WBA fact sheet

BIOGAS – AN IMPORTANT RENEWABLE ENERGY SOURCE

SUMMARY

"Biogas" is a gas produced by anaerobic fermentation of different forms of organic matter and is composed mainly of methane (CH_4) and carbon dioxide (CO_2). Typical feedstocks for biogas production are manure and sewage, residues of crop production (i.e., straw), the organic fraction of the waste from households and industry, as well as energy crops including maize and grass silage.

Biogas is supplied to a variety of uses or markets, including electricity, heat and transportation fuels. In many countries using the gas for direct combustion in household stoves and gas lamps is increasingly common, producing electricity from biogas is still relatively rare in most developing countries. In industrialized countries, power generation is the main purpose of most biogas plants; conversion of biogas to electricity has become a standard technology. To improve overall efficiency of biogas utilization, combined heat and power plants are often used, with part of the heat utilized for maintaining reactor temperature and sometimes for heat treatment of the incoming material.

A biogas plant on a farm, for example, has a number of different elements, such as the liquid manure store, the receiving and mixing area, the digester or reactor, the gas storage tank and storage for digester residue. In the case of a combined heat and power (CHP) application, there also needs to be grid connection for the electricity and a connection to the heat user. The cost of investment per kW installed electric capacity is about 5 000 Euro for an installation of about 150 kW in size; the specific investment cost/kW or MW capacity is higher for smaller plants and lower for bigger plants.

The global potential of biogas is large enough to provide a substantial share of future gas demand; estimations show that biogas could cover around 6% of the global primary energy supply, or one quarter of the present consumption of natural gas (fossil methane gas).

Each country should develop and implement an integrated biogas concept in order to promote the increased production of biogas. The big advantages of such a strategy would include better progress in mitigating climate change by reducing national GHG emissions, improving national energy security, and creating new employment in rural regions. International organizations should support these national efforts.

INTRODUCTION

Enhanced energy security and climate change mitigation are the main drivers for the transformation of the energy system from fossil to renewable sources. Biomass has to play a key role in this transformation to a low carbon economy. Worldwide, biomass (including putrescible waste and bio-wastes) accounts for more than two thirds of all renewable energy supplies. Among biomass sources, biogas is an interesting option with a large potential, offering many exciting possibilities to supplant and therefore reduce our dependence on fossil fuels. [1]

Currently the modern biogas production industry is just at the beginning of wider implementation. With the exception of a few countries, like Germany (which are

Photo: Bernd Wittelsbach

Biogas energy plant in Germany. Biogas already provides more than 3% of the whole of Germany's electricity consumption, as well as significant amounts of industrial heat, transport fuels, and volume injected into the natural gas grid.

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already demonstrating its real potential) only a tiny part of this global potential has been realized. Reasons for the slow deployment of biogas include: a lack of information about the possibilities of biogas, a lack of a trained labor force, high capital cost for the setting up of commercial plants, generally inadequate and unreliable government support policies and the competition of natural gas as a cheaper alternative in many parts of the world.

From an economic viewpoint national biogas development is effectively stimulated when a significant cost is put on disposal of putrescible wastes or of free emissions of greenhouse gases arising from this, and also when financial stimulus of biogas production roughly matches the previous levels of stimulus of natural gas sourcing or reticulation. This latter case may be via a carbon tax on fossil fuels, transferred to provide a cost share for biogas production and processing facilities.

A specific advantage of biogas technology is in the utilisation of organic wastes and other organic byproducts for energy production, as opposed to disposal via landfills, which inevitably leads to further emissions of greenhouse gases by the process of slow decomposition.

The purpose of this WBA fact sheet is to offer to the reader basic information about biogas as renewable energy source – the process, the feedstock, the versatility of biogas, the worldwide potential, the current global significance and the necessary policy measures for further development.

