MUNICIPAL SOLID WASTE

PROCESSING FACILITY FOR CONVERSION OF

BIODEGRADABLE WASTE TO BIOGAS/BIO CNG

IN TIRUPATI, ANDHRA PRADESH

A Detailed Project Report

Submitted By

MAHINDRA WASTE TO ENERGY SOLUTIONS LTD

In association with

TIRUPATI MUNICIPAL CORPORATION

MAHINDRA WASTE TO ENERGY SOLUTIONS LTD

POWEROL BUILDING, 2ND FLOOR,

GATE NO. 2, AKRULI ROAD,

KANDIVILI EAST, MUMBAI – 400101

Contents

Appendices

LIST OF FIGURES

NOMENCLATURE

Acronyms	Meaning
AD	Anaerobic Digestion
CNG	Compressed Natural Gas
GHG	Green House Gas
MWC	Mahindra World City
KVIC	Khadi and Village Industries Commission
PSA	Pressure Swing Absorption
NPBD	National Project on Biogas Development
CHP	Combined Heat & Power production
HRT	Hydraulic retention time
CO2	Carbon Di oxide
CH4	Methane
CNG	Compressed Natural Gas
NBMMP	Natural Biogas and Manure Management
FRP	Fibre reinforced plastic
H2S	Hydrogen sulphide
PCB	Pollution control board
PESO	Petroleum Explosive and safety organization

1. Project Title:

Municipal solid waste Processing facility for conversion of biodegradable waste to Biogas/Bio CNG.

2. Project type/Technology:

Green Initiative project, with the technology developed by Mahindra Waste To Energy Solutions Ltd.

3. Name & address of the contact person/organization:

Mr. P. Palaniappan,

CEO,

Mahindra Waste to Energy Solutions Ltd.,

2nd Floor, Gate No:2, Akruli Road, Kandivali, Mumbai – 400101.

Registered Office:

Mahindra Waste to Energy Solutions Ltd.

Mahindra Towers, G. M. Bhosale Marg,

P. K Kurne Chowk, Worli Mumbai,

Mumbai City MH 400018 IN.

4. Place of implementation:

Survey No: 731, Tukivakam Village,

Renigunta (mandal), Chittor (Dt),

Andhra Pradesh- 517502.

(North: Survey no 731-1, South: Peddacheruvu Bund, East : Survey No: 731-3, West : Survey No: 731)

5. Project Objectives:

Broad Objectives:

Energy is the mainstay of our standard of living, economy, and national security. Clean forms of energy are needed to support sustainable global economic growth while mitigating impacts on air quality and the potential effects of greenhouse gas emissions. Our growing dependence on foreign sources of energy threatens our national security. As a nation, we must work to reduce our dependence on foreign sources of energy in a manner that is affordable and preserves environmental quality. The solid waste which goes for land fill will be utilized to generate the biogas.

Biogas technology provides an alternate source of energy in India, and is hailed as an archetypal appropriate technology that meets the basic need for cooking fuel in rural and urban areas. Using local resources, viz. food waste, cattle waste, vegetable and other organic wastes, energy and manure are derived. Realization of this potential and the fact that India supports the largest cattle wealth led to the promotion of National Biogas Programme in a major way in the late 1970s as an answer to the growing fuel crisis. As an extension of technology, Mahindra in the process of developing alternate fuel technologies for rural and urban India for quite long time.

Mahindra with their engineering prowess has proved the benefits and unexplored potentials of biogas utilisation by installing the Mahindra World City biogas plant with purification system to produce bio-CNG gas which is equal to CNG gas to be utilised in vehicles and also tractors. While the nutrient rich slurry has been converted to organic by bio composting for farming.

As a part of the expansion plan Mahindra wished to carry forward the goodness and learnings of Biogas technology to Tirupati for their next project. Tirupati project is a 40 ton/day plant with state of technology, which is readily scaled up to 2 times to the previous plant. With this proven track record Mahindra implemented this project with the same technology implemented with their previous projects. After chennai, with a 20 TPD capacity, Indore Bio CNG facility was established under the viable gap funding model along with the Indore Nagar Nigam & Indore smart City Development Ltd, where municipality is supplying the segregated organic waste from Choithram Mandi to this scientific processing centre and Mahindra Waste to Energy Solutions Ltd is processing and producing Bio-CNG and Organic manure. The Bio-CNG generated at Indore plant is used for operating city buses as a transport fuel & kitchen application as a replacement of commercial LPG. These waste processing plants are substantially decreasing the amount of land filling, especially bio-degradable waste, which otherwise pollute the environment and produce greenhouse gasses (GHG) which is responsible for the climate change.

Bio-degradable waste management is to prevent green House Gas as far as possible, any damage to the environment caused by land filling such as pollution of surface water, ground water, soil, air and the production of greenhouse gasses that contribute to climate change. Food waste is one of the single largest constituent of municipal solid waste stream. Food waste is highly biodegradable and has a higher volatile solids destruction rate (86-90%) than bio solids. This means that even though additional material is added to the digesters, the end residual will only increase by a small amount. Arguably, the most important reason that food waste should be

anaerobically digested is for capturing the energy content. Unlike bio solids and animal manures, post-consumer food scraps have had no means of prior energy capture. In fact, in a study done by East Bay Municipal Utility District it was revealed that food waste has upto three times as much energy potential as bio solids. Guided by our experience from the MWC project, we propose to use the well proven KVIC with model yet again with suitable agitation mechanism for better efficiency. While for upgrading the gas PSA system is proposed as it is proven to be more energy efficient.

6. Brief Outline of Biogas & its benefit potential

(a) Biogas

Biogas is a renewable energy source, it consists mainly of methane (CH_4) and carbon dioxide (CO_2) and is formed from the anaerobic bacterial decomposition of organic compounds, i.e. without oxygen. Biogas can be produced from various organic source such as food waste, agro farm waste, poultry waste, animal waste etc… Presently, biogas is mainly used for cooking purpose in India. To tap full potential of biogas, need emerges for its commercialization by making it transportable. Biogas technology is being seriously promoted as an important option to meet the growing energy demand of rural areas in developing countries. It provides a clean and efficient fuel for several end uses such as cooking, lighting, water pumping and other motive power applications. It also ensures the recycling of nutrients in the bovine dung and other biodegradable feed stocks to the soil. One of the promising applications of biogas is for mechanical power generation through internal combustion engines to drive pumps, generators, grinding mills and other equipment in rural areas.

Applications of anaerobic digestion have increased during the past 30 years. The process involves the treatment of agricultural and industrial wastes of varying types in the production of biogas. Interest in the anaerobic treatment of agro-industry wastes is increasing because it is economical, has lower energy requirements and is ecologically sound, may lead to environmental benefits, pollution reduction, energy production and improvements in agricultural practices among several other advantages, compared with aerobic treatment processes.

Large scale production of bio methane with advance technology of purification, transportation & filling will bring sustainability in rural renewable energy. This may be replicated in urban solid waste management. The biogas plant can be used at centralized as well as decentralized level. Biogas plant will contribute in reducing greenhouse pollutant emission from unregulated dumpsites. Biogas technology is a particularly useful system in the Indian rural economy, and can fulfil several end uses. The gas is useful as a fuel substitute for firewood, dung, agricultural residues, petrol, diesel, and electricity, depending on the nature of the task, and local supply conditions and constraints, thus supplying energy for cooking and lighting. Biogas systems also provide a residue organic waste, after anaerobic digestion, which has superior nutrient qualities over the usual organic fertilizer, cattle dung, as it is in the form of ammonia. Anaerobic digesters also function as a waste disposal system, particularly for human waste, and can, therefore, prevent potential sources of environmental contamination and the spread of pathogens. Small-scale industries are also made possible, from the sale of surplus gas to the provision of power for a rural-based industry, therefore, biogas may also provide the

user with income generating opportunities. The gas can be used to power engines, in a dual fuel mix with petrol and diesel, and can aid in pumped irrigation systems.

Apart from the direct benefits gleaned from biogas systems, there are other, perhaps less tangible benefits associated with this renewable technology. By providing an alternative source of fuel, biogas can replace the traditional biomass based fuels, notably wood. Introduced on a significant scale, biogas may reduce the dependence on wood from forests, and this might reduce pressure on forests however, is contestable.

