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# *Methane Production from Organic Waste –An Overview*

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***Abstract***

*Production of biogas (methane-rich) by anaerobic digestion of organic waste provides a versatile energy source; methane can be used for the generation of renewable heat, electricity and fuel in replacement for fossil fuels, thus contributing to reducing greenhouse gas emissions and slowing down the climate change. Anaerobic digestion is a suitable technology for treating organic wastes with varying composition such as the organic fraction of municipal solids waste, biological sludge, agricultural residues, animal farm waste, fruit processing waste, animal by-products, food waste, glycerol (biodiesel by-product) and algal biomass. Anaerobic digestion treatments have often been used for biological stabilization of organic wastes. These treatment processes generate biogas which can be used as a renewable energy sources. Recently, anaerobic digestion of organic wastes has attracted more interest because of current environmental problems, most especially those concerned with global warming. When considering the organic waste treatment we have generally in mind organic mineralization, biological stabilisation and detoxification of pollutants. Most common organic wastes contain compounds that are mainly well biodegradable. They can be readily mineralized either through biological treatment (aerobic or anaerobic), or thermochemical treatment such as incineration, pyrolysis and gasification. Most organic wastes produced today originate in municipal, industrial and agricultural sector. Municipal waste (as well as municipal wastewater sludge) is generated in human biological and social activities and contains a large portion of organic waste readily available for treatment. Most of the organic*


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*wastes appear in solid form; however contain up to 90% of moisture, therefore thermochemical treatment such as incineration cannot be applied. To address sustainability in the treatment of organic wastes, environmental aspect, energy aspect and economical aspect of the treatment processes should be considered.*

*Thus, laboratory-scale research on this area has increased significantly. In this review paper, the summary of the most recent research activities covering production of biogas from organic wastes according to its origin via various anaerobic technologies was presented.*

***Keywords: -*** *Biogas, Organic waste, Methane, Anaerobic Digestion*

## INTRODUCTION

Energy, employment and environmental protection are the three major problems facing the country today. The solutions for these basic issues have to be searched not in isolation but in closer linkage which depend on maximum and efficient utilization of bio resources. [1] In the world, about 75% of the energy production is based on non-renewable sources, and this energy is obtained through the combustion of releasing gas emissions into the atmosphere. [2] Urbanization and rapid population growth are the main issues worldwide creating increased generation of solid waste per unit area. Particularly, urban and semi-urban areas of developing and poor countries are facing great challenges in managing solid waste [7] Now adays alternative energy sources like bio-fuels and biogas are becoming necessary. Anaerobic digestion is, therefore, extensively used in not only the treatment of sewage sludge but also the biogas production from other organic wastes, such as biowaste, grass silage, foodwaste, agrowaste, cow manure, and olive mill waste. In this context, AD for biogas production can be taken as a clean energy technology that is significantly helpful for the supply of energy.[5]Biogas has emerged as a promising renewable technology to convert agricultural, animal, industrial and municipal wastes into energy. Biogas development can be integrated with strategies to improve sanitation as well as reduce indoor air pollution and greenhouse gases. Currently, the total biogas production in India is 2.07 billion m3/year. This is quite low


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compared to its potential, which is estimated to be in the range of 29–48 billion m3/year. Hence, this study aims to identify both technical and non-technological barriers impending biogas dissemination in India. Biogas dissemination is affected by various waste, renewable energy, and urban policies. Barriers were therefore identified individually for rural and urban biogas systems existing in India using decomposition analysis. [55] Organic waste such as kitchen waste is regarded as waste and thrown, which then becomes the source of the pollution. This pollution results in many environmental problems as well as health problems leading to many diseases. For the management of the food waste, people prefer to compost the waste for using as manure in the field and ignore the energy that could be obtained from the waste. In this context, anaerobic digestion of organic waste could be better solution, as it minimizes the volume and mass of organic waste and also recovers energy at source at the same time.[7] anaerobic digestion (AD) has proved to be particularly effective for the treatment of organic waste streams, supporting renewable energy generation while avoiding risks of uncontrolled greenhouse gases emissions (GHGE) resulting from landfilling [6] Biogas is a mixture of different gases, i.e., primarily methane (CH4) and carbon dioxide (CO2) and small amounts of water vapor (H2O), hydrogen sulfide (H2S), hydrogen (H2), and siloxanes . Biogas is produced during anaerobic digestion (AD) of organic materials, carried out by a complex microbial community through multiple complicated biochemical reactions [3] The indiscriminate decomposition of these organic wastes results in large-scale contamination of land, water, and air. Of all the forms of solid organic waste, the most abundant is animal dung primarily from small farms, and it is from these farms that the pollution problem originating from waste disposal is more intense. Research continues to focus on the treatment of cattle dung for biogas production and possible optimization methods which could be used to enhance the production for practical applicability of the technology. Decomposition of 1 MT of grass waste can possibly release 50–110 m3 of carbon dioxide and 90–140 m3 of methane into the atmosphere. Methane is an important greenhouse gas with the ability of global warming 25 times greater than that of carbon dioxide and its atmospheric concentration has been increasing in the range of 1 to 2 % per year [4] Despite the climate emergency, there is still no consensus on renewable energies,


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which have to confront forms of social opposition that may well affect the success of any project (especially wind energy and biogas)[58] Environmental protection is an urgent and common problem which should be resolved by all parts in society. Without proper collaboration, spread of knowledge and resources through and inside national borders, it will not be easy to overcome the barriers. As far as research implications are concerned, this study provides a novel contribution to the literature by integrating the existing barriers to the wider uptake of biogas as a source of energy into a systematic classification. By analysing barriers from different contexts, the most frequent and crucial constraints of biogas uptake were identified. Although every country has its own development factors, the experience from one country can be useful for others. [45] Biogas is primarily composed of methane (CH4) and carbon dioxide (CO2) with smaller amounts of hydrogen sulphide (H2S). Biogas is one of the important renewable energy sources of the age and it offers the multiple benefits. From a resource-efficiency perspective it is very advantageous as the raw materials required for production of biogas include waste materials (agricultural crop residue, food waste, animal waste, aqua waste etc.), cultivated agricultural crops (rice, wheat, cereals etc.) and harvested materials (wheat straw, groundnut shells, coconut shells and rich husk). The various feed sources for biogas plants are given in the figure 1

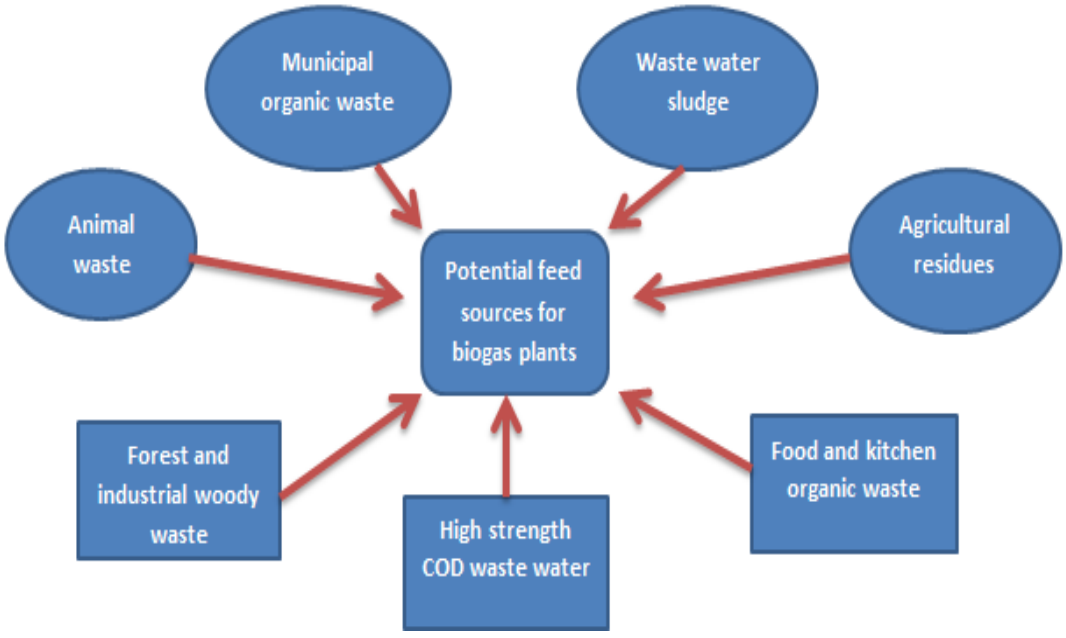



***Fig 1: Various Sources of Feed for Biogas Plants***


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**BIOMASS BASED ENERGY PRODUCTION**