BASICS

The term "biogas" is used for a gas produced by anaerobic fermentation of different forms of organic matter. Biogas is also produced under anaerobic conditions in nature, for example in swamps. This anaerobic process is driven by different varieties of bacteria, in anaerobic digestor tanks this is usually at a temperature of 30 – 40° C. During this biological process a major portion of the carbon compounds are converted to CH_4, CO_2 and water. Biogas consists mainly of methane, carbon dioxide, and some other minor components. The fermentation process also produces a residue or sludge that can be used as fertilizer, or after drying as feedstock for combustion in district heating or CHP plants.

TABLE 1: COMPOSITION OF BIOGAS, [2]

Matter	%
Methane CH_4	50 – 75
Carbon dioxide CO_2	25 – 45
Water vapor, H_2O	2-7
Nitrogen, N_2	< 2
Oxygen, O_2	<2
Others 1)	

1) Others: NH_3, H_2, H2S, trace gases

TABLE 2: ENERGY CONTENT OF BIOGAS AND BIOMETHANE [1]

	Unit	kWh	MJ
Biogas (average)	1 Nm³	6,0	21.6
Biomethane	1 Nm³	9.97	35,9
Biomethane	1 kg	13,9	50,0

The process itself occurs in airtight biogas digesters without oxygen. The rate of the process depends on the feedstock and several other parameters. The digestion time varies from several hours (for sugars, and alcohol) to several weeks (in case of hemicelluloses, fat, and protein).

The size of these digesters differs widely. Millions of small digesters are used in connection with family houses or small farms in Asian countries to produce gas for cooking; medium sized digesters can be found on farms around the world to produce mainly electricity and heat, and bigger digesters are in use for the digestion of waste from cities and municipalities, be it sewage sludge, waste from the food industry or collected from household organic waste bins.

A biogas plant on a farm has different elements such as the liquid manure store, the receiving area, the digester, the gas storage and, in case of the combined heat and power (CHP) application, grid connection for the electricity and a connection to the heat user. The cost of investment per kW installed electric capacity is about 5 000 Euro for an installation of about 150 kW in size; the specific investment cost is higher for smaller plants and lower for bigger plants. [2]

After production the raw biogas can be cleaned and upgraded to methane; it is then called biomethane, and in this pure form can be compressed and injected into gas grids or used as transport fuel. The energy content of raw biogas varies between 5 and 7 kWh/Nm³ of biogas depending on the composition; as an average 6 kWh/Nm³ biogas is assumed (i.e., assuming 60% methane content). For pure biomethane the energy content is approximately 10 kWh/m³.

A typical landfill also emits biogas produced as a result of microbial decomposition of wet organic matter in the absence of oxygen; the gas is normally called landfill gas, and for larger properly managed sites this is captured and used for energy production purposes (usually by fuelling a spark-ignition motor driving a generator), instead of being allowed to escape to the atmosphere and thus contribute to greenhouse gas emissions. On some landfills it is simply flared so that the methane is converted to the less damaging greenhouse gas carbon dioxide.

FEEDSTOCK

Biogas can be produced from most biomass and waste materials regardless of their composition and over a large range of moisture contents (although very high moisture content material of under 5% dry matter reduces biogas yield) with limited feedstock preparation. Woody biomass is not suitable for anaerobic biogas production due to its high lignin content. However, wood can be converted to methane by a thermal gasification process, the product of which is usually referred to as synthetic natural gas or SNG (this process is not the subject of this fact sheet).

Organic fraction in landfills

By extracting and processing the landfill gas (by removal of water and possibly hydrogen sulphide) so it can be used for energy purposes – usually as a fuel for gas engine-driven generators. Moreover, landfill gas utilization reduces green house gas (GHG) emissions.

Sewage sludge

Refers to the residual, semi-solid material left from wastewater treatment. Sewage sludge can be used as a feedstock for biogas. This is done in many wastewater treatment plants. The residues from digestion can be used as soil conditioner.

