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Research Article

# A Success Story of Biogas Bottling Plant at DFRS, Bhilwara: Providing Solution to Agricultural and Kitchen Waste Managemen

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**Abstract**

India, where majority of population lives in rural areas, faces problem of environmental pollution, food security, post-harvest losses, waste disposal and energy availability. The rural energy needs can be fulfilled through application of locally available waste management technologies. Agro-waste and kitchen waste are the two most viable options for energy generation in rural areas that can not only enhance the standard of living but also help the rural areas to be self-sustainable in energy and economic terms. This research paper presents biomethanation or biogas technology as one of the economic and feasible technology for converting rural agricultural and kitchen waste to clean energy in addition to environmental benefits. It also explains the techno-economic feasibility of biomethanation for energy generationfrom agro and kitchen waste using a case study of RKVY project of 120cubic meter (60cum × 2no.) biogas plant decomposing 3 tons of agricultural and kitchen waste at DFRS, Bhilwara (Rajasthan). The research station is using the biogas either to produce daily approximately 50 kg Bio-CNG, which is used for running CNG- based vehicles at the station or generating 80 units of electricity. Along with biogas; daily 700-800 kg bio- manure worth of Rs. 3 lakhs per annum is also produced. A screw press dewatering system for slurry has also been installed, giving bio- manure with 30% moisture content. This paper clearly depicts the techno-economic benefits, assistance and subsidies given for the development of biogas technology.

**Keywords:** *Biomethanation, agricultural waste, kitchen waste, energy security, clean energy.*

## Introduction

Power sector plays a vital role in the economic growth and human development of any country and it is growing at rapid pace. The total installed capacity has reached to 310 GW with generation mix of Thermal (69.4%), Hydro (13.9%), Renewable (14.8%) and Nuclear (1.9%). is evident that the renewable power has secured 2ndposition after Thermal and is spreading its wings rapidly in India. Keeping in view the energy shortage in the country there is a need to tap biomass resources such as cattle dung, kitchen waste, agricultural waste etc for generation of biogas through the involvement of entrepreneurs and industries to set up decentralized biogas based energy infrastructure in the country, at the potential sites where biomass available is plenty. India is implementing one of the World's largest programmes in renewable energy. The country ranks second in biogas utilization. Biogas can be generated and supplied round the clock in contrast to solar and wind, which are intermittent in nature. Biogas plants provide three-in-one solution of gaseous fuel generation, organic manure production and wet biomass waste disposal/management.

Biogas is a product of biomethanation process

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when fermentable organic materials such as cattle dung, kitchens waste, poultry droppings, night soil wastes, agricultural wastes etc. are subjected to anaerobic digestion in the presence of methanogenic bacteria. This process is better as the digested slurry from biogas plants is available for its utilization as bio/organic manure in agriculture, horticulture and pisciculture as a substitute/supplement to chemical fertilizers. In contrast, when biomass is subjected to combustion/gasification process, it ends up in the destruction of biomass and only ash is left after extraction of energy. Therefore, the biomethanation process of converting biomass into gaseous fuel is superior and a sustainable process that needs to be preferred for such biomass materials that can be processed in biogas plants.

Biogas comprises of 60-65 percent methane ($CH_4$), 35- 40 percent carbon dioxide ($CO_2$), 0.5-1.0 per cent hydrogen sulphide ($H_2S$) and traces of water vapours. It is almost 20 percent lighter than air. Biogas cannot be converted into liquid like liquefied petroleum gas (LPG) under normal temperature and pressure. The slurry coming from digester is rich in nitrogen which is an essential nutrient for plant growth. Biogas is an easy and healthy cooking fuel since methane emissions from untreated cattle dung and biomass wastes can also be avoided. Since there is no pollution from biogas plants, these are one of the most potent tools for mitigating climatic change and being earth saviours.