Nagy Valeria, Szabo Emese (2011) investigated the biogas is one of renewable energy. In fact the biogas is the indirect conversion of some solar energy stored in natural organic matter to gaseous energy carrier by anaerobic fermentation. So the biogas is the end product of the microbiological fermentation (metabolic product of the methane bacteria). It is a mixture, which consists of methane gas and carbon dioxide. Its energy content can be determined from methane quantity. Biogas and methane quantity getting from organic matter per volume depend on quality features of organic matter and also the technological parameters of the biodegradation. [8]

Emma Lindkvist , Magnus Karlsson, and Jenny Ivner,(2019)Studied in Systems Analysis of Biogas Production has the potential to recover nutrients and energy from organic by-products, as well as to substitute fossil fuels in the energy system. Resource efficiency relates to the economic, energy and environmental performance of the system studied. [57]

N.W.Ingole and Dr A.G.Bhole (2000) carried out work on biogas production from dried water hyacinth plant by digestion process. In this study, the raw material 'water hyacinth' the aquatic weed, is considered as a biomass for the generation of biogas because of its abundance, ready available and nuisance value. The prospects and problem bioenergy have many ramifications. Each and every component of biomass can prove an exhaustible resource of energy provided the same is tapper properly. Full understanding of nature and depth of bioenergy can make it a potent instrument for social and economic development of a particular region.[1] Yadvika , Santosh, T.R. Sreekrishnan , Sangeeta Kohli ,Vineet Rana(2003) reviews on the various techniques, which could be used to enhance the gas production rate from solid substrates. Biogas technology offers a very attractive route to utilize certain categories of biomass for meeting partial energy needs. In fact proper functioning of biogas system can provide multiple benefits to the users and the community resulting in resource conservation and environmental protection. [9] Subodh Kumar Sau, Prasanta Kumar Nandi, Apurba Giri , Tapas Kumar Manna investigated on Huge amount of tea waste is wasting from tea shop and pumpkins from the market. Human urine is unhygienic to the open environment, whereas it can be utilized as a biocatalyst for the enhancement of


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production of biogas from these wastes. In this study predigested tea and pumpkin wastes were treated with human urine to enhance the biogas production by improving the C: N ratio. India is an agricultural based country. Huge amount of vegetable and other organic wastes pollute the environment due to formation of natural and marsh gas known as greenhouse gas having greater global warming potential. However, this biogas is the only cheap alternative renewable source of energy. It is composed mainly of CH4 and CO2 .Methane has potential uses viz. as fuel, electricity generation, urea production etc. Anaerobic digestion is the process which breaks down organic matter to simple chemical component using four different stages. These are hydrolysis, acidogenesis, acitogenesis and methanogenesis. In the fourth stage acetate is converted to CH4 and CO2. Various works have been done by using agricultural and animal wastes to produce biogas [10] Ashenafi Tesfaye Bicks (2020) investigated under this study, daily food waste that is dropped at the backyard of the university student cafeteria is used for biogas generation. Biogas is produced when anaerobic digestion of organic matter like food waste, kitchen waste, and other biodegradable waste is digested under anaerobic condition. Biogas mainly consists of methane and carbon dioxide with a small quantity of gas such as hydrogen. It is colorless but while cooking it has a blue burning flame. The feed stoke used for conversion of biomass waste to biogas can be different depending on the availability of the waste at the local site, but the rate of methane yield depends on the property of the biomass type and digester type used. [11] Gregor D. Zupancic and Viktor Grilc (2012) Studied Most organic wastes produced today originate in municipal, industrial and agricultural sector. Municipal waste (as well as municipal wastewater sludge) is generated in human biological and social activities and contains a large portion of organic waste readily available for treatment. Agricultural waste is common in livestock and food production and can be utilised for biogas production and therefore contribute to more sustainable practice in agriculture. Industrial wastes arise in many varieties and are the most difficult for biological treatment, depending of its origin. Namely, many industries use chemicals in their production in order to achieve their product quality and some of these chemicals are present in the waste stream, which is consequently difficult to treat. [12] Sagor Kumar Pramanik , Fatihah Binti Suja , Biplob Kumar Pramanik and


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Shahrom Bindi Md Zain (2018) studied on Solid organic wastes create potential risks to environmental pollution and human health due to the uncontrolled discharge of huge quantities of hazardous wastes from numerous sources. Now-a-days, anaerobic digestion (AD) is considered as a verified and effective alternative compared to other techniques for treating solid organic waste. The paper reviewed the biological process and parameters involved in the AD along with the factors could enhance the AD process. Hydrolysis is considered as a rate-limiting phase in the complex AD process. The performance and stability of AD process is highly influenced by various operating parameters like temperature, pH, carbon and nitrogen ratio, retention time, and organic loading rate. Different pre-treatment (e.g. mechanical, chemical and biological) could enhance the AD process and the biogas yield. Co-digestion can also be used to provide suitable nutrient balance inside the digester [13]Gudina Terefe Tucho , Henri C. Moll , Anton J. M. Schoot Uiterkamp and Sanderine Nonhebel (2016) investigated on problems with biogas implementation in developing Countries from the perspective of labour requirements. Most households in rural developing countries depend on firewood from public forests or agricultural bio-wastes for cooking. Public forests, though, are declining due to an increasing population and inefficient use of wood. Use of agricultural wastes on the other hand involves loss of soil nutrients since these resources are used as a substitute for inorganic fertilizers. Biogas energy can be an alternative in providing clean energy for cooking as well as improving soil fertility with the slurry. However, the labour spent on producing biogas can limit its use as a source of energy and fertilizers. Therefore, this study aims to determine the labour requirement of different mono and co-digestion biogas energy systems. The assessment is made by using simple models involving different schemes of resources collection and transportation based on reported relevant literature.[43]Tatiana Nevzorova, Vladimir Kutcherov (2019) review on barriers to the wider implementation of biogas as a source of energy.Many countries have realised that biogas as a source of energy is an important component for sustainability transition. However, the total production volume of biogas is still relatively low. Such slow development raises a fundamental question—what are the current barriers hindering the wider uptake of biogas as a source of energy? In order to answer the question, a systematic state-of-the-art review of the barriers was conducted based on the Scopus database.


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The results of the review were summarised by country and were divided into two broad categories: developed and developing economies. Each group was analysed separately according to six types of barriers: (1) technical, (2) economic, (3) market, (4) institutional, (5) socio-cultural, and (6) environmental barriers. By analysing the barriers through different contexts, the most frequent and crucial constraints the biogas industry currently faces were identified and integrated into a systematic classification. In addition, possible solutions on how to overcome the most critical barriers were added. In that research work The distinguishing feature between research in developed and developing economies with respect to the implementation of biogas is that the former focus mostly on the transport sector while the latter mainly focus on domestic and agricultural biogas plants . Currently, developing countries have more barriers for biogas uptake. [45] Azeem Hafiz P, Rashid Ahamed, Muhamed S, Sharukh M (2016) Studied on Biogas as a Sustainable Energy Source in India. This paper reviews the status to biogas implementation in India. The renewable energy sources are one of the essential for the sustainability of the globe. India is the sixth largest fossil fuel consumer. The dependence of other countries for fossil fuels creates barriers in implementing unbiased political strategies. So biogas and other renewable energy sources have their relevance. The cost factor is one of the advantages of biogas. The government is in right direction for the implementation of biogas as fuels. But India has an infinitely extensible canvas synchronising with agricultural sector. The paper proposes the future strategies to be adopted by India for empowerment of biogas as a fuel.[54] Raveendran Sindhu, Parameswaran Binod, Ashok Pandey, Snehalata Ankaram, Yumin Duan, Mukesh Kumar Awasthi(2019) investigated on Biofuel Production From Biomass: Toward Sustainable Development. Biogas production is an eco-friendly strategy for energy production from biomass and the residue can be used as a soil conditioner. Biogas is produced by the anaerobic biological breakdown of organic matter. It primarily consists of methane and carbon dioxide. Flammable methane is the main component of biomass (50%e85%), representing the main energy source. It can be used in boilers for heat generation.