Manure

Manure is produced by intensively housed livestock in some countries is stored on farms for several months in liquid or solid form and then used as fertilizer. During storage, anaerobic digestion can take place in the bottom layers of manure producing methane that might be released to the atmosphere if it were not used for energy or flared. Blending manure with energy crops or other waste streams for anaerobic digestion is an attractive option to increase biogas production. [3] In developing countries, manure is often used in small family-scale anaerobic digesters and the gas is mostly used for cooking, with other applications being domestic lighting or running spark ignition engines.

The biogas plant in the municipality of Linköping, Sweden. Sweden is a world leader in upgrading and use of biomethane for transport. Biogas covers today 1% of the total road traffic in Sweden.

Energy crops

Energy crops (in the context of biogas production) are agricultural plants grown specifically for feedstock in biogas plants. Typical energy crops in Europe and North America are maize and sweet sorghum; sugar beet is also gaining importance in northern Europe. The mix of manure and maize is a common feedstock for biogas plants on farms in Europe.

Other agricultural feedstocks

Other agricultural feedstocks in use for biogas can be catch crops that are planted after the harvest of the main crop; they allow a second harvest on the same piece of land within one year. Ley crops (crops planted on land resting between commercial crop cycles) also have some potential and are already used in some places. Also green cuttings and other fresh leafy materials coming from the maintenance of the landscape, such as from trimming of trees, bushes and grass, can be used for biogas plants as well.

Waste streams for biogas

Different by-products or residues of the food processing and prepared food production industries – breweries, sugar plants, fruit processing, slaughter houses, etc., but

BIOGAS YIELDS

TABLE 3: EXAMPLES FOR AGRICULTURAL BIOGAS YIELDS [2]

Type	Nm³ biogas
1 milking cow 20m³ liquid manure/a	500
1 pig 1.5 – 6 m³ liquid manure/a	42-168
1 cattle (beef) 3 -11t solid manure/a	240 – 880
100 chicken -1,8m³ dry litter	242
Maize silage 40 -60 green weight/ha	7040 - 10560
Grass 24 – 43 t fresh matter/ha	4118 - 6811

