IJBPAS, May, 2012, 1(4): 604-616

ISSN: 2277–4998

International Journal of Biology, Pharmacy and Allied Sciences (IJBPAS)

'A Bridge Between Laboratory and Reader'

www.ijbpas.com

A REVIEW ON BIOGAS PRODUCTION FROM AGRICULTURAL WASTE

CHAUDHARY S, PATHAK B AND FULEKAR MH*

School of Environment and Sustainable Development, Central University of Gujarat, Gandhinagar- 382030

***Corresponding Author: E mail: mhfulekar@yahoo.com**

ABSTRACT

In developing countries like India, more than 80% of the population lives in the rural areas where more than 90% of the energy being consumed comes from non-commercial sources, the major one being fuel wood. The increasing cost of conventional fuel in urban areas necessitates the exploration of other energy sources. Biogas technology provides an alternate source of energy in rural India as a substitute for fossil fuels. The generation of biogas from food waste/refuse or peelings, agricultural and animal waste produces energy. The production of biogas from agricultural resources such as energy crops, perennial herbaceous grasses, agricultural residues, and aquatic weeds as an energy source for electrical energy may substantially contribute to the mitigation of GHG emissions by offsetting emissions from fossil fuel resources and by reducing emissions from the storage of animal waste. Therefore by utilizing agricultural waste for biogas production we can protect our environment and can also solve emerging energy crises problems.

Key words: Biogas, Energy Crises, Agricultural Waste, GHG

INTRODUCTION

The demand of energy has been increased over the years due to increasing world population and expansion of global industries especially for food and feed. Most of the energy is consumed in transportation, industries & factories, power generation, and community sectors. Moreover, inorder to fulfill our demand we are totally dependent on energy, taken from fossil oil, gas and coal **[1]**. As statistics indicate, the most commonly used fossil fuels in present scenario are oil and their products, natural gas and coal. Scenarios have shown that the energy demand will increase during this century by a factor of two or three **[2]**, as result of the population growth and energy consumption per capita **(figure 1)**. At the same time, concentrations of greenhouse gases (GHGs) in the atmosphere are raising rapidly, the fossil fuel derived CO_2 emissions being the most important contributor **[3]**. In order to minimize related global warming and climate change impacts, GHG emissions must be reduced to less than half of global emission levels of 1990 **[4]**. Another important global challenge is the security of energy supply, because most of the known conventional oil and gas reserves are concentrated in politically unstable **[5]** regions.

Fossil fuel energy will become rare and expensive in the future. Therefore there is a need for energy management by developing alternate resources, implementing energy conservation plans and strategies, increasing the efficiency of energy generation and consumption inorder to ensure a sustainable and pollution free energy.

The concept of the alternative energy is to get the other sources of energy to replace or substitute the need of crude oil and also to reduce the environmental degradation i.e. global warming, climate change. Biomass is composed of organic materials i.e. plants and animals residues. Biomass is the fourth largest sources of energy in the world, providing about 14% of primary energy. Every year in the world several million tons of agricultural wastes are being disposed through different ways such as incineration, land applications and land filling. This global waste has a high potential as a biorenewable energy resource and can be turned into high-value by-products. Developing countries, as a whole, derives 35% of their energy from biomass and in many, it offers over 90% of the total energy used in form of traditional fuels, e.g. fuel wood and dung. Since 90% of the world's population may reside in developing countries by 2050, biomass energy is likely to remain a substantial energy feed stock **[6]**. Various forms of biomass such as vegetation, animal dung and plant products are providing safe and convenient sources of energy as in the form of biogas and liquid fuel.

Biomass can play a major role in reducing the reliance on fossil fuels by making use of thermo-chemical conversion technologies. In addition, the increased utilization of biomass-based fuels will be instrumental in safeguarding the environment, creating new job opportunities, sustainable development and health improvements in rural areas. Biomass energy could also aid in modernizing the agricultural economy **(Table 1)**. A large amount of energy is expended in the cultivation and processing of crops like sugarcane, food grains, vegetables and fruits which can be recovered by utilizing energy-rich residues for energy production **[3]**. The integration of biomass-fuelled gasifies and coal-fired energy generation would be advantageous in terms of improved flexibility in response to fluctuations in biomass availability with lower investment costs **[7]**.