Upgraded biogas can be directly used in boilers. Biogas production from local agricultural waste using a laboratory-scale digester was evaluated . Various process variables affecting biogas production, like


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the nature of the feedstock and carbon-to-nitrogen ratio, were evaluated. Among the different agro-residues screened, wheat stalk, soybean straw, and black gram stalk were found suitable for biogas production.[50] Peter Jacob Jorgensen, PlanEnergi (2009) reported in biogas – green energy manual. All organic matter, with the exception of lignin, can be decomposed anaerobically to produce biogas, although the time taken to do so differs greatly. How long it takes depends on the composition of the biomass – the more complicated the molecules, the longer it takes a microorganism to break it down. Sometimes a biomass consists of a number of different substances that have an impact on the gas yield. biogas and methane yield when carbohydrates (cellulose), proteins and fats are completely digested. [56]

## ANAEROBIC TRANSFORMATION OF ORGANICS WASTE

Anaerobic digestion is a technology with wide application in the degradation and stabilization of organics. Under anaerobic conditions, the material is oxidized and transformed into biogas and liquid slurry containing the remaining compounds non-susceptible to anaerobic degradation along with components derived from microbial metabolism. The process involves several reaction mechanisms where anaerobic bacteria and archaea species transform biomass into a sequence of biological reactions. The performance of the reactor and the effect of inhibitory components have been extensively studied to find correlations between process parameters and microbial communities.[2] The use of residual materials and bio waste as feedstock for biogas production is part of integrated concepts for biofuel production and bio refinery. While it is important to use high quality organic substrates for the production of certain biofuels, biogas can be generated from various municipal, industrial, agricultural, and food-processing waste products. Here, we investigated the anaerobic digestion of DDGS, a by-product of bioethanol production, in lab-scale mesophilic reactors and analyzed the microbial community involved in the process [14] Anaerobic digestion (AD) systems have attracted remarkable attention within the scientific community. Anaerobic digestion system is created from (bio) reactors to perform a series of bi-metabolism steps including hydrolysis/acidogenesis, acetogenesis, and methanogenesis. So far there have been no studies providing a systematic and full review of the AD systems, including the coordination between the functional reactors in a system


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as well as the operation of each reactor. This paper aims to provide a comprehensive review of the AD systems for biodegradable waste including the modified systems. [15] Ann-Kathrin Ghattas, Ferdinand Fischer, Arne Wick, Thomas A. Ternes (2017) investigated the transformation of organic compounds is based on the presence of microorganisms with specific catalytic activities targeting certain functional moieties in the compound. Thus, theoretically, organic contaminants could serve as substrates or electron acceptors for anaerobic microorganisms in the environment as well as in technical processes. [16] Peter Weiland (2010) studied on biogas production of current state and perspective in anaerobic digestion has mainly been associated with the treatment of animal manure and sewage sludge from aerobic wastewater treatment. Nowadays, most of the agricultural biogas plants digest manure from pigs, cows, and chicken with the addition cosubstrates to increase the content of organic material for achieving a higher gas yield. Typical cosubstrates are harvest residues, e.g., top and leaves of sugar beets, organic wastes from agriculture-related industries, and food waste, collected municipal biowaste from households and energy crops. [17] A. Comparetti, P. Febo, C. Greco and S. Orlando (2013)according to current state and future of biogas and digestate production is an excellent way of using organic waste for energy generation, followed by the recycling of the digested substratum (digestate) as fertiliser. Many factors, like chemical composition and pH of raw materials, environmental temperature and microbial composition, influence the efficiency and reliability of the anaerobic digestion process. The values of biogas and methane average yields of the AD of several types of organic. The biogas yield is highly variable among the various raw materials: the highest average biogas yield (202 m3 / t) is obtained from maize silage, while the lowest (10 m3 /t) comes from slurry. The methane average yield of all types of organic waste is higher than 50%, and in 2 cases higher than 60%, i.e. for liquid pig manure (65%) and distiller grain (61%). [18] Shiv Prasad, Dheeraj Rathore, and Anoop Singh (2017) investigated the Biogas is generated by digestion process under anaerobic conditions whose application is rapidly emerging as a viable means for providing continuous power generation. The anaerobic digestion cycle represents an integrated system of a physiological process of participating microbial community and energy metabolism, as well as processing of raw


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materials under specific conditions. However, the microbial community is sensitive to variations in the operating conditions applied. Thus, the anaerobic digestion process, if improperly managed, would become unstable and result in reduced biogas production.[19] The organic matters are the main feedstocks in the biogas plant, which can fall into different categories. Evaluating the potential of biogas production based on organic matters from rural regions has been investigated. The highly fermentative wastes can decrease the quantity of feedstock in biogas plants. Microalgae with satisfactory features is a potential option for feedstock in biogas systems. In comparison with other biomass resources, microalgae has better efficiency, more convenient production, and higher content of lipid and polysaccharide that make it a flexible choice in biogas plants explored the production of biogas from sugars released from wheat straw with the aid of hydrothermal pretreatment based on the biorefinery procedure. In this case, the pretreatment process increased the gas yield by 10%.For achieving sustainable progress, the global trend of energy production is moving to the waste-to-energy (WTE) method which has multilateral benefits. Currently, biomass resources are being employed to generate energy. All around the world, biomass satisfies around 50 exajoule of the entire energy demand annually. [20] Spyridon Achinas , Vasileios Achinas, Gerrit Jan Willem Euverink (2017) these author review on a Technological Overview of Biogas Production from Biowaste. The global energy demand is high, and most of this energy is produced from fossil resources. Recent studies report that anaerobic digestion (AD) is an efficient alternative technology that combines biofuel production with sustainable waste management, and various technological trends exist in the biogas industry that enhance the production and quality of biogas. Further investments in AD are expected to meet with increasing success due to the low cost of available feedstocks and the wide range of uses for biogas (i.e., for heating, electricity, and fuel). Biogas production is growing in the European energy market and offers an economical alternative for bioenergy production. The objective of this work is to provide an overview of biogas production from lignocellulosic waste, thus providing information toward crucial issues in the biogas economy. Large-scale lingo cellulose-to-biogas production has significant potential, and research efforts toward its further development have already been carried out. These processes


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typically have technical problems that stem from a poor understanding of optimal reactor operation. The complexity of AD and the risk that is involved in investment in new technologies are two of the major constraints affecting AD improvement. [22]

**ANAEROBIC DIGESTION PROCESSES OF DIFFERENT WASTE.**

Haidong Zhou , Han Li and Fengfei Wang (2012) Studies on Anaerobic digestion of different organic wastes for biogas production and its operational control performed by the modified ADM1The modified ADM1 was used for modelling the anaerobic digestion of mono-substrates (biowaste, cow manure) and co-substrates (biowaste and corn silage, biowaste and manure, manure and corn silage) under different operational conditions, i.e., solid retention times (SRTs), organic loading rates (OLRs), interval times of feeding, and inflow ratios of two substrates. It should be pointed out that the changes of SRTs were achieved by the regulations of input flows, and OLRs were theoretically calculated and changed by the variable input concentrations of substrates.[5] Nagy Valeria, Szabo Emese(2011) investigated of This paper presents the biogas producing, wastes disposal experiments which we made under mezophyl circumstances with these wastes. Used wastes during the biogas (biomethane) production are: pig manure and distillation residue of fruit (fruit marc). The reason for the choice is that the first step of prevailing of ecological thinking is predomination of the principles of sustainability, indeed the most effective environmental investment is recycling of organic wastes. Besides the biologically active thin manure in high concentration and quantity, which is a source of potential environment pollutant in animal breeding, the residues of distillation can also serve as the basic material of biogas production, which takes form on the course of the production of alcohol, and in distillery. On the course of the production of 1 hectoliter alcohol take form 27.5 lit distillery residue (waste of alcohol production), the reaction of which is sometimes strongly acidic.[8] Amar Kumar Das, 2Shovan Nandi, 3Subrat Kumar Patra carried out work on Scope of Biogas generation from Kitchen wastes and its economical adoptability. The main objective of this review literatures by highlighting the production of Biogas, Factors affecting its generation from various organic matters like food wastes, kitchen wastes, municipal wastes and also strengths and weaknesses in biogas research and development capacity. In Modern age the extensive demand for


