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Simranjeet Kaur
College of Agricultural Engineering and Technology, Punjab Agricultural University, Ludhiana, Punjab, India

Dhiraj Kumar
Department of Renewable Energy Engineering, Punjab Agricultural University, Ludhiana, Punjab, India

Mohit Singla
Department of Renewable Energy Engineering, Punjab Agricultural University, Ludhiana, Punjab, India

Ritu Dogra
Department of Renewable Energy Engineering, Punjab Agricultural University, Ludhiana, Punjab, India

Corresponding Author:
Mohit Singla
Department of Renewable Energy Engineering, Punjab Agricultural University, Ludhiana, Punjab, India

Biogas to Bio-CNG from paddy straw: A review

Simranjeet Kaur, Dhiraj Kumar, Mohit Singla and Ritu Dogra

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Abstract
Quick industrialization and growing the urbanization besides automatic undeveloped give achieve up to a lofty call of energy in every one of forms such as thermal, electrical and mechanical. To minimum acceleration energy is accomplished by burning of fossils fuels like coal; lubricate which further leads to its overexploitation in unsustainable conduct. The overuse of fossils fuels has increased environmental turbulence leading to serious detrimental effects such as large scale climate changes and global warming. This further leads to a shortage of any permanent source and thereby increasing the imports of the fuels. But we are so expedient to have some sustainable and ecological forms of energy for example- biomass, solar and, etc. Due to its everlasting characteristics and availability make it a better alternative for the present and future. Due to increasing environmental pollution, the researches emphasized supplementary on the making of biogas and bio-CNG from paddy straw. Producing renewable energy from paddy straw helps to lessen the energy catastrophe and paddy straw management, which is completed by anaerobic digestion. The future lies in the conversion of paddy straw into biogas. Keeping efficient management and conversion of paddy straw in mind Biogas or Bio-CNG production is the best possible method to obtain the clean low-carbon output. Biogas or bio-CNG obtained by anaerobic absorption of paddy straw tin be old as an energy cause for a choice of application namely, heating, cooling, brake cooling, electricity age bracket and gaseous fuel for vehicular applications. Paddy straw has immense economic value in the form of fresh gas production. This paper focuses on the review of exploring the most promising alternatives of paddy straw management and transmutation of biogas to bio-CNG to mitigate environmental pollution.

Keywords: Biogas, bio-CNG, hydrogen gas, paddy straw, pre-treatments.

Introduction
The demand for developed industries' energy consumption has been extremely increased all around the world. The environment restraint the limited availability but high usages of fossil fuels have led to a bad outcome from the past few years. However, it has become the top priority to conserve natural resources. Therefore, it has become the need of the hour to look out for other alternatives for survival such as renewable energy sources e.g. biomass, biogas, and solar energy and so on. These sources are eco-friendly in nature and are best suited for sustainability in the long run as they do not produce any kind of pollution. Globally, scientists and researchers are looking out for a new substitute for energy production which is clean, safe, renewable and efficient. Undoubtedly, from an economic perspective, agriculture is imperative but the importance of agricultural waste for instance; wheat straw and paddy straw cannot be undermined. They play an important role in meeting society's escalating energy demand in a sustainable manner.

Rice is major consuming crop food, with intake apiece capita of 65 kg for each day accounting for 20% of total ingested calories. Rice assembly is estimated to step up appreciably in expectations to provide for the rising individual population. Todays, paddy ethos produces 660 million tonnes of crop growing residues [31], essentially paddy straw one of the generally copious agricultural by harvest accessible in generous quantity. In most of rice generating countries, paddy straw burns directly on farm resulting in environmental pollution that has been for a lengthened time [31]. Paddy straw may plus be miscellaneous with other waste straws, biomass, ligneous and impart biomass equipment apt for energy production.

Anaerobic digestion (A.D.) of agriculture residues and biodegradable waste is widely used as the best treatment options because it yields methane and carbon dioxide and traces of other gases which is suitable for energy production [32]. Anaerobic digestion generally involves four steps: Hydrolysis, Acid phase (acidogenesis and acetogenesis) and Methane phase.