Agricultural Waste

Agricultural waste is composed of crop residues such as- straw (field based residue), cotton stalks **[8]** or husks (process based residue), animal manures and slurries, by-products from industrial processing of agricultural products such as bagasse from sugar industry, EFB(empty fruit branches) from palm oil industry. Many agricultural residues can potentially be used as bioenergy sources which are generated through various agricultural activities. Production of methane-rich biogas through anaerobic digestion **[3]** of organic materials provides a versatile carrier of renewable energy, as methane can be used in replacement for fossil fuels in both heat and power generation and as a vehicle **[9]**, fuel, thus contributing to cutting down the emissions of greenhouse gases and slowing down the climate change. Methane gas is produced from energy crops i.e. sugar beet silage, maize and grass silage and crop residues (cassava pulp, pine apple peels, decanter cakes, cotton stalks &oil cakes, rice and barely stalks) could be an interesting option for increasing the domestic biofuels production.

Currently, around 5.1 billion dry tones of agricultural residues are produced globally (IEA 2010).This amount represents approx. **(Figure 2)**. 75 EJ or respectively 15 % of the current global primary energy demand of 500 EJ **[6]**.

Depending on the location it is assumed that 25 – 50 % of the agricultural residues could generally be used for bioenergy production on a sustainable basis.

India has 141 million hectares of arable land and agricultural/horticultural output is close to

800 million tons which generates nearly 700 million tons of waste. Hence, even after deducting approximately 450 million tons of waste which is used as fodder, 250 million tons of surplus agricultural waste could be used for Biomass Power Generation **[10]**. Thus in rural India, conversion of agricultural and animal residues through bio-methanation is one of the possible methods of using locally available biomass for production of energy. Biogas production from agricultural waste provides fuel supply and waste management system, both of which are becoming increasingly attractive, particularly in rural areas of developing countries.

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Organic waste such as dead plant and animal material, animal dung and kitchen waste can be converted into a gaseous fuel called biogas. Biogas is a mixture of gases that is composed chiefly of: methane (CH_4): 40-70 vol. %, carbon dioxide (CO_2): 30-60 vol. % other gases:1-5 vol.%, including hydrogen (H_2): 0-1 vol. %, hydrogen sulfide (H_2S): 0-3 vol. %.

Process of Biogas Production

Biogas can be produced by using anaerobic digesters. During this process biogas plant is fed with agricultural waste such as husks, straw, rice stalks, cotton stalks & oil cakes, barely stalks or biodegradable wastes including sewage sludge and cow dung. During the process, an air-tight tank transforms biomass waste into methane producing renewable energy that can be used for heating, electricity, and many other operations **(Figure 3)**. The pH of slurry should be around 7, which is not a problem when cow dung is used as substrate The digesters in various biogas production schemes may be operated either under mesophilic (20-25°C to 40-45°C) or thermophilic (50-55°C to 60-65°C) conditions, each involving different bacterial species. Mesophilic operation is safer **[11]** and more stable but, thermophilic operation is more likely to inactivate pathogens and animal parasites.

The whole biogas-process can be divided into three steps: hydrolysis, acidification, and methane production. It includes following steps **(Figure 4)**.

a. **Hydrolysis-** In the first step (hydrolysis), the organic matter is enzymolyzed externally by extracellular enzymes (cellulose, amylase, protease and lipase) of microorganisms. Bacteria decompose the long chains of the complex carbohydrates, proteins and lipids into shorter parts. For example, polysaccharides are converted into monosaccharides. Proteins are splited into peptides and amino acids **[6]**.