**Properties of Biogas**

- Biogas is a non-toxic, colorless and flammable gas.
- It has an ignition temperature of 650 – 750 °C.
- Its density is 1.214 kg/ m3
- About 60 percent methane and 40 percent CO2 content
- Calorific value is 20 MJ/m3 (4700 kcal).
- Almost 20 percent lighter than air.
- It liquefies at a pressure of about 47.4 kg/cm2 at a critical temperature of -82.1°C.
- Purified biogas (bio-methane) has a higher calorific value in comparison to raw biogas.

**Types of Biogas Plant**

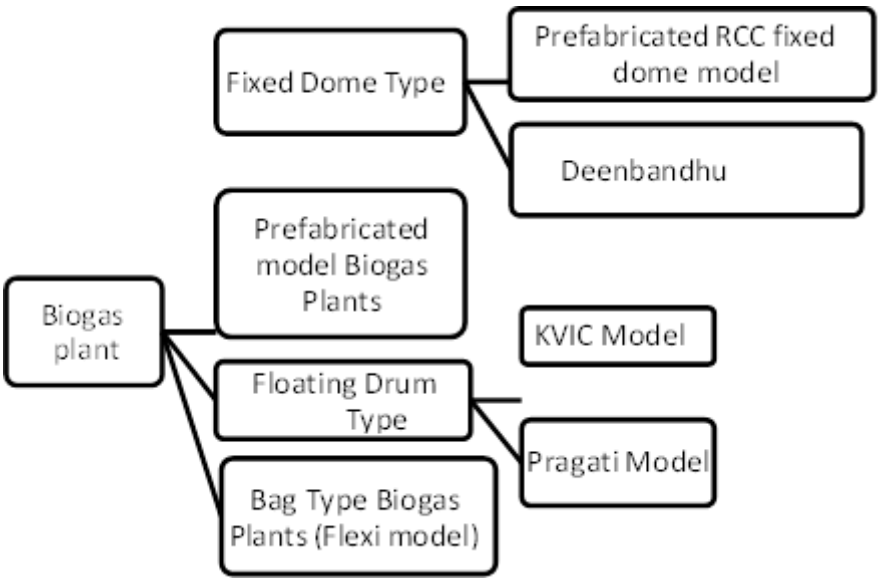



**Fig.1:** Types of Biogas Plant

**Materials and Methodology**

**Biomethanation**

**A Practical Approach for Managing Agricultural Waste**

The study was conducted in four different phases as mentioned below:

1. Lab study on biomethanation study from agricultural waste
2. Development of 120 cubic meter biogas generation per day capacity biogas plant

at DFRS, Bhilwara.
3. Direct and Indirect Benefits and Applications of the plant
4. Demonstration of the technology to the Farmers.

**Lab Study on Biomethanation Study from Agricultural Waste**

The objective of this work is to study the biomethanation potential and effect of organic matter on the availability of nutrients of different agricultural wastes supplied from DFRS, Arjia, Bhilwara. The supplied agricultural wastes consist of Barley waste, Mustard waste, Gram (Chana) waste and Taramira waste.

In the first step, study was conducted in the laboratory to analyze physico-chemical characteristics of different agricultural wastes to estimate the total amount of nutrients present in them. All the agro-residues being used as substrates were dried and grinded to small particles so that they can be easily digested. The physico- chemical properties of different agricultural waste are given below-

| Properties (%) | Barley | Mustard | Chana | Taramira |
|---|---|---|---|---|
| Moisture Content | 03.30 | 04.10 | 03.50 | 02.80 |
| Total Solid Content | 96.70 | 95.90 | 96.50 | 97.20 |
| Volatile Solid | 90.90 | 99.02 | 95.80 | 98.20 |
| Ash | 09.10 | 00.98 | 04.20 | 01.80 |
| Carbon | 52.73 | 57.43 | 55.57 | 56.96 |
| Nitrogen | 00.64 | 00.87 | 00.61 | 00.69 |
| Potash | 00.21 | 00.27 | 00.18 | 00.31 |
| Phosphate | 00.58 | 00.86 | 00.57 | 00.62 |