Anaerobic digestion is a complex, natural, multi-stage process of degradation of organic compounds through a variety of intermediates into methane and carbon dioxide, by the action of a consortium of microorganisms. The interdependence of the bacteria is a key factor in the anaerobic digestion process. Instability during both the start-up and operation of the anaerobic degradation process can be problematic due to the low specific growth rate of the methanogenic microorganisms involved. The amount of one type of organic waste generated at a particular site at a certain time may not be sufficient to make anaerobic digestion cost-effective all year round. Co-digestion then becomes an interesting alternative as it is a well-established concept. Raw Material for biogas production:

- Municipal waste
- Food, fruit and vegetable waste
- Animal waste
- diary manure and biomass
- Agricultural residue
- Energy crops

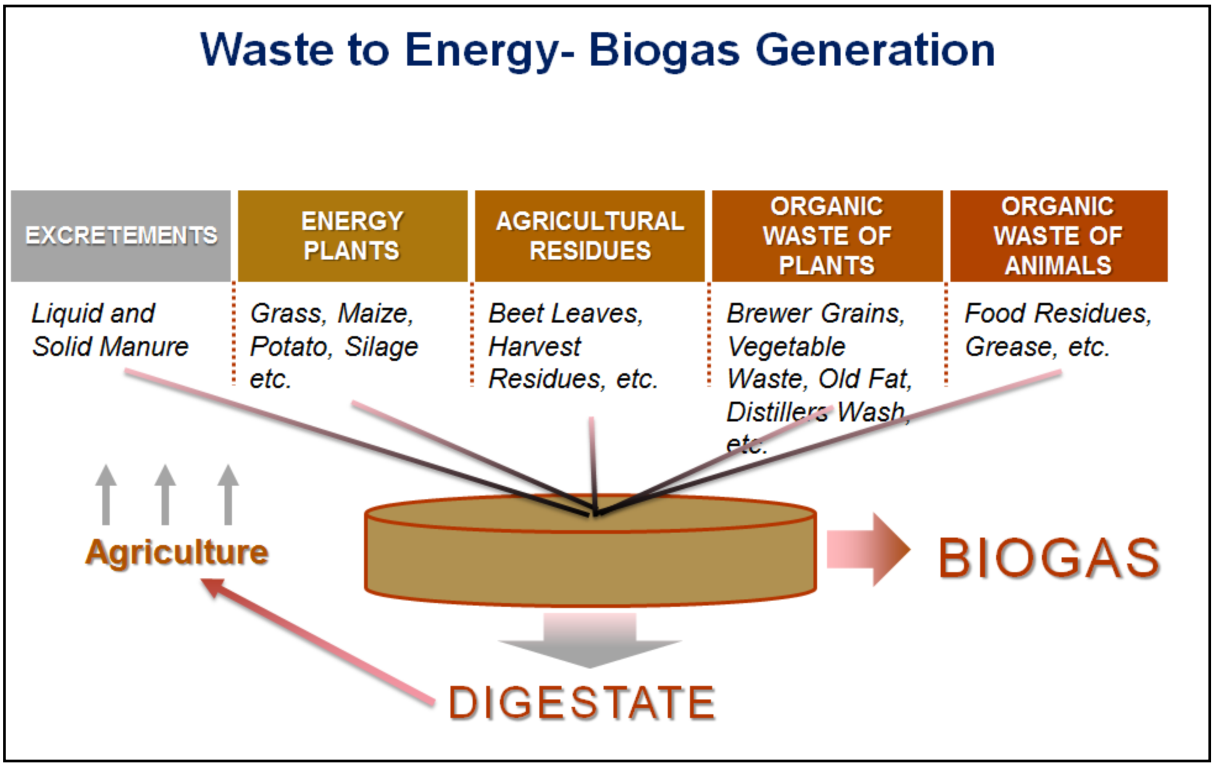


Fig 1. Biogas Generation from different raw material application

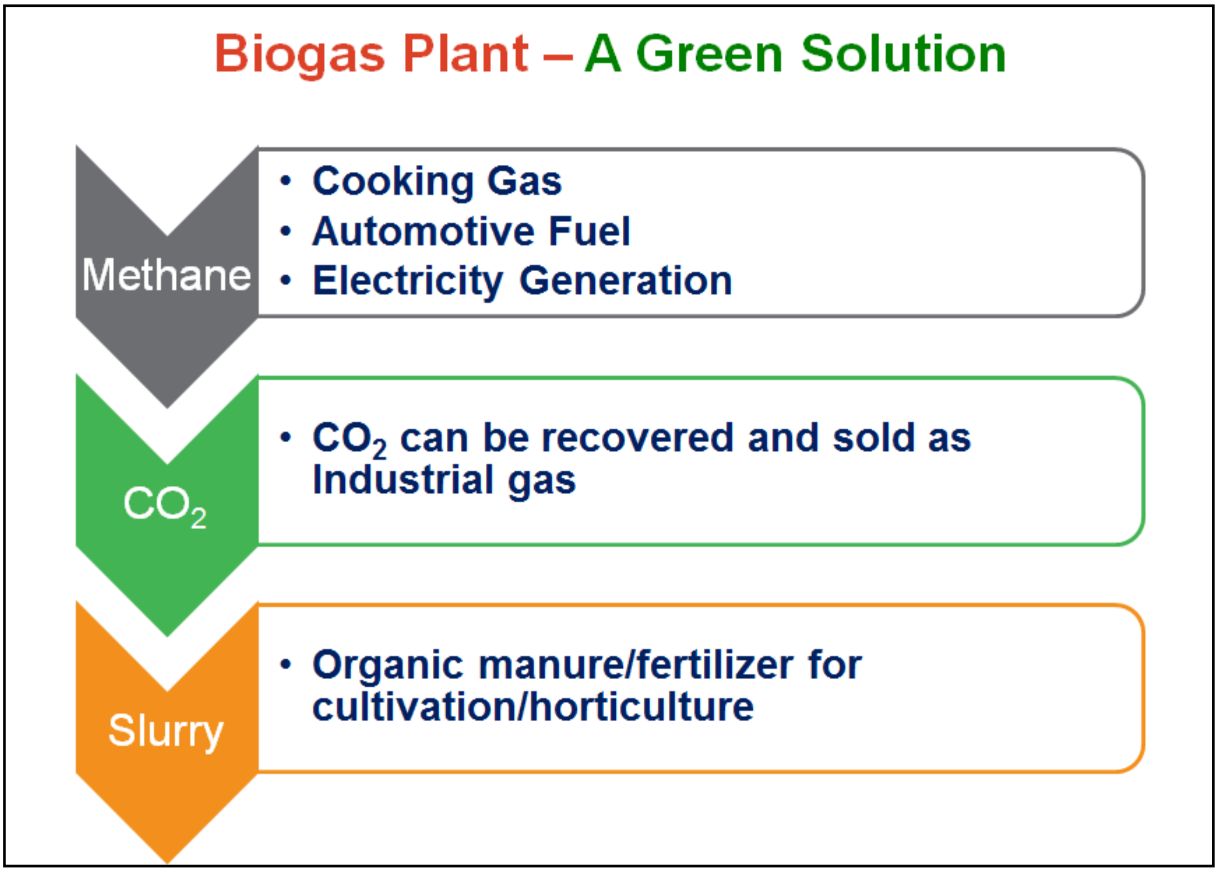


Fig 2. Biogas plant by products and its application

(b) . Green Products

There are mainly two products will produced from the plant. They are

1. Organic/ Bio manure
2. Biogas

Biogas plant slurry is an organic matter and it has rich nutrition content. Thus, the slurry can be de-watered or it can be mixed with garden waste to produce **Organic manure/fertilizer** for cultivation/horticulture. Manure is an excellent fertilizer containing nitrogen, phosphorus, potassium and other nutrients. It also adds organic matter to the soil which may improve soil structure, aeration, soil moisture-holding capacity, and water infiltration. Ever since agriculture has evolved, animal waste has been treated as a fertilizing element for the soil. The first step towards civilization was plantation and as time progressed, human beings developed new techniques of plantations and looked forward to improvise on the previous ones. It was a simple observation that the primitive man made, that led him to treat animal waste as manure.

To determine how much manure is needed for a specific application, the nutrient content and the rate nitrogen becomes available for plant uptake needs to be estimated. Nutrient content of manure varies depending on source, moisture content, storage, and handling methods. The principal value of manure is its extended availability of nitrogen of particular value in the more readily leached sandy soils. Manure is also helpful in improving soil fertility in cut areas from land levelling.