b. **Acidification-** Acid-producing bacteria, involved in the second step, convert the intermediates of fermenting bacteria into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2). These bacteria are facultative anaerobic and can grow under acid conditions. To produce acetic acid, they need oxygen and carbon. For this, they use the oxygen solved in the solution or bounded-oxygen **[12]**. Hereby, the acid-producing bacteria create an anaerobic condition which is essential for the methane producing microorganisms. Moreover, they reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphide and traces of methane **[6]**.

c. **Methane formation-** Methane-producing bacteria, involved in the third step, decompose compounds with a low molecular weight. For example, they utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural conditions, methane producing microorganisms occur to the extent that anaerobic conditions are provided, e.g. under water (for example in marine sediments), in ruminant stomaches and in marshes. They are obligatory anaerobic and very sensitive to environmental changes. In contrast to the acidogenic and acetogenic bacteria, the methanogenic bacteria belong to the archaebacter genus, i.e. to a group of bacteria with a very heterogeneous morphology and a number of common biochemical and molecular-biological properties that distinguish them from all other bacterial general. The main difference lies in the makeup of the bacteria’s cell walls **[6]**.

Classification of Biogas Plants

Biogas generates from the disintegration of organic substrate i.e. agricultural residues, being lighter than air, rises upwards. This gas is collected in various types of drums. Therefore, according to the method of gas storage, biogas plants are of three types:

Floating dome type biogas plant: This design consists of a tank or a well with a partition wall to prevent shorting of influent fresh dung slurry with the outgoing spent slurry. The gas produced is trapped under a plastic or a metallic drum **(Figure 5)**. With the continuous production more gas is trapped under this bell and the drum rises. This acts as a gas storage unit and when the tap above is released, the gas is discharged at more or less constant pressure.

Fixed dome type biogas plant: This is designed to reduce the overall cost of the biogas plant. In this, the slurry is fed to a spherical masonry plant **(Figure 6)**. When the gas is produced owing to the rigid nature of the masonry dome, the trapped gas exerts a pressure on the slurry surface and a corresponding amount of slurry is displaced into a wide outlet and inlet. As a result, the pressure of gas stored varies significantly.

Flexible Bag Biogas Plant

The Plant including the digester is fabricated by using rubber, high strength plastic, neoprene or red mud plastic. The inlet and outlet are made of heavy duty PVC tube. A small pipe of same PVC tube is fixed on top of the plant as Gas Outlet Pipe. Flexible bag biogas plant is portable and can easily be erected. It requires support from outside, up to the slurry level, to maintain the shape as per its design configuration, which is done by placing the bag inside a pit dug on site **[13, 14]**.

Potential sources for biogas production:

The quantities of biomass available worldwide are enormous and a wide range of these materials could be **[15]** used for biogas production:

1. **Animal manure-** cattle population is an integral part of the rural environment in the developing countries. Normally about 10 kg of dung is assumed to be available per day per animal. In addition, waste from piggeries, chicken farms etc. can be utilize for energy generation through biogas production.
2. **Agricultural waste-** there is no realistic estimation of agricultural crop residue available for biogas production. A crop residue such as wheat and rice straw and animal manure has been estimated at 4.2X101 tones annually.
3. **Aquatic plants-** water hyacinths, algae and some other aquatic plants under testing have shown a great potential for biogas production.

Selection of crops for methane production:

The most important parameter in choosing crops for methane production is the net energy yield per hectare, which is defined mainly by biomass yield and convertibility of the biomass to methane, as well as cultivation inputs. Energy crops used for biogas production should be easy to cultivate, harvest and store, tolerant to weeds, pests, diseases, drought and frost, have good winter hardiness and should be able to grow on soil of poor quality with low nutrient input. Many conventional forage crops are easy to cultivate and produce large amounts of biomass. Moreover, they have the advantage of being familiar to farmers and suitable for harvesting and storing with the existing methods and machinery. Furthermore, being bred for animal feed these crops are often characterized by good digestibility. Perennial herbaceous grasses (e.g. timothy *Phleum pratense* and reed canary grass *Phalaris arundinacea)* **[16]** are among the most efficient producers of herbaceous biomass. Crops that are relatively easy to cultivate and produce plenty of biomass are marrow kale *Brassica olearacea* spp. *acephala*, Jerusalem artichoke *Helianthus tuberosus* and rhubarb *Rheum rhabarbarum* **[3]**.