In the second step, different combinations of given agricultural waste were designed so that the C: N ratio ranges between 25:1 to 30:1. Some of the combinations considered are given below:

| Ag. waste | Weight taken | Carbon /gm VS | Nitrogen/ gm VS | C/N ratio |
|---|---|---|---|---|
| Combination 1: | | | | |
| Barley | 25 | 13.18 | 0.16 | 29.37:1 |
| Mustard | 24 | 13.78 | 0.20 | |
| Chana | 25 | 13.89 | 0.40 | |
| Taramira | 24 | 13.67 | 0.16 | |
| Combination 2: | | | | |
| Barley | 38 | 20.03 | 0.24 | 31.61:1 |
| Mustard | 25 | 14.35 | 0.21 | |
| Chana | 10 | 5.55 | 0.16 | |
| Taramira | 25 | 14.24 | 0.17 | |
| Combination 3: | | | | |
| Barley | 43 | 22.67 | 0.27 | 32.45:1 |
| Mustard | 25 | 14.35 | 0.21 | |
| Chana | 5 | 2.77 | 0.08 | |
| Taramira | 25 | 14.24 | 0.17 | |

Combination 1 having C: N ratio 29.37:1 was considered suitable and was selected for further study.

Before digesting the agricultural waste for biomethanation, pretreatment or presoaking of waste is strongly recommended by literature previously reviewed. Therefore, the best ratio of agricultural waste for presoaked in three different treatments to further study the effect of media taken for presoaking. The different treatments taken for presoaking are:

1. Agricultural waste + water
2. Agricultural waste + biogas spent slurry

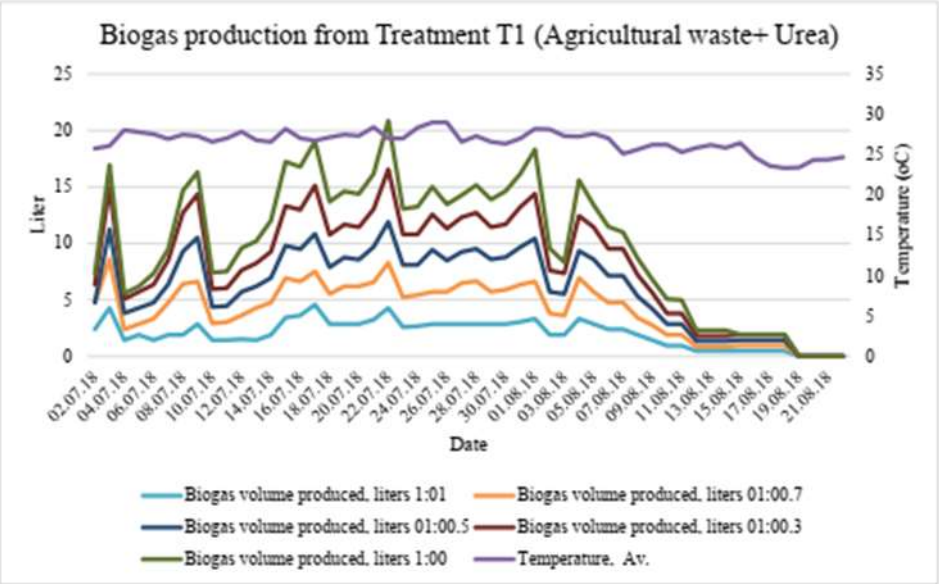
3. Agricultural waste + water + urea

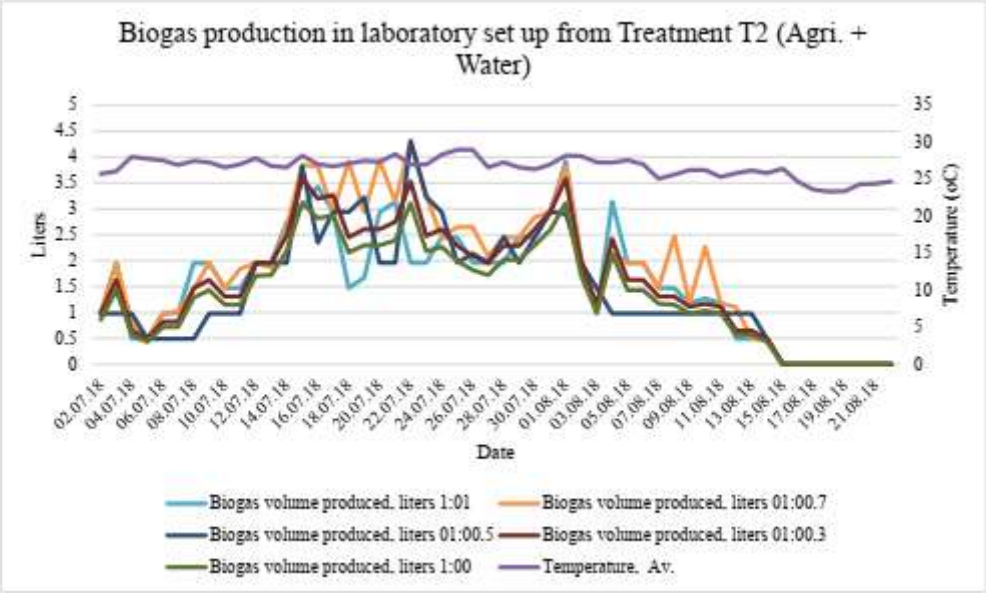
Urea is added in the treatments to maintain the C: N ratio. In each treatment 2 gms of urea was added to maintain uniformity. In the next step, experimental set up was laid for biomethanation of agricultural waste and cattle dung added in different ratios.