Bio-CNG is the purified system of biogas anywhere every the not needed gas are detached to produce larger than 95% unpolluted methane gas. It has the equivalent concerto to the commercially free physical chat as healthy as energy promise. As it is generated from biomass, it is careful a renewable font of energy and consequently, attracts everyone the business profit applicable to other renewable sources of energy.

Bio-CNG has the capacity to be the future of renewable fuel due to its abundance such as it can replace every LPG and CNG utility in India. Biogas is produced in a single-stage reactor from biomass. This biogas is a mixture of methane (CH_4), carbon dioxide (CO_2), and hydrogen sulfide (H_2S). The next phase in the process is to purify this biogas to get highly purified biomethane, wherein the component gases have the least impurities and adhere to the standards set by the government regulatory bodies. The purified biomethane so produced is then pressurized and filled in certified high-pressure cylinders mounted on the cascades. The Bio-CNG, so collected, is now ready to be dispensed for use in two-wheelers, autos, cars, as well as trucks and buses.

Bio-CNG, which is measured to be one of the good numbers, shows potential alternatives for renewable fuel in our time, the container is stored into gaseous usage for generating energy. Additionally, Bio-CNG does not have a say to the emerald address sound effects, fossils fuels besides, it is a renewable font of energy. Hence, researches are effective for energy construction by paddy straw.

This paper focuses on the review of exploring the most promising alternatives of paddy straw management and transmutation of biogas to bio-CNG to mitigate environmental pollution.

The necessity of paddy straw in gas formation

Today's energy system is obstructed for the reason that of appropriate issues as lucky as environmental, economic, and geopolitical concerns that give birth to implications remote into the potential. Bioenergy is one of them as a rule essential mechanism to alleviate conservatory chat emissions and sustainable development [12]. In India, paddy is refined in the neighbourhood around 43.95 million hectares and creation is about 106.54 million tonnes. Approximately, 160 million tonnes of straw is formed with a grain straw ratio of 1:1.5. Punjab fashioned 11.27 million tonnes of rice, which is 10.6% of every one of Indians full making for the day 2013-14 and fashioned an entire of 16.90 million tonnes of paddy straw. Of the paddy straw produced, a little measurement is old as fuel for up to date biomass nation- state plants, brick kilns, cardboard building, and swell farming and as a fuel for domestic biomass grill stoves in rural areas. The portion of the paddy straw that linger uncollected in the sports ground right and proper to a mutual harvesting technology are not burned and are in the end plowed ago into the fields, which serve as beneficial fertilizer for the forthcoming crops. Flooded rice fields, in addition, affix up extra methane, a budding conservatory chatter bent by the bacterial conservatory under anoxic conditions. But, payable to surplus paddy straw and harms connected with its storage, farmers retail paddy straw at an illiterate estimate of Rs 500 for each metric tonne most important to not quite two-thirds of its essence burned openly in the fields instantly arrange it for sowing the subsequently wheat crop [8]. Conversion of paddy straw to biogas stopping at methane fermentation is an of us come near to for minimizing environmental pollution from the raw leftover and conserving fossils fuels. From the perspective of environmental sustainability, methane fermentation is regarded as a promising progression for renewable energy origination and weaken stabilization [7]. In mishmash with authority to gab, whereby the carbon dioxide and carbon monoxide small percentage of biogas is converted to methane via electrolyzed hydrogen, the renewable chat budding of perishing biogas is approximately doubled.

Paddy residue burning has high global warming and pollution potential. Therefore, advocating the use of paddy straw for the production of bio-CNG. Stubble burning leads to loss of nutrients, health hazard, and accidents. Materials like- straw and animal dung are consider as waste in India. This can be used to produce natural energy [25]. A tonne of paddy straw generates 112 kg of CNG. This would add to the income of farmer and help replace existing polluting fuels [24]. Suitable to environmental merits, the let somebody in one of the biofuels such as bioethanol and biodiesel in the automotive fuel advertise will cultivate firm in the subsequent decade. An eminent rationalizes for being of interest in renewable energy sources is the matter for the inexperienced farmhouse effect. Bio-renewable gaseous fuels suffer gained a fortune of interest expected to their environmental and technological advantages [11].

