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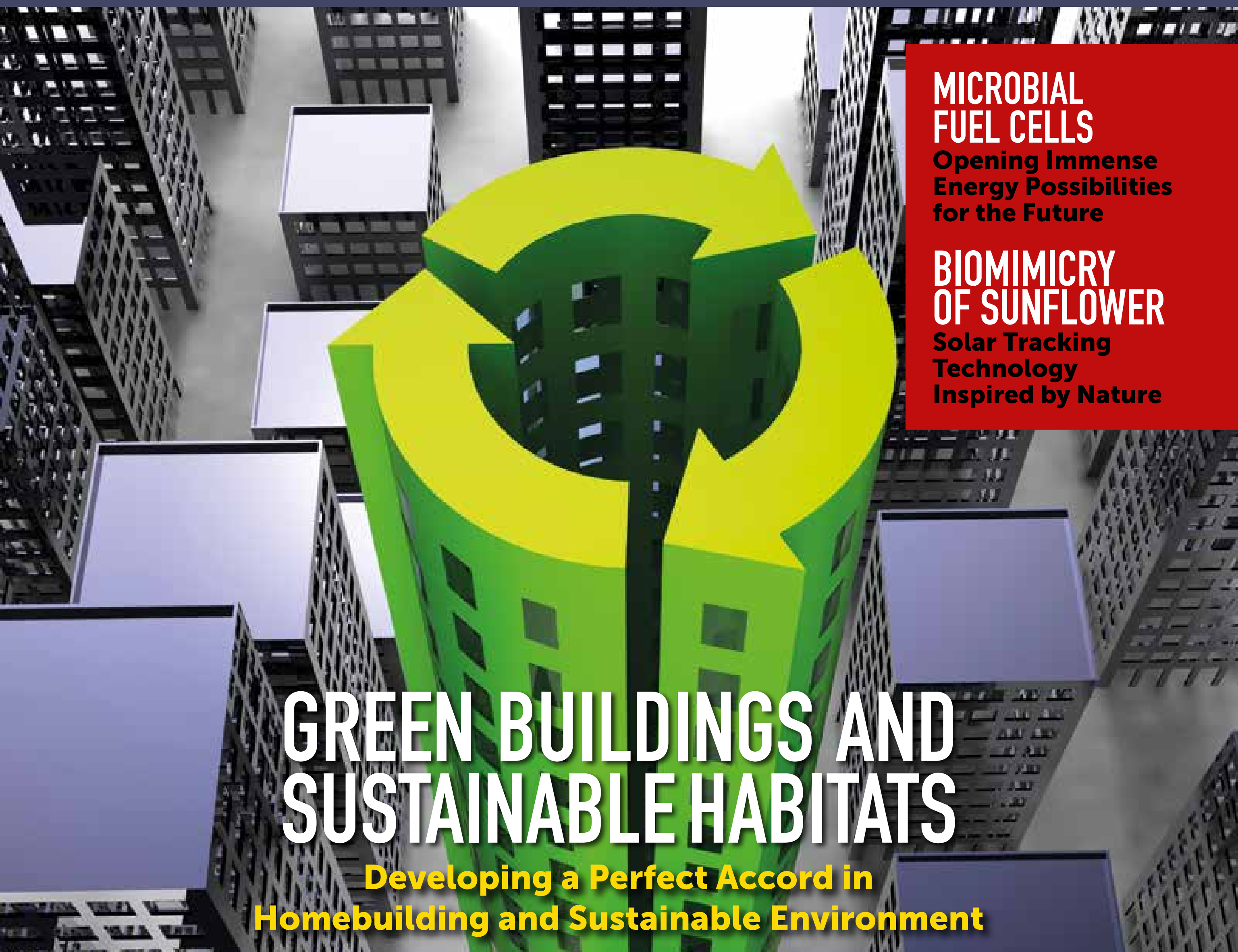

MICROBIAL FUEL CELLS
Opening Immense Energy Possibilities for the Future

BIOMIMICRY OF SUNFLOWER
Solar Tracking Technology Inspired by Nature

GREEN BUILDINGS AND SUSTAINABLE HABITATS
Developing a Perfect Accord in Homebuilding and Sustainable Environment