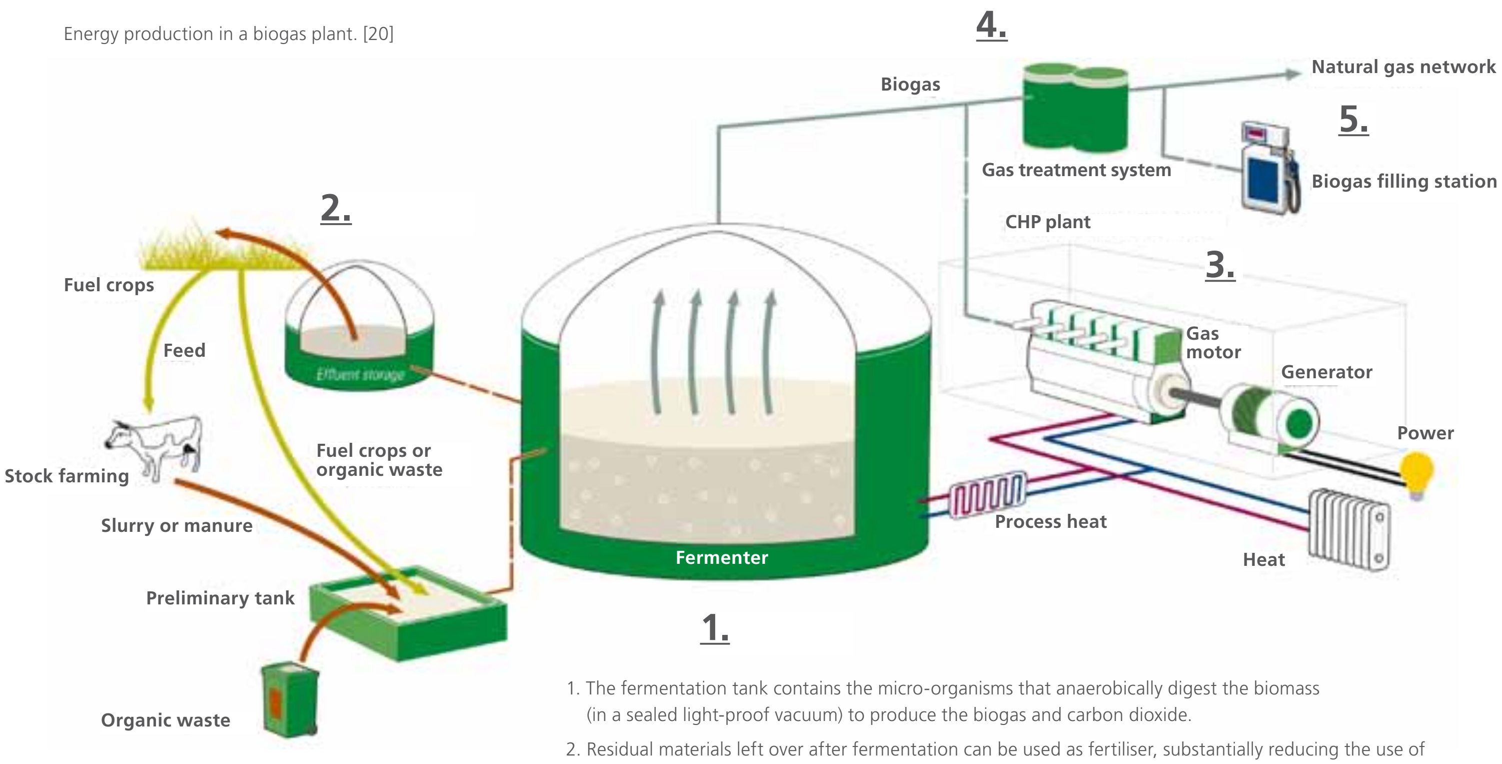
How much biogas is needed for a motor-generator of 100 kW_{el} output capacity?

A biogas plant with an installed capacity of 100 kW_{el}, an electrical efficiency of 35% and an annual production of 800.000 kWh electricity requires 470 000 Nm^3 biogas. This equals the biogas output from a manure slurry of 950 intensively housed milking cows, 6 000 pigs or 45 ha of maize.

TABLE 4: DIFFERENT APPLICATIONS OF BIOGAS [4]

Production of heat for cooking (small units in houses, farms - particularly developed in India and China)
Heat and electricity: typical combined heat and power units using a gas engine driven genset on farms, landfills, etc.
Injection into the gas grid after upgrading to biomethane
Transportation fuel after upgrading, compressing
Industrial uses for high temperature heat and steam (displacing natural gas use)
For targeted electricity production to offset the variability of wind and PV electricity

Energy production in a biogas plant. [20]



1. The fermentation tank contains the micro-organisms that anaerobically digest the biomass (in a sealed light-proof vacuum) to produce the biogas and carbon dioxide.
2. Residual materials left over after fermentation can be used as fertiliser, substantially reducing the use of mineral fertilizer in agriculture.
3. In a Combined Heat and Power (CHP) plant the biogas is combusted to produce both electricity and heat.
4. The Gas upgrading plant increases the methane content to 98% whilst improving the overall quality of the biogas by removing CO_2 and other impurities.
5. The upgraded biogas can then be fed directly into existing natural gas networks or can be used as a transport fuel.

also food waste, used kitchen oil, the organic fraction of municipal solid waste (MSW) can all be used as biogas feedstock. [4]

USE AND APPLICATION

Biogas covers a variety of markets, including electricity, heat and transportation fuels. Whereas using the gas for direct combustion in household stoves and gas lamps is common in some countries, producing electricity from biogas is still relatively rare in most developing countries. In industrialized countries, power generation is the main purpose of biogas plants; conversion of biogas to electricity has become a standard technology. To improve overall efficiency of biogas utilization, combined heat and power plants are often used.