Emission of biogas from paddy straw

Rice is the mainly foremost essential chow if diet and calories intake for over parts of the world's human being [4] people and paddy straw is one of the nearly all copious and renewable energy spring in the world [39]. For every ton of rice harvested, approximately 1.35 tonnes of paddy straw vestiges in prevent with energy ability [22]. Paddy is the world's third main crop behind maize and wheat [4] and the excess goods and ranks as the world's third-biggest agricultural residue [1]. Based on the as a rule current figures obtainable by the fare and farming method of the united nations, an aggregate of 718 million tonnes of rice was bent in 2012 [15], which equals to approximately 969 million tonnes of paddy straw accessible worldwide [23].

Paddy straw is fibrous, lignocellulosic biomass that absent in the deal with just the once the grain is harvested. The straw container is together and baled once upon a time it contains humidity pleased below 25%, which bottle be complete inside in 3-4 existence depending on climate conditions [22]. The breakdown of paddy straw by funds of anaerobic absorption is not a new concept. Paddy straw has been considered for the long-ago century by researchers [39, 27].

The current appeal in paddy straw absorption stems from an inclusive focus on efficiently by renewable energy sources and dripping wet behind the ears igloo chatter emissions contributing to climate change. Ordinary practices such as not built up grassland burning of paddy straw in the fields or tilling the straw support into the countryside give notably to the discharge of methane chat into the atmosphere [17, 16, 6].

Biogas is also called as methane-rich gas that is produced from anaerobic digestion of wastes. The first biogas production plant is thought to be built in India in 1897 and served the function of sewage treatment [19]. Biogas is a gas produced when organic wastage undergoes anaerobic digestion–fermentable material breaking down in the absence of oxygen by the action perturbative bacteria. The fermented remains become bio-slurry, cost-free, all-purpose organic manure. The biogas produced by anaerobic digestion in wastewater treatment, food processing industry and decomposition of wastes in landfills contains mainly methane and carbon dioxide gases [13].

The preset harvesting of paddy crop has led to the start tackle burning of paddy straw. The burning of millions of tonnes of paddy straw makes public portly quantities of conservational firm gases which creates anxiety for regional atmospheric chemistry. The Paddy straw which is the raw material is procured from the farmer's fields in the form of bales to be stocked in the storage unit of the plant, which is further fed into a pulverizing unit of capacity 1 tonne/hour through a conveyer belt. Paddy straw may both be old completely in the custom of bales or processed by heating, burning and compressing to outline peak density pellets which set aside for the feedstock to be transported over a longer distance. Paddy straw pellets may be manufactured by moisturizing chop paddy straw with a run and extruding and moisturized straw through dies, wherein the amounts of fill up and extrusion difficulty are controlled [35].

The customary found paddy straws of chopped sizes 3-5 mm was assorted with the beloved ratio of water, up to 15% of pure content, and fed to the anaerobic digester of the biogas plant. in other courses of action paddy straw, were broken up and assorted evenly with sodium hydroxide, sodium sulfide and dampen and stored at standard heat for 30 days [28], before this, the paddy straw was soaked in a 4 percent solution of sodium hydroxide for one day. Then, it was irradiated by microwave radiation for half an hour (this reduces the lignin and silica content in the straw by 65 and 88.7 percent respectively) [30]. After this pre-treatment, the sodium hydroxide or hydrochloric acid solutions were added and anaerobic digestion performed [28]. Sodium hydroxide pre-treatment may be an able organization for enhanced biogas fabrication from paddy straws.

Anaerobic absorption is the degradation of organic resources by bacteria in the nonappearance of oxygen. It is a multi-step biological development somewhere organic carbon is mostly converted to carbon dioxide and methane [3]. By ammonia as a supplemental nitrogen source, paddy straw may be converted into biogas by elevated- toll anaerobic absorption system. A mixture of grinding heating at 110℃ and ammonia action resulted in the peak biogas yields, which is 17.5% superior to the yield of untouched paddy straw [40]. The bent biogas is washed with hose down to eradicate dust and tar, dried and desulphurization by a fitting chemicals agent to eradicated sulfides [41] or the biogas may be purified with sodium hydroxide suspension to cut off carbon dioxide, hydrogen sulfide, nitrogen oxide and water [37]. A permeable key was old to confiscate carbon dioxide hydrogen sulfide from the biogas. Finally, the chatter was approved through an in force carbon molecular strain to eradicate impurities and water. Paddy straw may, in addition, be gasifier to produce methane or biogas containing carbon monoxide, hydrogen, and methane [20].