VIEWPOINT

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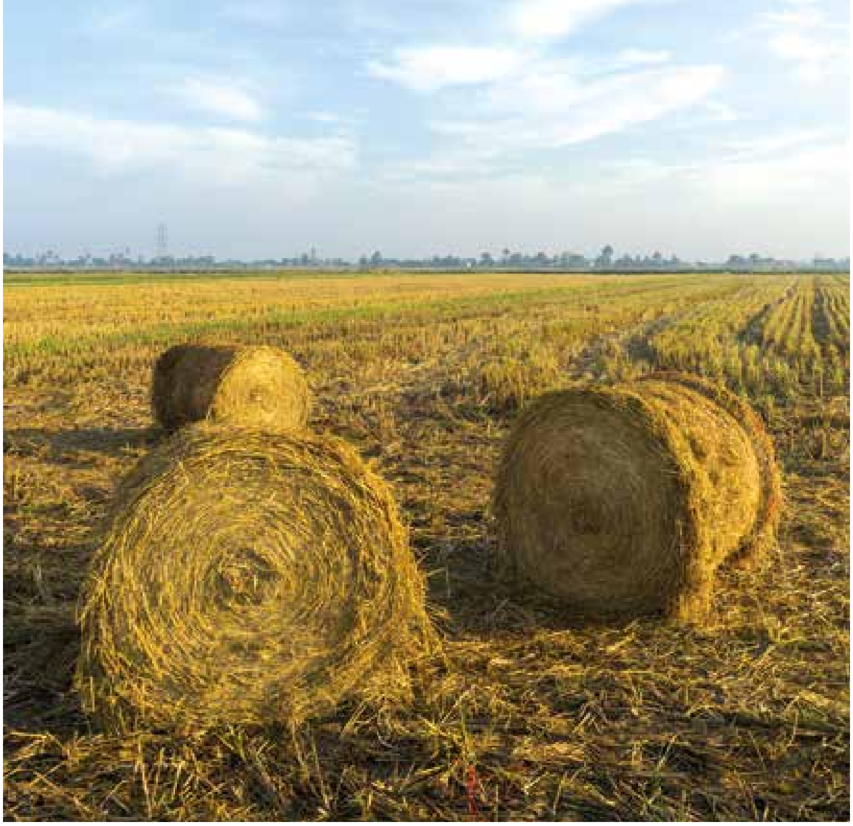
PADDY STRAW-BASED POWER GENERATION FROM BIOGAS

Fazilka District in Punjab Leading the Way!

Punjab has taken the lead to explore possibilities to gainfully use excessive biomass, in the form of waste material of crops, with encouraging results. In this article, **Dr Ram Chandra, Prof. V K Vijay, Prof. P M V Subbarao, S Nagpal, A Trivedi, B Jha,** and **Vandit Vijay** discuss about a case study of 1.0 MW power generation at Fazilka district in Punjab. This is the first biogas-based power plant in India which is operating on paddy straw for large-scale production of green energy. It is a novel initiative wherein agricultural waste is used to generate clean energy using biogas produced from paddy straw. Read on to know more…

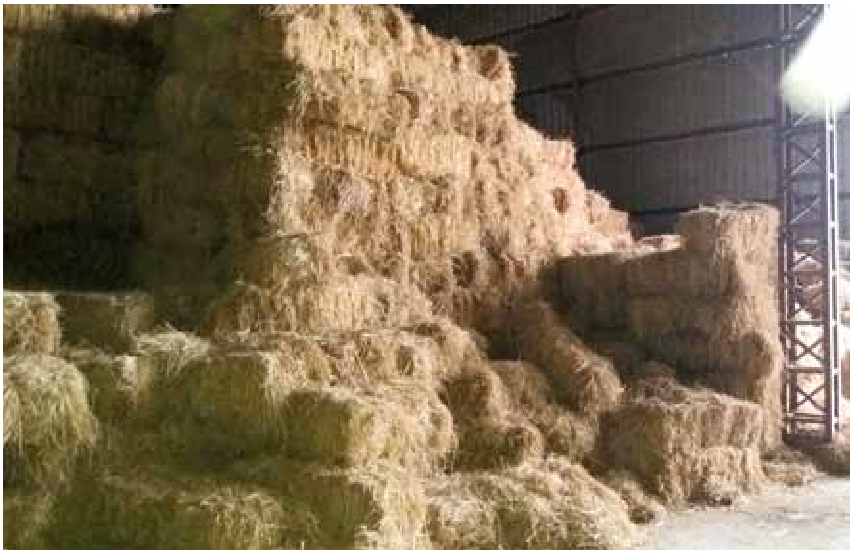
The deteriorating quality of life in urban hubs of India, especially in cities like Delhi, shackles our overall growth potential. "Delhi wakes up to air five times worse than the safe standard" as reported by a national daily, *The Times of India*, on Christmas in 2015. Delhi has been ranked poorly amongst the most polluted cities in the world. Furthermore, the case of paddy straw burning in Punjab and other northern parts of India causes serious concern over air pollution levels in Delhi and nearby areas, every year, during the paddy harvesting season. This burning causes a manifold increase in the pollution levels of the adjoining areas. The National Aeronautics and Space Administration (NASA), USA, had been alerting about the same since the past few years. This alarming increase in air pollution is a matter of great concern as we are aware that the air we are breathing is extremely unsafe and unhygienic for the current and future generations as well . We have become