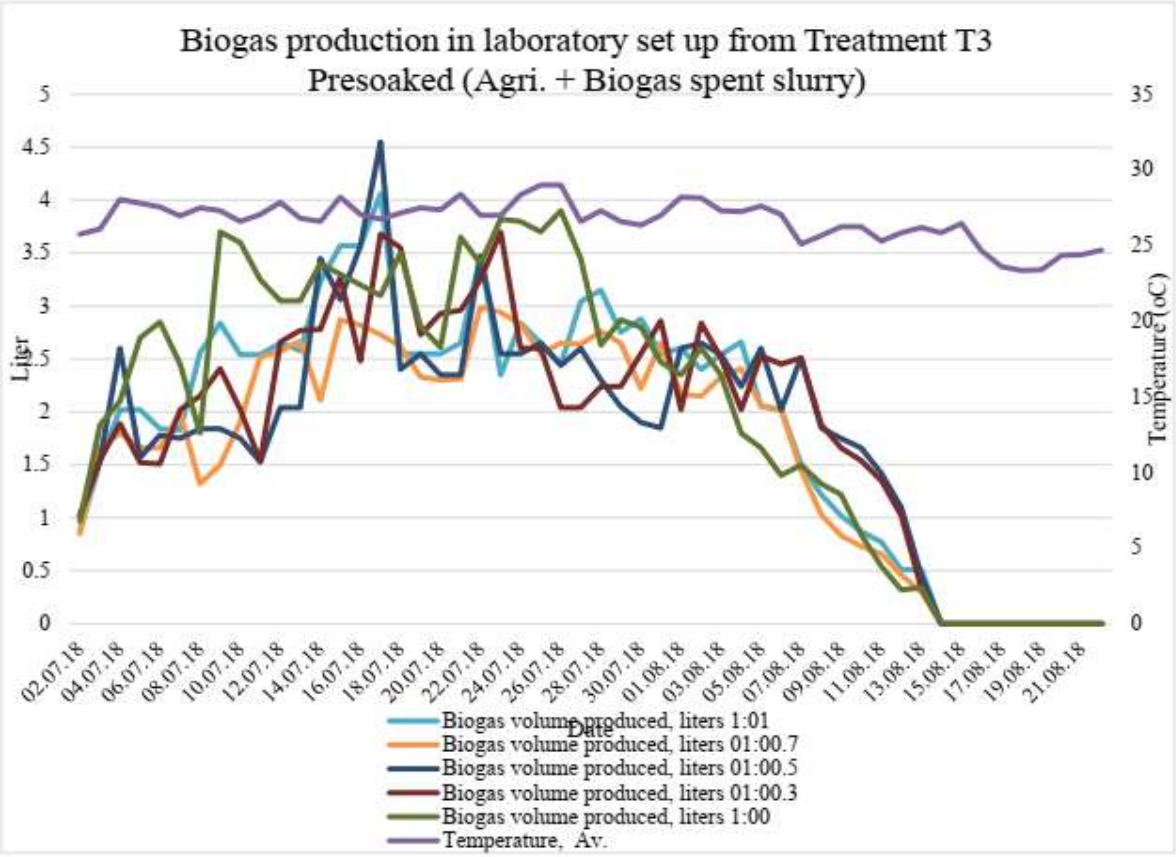
**Results and Discussion**

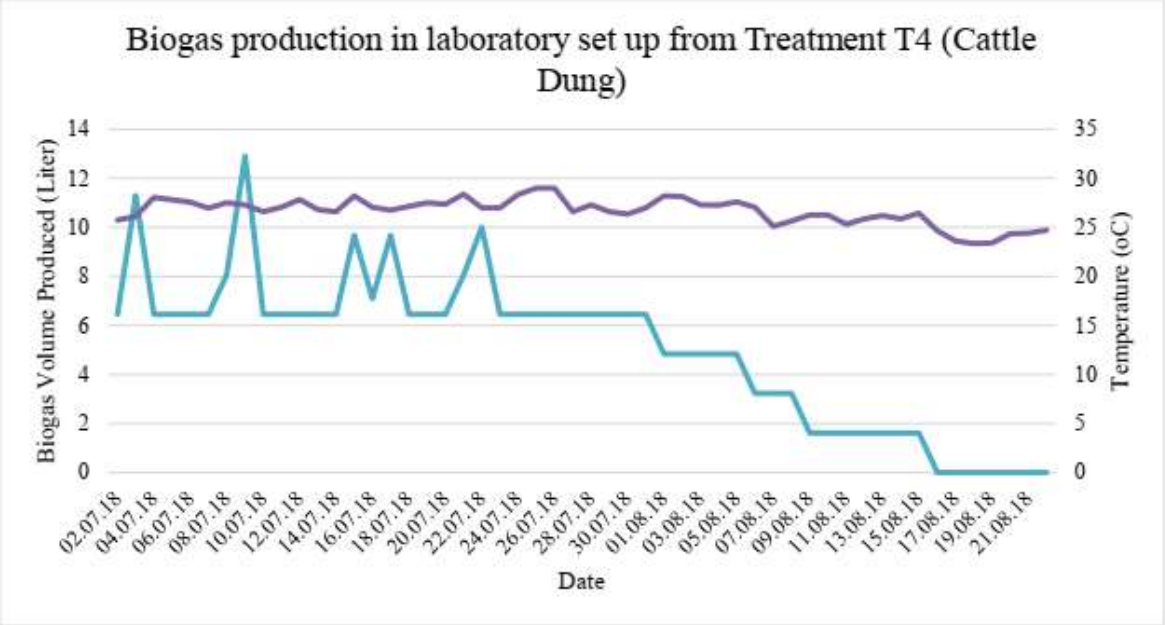
Three replications of each set or ratio were taken for the study andtheir average was considered as final result. The method adopted for the study was waterdisplacement method and biogas was checked by flame test. The incubation was done for 60 days.