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fossil fuels becomes a threat to the environment and a challenge for researchers. Some alternative renewable sources like Methanol, Ethanol, Hydrogen, Natural Gas, LPG, CNG, LNG, Biogas and Biodiesel, plastic fluids, etc which may be produced at a reasonable cost from various wastes. The fuels extracted from refused food wastes may be used either for running IC engines or cooking purposes at a very low cost. The reviews of different research results claim that biogas may be the cheapest and useable non-conventional energy sources. [20] Dr Nitin W Ingole (2015) studies on Development and Design of Biogas Plant for Treatment of Kitchen Waste. In that research paper generation of biogas by using different types of biodegrable waste material is only the option to get relief from critical fuel crisis. In this study attempts were made to study the process of biogas generation critically by using food waste as a substrate. The major biological reactions involved in anaerobic digestion as Hydrolysis, Acidification, Methanogenesis. Anaerobic digestion of food waste was carried out in the laboratory by developing a set-up of biogas plant to work as batch process. The measurement of biogas was done by water displacement method. Monitoring of the process was carried out daily. Sampling and its testing was done simultaneously. Based on the results obtained, design of digester for the village of known population was carried out. The maximum gas production observed to be 2.18 l of biogas per kg of food waste.[21]

**Biogas Production from Energy Crops**

Dr.A.G.Bhole and N.W.Ingole (2000) Problem associated with weed growth have worsened because of water becoming enriched by fertilizer runoff and from nutrients derived from human and agriculture wastes. Water hyacinth is nuisance weed in many rivers and lakes in potentials and yields have been reported from water hyacinth .water hyacinth productivity of upto 80 tons of dry products per acre has been reported by Yount J.L. and Crossman. This high productivity has attracted many researchers to use weed as biomass for production of energy fuel. The concept of utilization of water hyacinth not only brings the nuisance under control but also provides energy. The present production by using single phasic and diphasic digestion process. The percentage of methane in biogas production was approximately in the range of 61% to 63% in conventional single phase digester whereas in diphasic digestion process, the percentage of methane was observed to be 66% to 67% when tested using orsat


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apparatus for gas analysis.[23] Guangtao Wang and Jens Ejbye Schmidt (2010) investigated on Biological ensilage of perennial crops willow and miscantus as pretreatment to increase the biogas production. Biological ensilage with and without additives i.e., lactic acid bacteria were tested on willow and miscanthus substrate for their effect on biogas production and preservation of volatile solids content. In general, ensilage of willow and miscanthus with addition of biological additives had no significant influence on the biomass losses compared to that without addition of the additives. During ensiling process, the amount of biomass losse could be controlled under 2% and 3% for willow and miscanthus, respectively. Ensilage of willow as pretreatment method could increase methane potential. Taking the biomass losses into account, methane production from willow was increased by 12%, 22% and 22% after ensilage for 1, 3 and 5 months, respectively, compared to fresh willow. Ensilage of miscanthus gave no significant increase in methane production compared with fresh miscanthus. Moreover, due to biomass losses, the total methane production from silage minscanthus after 5 months was 3% lower than that from fresh miscanthus.[24] Kamrun Nahar (2012) studied on the biogas Production from Water Hyacinth. As an abundantly available source of biomass, the excessive growth of Water Hyacinth can be used as energy production as well as a resource of various important uses. By using water hyacinth biomass in Bangladesh, we can produce bio gas and many other useful items and hence increase employment opportunity and generate income. In that research paper study on one plant species that is water hyacinth, Due to vegetative reproduction and extremely high growth rate Water hyacinth spread rapidly. It has been used as a potential biomass for the production of biogas because of its high growth yield and availability in large amount throughout the year and all over the world. Biogas from Water hyacinth is done by a digester. To reach at an optimum condition for the production of maximum amount of gas, the lower volatile fatty acids (acetic acid) and Cow dung can be used with water hyacinth. Sustainability generally depends on the socio-economic development of a country and the availability and consumption of energy. The available sources of energy can be classified into non-renewable and renewable. In the renewable account, the energy is being deposited everyday whereas the non- renewable energy deposits are continuously depleted by our


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withdrawals. Due to continuous depletion in the natural resources by an increased consumption of the energy, alternatives of fossil fuels must be searched out. Bioenergy is the only alternative and cheap source of energy which can be made available especially for the rural agricultural people of Bangladesh. This paper describes the various uses of an important energy crop, Water hyacinth and the production of biogas using it as a feedstock, which could be collected from the water body and converted to gas, fertilizer and many other useful products.[25] N.W. Ingole and A. G. Bhole (2002) reported on utilization of water hyacinth relevant in water treatment and resource recovery with special reference to India. In that research paper author are evaluated on utilization of water hyacinth plant. The possibilities of utilizing water hyacinth in biogas digesters have been examined in the Central Mechanical Engineering Research Institute, Durgapur (India). It has been found that water hyacinth containing 60–70% moisture is fermented quickly. According to their process, the stem is ruptured to get rid of the extra moisture in a shorter time. Under optimum conditions, the fermentation starts within 2–3 days. A usable quality of gas is obtained after only 15–20 days. The calorific value of the gas increases after this period and reaches a peak value of 4,397–4,670 Kcal/m3 BTU/CFT after 20 days at 30–35°C. A retention time of 40–50 days is recommended for economic usage. The calorific value of gas increased to 5,413 Kcal/m3 after the second charging. It is estimated that 100 kg of semi-dried water hyacinth can give 400 l of gas daily. The compost obtained as a by-product has a high manure value. Average compost yield is about 10% of the weight of plant used. [26] Mohamad Y. Mustafa, Rajnish K. Calay, E. Roman (2016) reported a case study on biogas from organic waste. Anaerobic digestion (AD) is one of the preferred technologies for treating organic municipal solid waste (MSW) for the production of biogas and methane, which can be used as alternative fuel to liquid petroleum gas (LPG) and natural gas. The residue, after completion of the AD process, is a stabilized organic material that can be applied directly on agricultural land (without any maturing) as a bio-fertilizer, and thereby can replace artificial/mineral fertilizers and offer the possibility for recycling of nutrients (nitrogen and phosphorus). Thus, AD of bio waste combines the energy production with environmental benefits.


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Digester design criteria and performance of AD process attracted te attention of many researches. For example, Igoni et. al. investigated the designs of anaerobic digesters for producing biogas from municipal solid-waste and analysed the effects of various parameters such as temperature control, pH, C/N ratio, moisture content, waste particles and effects of mixing on biogas product characteristics. Zhang et. al. compared the digestion efficiency of source segregated domestic waste and the mechanically recovered fraction of MSW. They concluded that higher percentage of biodegradability, leading to higher energy potential, can be achieved if the organic fraction of MSW is segregated at the source.[27] Arkadiusz Piwowar (2019) Studied on development of the agricultural Biogas Market in Poland Production Volume, Feedstocks, Activities and Behaviours of Farmers. The main purpose of this study is to analyze the volume of agricultural biogas production in Poland and the structure of consumption of raw materials used for production of agricultural biogas. The analyses were carried out in the period of 2011–2017. The paper also presents results of empirical research on the agricultural practices as part of the subject area of the development of the agricultural biogas market in Poland. The aim of the questionnaire surveys of agricultural holdings was to obtain information on the use of the biomass from field crops and grasslands for energy purposes and the interest in the development of agricultural production towards the cultivation of energy crops. The results of the analyses were presented in the spatial arrangement of research.[44]

**ENHANCEMENT OF BIOGAS PRODUCTION.**

Md. Abdur Rashid Mia, Md. Rasel Molla, Tanzina Sayed, Md. Moksadul Amin, Tanzima Yeasmin,Md. Belal Uddin (2016) investigated on Enhancement of Biogas Production by Cellulytic Bacteria from Bagasse Using Methanogenesis. The main objective of our research work was enhancement of biogas production by cellulytic bacteria from bagasse using methanogens. Five liters capacity glass reactors were used. Five sets of batch modes anaerobic digesters were used under laboratory condition. Bagasse was used as feed materials. Bagasse is the by-product of sugar mill and it was used as raw materials for paper production in our paper mills.Now it is discarded and creates a problem of sugar mills to use and manage bagasse. The raw materials were diluted with supply water in the ratio of 1