so much helpless to the extent that the Government was forced to introduce the 'Odd–Even' formula for operation of private vehicles on roads so that the air pollution level of Delhi could be controlled to some extent.

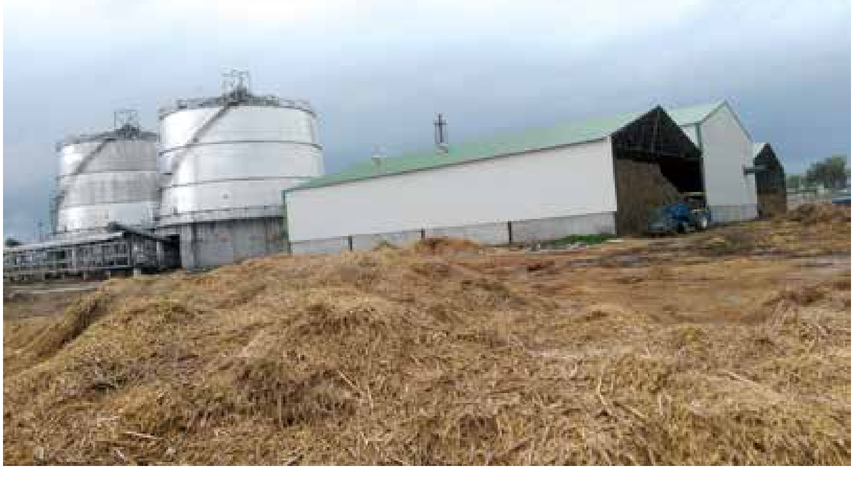
The second generation of biofuels' production from renewable energy resources, 'plant biomass', refers particularly to the lignocellulosic biomass/materials, as this makes up the majority of the cheap and abundant non-food materials available from plants. Therefore, lignocellulosic feedstock can offer the potential to provide novel biofuels of the 'second generation of biofuels'. The production of biogas and bioethanol from renewable biomass has been the major research focus around the world with a view to supplement petroleum fuels and reduce environmental pollution as well.

The use of biogas being an environment-friendly, clean, cheap, and versatile fuel and its production from various available biomass resources is a viable option for our country. Harnessing such a resource will not only promote rural industries, agriculture, dairy, and animal farming in a sustainable way but will also help in regulating environmental cycles effectively, since nutrients, such as nitrogen, phosphorus, and potassium as well as micro-nutrients (zinc, iron, manganese, and copper) conserved in the process, in the slurry, can be returned to the soil. It has been observed that the use of slurry as a fertilizer has many advantages as compared to farm yard manure. Weed seeds in the substrates are destroyed completely during the digestion process and they are richer in nutrients when compared to farm yard manure.



Picture 2: Paddy straw bales being used for pulverization

Biogas after methane enrichment is as good as natural gas for powering the internal combustion engines used for various power generation applications and automobiles. Thus, biogas is a good substitute of the conventional compressed natural gas which is derived from crude petroleum. Moreover, biogas production from plant biomass being CO_2 neutral, its combustion again lowers the emissions in comparison to gasoline, diesel fuel, and even natural gas.



Picture 1: A view of paddy straw-based biogas plant installed at Fazilka, Punjab

Installation of Biogas-based 1.0 MW Power Generation System in Fazilka

This is the first biogas-based power plant in India which is operating on paddy straw for large-scale biogas production. Sampurn Agri Ventures Private Limited (SAVPL) is a private limited company established in 2006 to set up a Project for Cogeneration of Power and Bio-Fertilizer, at village Panchanwali in Fazilka district, Punjab, India. The project of SAVPL was sanctioned as a mega project by the Government of Punjab in the month of December 2011. The installed biogas production system is based on a 100 per cent usage of paddy straw as substrate for biogas production. The initial startup of anaerobic digester was carried out by using cattle dung. The established facilities were supposed to produce nearly 12,000 m^3/day of biogas from 40.0 tonnes of paddy straw to run power generation system for 24 hours to produce electricity at 1.0 MW scale. But due to low amount of biogas production power generation, the unit was not able to run beyond four hours. Thereafter, the Indian Institute of Technology (IIT)