The result are shown graphically as-






The results shows that the biogas produced from Agricultural waste is very low when compared to that by purely cattle dung i.e. 95.74 lt. and 263.83 lt. respectively. But the biogas production could be increased by either adding urea (2 gms per in 2 lt. treatment) or by presoaking the waste in biogas spent slurry for 2 days before digesting. The results clearly shows that both the processes either of adding urea or of presoaking gives almost equal yield of biogas when compared i.e. 112.3 lt. in case of urea addition and 108.05 lt. in case of presoaking.

**Development of 120 Cubic Meter Biogas Generation Per Day Capacity Biogas Plant at DFRS, Bhilwara**

A 120 cubic meter biogas generation per day capacity BGFP project for generation, purification/enrichment, bottling of biogas has sanctioned by the RKVY with Rs. 100 lakhs during the year 2016-17 to Dryland Farming Research Station, Arjia, Bhilwara (Rajasthan).Accordingly, the biogas bottling plant under Technology Demonstration under policy of RKVY has been commissioned on 17.03.2018.

Biogas Project at Village – Arjia, District- Bhilwara (Rajasthan)

Raw material platform

Mixing Unit

Digester Inlet and outlet

Hot water circulation unit


Bio-Slurry tank

Mixing unit Size: - 5'9'' X 5'9'' X 2'6"

**Biogas Unit Specification**

| Particular | Use | Specification |
|---|---|---|
| **Biogas productionunit** | To produce biogas and bio-slurry through anaerobic digestion of organic material as agro-waste, fruit waste, vegetable waste, cattle dung etc | 60 X 2 = 120 $M^3$/day biogas generation capacity with MS Dome Facilitated with-<br>• pH meter to measure pH inside thedigesters<br>• Temperature meter to measure temperature inside the digesters<br>• Hot water circulation unit maintain specific temperature insidedigesters |
| **Raw material platform** | To store raw material | Raw Material Platform with Slopsection up to 45 feet |
| **Digester Inlet and outlet** | To inlet and outlet of raw and digested material respectively | 3×3×1 $ft^3$ |
| **Bio-Slurry tank** | For storage of bio-slurry | 15×15×5 $ft^3$ |
| **Biogas storage Balloon** | To store biogas for purification and power generation | 12 $m^3$ biogas storage capacity |
| **Purification Unit** | To purify biogas | Vacuum pressure swing adsorption (VPSA) type purification unit *Facilitated with-*<br>Blower, cooling tower, vacuum pump, pre removal column for H2S and CO2, VPSA unit, Bio-CNG<br>storage tank |
| **Compression unit** | 200 bar with Attachments, Motor Specification:- 3 Pahse, 10 HP,<br>1450 rpm | To compress the Bio-CNG to fill it in<br>bio-CNG cylinder cascade and to useit as vehicle fuel |
| **Power Generator** | 15KVA Capacity, 100 AHBattery | To generate electricity using biogasand bio-CNG |

**Direct and Indirect Benefits and Applications of the Plant**

A total of 3 ton waste (i.e. mixture of cattle dung, kitchen waste and agricultural waste) is fed for biogas generation. The generated

biogas from the plant is purified from vacuum pressure swing adsorption purification unit in which zeolite molecules traps the impurities like $CO_2$, $H_2S$ etc. and gives purified gas having 95% $CH_4$. Out of the total 120 cubic meter biogas, 45 kg of CNG is produced per day. The purity of the enriched biogas is continuously monitored by Gas Chromatography system along with calibration of analyzers. The purified biogas is equivalent/ similar to CNG.

The purified biogas is compressed to 200-bar pressure for filling in cascade cylinders. The compressed biogas is used for transportation. The station is selling Bio-CNG at a cost of Rs. 45 per kg. Bio-CNG driven vehicle gives 24.11 Km/kg mileages. Raw biogas is also used for electricity generation and cooking meals. The produced electricity is used to operate biogas dewatering machine.