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to 9 for bagasse. The characteristics of the influent slurry in term of Total Solid (T.S)%, Volatile Solid (V.S)%, PH and temperature ranges were determined every 7 days intervals for bagasse. The percentage of methane of biogas obtained from bagasse was 80%. The S1 strain (Monococcus sp.) and S3 strain (Streptococcus sp.) of cellulytic bacteria produced 3.45×10-3(m3/day/kg feedstock) biogas and 3.85×10-3 (m3/day/kg feedstock) biogas at 22th day respectively whereas control produced 2.85×10-3(m3/day/kg feedstock) biogas at 34th day by using bagasse as feedstock. The results clearly demonstrated that the rate of biogas production was increased by S1 strain and S3 strain of cellulytic bacteria. The cumulative biogas production was found 54.20×10-3m3, 66.21×10-3m3 and 61.59×10-3m3 for control, S1 strain and S3 strain of cellulytic bacteria, respectively. In conclusion, the results obtained from the laboratory based present research can be used to predict and design biogas reactor in field condition. We can get higher amount of biogas from bagasse by cellulytic bacteria together conventional methanogenic bacteria within short period of time. Anaerobic treatment of bagasse for biogas and biofertilizer may be a new sustainable technology for disposal management of Sugar Mills of Bangladesh. So it will be an alternative renewable energy source of Bangladesh and thereby our people and country will be benefited economically and environmentally[29] Muhammad Rashed Al Mamun and Shuichi Torii (2017) studied on Enhancement of Methane Concentration by Removing Contaminants from Biogas Mixtures Using Combined Method of Absorption and Adsorption. In that research work on generated biogas from the wastes of cafeteria, vegetable, food, and cattle manure. The source of material used in biogas production has a significant effect on the composition of biogas. The results showed that the CaO solutions are capable of reducing CO2 concentration below 6%. Removal of H2S was investigated by treating the raw biogas with FeCl2, Feo, Fe2O3, and activated carbon. Approximately the H2S concentration was reduced to 89%, 90%, 86%, 85%, and 96% for treating the raw biogas with pH for 10 g of Fe2O3, Feo FeCl2, and without pH for Feo, and activated carbon for R1 mixture of Cao, Fe2O3, Silica gel, R2 mixture of Cao,Fe, Na2SO4, R3 Mixture of Cao, FeCl2, Silica gel, R4 mixture of CaO, Fe, Silica gel and R5 mixture of CaO, Activated carbon, Na2SO4 respectively. Removal of H2O was investigated by treating the raw biogas with Na2SO4 and silica gel. The H2O


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concentration was reduced to 0.2%, 0.7%, 0.2%, 0.2%, and 0.3% for treating the raw biogas with 10 g of Na2SO4 and silica gel, for R1, R2, R3, R4, andR5, respectively. The conclusions are also confirmed in regard to performance run R5 which is the best purification process. The possibility for the enrichment of above 95% in biogas using combined chemical absorption and adsorption indicates the practical application of this process.[30] Ivan Kushkevych, Monika Vitezova, Tomas Vitez, Milan Bartos(2017) studied on Production of biogas: relationship between methanogenic and sulfate-reducing microorganisms. This research is important for understanding the relationship between methanogenic microbial populations and other bacterial physiological groups, their substrate competition and, in turn, can be helpful for controlling methanogenesis in bioreactors. The production of high-quality methane depends on many factors, including temperature, pH, substrate, composition and relationship of the microorganisms. The qualitative and quantitative composition of methanogenic and sulfate-reducing microorganisms and their relationship in the experimental bioreactors has never been studied. The aim of this research was to characterize, for the first time, the diversity of the methanogenic microorganisms and sulfate-reducing bacteria, and study their relationship and biogas production in experimental bioreactors. Amplification of 16S rRNA gene fragments was carried out. Purified amplicons were paired-end sequenced on an Illumina Mi-Seq platform. The dominant morphotypes of these microorganisms in the bioreactor were homologous (99%) by the sequences of 16S rRNA gene to the Methanosarcina, Thermogymnomonas, Methanoculleus genera and Archaeon deposited in GenBank. Three dominant genera of sulfate-reducing bacteria, Desulfomicrobium, Desulfobulbus and Desulfovibrio, were detected in the bioreactor. The phylogenetic trees showing their genetic relationship were constructed. The diversity and number of the genera, production of methane, hydrogen sulfide and hydrogen in the bioreactor was investigated.[31] Ana C. Faria, C.V. Miguel, Luís M. Madeira (2018) evaluated from Biogas upgrading based on the Sabatier process with in situ water removal by thermodynamic analysis. This analysis of biogas upgrading based on CO2 conversion by the Sabatier reaction and featuring water removal showed that the optimum water removal fraction, which maximizes the methane production, depends on the CH4/CO2 ratio in the


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biogas stream (as well as on the operating temperature and pressure). Except for high CH4/CO2 ratios, the water removal approach can be quite advantageous (up to a certain point) not only in terms of methane yield, but also in terms of CO reduction.

However, a considerable fraction of CO2 is obtained during biogas production, which requires a further separation step for biogas upgrading. Instead of a separation process, an alternative would be converting the CO2 present in the raw biogas into more CH4 (Table 1) and using renewable-based H2 (the so-called Power-to-Gas concept). In this regard, the present work studies, from the thermodynamic point of view, the influence of the temperature, pressure, and water removal fraction (R) on the methane production for different biogas feed compositions. [32] Mathieu Dumont, Luchien Luning, Ismail Yildiz, klaas koop (2013) Investigated on Methane emissions in biogas production. In that research work in biogas is produced by anaerobic digestion of manure, energy crops (mainly maize), wastewater treatment sludge and organic waste. Biogas is a renewable energy source. Sustainability requirements are increasingly important. As a greenhouse gas, methane is 25 times stronger than carbon dioxide, so small leakages of biogas have a strong negative effect on the total greenhouse gas performance of the energy production pathway. This chapter covers an overview from the literature concerning methane emissions from different steps in the biogas production chain with reference to relevant selected articles.

***Table 1. Possible reactions occurring during the Sabatier process***

| **Process** | **Reaction** | **$\Delta H_f^{298K}$ (kJ mol-1)** |
|---|---|---|
| Sabatier | CO2+4H2=CH4+2H2O | -165 |
| Reverse water-gas shift | H2+CO2=CO +H2O | 41 |
| CO | CO+3H2=CH4+H2O | -206 |
| methanation | 2CO=C+CO2 | -172 |
| Carbon formation | CH4=2H2+C | 74 |
| | CO+H2=H2O +C | -131 |
| | CO2+2H2+2H2O+C | -90 |


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A number of recent articles and presentations on methane emissions from biogas production have been reviewed. This research focuses only on biogas production and utilization of the biogas until the points where the biogas is supplied to a grid either as upgraded biogas (green gas) or as electricity and heat. Storage of the digestate is included. Excluded are emissions from the production and transport of (co) substrates and the distribution and final use of upgraded biogas.[33]Amir Izzuddin Adnan, Mei Yin Ong, Saifuddin Nomanbhay, Kit Wayne Chew and Pau Loke Show (2019) review on technologies for biogas upgrading to biomethane. Anaerobic digestion and the production of biogas can provide an efficient means of meeting several objectives concerning energy, environmental, and waste management policy. Biogas contains methane (60%) and carbon dioxide (40%) as its principal constituent. Excluding methane, other gasses contained in biogas are considered as contaminants. Removal of these impurities, especially carbon dioxide, will increase the biogas quality for further use. Integrating biological processes into the bio-refinery that effectively consume carbon dioxide will become increasingly important. Such process integration could significantly improve the sustainability of the overall bio-refinery process. The biogas upgrading by utilization of carbon dioxide rather than removal of it is a suitable strategy in this direction. The present work is a critical review that summarizes state-of-the-art technologies for biogas upgrading with particular attention to the emerging biological methanation processes. It also discusses the future perspectives for overcoming the challenges associated with up gradation. While biogas offers a good substitution for fossil fuels, it still not a perfect solution for global greenhouse gas emissions and further research still needs to be conducted [34] Judith Gonzalez, Marta E. Sanchez and Xiomar Gomez (2018) Studied on Enhancing Anaerobic Digestion: The Effect of Carbon Conductive Materials. Anaerobic digestion is a well-known technology which has been extensively studied to improve its performance and yield biogas from substrates. The enhancement of biogas yields of organic substrates mostly keep relation with the increase in the degradation rate This can be performed by the application of different types of pre-treatment to the organic compounds, but this implies a high energy demand. This review also presents the effects reported on by different research works when evaluating the performance of the digestion process