Case Study

1. **The study of biogas production from rice chaff (karukka) as co-substrate with cow dung**

   During study the rice chaff is co-digested with cow dung for biogas production at laboratory. Approximately, 1.5 Kg of cow dung was collected, dried and thereafter crushed mechanically using a mortar and pestle to ensure homogeneity. Similarly rice chaff (1.5 kg) obtained as waste from paddy crop was crushed and boiled to a coarse. After that a set of 3 fixed dome plastic bio-digester with a capacity of 1 L was used and the digestion of different proportion for rice chaff with cow dung was undertaken by batch-type anaerobic digestion at mesophilic condition between (26-30^{o}C) for a period of 60 days. Thus, the biogas produced in the digester by the fermentation slurry passed through the connecting tube, the produced gas passed through brine solution, was collected by water displacement method which was subsequently collected and measured in gas collecting unit form. Experiment study was conducted for three different proportion case (i) 50% weight of boiled rice chaff plus 50% weight of cow dung (ii) 75% weight of rice chaff(boiled) plus 25% weight of cow dung (iii) 50% weight of raw rice chaff (without boiled) plus 50% of cow dung. The result showed a cumulative biogas production of 161.5ml in case (i) for the retention time of 60 days. In case (ii) showed the biogas production of 140.5 ml for the retention time of 70 days and in case (iii) there was no significant gas production due to high percent of lignin in raw rice chaffs **[17]**.

2. **Evaluation of the biogas productivity potential of some Italian agro-industrial biomasses**

During study agriculture residue taken is rice straw, barley straw, grape stalks, grape marcs, maize drying up residues (pith, seeds and stalk), tomato skins and seeds, and whey. The trials were carried out in 21 glass digesters kept in a thermostat controlled at room temperature i.e. 40^0c for 40 days. For this purpose rice and barley straws were chopped into pieces and after that each substrate is tested for pH, total solid, volatile solids, total nitrogen, hemicelluloses, cellulose etc. In all trials, the percentage of methane in biogas gradually increased upto the greatest value during $I^{st\ week}$, then it stabilized between 50-60%.through this study it is concluded that from all residues whey and maize residue produces highest biogas whereas grape stalks and grape marcs produce lowest amount of specific methane due to their high lignin content **[18]**.

Option for Future

In view of the prevailing situation, promotion of the biogas technology (B.T.) seems to be one of the best options which could, not only partially offset the fossil fuel and fuel wood consumption but also could facilitate recycling of agro-animal residues **[19]** as a bio-fertilizer. Moreover, being clean and renewable, it would also contribute towards environment protection, sustenance of ecosystem and conservation of biodiversity. The future of power generation for human use is directly linked to the recognition of agricultural waste as an important raw material for power plants. After all, this recyclable waste is available all over world in large quantities at cheap rates and can be drawn without causing any environmental damage. The other good thing is most of these processes ensure minimum emission into the atmosphere. Technologies using biomass for power generation require governmental support and only then can these be implemented on a large scale. As technologically advanced societies begin to rely on alternative energy sources the possibility of securing a better future may actually become a reality. There is however, a tremendous need to promote public awareness, in particular, among youth and women, on the use of bio-energy (biogas) and bio-fertilizer and sustainable use of natural resources.

Table 1: Worldwide Resource in Biogas*

World biogas ressource	Produced biogas (TOE/year)	Biogas which can be valued (TOE/year)
Urban and industrial solid waste	750	60 to 100
Urban and industrial waste water	50	40 to 50
Agricultural by-products	1000	40 to 150
TOTAL	1800	140 to 300
Biogas/worldwide consumption of natural gas	100%	8% to 17%