The slurry which comes out of the biogas plant is directly or after drying used as bio/organic manure for improving soil-fertility and reducing use of chemical fertilizers. The liquid slurry consisting 90-92% moisture which further dewatered by mechanical operated screw press machine. Dried slurry (at moisture content of 30% w.b.) of biogas plant is used as an organic fertilizer in their nearby agro fields. The slurry is rich in main nutrients such as Nitrogen, Potassium and Sodium (NPK) along with micronutrients - Iron & Zinc etc. As such there is no pollution from biogas plant. The slurry/manure of biogas plant is being sold to the farmers and used in liquid/solid form by them in agricultural crops. The field trials have indicated 30% - 50% growths in agro-production and substantial improvements in the quality. The research station is selling dried slurry is at a cost of Rs. 5/- per kg and liquid slurry at a cost of Rs. 2/- per liter.

Two Digester: 60 m3 Bio-gas Production per Day Each Digester

Crusher (Output Capacity:-200-250 Kg/hr.)

Biogas to Bio-CNG Purification Unit:- Adsorption Filter System for Removal of H2S, CO2, and other impurities gases


Bio-CNG compressor 200 bar Capacity

12 KVA Capacity Biogas Generator

Dewatering unit:-200-250 Kg Per Hour Output Capacity

Bio-CNG Two Cascade Set: - 1.4 X 13.5 Kg = 54 Kg, 2.3 X 9.7 kg = 29.1 Kg

12 cubic meter size biogas storage balloon

**Economic Feasibility**

1) For 120 cubic meter biogas plant, daily 3000 kg of cattle dung and 3000 kg of water is required.

| | | | |
|---|---|---|---|
| Cattle dung requires throughout the year | = | 365 days × 3000 kg | = 1095 Ton |
| Water required throughout the year | = | 365 days × 3000 kg | = 1095 Ton |
| **Total quantity** | | | = 2190 Ton |

If a 120 cubic meter biogas plant is used continuously for a month, it produces 1350 kg of C.N.G.

| | | |
|---|---|---|
| Monthly Saved Cost of CNG | = | 1350 kg × Rs. 45/- = Rs. 60,750/- |
| Yearly saving | = | Rs. 60750/- × 12 = Rs. 7,29,000/- |

2) Approximately 25% of fed slurry is converted into biogas and remaining 75% portion will be back from outlet as digested slurry. This digested slurry is dried up to 25% w.b. moisture content. A total of 648 ton dried digested manure can be utilized as organic enriched bio-manure/bio-fertilizer.

Annual revenue generated from fertilizer = 648 ton × Rs. 5000/-=Rs. 32.4 Lakhs

3) Total investment =Rs. 58 lakhs

If cattle dung buy at a cost of Rs. 1 per kg,

Yearly expenditure incurred for purchasing of 1095 ton of dung = Rs. 10.95 Lakhs

**Total** **= Rs. 68.95 Lakhs**

4) Returns

First year returns

C.N.G.produced = Rs. 7,29,000/-

Yearly income from slurry = Rs. 32,40,000/-

**Total** = **Rs. 39,69,000/-**

Difference of plant investment& refund of first year is Rs. 29, 26,000/-. Recovery of beneficiary's investment 1.73 years, if the plant is operating on condition of purchasing the cattle dung at Rs. 1.00/ kg

**Demonstration of the Technology to the Farmers**

## Conclusion

The bio gas plants have been tested for their utilities for decades and power generation is not a new chapter in this regard. It has served as a new avenue to utilize this resource commercially and on the large scale. Since the agricultural and other biomass wastes have always been a problem in regard to their proper management, this developed technology could be a better solution. The technology has been well tested at Dryland Farming Research Station, MPUAT, Arjia, Bhilwara and is running successfully. This technology is available for farmer's demonstration and training purposes. The technology can be successfully be implemented on the community level with easy operation and maintenance.

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