After fermentation the biogas is normally cooled, dried of water vapour and cleaned of hydrogen sulphide to produce a good combustion gas for gas engines. The illustration above gives an overview about the different ways to use biogas.

Upgrading

Biogas produced from anaerobic digestion cannot be used directly as vehicle fuel or injected into a gas grid; it must be upgraded to biomethane first. The gas is cleaned of particles, water and hydrogen sulfide to reduce the risk of corrosion. The gas is upgraded by removing carbon dioxide to raise the energy content and create a gas with constant quality [5] consisting of about 98% methane [4].

Several techniques for removing carbon dioxide from biogas exist today and they are continually being improved. These methods include water scrubbing, pressure swing absorption (PSA), organic physical scrubbing, chemical scrubbing and upgrading using membrane technology.

Emerging biogas concepts for infrastructure and supply

Different requirements for biogas use, such as heat generation or upgrading the injection into a gas grid, requires different configurations of the biogas plants locations and size. Early on, when biogas was beginning to be used to produce energy, CHP units were often placed at the same location. More recently new concepts have emerged involving the production of the biogas in one place and the subsequent transportation of the biogas to a central CHP plant, or an upgrading station, located near a gas pipeline for injection into the regional gas grid.

Support policies

It is true that modern biogas production is only developing rapidly in regions with a consistent and effective government support policy. The main elements of a typically successful support policy are:

Guaranteed access to the electricity and gas grid, reasonable feed-in tariffs for electricity and biomethane, investment grants, education and training of the labor force, support policies to include the use of heat, some variation of a carbon tax on equivalent fossil fuels, support for methane fuelled vehicles.

As with natural gas, biogas (particularly in its upgraded form) is a high quality energy carrier. It should therefore primarily be used for energy services that demand high quality energy such as combined heat and power generation, or transport.

THE GLOBAL POTENTIAL

The feedstock is diverse. To quantify the potential the following classification can be used:

Agricultural feedstock such as;

- Manure
- By-products like straw, green mass from cash crops, landscape management
- Energy crops

Waste streams coming from;

- Organic fraction of Municipal Solid Waste (MSW)
- Biodegradable fraction of industrial waste (food industry)
- Sewage sludge

TABLE 5: POTENTIAL FOR BIOGAS IN PJ (BILLION M³ BIOMETHANE), CH_4: EU 27, CHINA, WORLD						
Type of resource	EU 27 [4] PJ	EU 27 [4] Billion m³ CH4	China [8,9] PJ	China [8,9] Billion m³ CH4	World [7] PJ	World [7] Billion m³ CH4
Manure	738	20.5	2591	72		
Residues (straw from grain, corn, rice, landscape cleaning)	407	11.3	1152	32		
Energy crops	978	27,2	1799	50		
Total from agriculture	**2123**	**59**	**5542**	**154**	**22674**	**630**
Urban waste (organic fraction of MSW)	360	10	2591	72		
Agro-industry waste (organic fraction)	108	3	1152	32		
Sewage sludge	216	6	576	16		
Total waste, billion m³ CH_4	**684**	**19**	**4319**	**120**	**13316**	**370**
Total (agriculture and waste)	**2807**	**78**	**9861**	**274**	**35990**	**1000**
Total in EJ	**2.8**		**9.9**		**35,9**	

The potential is reported in units of biomethane (1m³ biomethane = 1.67 Nm³ biogas) to make it readily comparable with natural gas.

For the EU27 the potential, excluding energy crops, was estimated as 50.7 billion m³ biomethane with 31.7 billion m³ coming from agriculture and 19.0 billion m³ from the waste sources [4]. The total potential, including energy crops on 5% of the arable land, was estimated to be 77.9 billion m³ (2804 PJ). This corresponds to 15% of the present consumption of natural (fossil) gas in the European Union.