**According study of ADEME*

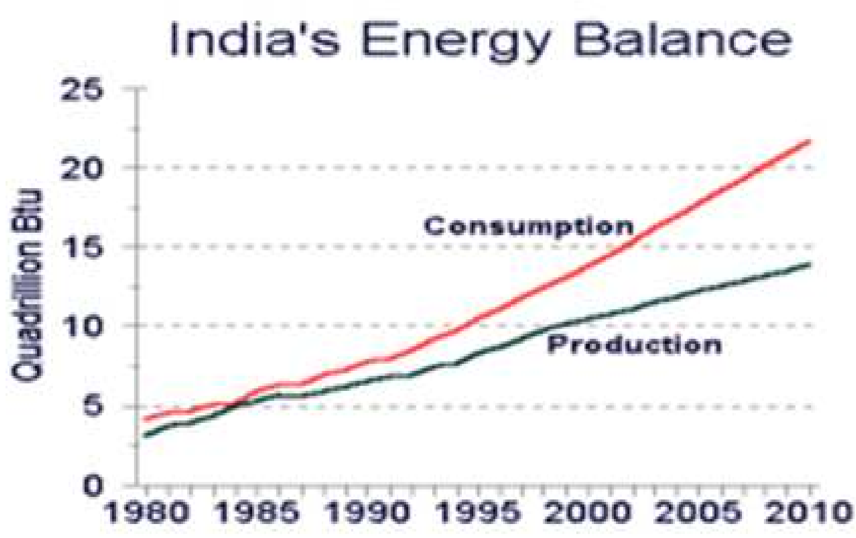

Figure 1: US Energy Information Administration

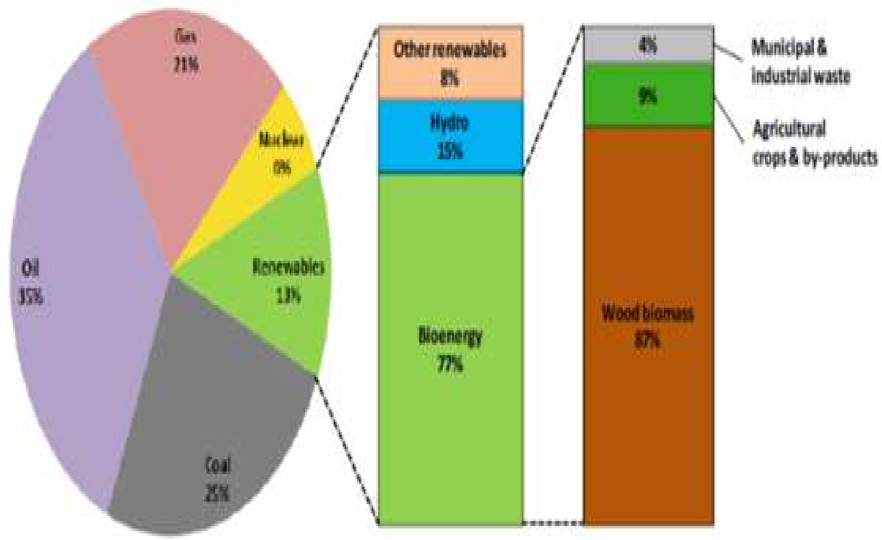

Figure 2: Bioenergy – A Sustainable and Reliable Energy Source

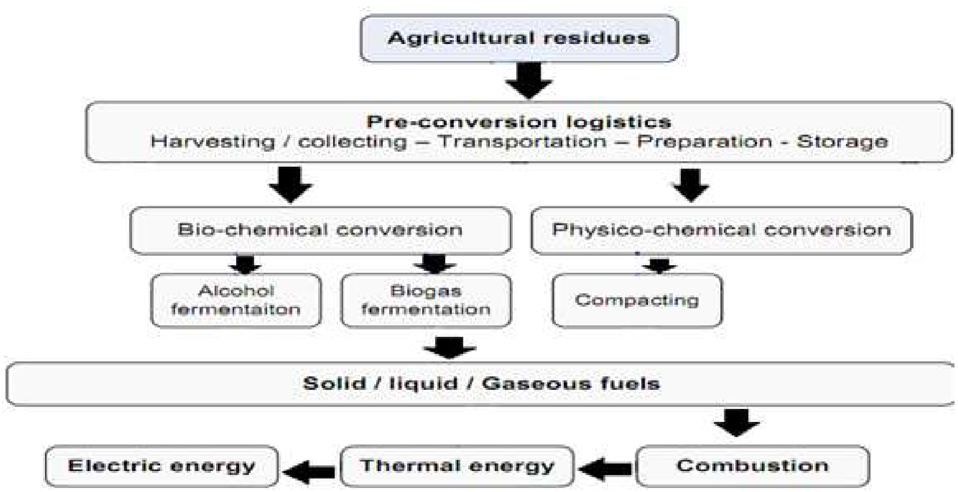

Figure 3: Process of Biogas Production from Agricultural Residues

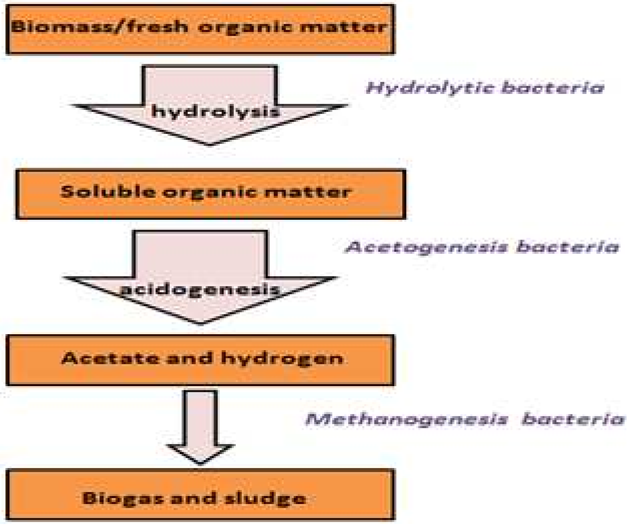

Figure 4: Mechanism of Biogas Production

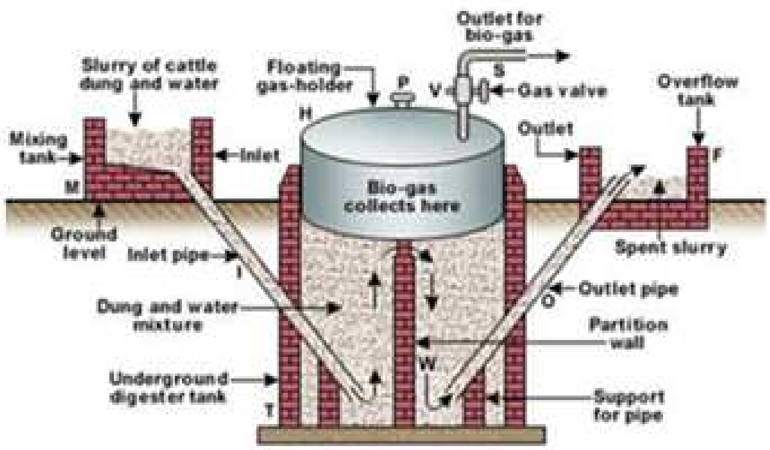

Figure 5: Floating Gas: Holder Type Biogas Plant

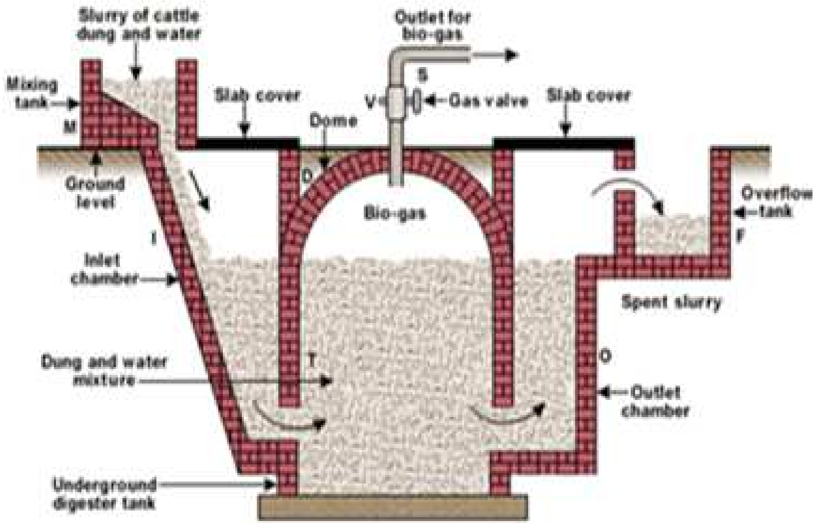

Figure 6: Fixed Dome Type Biogas Plant

- **Source: http://kits.webshop.org**

CONCLUSION

Keeping in view all reserves of the fossil fuel and the economy concerns, biogas is considered to become one of the most important alternative fuels and will potentially replace partially natural gas and oil. No negative or other side effects causing environmental degradation can be observed, as biogas can be produced from all types of "green" biomass. The production of biogas from agricultural resources such as energy crops, perennial herbaceous grasses, agricultural residues, and aquatic weeds as an energy source for electrical energy may substantially contribute to the mitigation of GHG emissions by offsetting emissions from fossil