Nutrient content and rate of availability varies widely, depending mostly on manure source, handling methods, and water content. Fresh manure which includes both liquid and solid fractions with the least handling and then work in immediately after spreading will retain the most nitrogen. Today when the world has been piled up with

numerous new experiments and inventions, agriculture has not been untouched. New fertilizers with advanced features have flooded the national and international market and have challenged the traditional and old methods.

Fig 3. Organic Fertilizer

But the traditional methods are poised to stay for a longer run and thus organic manure retains its position strongly and effectively as it is not at all harmful for the soil and is best to use in today's polluted world front. With its long lasting effects, the organic manure will stay steady and stronger for longer.

Biogas can be converted into bio methane with the help of two steps; a cleaning process to remove the trace components and an upgrading process to adjust the calorific value. Upgrading is generally performed in order to meet the standards for use as vehicle fuel or for injection in the natural gas grid. A number of techniques are available for the up gradation of biogas. These techniques include chemical absorption method, high pressure water scrubbing, pressure swing adsorption, cryogenic separation and membrane separation method.

Thus this project is a green initiate and there will not be any discharge from the plant. Thus there will not be any leftover from the plant.

7. National Status of work done on similar area / topic:

Biogas has been used since around 1960's as household cooking fuel. More than 4 million biogas plants has been installed across the country through major 5 Year plans. The Khadi and Village Industries Commission (KVIC) was the sole agency promoting Biogas technology in India. Later during the 5th five year plan, NPBD (National Project on Biogas Development) was formed and after the formation of MNRE, NPBD was renamed as NBMMP (National Biogas and Manure Management Programme). Off-grid and de-centralised power generation has been in focus lately. Biogas generation and bottling plants 14 Nos. with an aggregate capacity of 23,116 cum/day have been sanctioned by MNRE.

The Government of India, recently approved the National Policy on Biofuels – 2018. This policy encourages to convert the Municipal waste into biofuels including Bio-CNG with lot of additional benefits like improved health, cleaner environment, reducing the dependency of the import fuel, creation of additional employment and encourages the municipalities to dispose the waste in scientific way.

Recently, State-run oil marketing companies Indian Oil Corporation (IOC); Bharat Petroleum Corporation (BPCL) and Hindustan Petroleum Corporation (HPCL) companies taking lead to buy back the Bio-CNG produced by the local players with minimum guaranteed price. The government aims to increase the contribution of gas in India's energy mix to 15% from the current 6.5%, surely Bio-CNG plants have role to reach these targets.

- Mahindra World City Biogas Plant, Mahindra World City – Chennai (Inaugurated by Hon. Minister of Coal Power and New and Renewable Energy Shri Piyush Goyal on 2nd January 2016) with a capacity of 1000 Cum/day

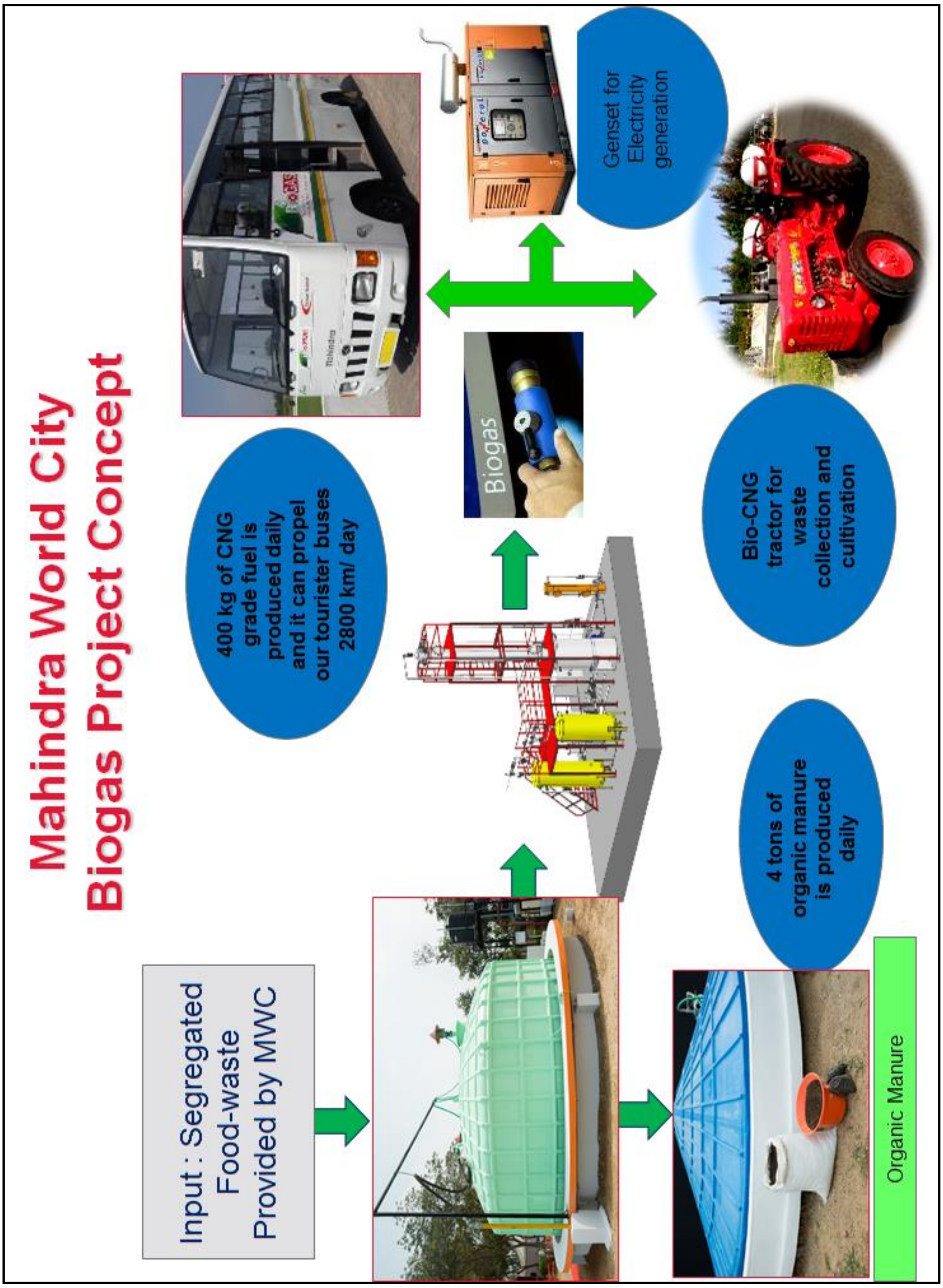


Fig 4. Mahindra world City project concept

Fig 5. Biogas digester with purification system

Fig 6. Biogas digester two stage

- Indore Smart city Development, Indore, Madhya Pradesh with the capacity of 2000 cum/day. Developed and operated by Mahindra Waste To Energy Solutions Ltd.

Fig 7. Indore Plant View

- Maharashtra Industrial Development Corporation (MIDC), Aurangabad, Maharashtra with capacity of 3000 cum/day. Developed and operated by Mahindra Waste To Energy Solutions Ltd.

Fig 8. Aurangabad (MIDC) Plant View

- Maltose Agri Products Pvt. Ltd., Doddaballapur, Dist. – Bangalore rural (Karnataka) with a capacity of 1000 cum/day.
- Ashoka Biogreen Pvt. Ltd. Talwade, Tahasil Trimbak. Dist.-Nasik (Maharashtra) with a capacity of 500 cum/day.
- Shashi Energies, Near Green Vally Public School, Ratiya Road Tohana, Tehsil.- Tohana, Dist.- Fatehabad (Haryana) with a capacity of 600 cum/day,

are among the commissioned plants producing purified biogas but then the gas produced in mostly consumed for power generation/cooking applications, application of purified Biogas as a vehicular fuel which can be more economical at the same time possess huge potential for greenhouse gas reduction. The rapid development of India's tremendous economy is following a path of exclusive fossil energy based growth or is diverting towards a sustainable integration of renewable energies into their energy consumption, is a question of how fast renewable energy companies are developing alternative concepts and how fast these concepts become technically, economically, socially accepted.