Several studies in Europe show that the potential for biogas without using energy crops is of the order of 3,6 PJ per 1 Million inhabitants. Also different studies on the biogas potential in China are available. A brief summary is shown in table 5.

As seen in table 5, the potential of biogas would be sufficient to cover 6,7% according to table 5 of the global primary energy supply of 532 EJ in 2010. [6]

BIOGAS AROUND THE WORLD

Experience with domestic biogas technology in Developing Countries

Around the world, the implementation of domestic biogas technology has occurred in countries where governments have been involved in the subsidy, planning, design, construction, operation and maintenance of biogas plants. The giant biogas countries China and India (April 2010 to March 2011) produced 2.8 million and 150,000 biogas plants respectively in 2011, arriving at impressive cumulative numbers of 42.8 million and 4.5 million units installed of all sizes from a few m³ volume upwards. [10]

The Netherlands Development Organization, SNV, supports national programs on domestic biogas that aim to establish commercially viable domestic biogas sectors in which local companies market, install and service biogas plants for households in developing countries. The countries [11] supported by SNV have installed a total of more than 475,000 plants by the first half of 2012. Financial support was provided by a wide spectrum of national and international organizations.

The United States

The U.S. has over 2,200 sites producing biogas: 191 anaerobic digesters on farms, approximately 1,500 anaerobic digesters at wastewater treatment plants (only 250 currently use the biogas they produce) and 576 landfill gas projects. By comparison, Europe has over 10,000 operating digesters; some communities are essentially fossil fuel free because of them. [12]

Europe

In order to reach the EU member state targets for renewable energies for 2020 and to fulfill European waste management directive requirements, anaerobic digestion is seen to be one of the key technologies.

In total, 21.1 billion m³ of biogas, corresponding to 12.7 billion m³ biomethane, was produced in 2010 in the European Union.The electricity production from biogas in 2011, with a growth rate of 18.2% reached 35.9 TWh, while over the same period biogas heat sales to factories or heating networks increased by 16%. [13]

Germany: Industrial scale

Germany is Europe's biggest biogas producer and the market leader in biogas technology. [14] In 2012, the number of biogas plants reached 7470, including 80 units producing biomethane. [15]

The total electric output produced by biogas in 2012 was 20 TWh, equating to the supply of 5.7 million houses with electricity. [16] Biogas already provides more than 3% of the whole of Germany's electricity consumption, as well as significant amounts of industrial heat, transport fuels, and volume injected into the natural gas grid. [17]

Sweden: World leader in the use of biogas for transport

Sweden is a world leader in upgrading and use of biomethane for transport, and has many 'biogas vehicles', including private cars, buses, and even a biogas train and a biogas-powered touring car team. At the end of 2012, there were nearly 44,000 gas vehicles in Sweden: 1800 buses, nearly 600 trucks and the rest being cars and light transport vehicles (often part of municipal fleets). Compared to the end of 2011 (one year later), the number of gas vehicles increased by about 14 percent [18]. Over a similar period of time the number of upgrading plants has reached 47 plants, representing a 22% growth in numbers since 2008.

China: Leader in household biogas plants

In China the renewable energy policy is driving the steady development and implementation of biogas. As of 2013, China has nearly 42 million small biogas digesters in operation, producing biogas for households, for cooking, and a further 60,000 small, medium and large scale installations producing biogas for industrial purposes. Total biogas output in 2010 is estimated at 15 billion m^3 biogas, equivalent to 9 billion m^3 biomethane. China has ambitious targets for 2020 [8]:

- 10,000 new agricultural biogas projects
- 6,000 new industrial biogas projects
- Installed biogas generator capacity: 3000 MW
- Total biogas output: 50 billion m^3 biogas, equivalent to 30 billion m^3 of biomethane.

In Chine it is envisaged that in the future a percentage of the biogas produced will be upgraded and subsequently injected into the gas grid network for use as transport fuel, CHP or industry.