resources and by reducing emissions from the storage of animal manure. Therefore by utilizing agricultural waste for biogas production we can protect our environment and can also solve emerging energy crises problem.

REFERENCES

[1] Chaiprasert P, Biogas Production from Agricultural Waste in Thailand, Journal of Sustainable Energy & Environment Special Issue, 2011, 63-65.

[2] Weilard P, Biogas Production: Current State & Perspectives, Applied Microbial biotechnol, 85, 2010, 849-860.

[3] Lehtomaki A, Biogas Production from energy crops and residues, Jyvaskyla Studies in biological and environmental sciences, 2006.

[4] Ionel I and Eugen A, Biogas Production from Agricultural residues, From History to Results and Perspectives, Wseas Transactions on Environment and Development, (6), 2010.

[5] www.asiaing.com/potential/

[6] https://energy pedia. Info/ index. php/

[7] www.indrapower.in/renewable

[8] Iscia A and Demirer GN, Biogas production potential from cotton wastes, Renewable Energy, 32 (5), 2007, 750–757.

[9] Weilard P, Biogas Production: Current State & Perspectives, Applied Microbial biotech., 85, 2010, 849-860.

[10] Karellas S, Boukis I, Kontopoulos G, Development of an investment decision tool for biogas production from agricultural waste; Renewable and Sustainable Energy Reviews 14, 2010, 1273-1282.