8. International Status of work done on similar area / topic

The world markets for biogas increased considerably during the last years and many countries developed modern biogas technologies and competitive national biogas markets throughout decades of intensive R&D complemented by substantial governmental and public support. The European biogas sector counts thousands of biogas installations, and countries like Germany, Austria, Denmark and Sweden are among the technical forerunners, with the largest number of modern biogas plants.

Important numbers of biogas installations are operating also in other parts of the world. In China, it is estimated that up to 18 million rural household biogas digesters were operating in 2006, and the total Chinese biogas potential is estimated to be of 145 billion cubic meters while in India approximately 5 million small-scale biogas plants are currently in operation. Other countries like Nepal and Vietnam have also considerable numbers of very small scale, family owned biogas installations.

Most biogas plants in Asia are using simple technologies, and are therefore easy to design and reproduce. On the other side of the Atlantic, USA, Canada and many Latin American countries are on the way of developing modern biogas sectors and favorable political frameworks are implemented alongside, to support this development.

Important research efforts combined with full scale experience are carried out around the world, aiming to improve the conversion technologies, the operational and process stability and performance. New digesters, new combinations of AD substrates, feeding systems, storage facilities and other equipment are continuously developed and tested.

Alongside the traditional AD feedstock types, dedicated energy crops for biogas production were introduced in some countries and the research efforts are directed towards increasing productivity and diversity of energy crops and assessment of their biogas potential.

Cultivation of energy crops brought about new farming practices and new crop rotation systems are about to be defined, where intercropping and combined crop cultivation are subject of intensive research as well. Utilisation of biogas for combined heat and power production (CHP) is a standard application for the main part of the modern biogas technologies in Europe. Biogas is also upgraded and used as renewable

biofuel for transport in countries like Sweden, Switzerland and Germany, where networks of gas upgrading and filling stations are established and operating. Biogas upgrading and feeding into natural gas grid is a relatively new application but the first installations, in Germany and Austria, are feeding "bio methane" into the natural gas grids. A relatively new utilisation of biogas, in fuel cells, is close to the commercial maturity in Europe and USA. Integrated production of biofuels (biogas, bioethanol and biodiesel) alongside with food and raw materials for industry, known as the concept of bio refineries, is one important research area today, where biogas provides process energy for liquid biofuel production and uses the effluent materials of the other processes as feedstock for AD. The integrated bio refinery concept is expected to offer a number of advantages related to energy efficiency, economic performance and reduction of GHG emissions. A number of bio refinery pilot projects have been implemented in Europe and around the world, and full scale results will be available in the years to come.

Biogas no longer is a by product of landfill or waste water treatment it has proved the capability to be a standalone source of renewable energy. Biogas production from available waste has been used worldwide for power generation CHP (Combined heating and Power generation) or as automotive fuels. Germany and Sweden has been in the technology frontier in Biogas Technology. Biogas in Germany is used mainly for electricity production, while in Sweden the primary use is vehicle fuel.

In the farm sector Valtra owned by the AGCO Corporation has introduced Biogas tractor has introduced concept tractor N 101 which can operate on biogas in the dual fuel mode. Wherein the primary fuel can be either diesel or biodiesel and purified biogas is used as the secondary fuel. At the same time under the Steyr brand, CNH

Global N.V., a worldwide manufacturer of agricultural and construction machinery majority-owned by Fiat S.p.A., has presented what they say is the first production tractor powered by natural gas which has a dedicated turbocharged monofuel natural gas engine made by FPT (Fiat Power Train),the Steyr Profi 4135.

The existing biomass resources on our planet can give us an idea of the global potential of biogas production. This potential was estimated by different experts and scientists, on the base of various scenarios and assumptions. Regardless the results of these estimations, the overall conclusion was always, that only a very small part of this potential is utilised today, thus there is a real possibility to increase the actual production of biogas significantly.

9. Identification of gaps & Need of the project

Biogas gas generation technology is a mature technology but the biogas enrichment technology needs to be proven for its consistency in large scale operation. Further research in this area is most essential to drive the purification technology to mainstream of biogas arena. Mahindra Waste to Energy Solutions Ltd, has demonstrated the value and potential of biogas for various utilisation at Indore Municipality. An integrated scientific waste management facility is the most viable solution to alleviate the waste issue in the country. Each waste stream is treated scientifically and environmentally friendly way to ensure the maximum energy recovery, which would otherwise cause serious public health and environmental damage. Biogas usage as a cooking fuel is a very primitive way and is well established in the rural areas of our country, taking this further replacing LPG with biogas is possible with the available technology and urban usage of biogas as cooking fuel can be thus made possible. This

also helps to replace subsidised fuel with energy efficient sustainable fuel at lower price compared to LPG.

Various countries have developed or adapted international standards for bio-CNG as a transport fuel and in India, policy and regulations need to be adapted to internal standards or develop one to meet the local requirement, so that bio-CNG can be introduced in the commercial public transportation as fuel. The below figure illustrates the benefit of Bio-CNG as a vehicular fuel.

CO_2 Equivalent emissions / MJ

CARB LCFS Carbon Intensity Reductions for Natural Gas:

Light-Duty Vehicles	Carbon Intensity of Fuel gC02e/MJ	EER	Total	Reductions Relative to Gasoline
Gasoline (baseline - CA RFG w/ EtOH mix)	95.86	1	95.9	NA
CNG ICE	68	1	68	29%
Biomethane CNG ICE	11.26	1	11.26	89%
CNG 20% Biomethane ICE	56.602	1	56.6	41%

Heavy-Duty Vehicles	Carbon Intensity of Fuel gC02e/MJ	EER	Total	Reductions Relative to Gasoline
Diesel Fuel	94.71	1	94.7	NA
CNG ICE	68	0.9	75.6	20%
Biomethane CNG ICE	11.26	0.9	12.38	87%
CNG 20% Biomethane ICE	56.602	0.9	62.9	34%

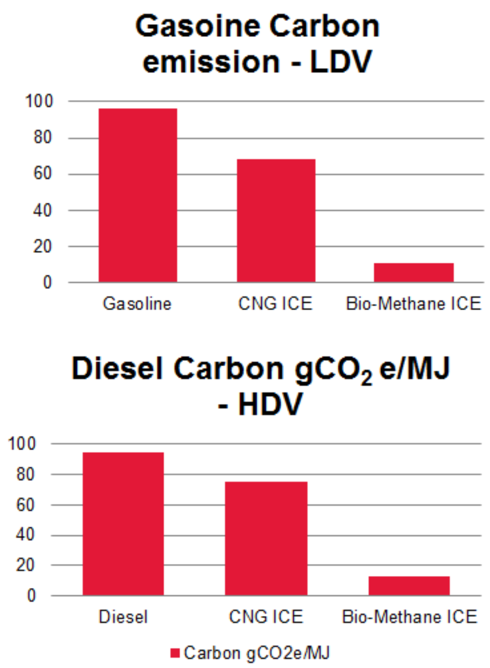


Fig 9. Emission advantage with Biogas Engine

Few attempts are made to produce, enrich and utilise biogas as a cooking fuel, however this needs to be investigated and explored further. The plan includes collection of food waste and utilising the same for biogas production and the purified biogas will be filled in small cascades and send to hotels for using the gas for cooking purpose, with biogas stove.