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supplemented by carbon conductive materials, with the main focus on the use of biochar. The use of carbon conductive materials aids in the degradation rate of substrate by allowing an alternative route for electron transport. The use of biochar and recently hydrochar seems to be a feasible way for increasing the performance of anaerobic digesters and opens a new approach for the global valorisation of organic wastes by the integration of anaerobic digestion and thermal processes. This combined configuration allows for increasing the efficiency of the whole treatment process and greatly reduces the amount of material needing final disposal. This review offers an introduction to this interesting approach and covers the different experiences performed on the use of carbon conductive materials proposing it as a feasible alternative for the production of energy from biomass, considering also the integration of anaerobic digestion and thermal valorisation.[35] Maizirwan Mel, Muhammad Amirul Hussin Sharuzaman and Roy Hendroko Setyobudi(2016) evaluated of enhancement biogas production to Removal of CO2 from biogas plant using chemical absorption column. Biogas typically refers to a mixture of gasses produced during the breakdown of biodegradable organic matter in the absence of oxygen. It is primarily comprises 45-75% (v/v) of methane (CH4), 25-55% (v/v) of carbon dioxide (CO2),2000 ppm of trace element hydrogen sulfide (H2S), and ammonia (NH3). The presence of CO2 and H2S may affect the performance of biogas. Hence, its removal before its use is crucial to improving the quality of biogas. In this work, a method to purify both gasses, CO2 and H2S were employed by using a sodium hydroxide solutions (NaOH). CH4 composition after treatment was also studied as removal of impurities is interrelated to CH4 enhancement. The concentrations of sodium hydroxide were varied as well as the biogas flow rate. Experiments that revealed the highest removal efficiency had been achieved at 14% concentration of sodium hydroxide solution used and the maximum absorption capacity was achieved when CH4 increment is about 54.9% from its original value. In the continuous flow, the composition of CH4 increased up to 26% of H2S removal, however, was unable to achieve the target due to its low concentration (ppm) in biogas mixtures. Hence, there are no significant changes in its concentration that are worth to be analyzed.[36] Srinivas Kasulla, and SJ Malik (2021) Biogas production from sugarcane press mud has enormous


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potential for energy age. Nonetheless, to empower the enhancement of the anaerobic digestion (AD) measure substrate trademark ought to be painstakingly assessed. In this paper the biogas improvement has been talked about and completed. Tests of press mud from different locales from the nation were investigated as far as aggregate and unstable solids, macronutrients, minor components and dietary benefit. Biochemical methane potential was performed to assess the energy capability of the press mud as per various sorts of sugarcane plants. Methane yields changed extensively, for the most part because of the various areas, water quality, soil structure and manures utilized for developing the sugar stick just as sugar and additionally ethanol creation measures.[39] Federica Liberti, Valentina Pistolesi , Mawaheb Mouftahi , Nejib Hidouri, Pietro Bartocci, Sara Massoli , Mauro Zampilli and Francesco Fantozzi (2019) Studied a case Study of an Existing Biogas Plant an Incubation System to Enhance Biogas and Methane Production in Umbria, Italy. This study reports the results of experimental tests of anaerobic digestion on a laboratory and industrial scale, aimed at verifying and quantifying the increase in the biological efficiency of the anaerobic digestion process, in terms of biogas production and/or methane content, deriving from the use of a mix of nutrients and sucrose in an incubation pre-treatment plant. The main results show an increase of 12 v% in methane production from the industrial biogas plant when coupled with the anaerobic digester. This improvement can have significant economic advantages. In fact, this work shows that the net present value of the plant can increase about 30%. The equity payback period can decrease to 5.8, compared to the value of 7 calculated for the reference scenario (i.e., anaerobic digestion without an incubator). The main risks of the investment are electricity export rate, initial costs, and fuel costs [40] Khuthadzo Mudzanani , Estavan Heerden , Ryneth Mbhele and Michael O. Daramola (2021) The present study intends to evaluate a synergy towards enhanced biogas production by co-digesting municipal sewage sludge (SS) with brewery spent grain (BSG). To execute this, physicochemical and metagenomics analysis was conducted on the sewage sludge substrate. This study aimed to improve the anaerobic digestion process of sewage sludge by co-digesting with brewery spent grains. The first objective was to understand the physicochemical and the microbial community involved in the AD and the complex interaction among


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microbes in an AD environment. The physicochemical and the metagenomics analysis was conducted using the Standard Methods for the Examination of Water and Wastewater. Anaerobic co-digestion was carried out with batch and semi-continuous laboratory setup. Therefore, the anaerobic co-digestion of SS and BSG might be considered as a cost effective solution that could contribute to the energy self-efficiency of WWTPs and sustainable waste management.[42] Anna Karlsson, Annika Bjorn, Sepehr Shakeri Yekta, Bo H. Svensson (2014) report of biogas research center on improvement of the biogas production process in anaerobic digestion processes and a number of strategies may be chosen. Increased organic loading in existing plants will in most cases demand the introduction of new substrate types. However, to substantially increase the Swedish biogas production new, large-scale biogas plants digesting new substrate types need to be established. Better utilization of existing digester volumes can be linked to: Increase of organic loading rates and/or reduced hydraulic retention time - optimizing the anaerobic microbial degradation by identifying rate-limitations, its causes and possible remedies such as: 1) Nutrient and trace element balances 2) Needs and availability of trace element 3) Process design aiming at an increase of the active biomass (e.g. recirculation of reactor material, two stage processes) 4) Process inhibition (enzymatically regulated product inhibition and toxicity) 5) Improved pre-treatment to increase degradation rates and VS-reduction

- Mixing and rheology
- Better monitoring and control
- Co-digestion with more high-potential substrates

Substrates as food wastes, sewage sludge, cattle manure, certain energy crops and algae are good bases to obtain processes with good nutrient- and trace element balances. These kinds of substrates can often be implemented for “mono-substrate” digestion, while substrates dominated by carbohydrates or fats needs to be co-digested or digested in processes modified. The present report reviews a number of fields that are linked to improvements in the biogas production process as based on the 1 to 5 points above.[49]Amir Izzuddin Adnan, Mei Yin Ong , Saifuddin Nomanbhay , Kit Wayne Chew and Pau Loke Show(2019)review on technology for biogas upgrading to bio methane. Anaerobic digestion and the production of biogas can provide an efficient means of meeting several objectives concerning energy, environmental, and waste


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management policy. Biogas contains methane (60%) and carbon dioxide (40%) as its principal constituent. Excluding methane, other gasses contained in biogas are considered as contaminants. Removal of these impurities, especially carbon dioxide, will increase the biogas quality for further use. Integrating biological processes into the bio-refinery that effectively consume carbon dioxide will become increasingly important. Such process integration could significantly improve the sustainability of the overall bio-refinery process. The biogas upgrading by utilization of carbon dioxide rather than removal of it is a suitable strategy in this direction. The present work is a critical review that summarizes state-of-the-art technologies for biogas upgrading with particular attention to the emerging biological methanation processes. It also discusses the future perspectives for overcoming the challenges associated with up gradation. While biogas is not the perfect solution for global greenhouse gas emissions, its place in the world of waste management has been very much solidified and will continue to evolve in the coming years. Biogas offers a good substitution for fossil fuels, it still not a perfect solution for global greenhouse gas emissions and further research still needs to be conducted. [51] M.S. Miah , Chika Tada, Yingnan Yang, Shigeki Sawayama (2004) Evaluated on Aerobic thermophilic bacteria enhance biogas production. The enhancing effect of aerobic thermophilic (AT) bacteria on the production of biogas from anaerobically digested sewage sludge (methanogenic sludge) was investigated. Sewage sludge (5%, w/w) was incubated at 65°C with shaking for a few months to prepare the AT seed sludge. AT sludge was prepared by incubation of the AT seed sludge (5%, v/v) and sewage sludge (5%, w/w) at 65°C with shaking. The addition of this AT sludge (1.2% to 0.5% of total volatile solids) to methanogenic sludge enhanced the production of biogas. The optimum volume of the addition and the pretreatment temperature of the AT sludge for optimum biogas production were 5% (v/v) and 65°C. Batchfed anaerobic digestion was covered with the addition of various AT sludges. The AT sludge prepared with the AT seed sludge improved the biogas production by 2.2 times relative to that from the sewage sludge addition. The addition of sludge without AT seed sludge weakly enhanced biogas production. An aerobic thermophilic bacterium (strain AT1) was isolated from the AT seed sludge. From evaluated results allow us to draw the following conclusions. a) The improvement of biogas production and VS


