did not influence the yield of biogas.

However, addition of iron as ferrous sulphate at 50 mM level showed faster bioconversion of both the cow dung and poultry waste.

addition of iron at 20 mM level increased the population of methanogens, and that methanogenesis was also enhanced by 40 and 42 per cent in cow dung-fed digesters as well as in a poultry waste-fed digester, respectively.

In the case of cobalt, addition of cobalt (0.2 mg l^{-1}) improved the gas yield and methane content of gram clover silage-fed digester.

A.3. BIOMASS FEED STOCK OPTIONS FOR BIOGAS PLANTS

Biomass Feed Stocks are Broadly Classified into Three Types

Type –I : Agricultural, Forestry Waste & Energy Plantations
Type – II : Animal, Municipal Solid Waste & Marine Waste.
Type – III : Industrial Waste & De-Oiled Cake

- *Agricultural Waste* : Agricultural crop residues of various Plants & Trees
- *Forestry Waste*: Waste like Stems, Leaves, Fruits, Seeds etc
- *Energy Plantations*: Plants which give quick yield (<50 days to 75 days)
- *Animal Waste*: Manure of Animals, Poultry waste & Slaughter House waste.
- *Mandi Waste*: Wastes collected from Wholesale Vegetable Markets
- *Municipal Solid Waste*: Organic Solid waste collected from Towns etc.
- *Marine Waste*: Waste generates from Fish oil mills, Fish exporting units & Dead Fish
- *Industrial Waste*: Waste generates from Sugar Industries, Oil extraction Units etc
- *De-oiled Cake*: Waste Cake which obtains from, after Oil extraction Units.

A.3.1VARIOUS BIOMASS FEED STOCKS FOR BIOGAS GENERATION		
TYPE-I	**TYPE-II**	**TYPE-III**
AGRICULTURAL & FORESTRY WASTE	**ANIMAL WASTE & MUNICIPAL SOLID WASTE**	**INDUSTRIAL WASTE**
Rice Straw	Cow Dung	Condensed Molasses Solubles
Cane Trash	Buffalo Dung	Palm Oil Secondary Sludge
Communist Weed	Slaughter house waste	
Subocul Tree Leaves	Poultry waste	
Glyriciaa Leaves	Mandi waste	
Tiger Grass	Organic municipal solid waste	**DE-OILED CAKE**
Palm Leaves		Jatropha Seeds
Grapes crops residue		Pongamia Seeds
Sunflower crops residue		Garcinia Seeds
Tapioca crops residue		Mulla - Harhlu Seeds
Cashew fruits		Dhoopa Seeds
		Rubber Seeds
		Rampatri Seeds
		Mulla-Haralu Seeds
		Jack Fruit Seeds
		Kumti Seeds
		Toody Palm Seeds
		Bharani Seeds
ENERGY PLANTATIONS	**MARINE WASTE**	Marati Seeds
Fodder Sorghum	Fish Broth	Halle Kai Seeds
Sweet Sorghum	Dead Fish	Gurgi Beeja Seeds
		Sunflower seeds
		Sesame

From above Feed stocks options, analysis has been carried out on following materials which are being evaluated for "pilot Projects" that are under implementation in India.

URBAN / INDUSTRIAL WASTE

Sl. No	BIOMASS	BIOGAS YIELD Cu.m/MT	REMARKS
A.1	OIL MILL WASTE		
A.1.1	De Oiled Cake	550	Residual Cake after extrusion/extraction of oil from non edible seeds (e.g. Pongamia Jetropha, Rubber, Dhoopa, etc)
A.1.2	Edible Oil Secondary Effluent	400	Effluent of vegetable oil refineries (e.g. palm)
A.1.3	Fish Oil Secondary Effluent	400	Effluent of Fish Oil Processing unit
A.1.4	Fish Solid Waste	400	Solid Waste from Fish Processing and Packing industries
A.2	DISTILLERY WASTE	400	CMS (Condensed Molasses Soluble) / Spent wash of Distilleries
A.3	DAIRY WASTE	60	Manure of Cow & Buffalo Farms
A.4	GRAIN MILL WASTE	550	a) Small/tender grains of wheat/rice, which are separated prior to milling b) Rice bran
A.6	MANDI WASTE	180	Waste of wholesale vegetable markets

AGRICULTURAL WASTE / ENERGY PLANTATIONS

Sl. No	BIOMASS	BIOGAS YIELD Cu.m/MT	REMARKS
B.1	**CROP RESIDUES**		
B.1.1	Cane Trash	180	Leaves of Sugar cane, which are burnt in the fields
B.1.2	Rice Straw	180	Straw of Rice plant, used partially as cattle fodder and balance burnt in field
B.1.3	Wheat Straw	180	Straw of Wheat plant used largely as cattle fodder
B.2	**ENERGY PLANTATIONS**		
B.2.1	Fodder Sorghum	180	Quick yield (< 50 days) water resistant plant. Useful as fodder / feedstock for ethanol / biogas plants
B.2.2	Sweet Sorghum	400	Quick yield (< 75 days) but sensitive to excess water. Useful as food / fodder / feedstock for ethanol / biogas plants