10. Implementation chart/ Work Methodology:

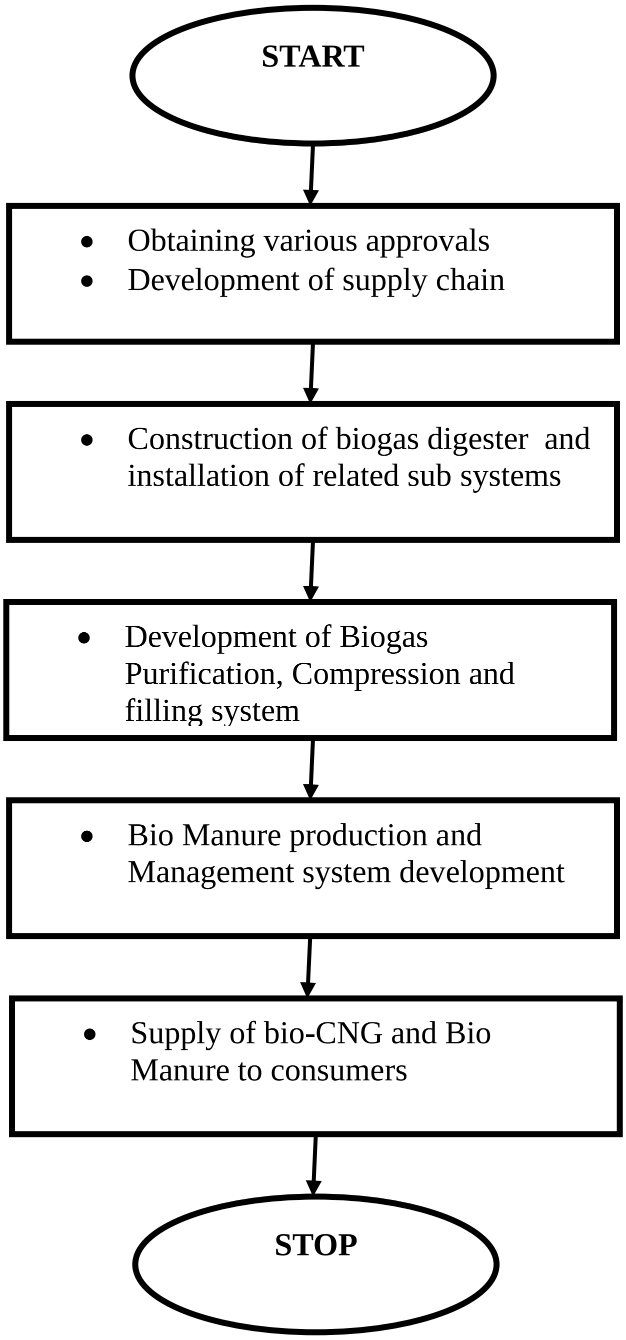


Fig 10. Project Flow chart

11.Action Plan proposed for project duration

Activities	**0-1 months**	**1-3 months**	**4 Months**
• Obtaining various approvals such as PCB, PESO, local Panchayat, fire safety etc… • Designing the biogas Digester, purification and bottling system as per maximum designed capacity. • Development of the supply chain system for waste collection, segregation and feeding system and also the gas supply and utilisation. • Sign off agreement with raw material suppliers and estimation of maximum feeding capacity.	✓		
• Construction of biogas digester and fabrication and installation of purification and bottling system. • Development of cascade for CNG filling and gas supply and dispensing system for filling multiple cascades • Development of facilities for generation of organic manure		✓	
• Production of Enriched biogas for cooking application and supply consumers • Generation of bio manure and supply to consumers			✓

12.Technology for Project:

The main aim of the project is to incorporate competent biogas technology and implementation to support the rural India by setting up of field scale biogas plant; to be located based on the continuous availability of raw material. Anaerobic digestion is the prominent technology used for degradation of biodegradable organic waste. Anaerobic Digestion (AD) is a biological process that happens naturally when bacteria breaks down organic matter in environments with little or no oxygen. It is effectively a controlled and enclosed version of the anaerobic breakdown of organic waste in landfill which releases methane.

An anaerobic digestion system is the central processing plant that converts the organic waste slurry into Biogas, which is further converted into Compressed Bio gas (CBG) /Electricity. Waste water from the system is re-circulated to ensure zero fresh water requirement or discharge. By-product generated from the process will be nitrogen rich, organic fertilizer that replaces conventional chemical fertilizers for farming and gardening purpose. There are a number of bacteria that are involved in the process of anaerobic digestion including acetic acid-forming bacteria (acetogens) and methane-forming archaea (methanogens). These organisms feed upon the initial feedstock, which undergoes a number of different processes converting it to intermediate molecules including sugars, hydrogen & acetic acid before finally being converted to biogas. The operations will be done in continuous mode. Every day waste will be received and processed. The waste will be fed into the digester during 24 hours in a distributed mode depending on the arrival of waste from the source.

This project also aims at creating an eco system to provide green energy where the collection of waste material for generation of bio-CNG and organic fertilizer can be decentralised to help the local villagers and farmers as per their need. Field scale plant will be installed at the site in collaboration with the villagers.

a. Anaerobic Digester (AD)

Production of methane-rich biogas through the AD of organic materials provides a versatile future of renewable energy. Biogas is generated when bacteria degrade biological material in the absence of oxygen; in a process known as anaerobic digestion. Since biogas is a mixture of methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide and traces of water vapour. It is a renewable fuel produced from waste treatment. Anaerobic digestion is basically a simple process carried out in a number of steps by many different bacteria that can use almost any organic material as a substrate – it occurs in digestive systems.

AD is a biochemical degradation process, in which biodegradable organic matters are decomposed by bacteria forming gaseous byproduct. The byproduct is consisting of methane (CH_4), carbon dioxide (CO_2), and traces of other gases. AD can be divided into four stages:

i. Hydrolysis,
ii. Acidogenesis,
iii. Acetogenesis or Dehydrogenation and
iv. Methanation

In the first stage the hydrolyzing microorganisms converts the polymers and monomers into acetate, hydrogen and some amount of volatile fatty acid (VFA) such as butyrate and propionate. Then a complex consortium of hydrolytic microorganisms

excretes the elements of organic materials such as cellulose, cellobiase, xylanase, lipase, protease and amylase into amino acids and long chain fatty acids. Bacteriocides, Clostridia, Bifidobacteria, Streptococci and Enterobacteriaceae are some common bacteria that are found in the digester. The different stages of AD are shown in Figure. The higher VFA that are formed by hydrolysing microorganisms are again converted into acetate and hydrogen by obligate hydrogen producing acetogenic bacteria. These bacteria typically characterized as homoacetogenic named as Acetobacterium woodii and Clostridium aceticum.

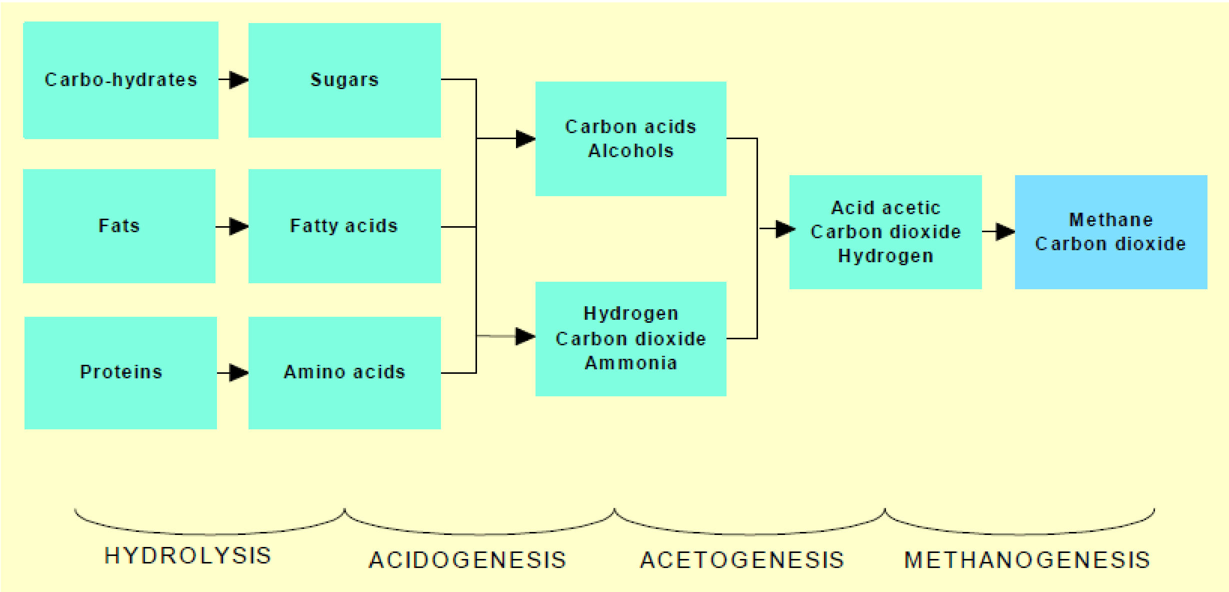


Fig 11. The main process steps of AD

The metabolism of acetogenic bacteria is inhibited rapidly by the hydrogen accumulation. Therefore, it is essential to maintain an extremely low partial pressure of hydrogen inside the digester for the survival of acetogenic and hydrogen producing bacteria. The daily biogas production can also be increased by adding hydrogen producing bacteria to the digester slurry. At the end of biochemical degradation process two groups of bacteria produce CH4 or hydrogen and CO2 from acetate. During AD only a few species e.g. Methanosarcina barkeri, Metanonococcus mazei, and Methanotrix

soehngenii are able to degrade acetate into CH_4 and CO_2, whereas all other bacteria use the hydrogen to form CH4.