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reduction by the addition of AT sludge could be caused by aerobic thermophilic bacterial activity in the AT sludge. b) The optimum additional volume and incubation temperature of AT sludge were 5% (v/v, 1.2% VS) and 65°C. c) Geobacillus spp. could play an important role in the enhancement of biogas production by methanogenic sludge.[53]

**FUTURE CHALLENGE OF BIOENERGY PROCESSES**

Tom Bond, Michael R. Templeton [2011] Reported on the history and future of domestic biogas plants in the developing world Technologies which recover biogas do so by harnessing anaerobic degradation pathways controlled by a suite of microorganisms. The biogas released acts as an environmentally sustainable energy source, while providing a method for disposal of various wastes. Biogas contains 50–70% methane and 30–50% carbon dioxide, as well as small amounts of other gases and typically has a calorific value of 21–24 MJ/m3. Various appliances can be fuelled by biogas, with stoves offering an application appropriate for deployment in developing countries. Widespread dissemination of biogas digesters in developing countries stems from the 1970s and there are now around four and 27 million biogas plants in India and China respectively. These are typically small systems in rural areas fed by animal manure. However, in many other countries technology spread has foundered and/or up to 50% of plants are non-functional. This is linked to inadequate emphasis on maintenance and repair of existing facilities. Hence for biogas recovery technology to thrive in the future, operational support networks need to be established. There appear to be opportunities for biogas stoves to contribute to projects introducing cleaner cookstoves, such as the Global Alliance for Clean Cookstoves. Beyond this, there remains potential for domestic plants to utilise currently underexploited biogas substrates such as kitchen waste, weeds and crop residues. Thus there is a need for research into reactors and processes which enable efficient anaerobic biodegradation of these resources.[28] Kokan Kubota, Kenichi kuroda Koji Akiyama investigated in present status and future prospects of biogas powered fuel cell power units . Biogas energy is being watched with keenest interest as environmentally-friendly, alternative energy source instead of petroleum.it is proposed the biomass energy will be introduced worldwide in large quantities [59]. Safoora Mirmohamadsadeghia, Keikhosro Karimi, Meisam Tabatabaei , Mortaza Aghbashl of


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(2019) investigated on review paper on Biogas production from food wastes: A review on recent developments and future perspectives. Biogas is one of the most economically viable and environmentally friendly renewable energy resources and also given the unique advantageous of this renewable energy carrier, there has been a renewed interest globally in AD of various organic wastes including food wastes for biogas production .Food wastes are the originally nutritious and safe-for-human-consumption substances after being discarded which no longer have food applications. According to the Food and Agriculture Organization of the United Nations (FAO) (2019) report, about 33% of the human food, totalling about 1.3 billion tonnes annually, is wasted worldwide. The food loss per capita in Central and West Asia and North Africa is 6–11 kg per year, while it is 95–115 kg per year in North America and Europe. The production of food wastes occurs within all the stages of food supply chain, including agricultural processing, sorting, storing, transporting, distributing, selling, preparing, cooking, and serving. The food wastes are estimated to have direct economic consequences of about US$ 750 billion annually .Food wastes contain high amounts of moisture, volatile solids, and salinity; and are consequently considered as the main source of GHG emissions, unpleasant odour release, attraction of vermin, and contamination of groundwater [3]

***The future of biogas in a circular/green economy***

Kasap ,Rmazan Aktas ,Emre Dulger (2012) investigated on Economic and Environmental Impacts of Biogas. As a result, biogas can be an alternative for closure of our country's energy deficit, keeping the national capital in the country, and preventing the emission of greenhouse gases into the atmosphere. It should be seen fertilizer as a source of energy, not a waste. Biogas, which is produced by the decomposition of animal and vegetables waste, is possible to use as a source of domestic, clean and alternative energy instead of natural gas or LPG gas for all needs b to use as a source of domestic, clean and alternative energy instead of natural gas or LPG gas for all needs by storing .Biogas for villages and farms and natural gas for our cities will be became future source of energy after a certain period of time. In addition to the production of biogas electricity, formation of environment and air pollution caused by waste is also reduced to the minimum. Remaining waste of biogas is called biofertilizer.it is very efficient plant


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fertilizer which is used in sustainable agriculture. Electricity generation from biogas has been increasing rapidly in recent years. Generated electricity is given to the public power network. Besides, heat that occurred during this process is used to warm the facilities, which are located close to plants such as greenhouses and housing. [37] S. Abanades, H. Abbaspour, A. Ahmadi , B. Das ,M. A. Ehyaei , F. Esmaeilion , M. El Haj Assad ,T. Hajilounezhad , D. H. Jamali , A. Hmida , H. A. Ozgoli , S. Safari • M. AlShabi • E. H. Bani‐Hani (2021) investigated in critical review of biogas production and usage with legislations framework across the globe. With the new applications of biogas, the worldwide biogas industry has increased by more than 90% between the years 2010 and 2018, while further growth is still expected. However, the biogas industry varies significantly in different locations over all the world. Different countries have developed several types of biogas systems which are mainly dependent on different environments as well as on energy demand and supply chain. In this study, the production processes and specific applications of biogas in recent years were reviewed and discussed. In the lack of oxygen, the disintegration of organic material produces biogas that mostly consists of carbon dioxide and methane. In recent years, the exploitation of biogas and the expansion of its potential applications have gained popularity due to factors like climate change, reasonable energy prices, and an increase in distributed generation. Biogas also traditionally known as an off-grid energy resource and can be used in various applications consisting of electricity production and CHP systems.[60] Sunil Kumar Srivastava (2020) studied on Advancement in biogas production from the solid waste by optimizing the anaerobic digestion. Considering the recent development and existence of the current economic viability of biogas production, new prospects will be the focus in the future. Although various research works have been carried out in the past to improve pretreatment, coordination between microorganisms in the digestion, optimization of AD, recycling/reuse of digestate and sludge, but still a knowledge gap exists that needs extra efforts and technological advancement which can offer a more economic viable situation for biogas production. The efficiency of a biogas plant can also be improved through the recovery of value-added products like biochar, bio-oil, and sludge as organic manure for agriculture and pozzolanic material in the cement industry. In future,


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solid waste should be considered as wealth. Since biogas contains ~ 90% (CH4 and CO2), it can be converted into methanol. Researchers worldwide have been inventing new catalysts for catalysing this carbon source into methanol in an economic way, but still research is moving forward, and in the future a sustainable method will be developed to fulfill the dream of turning waste into wealth.[52] Cady R. Engler, Ellen R. Jordan, Marshall J. McFarland, and Ronald D. Lacewell studied on Economics and Environmental Impact of Biogas Production as a Manure Management Strategy. Conversion of animal waste to biogas through anaerobic digestion processes can provide added value to manure as an energy resource and reduce environmental problems associated with animal wastes. An anaerobic digester located at the Kirk Carrell Dairy in Johnson County near Godley, Texas, has been renovated as a demonstration of current anaerobic digestion technology for treatment of animal waste and recovery of energy. Economic analysis indicates that energy credits alone are not enough to offset the cost of investing in a biogas production facility. Annual operating costs were estimated to be $21,400 with energy credits of $14,300 for electricity produced and used on-site. Credits for reduction of odors, insect pests and other environmental problems have not been included in the analysis. Another environmental benefit from using biogas as an energy resource is that there is no net production of greenhouse gases. The carbon dioxide released during biogas combustion originally was organic plant material and so is just completing a cycle from atmosphere to plant to animal and back to the atmosphere. Methane is a more severe greenhouse gas than carbon dioxide and capture of biogas as a fuel prevents the release of methane into the atmosphere. Land application of solids and anaerobic lagoon treatment of liquid wastes releases a substantial amount of methane to the atmosphere. Capture of the methane for use as a fuel would significantly reduce the net greenhouse gas production from confined animal feeding operations (CAFOs).With the increasing size and regional concentrations of confined animal feeding operations (CAFOs), there is growing public concern over potential impact on environmental quality caused by CAFO-generated wastes. In response to this, regulatory agencies are scrutinizing animal waste management practices and revising regulations to reduce environmental impact. [38]


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***Recent advances in biogas production.***