Picture 3: Paddy straw pulverization unit using hammer mill

Delhi, was asked to provide technical help to improve the performance of the system. At present, the performance has been significantly improved to produce electricity for 6–8 hours though various level interventions carried out by IIT Delhi in order to increase biogas productivity. At present, the paddy straw processing capacity of the system is about 10.0 tonnes/day. Picture 1 shows the installed paddy straw-based biogas plant.

The system comprises the following sections—(i) Feed preparation unit; (ii) Substrate feeding unit; (iii) Biogas generation unit; (iv) Hydrogen sulphide scrubbing unit; (v) Power generation and grid feeding unit; and (vi) Biofertilizer production unit.

The brief details of individual units have been provided below.

Paddy Straw Feed Preparation Unit

The paddy straw received, in bales, from the entire region of Fazilka, Punjab, is stored in storage unit. Further, the paddy straw is manually spread over the width of the conveyer belt to be fed into the pulverization unit for its size reduction to a level of 3–5 mm. Picture 2 shows paddy straw being used for feed preparation. The average capacity of paddy straw pulverization unit is 1.0 tonnes/h. This unit is powered by an electric motor of 75.0 kW, which consumes nearly 94 kWh energy per hour of operation.

Picture 4: A visual of continuously stirred tank reactor digester of 2,000 m^3

This unit also consists of a pulverized paddy straw collection system followed by an aspirator system for the collection of dust generated during the pulverization process. The aspirator unit is powered through electrical power of 30 kW, which consumes 37.5 kWh energy per hour of operation. Picture 3 shows paddy straw pulverization unit.

Substrate Feeding Unit

The pulverized paddy straw is taken from conveyer belt to a blending tank where it is mixed with water obtained from solid–liquid separation of biogas spent slurry taken from digestate of biogas plant. In this tank, the total solids concentration is maintained at a level of 10–15 per cent. The blended substrate is fed to the anaerobic digesters through a pump comprising blended substrate handling capacity of 30 m^3/h. This pump is powered from an electrical motor of 18.65 kW, which consumes nearly 23 kWh energy per hour of operation.

Biogas Generation Unit

This unit consists of three anaerobic reactors wherein the water capacity of two reactors is 3,400 m^3 and for one reactor [continuously stirred tank reactor (CSTR type)] is 2,000 m^3. The prepared paddy straw substrate is first fed to two digesters through the feeding unit where substrate manages to hold for nearly 30 days of retention time to produce biogas. The digestate of these two reactors (leachates coming out) is thereafter sent to the CSTR reactor where it holds for nearly 10 days of retention time for further biogas production. Picture 4 shows the CSTR-type digester. These reactors operate nearly 10–15 per cent of total solids concentration at mesophilic temperature and are equipped with stirring mechanism to mix the substrate, occasionally, as per the requirement.

This anaerobic digester produces nearly 3,000 m^3 of biogas per day with methane and carbon dioxide content in the range of 50–55 per cent and

40–45 per cent, respectively. The hydrogen sulphide content in produced biogas varied from 500 to 800 ppm.

Hydrogen Sulphide Scrubbing Unit

This unit comprises a hydrogen sulphide scrubber. The biogas produced from anaerobic digesters is passed through

Picture 5: A visual of installed hydrogen sulphide biological scrubber

this scrubber at a flow rate of nearly 500 m^3/h to reduce the concentration of hydrogen sulphide gas from the biogas. It is an essential requirement to reduce hydrogen sulphide level below 50 ppm to use biogas as fuel to operate the engine. The engine is coupled with an alternator to generate electricity. The unit also consists of 5.5 kW electric motor to power a booster pump, which passes the raw biogas through the scrubber unit. An electric motor having 5.5 kW power is used to circulate the digested slurry in the scrubbing unit. The total power consumption in hydrogen sulphide scrubbing unit is 11 kW, which utilizes 13.75 kWh energy per hour of operation. Picture 5 shows hydrogen sulphide removal unit. In this unit, the conversion of hydrogen sulphide takes place into formation of ammonium sulphide and phosphoric acid with the help of DAP (di-ammonium phosphate) through recirculation of slurry. The product, thus obtained, has large potential application for rejuvenation of saline soils.