Parametric Influence on Biogas Production:

Several mechanical, thermal, chemical and biological pre-treatment methods have been considered to improve the performance of digester by easy accessible of intermolecular matters to anaerobic micro bacteria. The stability of the process and the rate of gas production depend upon the temperature, pH balance, carbon/nitrogen (C/N) ratio, hydraulic retention time (HRT) and organic feed rates.

CH_4 and CO_2 are the principal gases that are produced during the process of digestion. Small amount of hydrogen sulphide (H_2S) is also produced, which can be characterized by the order of the digester gas. The optimized methane gas production is dependent on the rate of optimized decomposition. Anaerobic bacteria communities can endure temperatures ranging from below freezing to above 57.4 ^{o}C, but they thrive best at temperatures of about 36.9 ^{o}C, (mesophilic) and 54.6 ^{o}C (thermophilic). Bacteria activity, and thus biogas production, falls off between about 39.6 ^{o}C, and 51.9 ^{o}C and gradually from 35.2 ^{o}C to 5 ^{o}C. For the optimum growth of the microbes during anaerobic digestion, the suitable pH level of 6.5 to 7.5 has to be maintained by feeding the digester at an optimum loading rate. The amount of CO_2 and VFAs produced during the process of digestion affects the pH of the digester slurry. For normal digestion, the concentration of VFA and acetic acid in the feed stock should be below 2000 mg/lit. The pH level of 6.5.0-7.5 gives higher CH4 production of 75%. During AD microorganisms utilize carbon 25-30 times faster than nitrogen. High C/N ratio indicates low biogas production. Similarly low C/N ratio indicates accumulation of ammonia that increases the pH level of the digested slurry more than 8.5. Thus, to meet this requirement, microbes need 20-30:1 ratio of C to

N. HRT is the average time spent by the input feed stock inside the digester before it comes out. Generally the HRT depends upon the tropical climate condition. Shorter HRT is likely to face risk of less active bacterial action while longer HRT requires larger volume of digester and hence requires high capital investment. For mesophilic digestion where temperature varies from 25-40 ^{o}C the HRT is greater than 20 days.

The stability of the AD process is reflected by the concentration of intermediate products like the VFA. The VFA are intermediate compounds (acetate, propionate, butyrate, lactate), produced during acidogenesis, with a carbon chain of up to six atoms. In most cases, AD process instability will lead to accumulation of VFA inside the digester, which can lead furthermore to a drop of pH-value. However, the accumulation of VFA will not always be expressed by a drop of pH value, due to the buffer capacity of the digester, through the biomass types contained in it. Animal manure e.g. has a surplus of alkalinity, which means that the VFA accumulation should exceed a certain level, before this can be detected due to significant decrease of pH value. At such point, the VFA concentration in the digester would be so high, that the AD process will be already severely inhibited.

Practical experience shows that two different digesters can behave totally different in respect to the same VFA concentration, so that one and the same concentration of VFA can be optimal for one digester, but inhibitory for the other one. One of the possible explanations can be the fact that the composition of microorganism populations varies from digester to digester. For this reason, and like in the case of pH, the VFA concentration cannot be recommended as a stand-alone process monitoring parameter.

The amount of manure fed into a digester each day has an important effect on its operation. This is measured by volume added in relation to the volume of the digester,

but the actual quantity fed to the digester also depends on the temperature at which the digester is maintained. In order to determine the unit size of a biogas unit, the following mathematical equation must be achieved:

Digester size (m^3) = Daily feed-in (m^3 day-1) × Retention time (day)

The digester size can be defined as the total size of the biogas unit, which includes the effective size of any volume occupied by the fermented material and the volume of gas storage. Size of the daily feed-in is the size of a mixture of raw material with water added to the digester once daily or several times and the average concentration of total solids of 10%, where mixing the organic wastes with water depends on its water content. In the case of wet animal wastes, such as manure the proportion of mixing is 1:1. Generally, Storage capacity has to be calculated by average live weight of animals kept in husbandry systems, amount of added water, periods of no fertilization of crops, and the animal species.

In order to plan a biogas plant and to design a digester, several design parameters must be determined which are: ratio of gathered waste from manure to total waste, quantity of daily liquid organic matter deposition into the digester, hydraulic retention time, density and quantity of daily dry organic matter deposition into the digester. The aforementioned design parameters are used to determine the total volume of the materials that are intended to be stored in the tank and are equal to the internal volume of the tank. Additionally, the gas holder design should take into consideration that a part of the tank (about 10%) is empty and the gas may not fill it, because it is the place where the gas holder clearance volume on the floating water accumulate. Even in case of

designing other storage tanks (e.g. liquid organic matter tank) it is required to leave 10% of the tank volume empty.

Biogas can be stored at low, medium, and high pressures. The density of biogas is approximately 1.2 kg/m3, which is proximate to air at ambient condition . Hence, it requires a larger volume to store instead in compressed form. The critical pressure and temperature is of 75-98 bar and -82.5 oC. This indicates that it can change its gaseous phase to liquid phase, when compressed up to the critical state. Basically, methane is the main constituent in biogas to make it energy equivalent. Biogas contains CO2 19% by volume, 37.38% by mass and H2S 20 ppm by volume basis. Biogas can be transportable via pipeline or by cylinders only after removing CO2, H2S and water vapour.

b. Gas Enrichment

Biogas which is a clean and environmental friendly fuel emerged as one of the potential alternative fuels. Raw biogas contains about 60-70% methane (CH4), 30-40% carbon dioxide (CO2), traces of hydrogen sulphide (H2S) and fractions of water vapours. But its wide spread use is hampered by the associated problems like low energy density due to the presence of impurities, generation at low pressures and the absence of means for storing and transporting. In this context this work intends to design and establish a facility at the site of biogas production in the campus for purifying, compressing, bottling and making it transportable.

There are three steps to upgrading biogas to bio-methane. They are:

i. Removal of hydrogen sulphide,

ii. Removal of moisture, and

iii. Removal of carbon dioxide.

The simplest way to remove moisture is through refrigeration. The processes are presented roughly in the order of their current availability for and applicability to biogas upgrading. Some technologies are more suitable than others, typically because of cost considerations, ease of operation, and other concerns such as possible environmental effects.

A variety of processes are being used for removing CO2 from natural gas in petrochemical industries. Some of them will also remove H2S. Several basic mechanisms are involved to achieve selective separation of gas constituents. These may include physical or chemical absorption, adsorption on a solid surface, membrane separation, cryogenic separation and chemical conversion. The following processes can be considered for CO2 removal from biogas. :

- Water scrubbing
- Pressure swing adsorption
- Chemical scrubbing with amines
- Chemical scrubbing with glycols
- Membrane separation
- Cryogenic separation
- Other processes

The technologies available for removal of CO2 from biogas are typically used for larger scale applications such as upgrading natural gas from “sour” gas wells, sewage treatment plants, and landfills. Because of the different contaminants, scales, and applications, removal of CO2 from dairy manure biogas will differ significantly from these applications and requires a case-by-case analysis.

Biogas can be stored as compressed biomethane (CBM) after purification. At high pressure storage gas scrubbing is important because impurities like H2S and water vapor are likely to condense and cause corrosion. After removal of CO2, H2S and water vapor from the biogas, the product remains is called as biomethane.

13. Feed Stock Availability

A concession agreement has been arrived the Tirupati municipality for supplying the segregated municipal waste to the plant. All kind of wet waste can be utilised in Biogas plant for the production of Bio- CNG and organic fertiliser are as followed

1. Market Waste
2. Market Vegetable waste
3. Kitchen Waste
4. Fruit Waste
5. Press Mud from Sugar manufacturing Industries
6. Silkworm Waste
7. Agricultural Residue
8. Dairy manure

14. Development of Biogas and bio-manure plant.

The following activities are involved in the development of biogas plant.

i. **Feed Preparation**:

Collection of source segregated waste to be screened before fed into the conveyor for grinding the food waste. The crushing process is implemented prior to the anaerobic digestion in order to increase the surface area and to promote an accelerated degradation of the organic matters.