Huang, *et al*. studied that it was not compulsory that the hydrogen prosperous gab bottle additionally is formed from paddy straw by means of the microwave together with pyrolysis. The core gears in the gaseous food were hydrogen, carbon dioxide, carbon monoxide, and methane and polycyclic pungent hydrocarbons where three key kinds of compounds in the liquid product. From the view of energy consumption, end to 60% of the key energy may perhaps be consequent and utilized as bioenergy [20, 21]. Anaerobic absorption is old for the creation of biogas from paddy straw, everywhere pre-treatment methods own major personal property on the digestibility of straw [34]. For increasing Industrialized biogas, biohydrogen and producing system from biomass, the pattern of anaerobic bacillus and anaerobic Clostridium may have the fun crucial role [10].

Transmutation Biogas to Bio-CNG

Bio-CNG, a methane plentiful compressed fuel, is additionally termed as compressed biomethane. Bio-CNG is produced from cleaned biogas containing supplementary than 97% methane at a stress of 20–25 MPa. It is precisely parallel to the even CNG in conditions of its fuel properties, economy, engine act efficiently and emission [9]. Biogas is a number sequence of separate gases that shaped by the breakdown of degradable equipment such as agricultural crop residues, civic wastage, stand materials, dirt and olive expenditure or cuisine depletion in the absence of oxygen. As this pattern of gases is extending purified and processed, it is called bio compressed sincere gas. It is parallel to effortless chatter in expressions of its symphony and properties and is cleaner alternatives to fuels such as gas and diesel.

Bio-CNG contains about 92-98% methane and lone 2-8% carbon dioxide, though biogas contains 55-65% methane with 35-45% carbon dioxide [27]. Bio-CNG is shaped from biogas, through a clean and expedient manner concerning desulphurization, expansion, and compression. First, the biogas is desulphurized, if the hydrogen sulfide satisfy is over 1,500 rpm. Then, the desulphurized biogas is upgraded to create its arrangement similar to CNG, followed by the compression and bottling of the ensuing bio-CNG [18]. Biogas created from anaerobic absorption of biodegradable biomass contains a big quantity of impurities like water, nitrogen, oxygen-hydrogen sulfide, ammonia, and carbon dioxide. Therefore, biogas had to be purified earlier to the conversion into bio-CNG. Generally, the hassled run scrubbing, compound fascination, physical fascination, and biological filtration methods were second- hand to cleanse the biogas before conversion [5]. However, the harried irrigate scrubbing was the mainly frequently second- hand approach as it offers numerous recompense and privileged percentage of methane purity compared to the other purifying methods [38].

The unsoiled biogas containing other than 97% methane and a lesser amount of than 2% oxygen is measured for the invention of bio-CNG. In general, two approaches preponderatingly material and compound get in touch with are functional for this conversion. The pollution minus cleaned biogas afterward undergoes an area of high-pressure compression demands between 20 and 25MPa and converts into bio-CNG which occupies take away than 1% of its habitual volume. It is obligatory to hoard bio CNG as it affects vehicle stodgy time, rich completeness and energy eating [14]. Biogas generated from the anaerobic absorption method consists primarily of methane and carbon dioxide, with the stability of nitrogen and copy amounts of hydrogen sulfide and irrigate vapour. Methane bottle is old right away as fuel for cooking and heating and in addition, it converts into electricity by a generator, or compressed and second-hand as a different fuel for motor vehicles. In 2011, 57% of the biogas fashioned in Europe was from biomass sources plus decentralized agricultural plants, house-holds wastages, and untrained expenditure methanation plants or central co absorption facilities [13]. The assembly of biogas through anaerobic absorption is painstaking to be one of the cleanest approaches to getting your strength back energy from biomass [13, 29].