Global production

Exact global data on the energy supply by biogas is not available. It can be roughly calculated that globally biogas delivers 30 – 40 billion m^3 biomethane equivalent, corresponding to 1080 – 1440 PJ, thus, only a very small fraction of the potential of biogas for energy has been realized so far.

THE BENEFITS OF BIOGAS TECHNOLOGY

Biogas plants provide multiple benefits at the household, local, national, and international level. These benefits are appreciated differently in different countries, and can be classified according to their impact on energy security, employment, environment and poverty.

Environmental benefits

Anaerobic digestion of wastes results in reduced contamination of groundwater, surface water, and other resources. Anaerobic digestion effectively destroys such harmful pathogens as E.coli and M. avium paratuburculosis. Effluent from biogas digesters can serve as high quality organic fertilizer, displacing import or production of synthetic nitrogenous fertilisers. Finally, anaerobic digestion serves to reduce the volume of wastes and the associated problem of their disposal.

The impact on the greenhouse effect

Biogas produced on a sustainable basis can significantly reduce greenhouse gas (GHG) emissions. Of the worldwide 30 million tons of methane emissions per year generated from the different animal waste management systems like solid storage, anaerobic lagoon, liquid/slurry storage, pasture etc. about half could be avoided through anaerobic treatment. It is estimated that through anaerobic treatment of animal waste and energy use of the methane produced, about 13,24 million tons of CH_4 emission can be avoided worldwide per year. [19]

Economic and social benefits

Increased employment

Promoting biogas production from organic wastes and sustainably produced feedstocks results in creation of permanent jobs and regional development. The involvement of many interested parties in planning, construction, cost estimation, production, control and distribution is needed to ensure the successful development of biogas technology.

Sustainable energy resource:

The development of biogas represents a strategically important step away from dependence on fossil fuels whilst contributing to the development of a sustainable energy supply and enhanced energy security in the long-term.

Decentralized energy generation:

One of the advantages of biogas technology is that it can be established locally, without the need for long-distance transportation or import of raw materials. Small or medium-sized companies and local authorities can establish biogas plants anywhere (i.e. they need not be sited in any particular location; for example, in or close to large cities).

Sustainable waste management:

Utilizing organic wastes reduces the amount that must be taken care of in some other way, for example by combustion, or transport to landfills.

Clean fuel for industry:

Methane is a fuel in demand by industry; partly because it is a gas that gives a high quality combustion that can be precisely controlled. Methane burns with a clean and pure flame, which means that boilers and other equipment are not clogged by soot and cinders. This leads to a cleaner workplace environment and possibly a reduced maintenance costs for the plant.

POSITION OF WBA

The WBA advocates that Biogas production should be an important part of the strategy to reduce GHG emissions and improve energy security everywhere, because biogas production uses feedstock that otherwise is not used at all but emits greenhouse gases through decay and causes a number of environmental problems. Biogas also replaces fossil fuels further reducing emissions of greenhouse gases.

The deployment of biogas technology requires a decentralized approach involving many new entrepreneurs. The construction and successful operation of biogas plants needs an integrated support policy by the governments comprising the following elements:

- Training and education of the labor force
- Monitoring and continuous improvements in the plant's operation
- Access to the electricity and the gas grid
- Reliable long-lasting financial support in the form of tariffs for the electricity or biomethane sold to the grid and to vehicle fuels.

WBA advocates that each country sets up a biogas development plan with the target to use at least 30% of the biogas potential by 2030. Such a plan should not only contain quantitative targets but also an array of measures and a system of monitoring to reach the targets. This should be valid for countries in the developing world as well as the developed world.

The global institutions such as the organization of the UN with its affiliates, the World Bank, and the coming Green Climate Fund, should offer financing instruments that support small and medium sized biogas plants and not only large-scale applications.

WBA is convinced that such an integrated approach to the development of biogas would enhance the national energy security, generate employment (especially in rural areas) and contribute positively to climate change mitigation.

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