Power Generation and Grid Feeding Unit

The power generation unit consists of an MWM, German-make 100 per cent biogas engine generator (six cylinders) with a capacity to produce 1.2 MW per hour electrical energy through an alternator of three phase 415 V.

The consumption of biogas is nearly 500 m^3 biogas per hour. Picture 6 shows the installed power generation unit.

At present, the amount of available biogas enables to operate power generation unit for about six hours of operation which generates nearly 6,000 kWh of electrical energy per day.

Picture 7 depicts the control panel readings for power generation values installed with the power generation unit.

The electricity produced from the power generation unit (three phase, 415 V) is being fed to the national electricity grid through an 11 kV transformer and necessary power control systems.

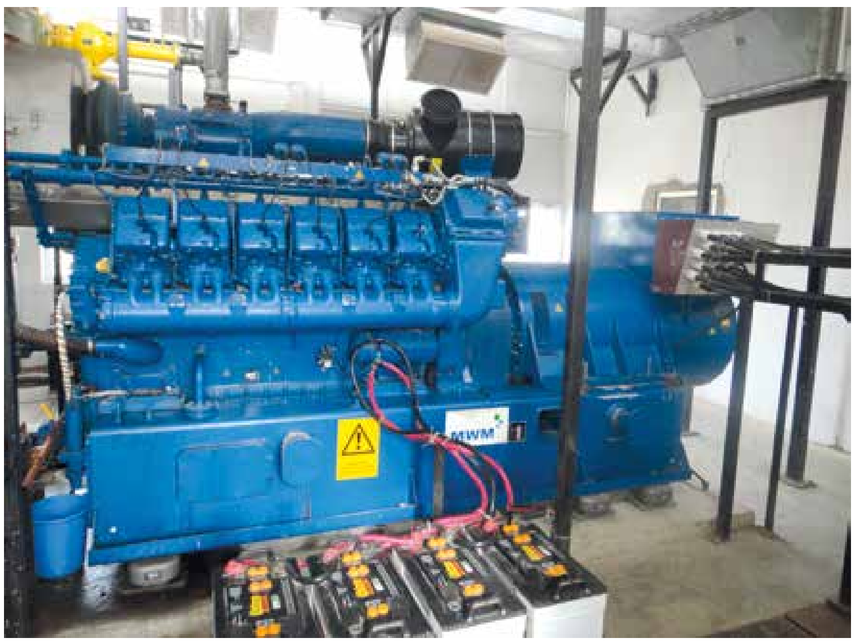
Biofertilizer Production

Biofertilizer production unit comprises of slurry dehydration system (solid–liquid screw separator press).

This unit has two horizontal solids–liquid separating machines with a slurry handling capacity of 8.0 m^3/h. The system is able to separate solids material that is nearly 600 kg/h with a moisture content of about 65 per cent.