Conclusion

The soprano methane comfort and high energy usefulness pooled with the dwindling magnitude of humidity, hydrogen sulfide and impurities which makes bio-CNG a perfect fuel for automobile and capability creation the glum discharge levels of bio-CNG moreover makes it eco affable fuel than biogas. Bio-CNG produced in four main steps (extraction, purification, pressurizing and storage and dispersion). In extraction, biogas is produced in a single–stage reactor from biomass through a process. This biogas is a mixture of methane (CH_4), carbon dioxide (CO_2) and hydrogen sulfide (H_2S). In purification, Bio-CNG is the purified form of biogas where all the unwanted gases are removed to produce more than 95 percent pure methane gas. Bio-CNG is exactly similar to the commercially available natural gas, next in pressurizing and storage phase in this the purified biomethane is pressurized and filled in certified high-pressure cylinders mounted on the cascades and at the end the bio-CNG, so collected, is ready to be dispensed for use in cooking and housing power supply as well as automobile vehicles.

Burning of paddy straw dregs causes simple pollution of soil and stream on the citizen as fondly as regional scales. It is experimental that straight to the burning of paddy straw consequences in nutrient losses viz. 3.85 million tonnes of organic carbon, 59,000 tonnes of nitrogen, 20,000 tonnes of phosphorus and 34,000 tonnes of potassium. It besides adversely effects the nutrient finances in the soil. It fallout in the giving out of smoke which if added to the gases exhibit in the spread methane, nitrogen oxide and ammonia, tin initiate really climax environmental pollution. Burning of crop rest additionally filtrate additionally contributes indirectly to the bigger ozone pollution and universal warming problem. The production of biogas from waste and renewable resources is a promising answer to the environmental and energy challenges facing the world. This review study aimed at exploring the most promising alternatives of paddy straw management techniques in economic terms in the form of bio-CNG formation and commercialization. Paddy straw is one potential source of renewable energy and converted into a suitable form of energy, usually, biogas, bio-methane (Bio-CNG), and electricity or as a fuel for an internal combustion engine, can be cognizably achieved using a number of different routes, each with specific pros and cons. The collection and treatments of paddy straw through anaerobic digestion is not only a viable choice for producing clean, renewable energy, but it will furthermore eliminate a most important spring of untrained line chat emanation from usual practices of unbolting burning or tilling the straw neither into the fields. The upgraded biogas preserve be old as approx. of fossils fuels such as assembly of high temperature and stream, electricity production, vehicle fuel, and feedstock for the creation of bio-based chemicals, the substrate in fuels cells and swap for biological chatter for domestic and built-up use. This paper reviewed the mess of the sculpture of biogas purification, upgrading technologies and commercials influences of biogas and bio-CNG. Gab characteristic necessities displace outlay is the criterion for the choice of proper technology. In recent times, pressures on the global environment have led to calls for increased use of renewable energy sources, instead of fossil fuels. Paddy straw is an abundant agricultural by-product of low commercial value is available in large quantities. If utilized efficiently, paddy straw can provide appropriate feedstocks for competitive bioenergy production.

Table 1: Summary of different processes and operating parameters used by various researchers