Ilona Sarvari Horvath, Meisam Tabatabaei, Keikhosro Karimi, Rajeev Kumar (2016) give a brief review on Recent updates on biogas production is the reduction of green house gas emissions and thus preventing the climate change. It is therefore important to replace fossil fuels with renewable sources, such as biogas. Biogas can be produced from various organic waste streams or as a by product from industrial processes. Beside energy production, the degradation of organic waste through anaerobic digestion offers other advantages, such as the prevention of odor release and the decrease of pathogens. Therefore, the interest in using different membrane configurations is driven by the requirement for increasing productivity. However, with high particulate and/or cell concentrations, the operation of these kinds of systems can be problematic due to fouling. Thus, full-scale implementation of the An MBR technology will be highly dependent on flux levels achieved during long-term operation. Finally, since AD is a complex microbial process, a broad range of studies have recently aimed at understanding the relationship between the microbial community structure, operating conditions, and process performance. By using novel newly-developed molecular biology tools, it would be possible to control and regulate the process in an effective way. To date, these techniques were mainly applied for the digestion step itself, however, it is necessary to pay attention to the whole biogas production system, including storage and feeding together with the post digestion step in the future as well [41] Lidija Cucek , Kefah Hjaila , Jiri Jaromir Klemes, Zdravko Kravanja (2017) studied on onion diagram implementation to the synthesis of a biogas production network. Anaerobic digestion producing biogas is a complex process comprising of a population of anaerobic microorganisms at four key stages, hydrolysis, acidogenesis, acetogenesis and methanogenesis. Parameters such as selection of feedstocks, pH, temperature, dry matter content and others significantly influence the process. Anaerobic digestion represents the core of the biogas production process. It could be represented by a centre of the onion diagram “reactor”. Anaerobic digestion directly influences the biogas production process (second layer of the onion), and further its supply network (third layer), the company (fourth layer) and finally material, energy and waste treatment system of the company (fifth layer). This contribution introduces a synthesis approach based on onion diagram applied to biogas production systems. Proposed


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approach consists of the following steps where the hierarchy/dependencies are considered between the onion layers: i) reaction layer using the models for anaerobic digestion, ii) process layer by optimising the biogas production process, iii) supply network layer by optimising the whole supply network of biogas production, iv) company layer by the synthesis of biogas production together with the surroundings (farm, food-processing industry, etc.), and v) integrated company layer which includes improved energy and mass integration and treatment of water, waste and emissions. Applying the onion structure for optimisation of biogas production can help to improve the sustainability of the process especially due to a complexity of each "layer".[46] Chayanon Sawatdeenarunat, Chinnapong Wangnai , Warinthorn Songkasiri, Pornpan Panichnumsin, Kanyarat Saritpongteeraka, Piyarat Boonsawang, Samir Kumar Khanalk , Sumate Chaiprapat(2019) reported on biogas production of different Industrial wastewater is one of the major sources of aquatic pollution which could significantly endanger surrounding environments and ecosystems. A wide range of these wastewaters especially from agro and food industries contain biodegradable substances which can severely deplete dissolved oxygen in an aquatic environment. Their large increase in volume is rooted from higher demand for food of our expanding global population and modern consumer lifestyle. Anaerobic digestion (AD) has several advantages compared to anaerobic wastewater treatment including a production of renewable energy, majorly in a form of biogas, substantially lower energy requirement, and less sludge to dispose. Applications of AD for various industrial wastewaters were reportedly attainable in simple low-rate digesters or more advanced high-rate systems at different degrees of efficiency. Many success cases of full-scale AD of industrial effluents (i.e., citric acid production, food processing, beverage, etc.) have been reported. The organic conversion efficiency of these wastewaters must be driven to approach 100% which will enhance bioenergy production and at the same time save tremendous aeration energy in the ensuing treatment train to meet regulated discharge standards. With advances in biotechnology as well as material and process engineering, AD of industrial effluents could someday not only convert virtually all organics to bioenergy but also provide ultimate treatment to replace the aerobic counterpart. [47] Arijana Busic, Semjon Kundas, Galina Morzak, Halina Belskaya,


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Nenad Mardetko, Mirela Ivancic santek, Drazenka Komes, Srdan Novak and Bozidar santek (2018) Studied on Recent Trends in Biodiesel and Biogas Production. On the basis of this consideration, it is obvious that biodiesel and biogas are very important renewable energy sources. Currently, biodiesel is mostly used as transportation fuel and biogas for production of electricity and heat. The main advan¬tage of these two renewable energy sources lies in the fact that for their production, a relatively wide range of renewable raw materials can be used. Biogas is generated from organic material by the action of microorganisms in the absence of air in a process called anaerobic digestion or methanogenesis. The nature of the raw materials and anaerobic digestion conditions has con¬siderable impact on the chemical composition of biogas. Raw biogas mainly contains methane in the amount of 40-75 %, and carbon dioxide ranging from 15 to 60 % .After the re-moval of CO2 and other impurities, which are however present in trace amounts, the final product is called biomethane, typ¬ically containing 95-97 % CH4 and 1-3 % CO2 . Biomethane can replace natural gas as a feedstock for producing chemi¬cals and materials. The main energy crops currently used on a commer¬cial scale for biogas production are sugar and starch crops. Among them, sugar beet, corn (grain) and potatoes are the most intensively studied, but many other less conventional starchy crops with potential for biogas utilization have been reported too.[48] Sunil Kumar Srivastava (2020) studied on Advancement in biogas production from the solid waste by optimizing the anaerobic digestion. This review has emphasized the efficient utilization of organic municipal solid waste as well as agriculture waste in an anaerobic digester for the production of biogas as a sustainable renewable energy. Recent advances in biogas production along with previous research work have been discussed to offer a comprehensive synopsis of the accumulated knowledge. This review also elucidates about the design of an anaerobic digester, the prospect of anaerobic digestion and opportunity in new advances in technology. Biogas is one of the most accepted sustainable renewable energy. The characterization, elimination of contaminants, pretreatment, anaerobic digestion in optimum condition and utilization of energy crops enhanced the efficiency of an anaerobic digester. Pretreatment of segregated organic solid waste increased its putrescibility and further biogas production. The optimized parameters in this review were pH,


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temperature, loading rate, C/N ratio and solid/liquid ratio of the feedstock. The flow rate of the feedstock was optimized according to the available volume of the digester, residence time and the characteristics of the feedstock. The design of an anaerobic digester should be preferably cylindrical in shape, with a diameter ranging from 6 to 40 m, the depth ranging from 7.5 to 15 m and the conical floor having a slope around 15%. A comprehensive reform in technical, economic, and social policies is essential to accomplish a sustainable energy system considering biogas as a future renewable energy.[52]

## CONCLUSION

In this study, the production processes and specific applications of biogas in recent years were reviewed and discussed. In the lack of oxygen, the disintegration of organic material produces biogas that mostly consists of carbon dioxide and methane. In recent years, the exploitation of biogas and the expansion of its potential applications have gained popularity due to factors like climate change, reasonable energy prices, and an increase in distributed generation. Biogas also traditionally known as an off-grid energy resource and can be used in various applications consisting of electricity production and cogeneration/Combined Heat & Power systems. The review suggests organic waste can be used as an economical and sustainable source of renewable energy. It can effectively replace an existing source of energy in significant proportions. In the primary stage, the characterization of organic waste should be carried out, followed by the removal of contaminants just before pretreatment of organic solid waste. Various techniques of pretreatment invented by the researcher can be used for the pretreatment of segregated organic solid waste. These pretreatment techniques improve the putrescibility of organic solid waste caused by enhancement in the efficiency of an anaerobic digester. The putrescibility of solid waste along with residence time plays a major role in biogas production. Biogas production is a promising technique for food wastes and Municipal Solid waste management. However, some operational challenges, such as the presence of undesired materials in Municipal Solid waste management, high potentials for acidification, and low process stability, have limited the widespread application of this technique. Optimizing operational parameters, as well as applying additives, digestate recirculation, frequent feeding, and feedstock pretreatments are among the


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methods to improve biogas production process from food wastes. Nevertheless, further studies are required to develop more economic processes in the view of the biorefinery approach based on the existing digesters.

With the new applications of organic waste for biogas production, the worldwide biogas industry has increased in recent years up to 2021, while further growth is still expected. However, the biogas industry varies significantly in different locations over the entire world. The renewable energy sources are one of the essential for the sustainability of the globe. India is the sixth largest fossil fuel consumer. The dependence of other countries for fossil fuels creates barriers in implementing unbiased political strategies. So biogas and other renewable energy sources have their relevance. The cost factor is one of the advantages of biogas. The government is in right direction for the implementation of biogas as fuels. But India has an infinitely extensible canvas synchronising with agricultural sector. The paper proposes the future strategies to be adopted by India for empowerment of biogas as a fuel using biogas production by modified process.

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