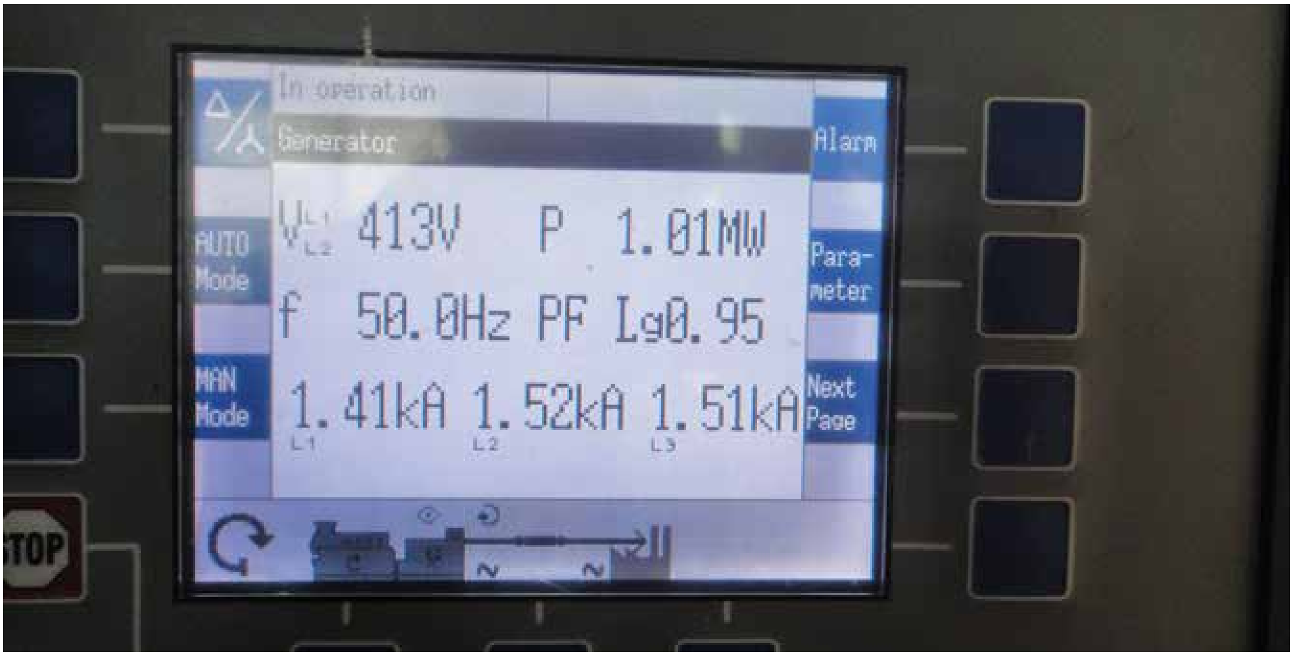
The separated liquid is recycled to prepare paddy straw substrate in blending tank. The obtained biosolids are air dried and used as biofertilizer for land applications. The added advantage of biogas generation from paddy straw is production of silica rich biofertilizer. The silicon (Si) is a beneficial plant nutrient and yield responses to its application have been frequently demonstrated in Si-accumulator crops, such as rice and sugarcane. Increased crop yields are the result of simultaneous increases in plant tolerance to a wide range of stresses.

The applied silica results in yield increase of up to 35 per cent.



Picture 6: A view of installed power generation unit

IN NORTHERN STATES OF INDIA, OPEN FIELD BURNING OF PADDY STRAW AND OTHER AGRO RESIDUES CAN BE AVOIDED THROUGH INSTALLATION OF COMMERCIAL BIOGAS PRODUCTION INDUSTRIES BY USING AGRO BIOMASS FOR BOTH POWER GENERATION AND BIOFERTILIZER PRODUCTION TO ENRICH SOIL HEALTH CONDITIONS. THE PRESENT LEVEL OF UTILIZATION OF PADDY STRAW AT FAZILKA, PUNJAB, SHOWED A SAVING OF 120.0 GJ/DAY ENERGY, WHICH OTHERWISE WOULD HAVE BEEN RELEASED INTO THE ATMOSPHERE BY THEIR DIRECT COMBUSTION IN FARMER'S FIELD ALONG WITH THE RELEASE OF ENORMOUS POLLUTANTS.



Picture 7: A view of control panel readings for power generation values

Environmental Benefits

In northern states of India, open field burning of paddy straw and other agro residues can be avoided through installation of commercial biogas production industries by using agro biomass for both power generation and biofertilizer production to enrich soil health conditions. The present level of utilization of paddy straw at Fazilka, Punjab, showed a saving of 120.0 GJ/day energy, which otherwise would have been released into the atmosphere by their direct combustion in farmer's field along with the release of enormous pollutants. In addition to the above daily savings in terms of various pollutants resulting from direct combustion of paddy straw, biomass amounts to 30 kg of particulate matter, 600 kg of carbon monoxide, 14.6 tonnes of carbon dioxide, and 20 kg of sulphur dioxide emissions, which has significant toxicological properties and are notably potential carcinogens.

In the present case, the overall thermal efficiency of power generation from biogas, produced from paddy straw, is nearly 20.0 per cent. The utilization of nearly 4,000 tonnes/year of paddy straw by this biogas-based power plant in Fazilka is the main reason for reporting of minimum burning of paddy straw in this region. The present productivity of biogas production from paddy straw is nearly 300 m^3/tonne. The installed system for biogas production has large scope for improvement in its performance for increasing biogas production, methane content in produced biogas, and operating hours of power generation unit.

The non-existence of any governmental standard for biogas spent slurry biofertilizer is a major hurdle in commercial sale of this organic fertilizer. However, there are standards for city compost, vermicompost, and phosphate-rich organic manure in the Fertilizer Control Order. Therefore, this requires urgent attention and needs to develop standards for biogas spent slurry biofertilizer by the Fertilizer Control Order in order to remove the barriers for its marketing and strengthen the biogas sector. EF

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