	Researchers/ Year	Operating parameters	Study	Result
1	Zhang R and Zhang Z (1999) [39]	Reactor temp- 35±1°C Pre-treatment methods – physical, thermal and chemical.	Gasification of rice straw	Higher biogas yield(17.5%) was found in combination of grinding (10 mm length), heating(110℃) and ammonia treatment (2%) then untreated straw
2	Glissmann K and Conrad R (2000) [15]	First incubation: 25 °C Second incubation: 25°C Centrifugation: 13000 rpm at 4 °C for 15 min	Methanogenic degradation of rice straw	Effect of adding rice straw on fermentation was observed only in the early phase of degradation.
3	Kim S and Dale B E (2004) [21]	-	Production of bioethanol from waste crops	Rice straw, wheat straw and corn stover convert into bioethanol (291 GL) in Asia.
4	Arvanitoyannis I S and Tserkezou P (2008) [3]	Incineration: 870-1370 °C Corn waste: pH - 7.2 to 7.5 Rice straw: pH-7	Treatment of rice and corn waste.	Composting is the better alternative use rice straw. Biomass combustion have low impact on environmental than the burning of fossil fuels
5	Chang J *et al* (2008) [9]	Compost - dried at 85 °C for 3h. Fermentor purged with nitrogen at 40 °C growing temp. Mixed microflora was heated at85 °C for 15min.	Development of industrial bio-fuel and bio hydrogen system	By combining the anaerobic bacillus and anaerobic clostridium may help in development of bio fuels and bio hydrogen production system.
6	Huang Y F *et al* (2008) [19]	Frequency – 2.45 GHZ. Power – 2000 W. Nitrogen (50 ML/ min) purged into the system. Rice straw – 3 to 5g.	Production of hydrogen rich fuel from rice straw using microwave-induced pyrolysis**.**	Reduction of fixed carbon was significant in the range of 400- 550 W microwave power.
7	Huang Y F *et al* (2010) [18]	Frequency – 2.45 GHZ. Power – 2000 W. Nitrogen (50 Ml/ min) purged into the system.	Production of hydrogen fuel gas from rice straw through microwave induced pyrolysis.	The produced gas contains max amount of hydrogen was 50.67 vol%.
8	Lei Z *et al* (2010) [25]	PH – 7.1- 7.2. Operating Temp of reactors - 22±2 °C.	Methane production from rice straw.	Addition of phosphate (465 mg-P/L) has stimulating effect and accelerates the anaerobic digestion. Experimental results simulated with separated two stage first order kinetic model.

9	Lubken M *et al* (2010) [27]	-	Microbiological fermentation of and prospects of mathematical modelling.	For optimal production of biogas, detailed knowledge of the biochemical processes in the fermenter is necessary. With the use of mathematical models can help to achieve better understanding of the process.
10	Porcar M and Dominguez-Escriba L (2010)	-	Rice straw management	Converting the rice straw into bioethanol is better method of managing the agricultural waste. Various pre-treatment methods, hydrolysis and fermentation overcomes the hurdles in conversion of rice straw into bioethanol.
11	Zhao R *et al* (2010) [37]	Pre-treatment temp- 35 °C (for 30 days).	Methane production from rice straw	Methane production was significantly increased by 35.84% using dilute organic acid pre-treatment. Acid in hydro lysates also converted into methane gas.
12	Chandra R (2011) [8]	Fuel injection timing: 27 ° before TDC	Performance evaluation of an IC engine on CNG, methane enriched biogas.	Due to conversion from CI to SI mode, power deteriorations was observed to be 31.8%, 35.6% and 46.3% on compressed natural gas, methane enriched biogas and raw biogas, respectively, in engine.
13	Farzaneh-Gord M *et al* (2011) [13]	Reservoir temperature: 300 K Reservoir pressure: 20.5 MPa	Effect of storage types on performance of CNG filling stations.	Filling Time required for bringing up the NGV on-board cylinder to 20 MPa pressure in the buffer storage system is about 66% less than cascade storage system.
14	Sari F P and Budiona (2014) [30]		Application of pre-treatments on rice straw	Pre-treatments used for decreasing the recalcitrance, crystallinity of cellulose, increase accessible surface area and reduce lignin content.
15	Yang L *et al* (2014) [36]	Consortium (bacteria) – 30/7.0(T °C/pH). Temp – 35- 40 °C. Pressure – 900- 1200 kPa.	Converting biogas to transportation fuels.	Different methods used for conversion biogas to transportation fuel viz. physical approach: compression and and liquefaction, chemical approach: catalytic reforming, for converting methane gas into syn-gas. Reforming is also used for the production of highly pure hydrogen. Direct oxidation significantly produces methanol.
16	Demirbas A *et al* (2016) [11]	PH- 5.5 - 8.5. Temp – 30 – 60 °C.	Biogas production from municipal sewage sludge.	Sewage sludge is good organic fertilizer. It improves the organic matter and macro and micro nutrients to the soil.
17	Phutela U G and kaur K (2016) [28]	-	Bio gas from paddy straw.	Paddy straw was suitable feedstock for production of biogas.
18	Krar P (2018) [22]	-	Bio-CNG incentives to usher paddy stubble-based green projects.	High quality manure was produced leads to increases farmer income.

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