Similarly the poultry litter has to be thoroughly mixed and the calcium needs to be removed before fed into the digester. The food waste and the poultry litter needs to be thoroughly mixed before fed in to the digester.

From a microbiological point of view, the ideal situation for a stable AD process is a continuous flow of feedstock through the digester. In practice, the feedstock is added quasi continuously to the digester, in several batches during the day. This saves energy as feeding aggregates are not in continuous operation. There are various feeding systems and their selection depends again on feedstock quality, herewith their pumpability and on feeding intervals.

Special attention must be paid to the temperature of the feedstock which is fed into the digester. Large differences between the temperature of the new feedstock and the operation temperature of the digester can occur if the feedstock has been sanitised (up to 130°C) or during winter season (below 0°C). Temperature differences disturb the process microbiology, causing losses of gas yield and must therefore be avoided.

There are several technical solutions to this problem, such as using heat pumps or heat exchangers to pre-heat /cool the feedstock before insertion in the digester. Thus the feed collection and grinding and feed preparation systems play a major role.

ii. **Digester:**

Biogas is produced by the biological degradation of the substrates that takes place in the first and second stage digesters. Under anaerobic conditions, temperature around 35°C and a continuous mixing, biogas is being produced by the conversion of the dissolved organic matters. The basic KVIC model biogas digester with water sealing technology along with agitation mechanism has been proved to be efficient from our past experience in Mahindra World City. The digester to be designed for daily feeding

capacity of 40 Tons. The agitator plays a major role in the digester to avoid the bottom settling as well as crest formation. A minimum stirring of biomass inside the digester takes place by passive stirring. This occurs by insertion of fresh feedstock and the subsequent thermal convection streams as well as by the up-flow of gas bubbles. As passive stirring is not sufficient for optimal operation of the digester, active stirring must be implemented, using mechanical, hydraulic or pneumatic equipment. Up to 90% of biogas plants use mechanical stirring equipment.

The digester content must be stirred several times per day with the aim of mixing the new feedstock with the existing substrate, inside the digester. Stirring prevents formation of swimming layers and of sediments, brings the micro-organisms in contact with the new feedstock particles, facilitates the up-flow of gas bubbles and homogenises distribution of heat and nutrients through the whole mass of substrate. In the proposed plant the mechanical and hydraulic agitations will play a major role in avoiding the above said problem.

Fig 12. Biogas digester system

iii. Purification System:

Biogas can be converted into bio methane with the help of two steps; a cleaning process to remove the trace components and an upgrading process to adjust the calorific value. Upgrading is generally performed in order to meet the standards for use as vehicle fuel, bottling application or for injection in the natural gas grid. A number of techniques are available for the up gradation of biogas.

These techniques include chemical absorption method, high pressure water scrubbing, pressure swing adsorption, cryogenic separation and membrane separation method.

Purification system play a major role in generating the gas which is equivalent to the grade specified by BIS. Development of purification system to be done by identified supplier. The system is cost effective and the purity level of the gas should be maintained as per IS 16087 norms and should satisfy PESO requirement of gas cylinder rule 23.

H_2S & CO_2 and moisture content will be removed from biogas.

Fig 13. Purification system

iv. **200 Bar Compressor Gas Compressor:** It is proposed to an ATX proof robust compressor by considering the durability and safety. Procurement of Bio-CNG compressor will be from an identified supplier.

Fig 14. Bio-CNG high pressure Compressor

v. Cascade Gas storage and Filling:

Gas storage and system integration work will be done by identified supplier. The standard Industrial grade cylinders certified by PESO will be used for gas storage.

Fig 15. Bio-CNG storage Balloon and Gas filling

vi. Bio-manure Production

A biogas plant is not only a supplier of energy. The digested substrate, usually named digestate, is a valuable soil fertiliser, rich in nitrogen, phosphorus, potassium and micronutrients, which can be applied on soils with the usual equipment for application of liquid manure. Compared to raw animal manure, digestate has improved fertiliser efficiency due to higher homogeneity and nutrient availability, better C/N ratio and significantly reduced odours. Digestate is a very complex material therefore its using has effect on the wide range of physical, chemical and biological properties of the soil, depending on the soil types. The recycled organic wastes are suitable for contribution to maintain the soil nutrient levels and soil fertility. From the production of feedstock to the application of digestate as fertiliser, the biogas from AD provides a closed nutrient and carbon cycle. The methane (CH4) is used for energy production and the carbon dioxide (CO2) is released to the atmosphere and re-uptaken by vegetation during photosynthesis. Some carbon compounds remain in the digestate, improving the carbon content of soils, when digestate is applied as fertiliser. Biogas production can be perfectly integrated into conventional and organic farming, where digestate replaces chemical fertilisers, produced with consumption of large amounts of fossil energy.

Plants, animals and humans require trace amounts of some heavy metals like copper (Cu), zinc (Zn), while others like cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb) are toxic for them. Heavy metal content of the feedstock usually originates from anthropogenic source and is not degraded during AD. The main origins of the heavy metals are animal feed additives, food processing industry, flotation sludge, fat residues and domestic sewage.

The slurry from the plant will be used to produce organic manure. Initially the slurry will be separated for liquids and the separated liquids will be recirculated back to the plant. The solids separated from the plant as well as the portion of liquid slurry will be used to produce the organic manure along with the agri waste. The organic manure is a cost effective and eco-friendly replacement to conventional chemical fertilizers used for gardening and landscape purpose.

15. Plant Capacity

- The digestion capacity of the proposed biogas plant will be 4000 m3/day.
- Gas production capacity: The plant can process 40 tons of market waste & kitchen waste daily and it will produce around 4000 cum of raw biogas daily. The raw biogas will be further enriched to meet the gas quality equivalent to the standards specified by BIS. After purification the final output of the Bio-CNG will be around 1680 kgs/ day.
- Organic Manure: The expected organic manure production from the plant is around 3.5 tons/day.

9. Budget Estimation:

Budget Estimation			
Sl.No	**Description**	**Qty**	**Budget in Lakhs**
1	Raw Material conveyor (5 tons/hr)	4 Nos	40
2	Raw material grinder (5 tons/hr)	3 Nos	37
3	Feed preparation tank	1 Nos	7
4	Feed preparation – Food Waste & homogeneous mixing tank	1 Nos	7
5	Raw material feeding system	1 Nos	6
6	Two stage anaerobic digester with of 40 tons/day capacity with FRP floating gasholder with water sealing system.	2 Nos	249
7	Slurry collection tank	1 No	16
8	Slurry de watering system	1 No	19
9	Biogas balloon 500 cum capacity	1 No	30.54
10	Biogas enrichment system of 300 cum/hr capacity	1 No	109.2
11	Biogas Compressor 120 cum/hr	2 No	85.1
12	Solid liquid separator	1 No	15
13	Gas filling station	1 No	3.63
14	Shredder machine	1 No	7
15	Compost sorting and Sieving machine	1 No	13.54
16	Agitators	6 Nos	27.6
17	Biogas flow meter	1 Nos	3
18	Online monitoring system – digester PH, Temperature, gas CH_4, CO_2, H_2S, Moisture	1 No each	13
19	Plant instrumentation, EB and low cost automation		7.68
20	DG	1 nos.	7.87
21	Fire Safety Equipments	9 nos.	0.4
22	Earth Mover	1 no.	6.06
23	Crane	1 nos.	25
24	Belt conveyor	1 nos.	15
25	Office room, Electrical room, Compost platform	1 No	27.01
	Total		**777.63**

10.Financial Analysis

Gas Generation & Availability Calculation		
Sl.No.	**Description**	**Gas**
1	Raw Biogas generation capacity	4000Cu m/Day
2	Bio- CNG production /day with 90% system efficiency	1680kgs/Day
3	Gas available for sales	1680kgs/Day
4	Manure production	3.5 Tons/Day

a. Revenue calculations:

1	Revenue from gas/year @Rs.46/kg	270
2	Revenue from Manure/year Rs.3.5/kg	43
3	Total revenue by selling the products/year	313 lakh/year

b. Expenditure calculations

S.No	OPERATION AND MAINTENANCE	Per year in lakhs
1	Minimum 13 operators to run the plant @ Rs.17.5k	27.3
2	2 supervisors @ Rs.25k	6
3	3 Purification operators (diploma in Mechanical Engineering.) @Rs.30 k	10.8
4	1 Maintenance Engineer (diploma in Electrical Engineering) @ Rs.30k	3.6
5	Mechanical wear & Tear - The engine AMC, oil, and other routine maintenance should be carried out by the bidder.	24
6	Periodic compost analysis report- Monthly basis.	1.8
7	Electricity 200 KW/hr @ 17 hrs/day Rs.7/unit price	30
8	Water charges	3
9	Diesel charges/JCB rental charges	15
10	Administrative charges	7.8
	Total Expenditure / annum	129.3