[11] Aladeitan Y, The use of biogas technology in small scale farms in Nigeria, Pelagia Research Library Der Chemica Sinica, 2(6), 2011, 265-268.

[12] Asgari M, Safavi K, Mortagaeinezahad F, Landfill Biogas Production processs, International Conference on food Engineering and biotechnology IPCBEE, 9, 2011 ACSIT Press, Singapore.

[13] http://www.inforse.dk/asia/M_III_biogas.htm

[14] www.inforse.org/asiaM _III_biogas

[15] Paepatung N, Napharatana A and Songkasiri W, Potential Sources of Biogas Production, Asian J. Energy Environment, 10 (01), (2009), 19-27.

[16] Kryzeviciene A, Jasinskasand A, and Gulbinas A, Perennial grasses as a source of bioenergy in Lithuania, Agronomy Research, 6 (Special issue), 2008, 229–239.

[17] Vivekanandan S, and Kamaraj G, The study of biogas production from rice chaff (karukka) as co-substrate with cow dung, Indian Journal of Science and Technology, 2011, 4 (6), 657-659.

[18] Dinuccio E, Balsari P, Gioelli F, Menardo S, Evaluation of the biogas productivity potential of some Italian agro-industrial biomasses, Bio recourse Technol., 101 (10), 2010, 3388-93.

[19] Hassan M, Capacity building for sciences and technology COMSAT's series of publication on science and technology, 2003, 249-253.