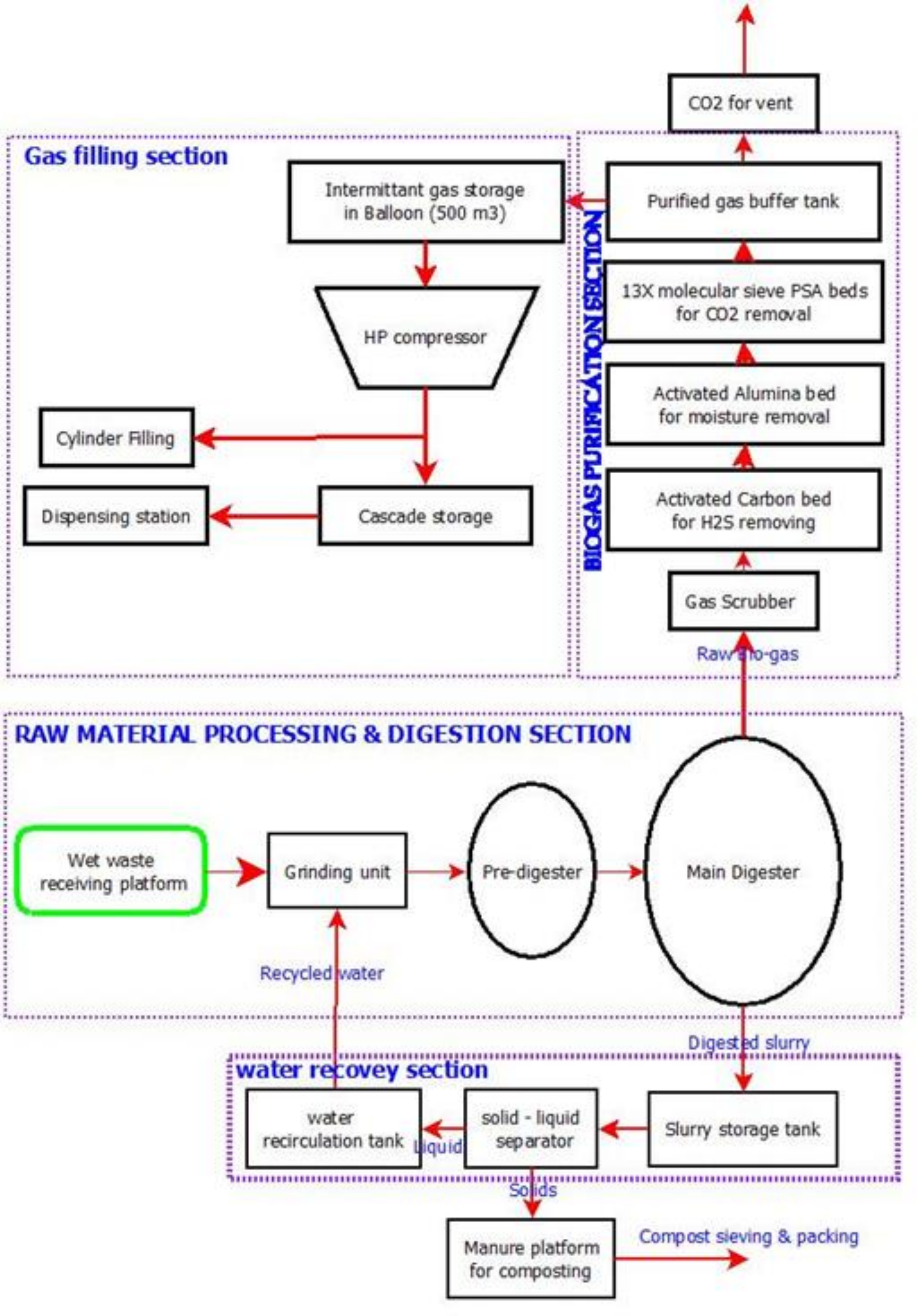
c. Payback Calculations

Sl. No	Description	Cost in lakhs
1	Revenue	313
2	Expenditure	129
3	Interest @ 7.45% for capital investment	57.961
4	Profit before tax	126.04
5	Net profit by considering 10 years tax holiday	126.04
6	Total Payback approximately	6.2 Years

In the above calculations' followings were not included,

1. All Government taxes for Raw material purchase and output product sales (Gas and Manure).
2. Service provider – service tax not included.
3. Government approvals and consultation charges.
4. Land Lease rent charges
5. Expense escalations year on year.
6. Vehicles for waste collection and distribution.
7. **Gas filling storage Cascades Rent charges.**

APPENDIX-I

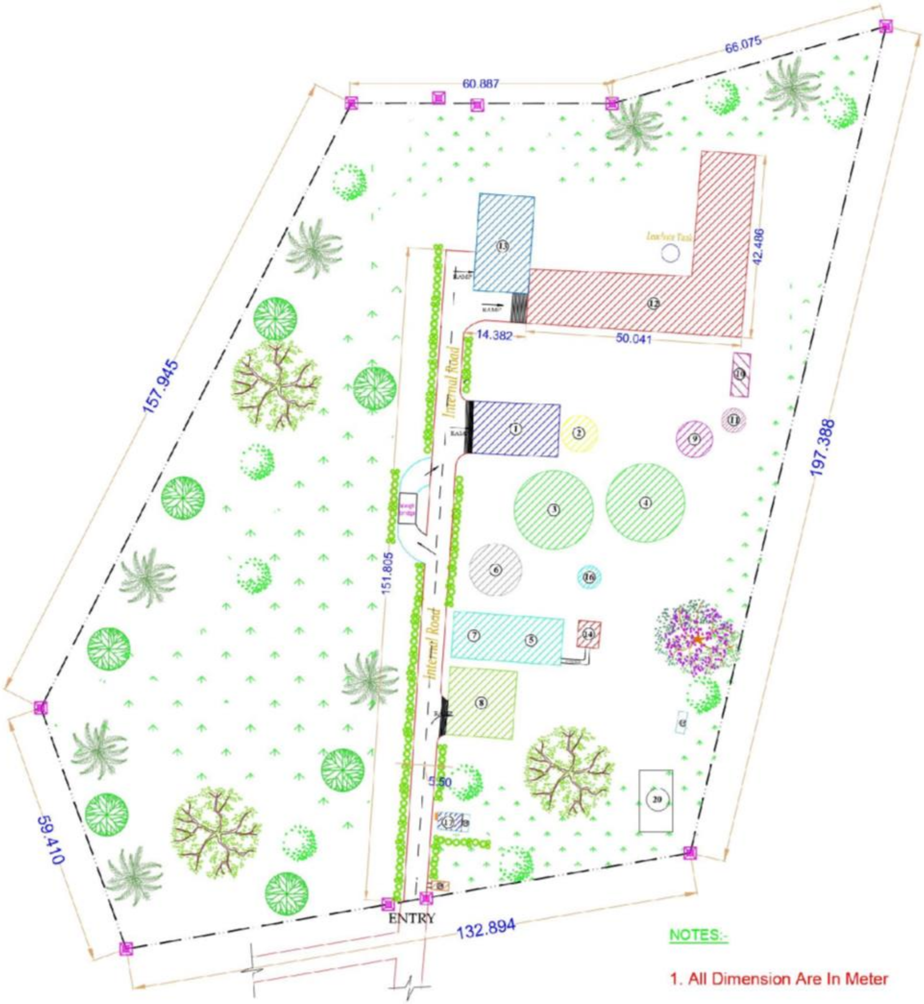


Process Flow Diagram (PFD) of 50 TPD Bio-CNG plant, Tirupati.

APPENDIX-II

PLAN SHOWING "BIO WASTE TO BIO GAS- CLEAN AND GREEN FUEL FOR FUTURE "

IN SY NO:731 PART OF THUKIVAKAM VILLAGE & PANCHAYATH, RENIGUNTA MANDAL, CHITTOOR DISTRICT,ANDHRA PRADESH



NOTES:-

1. All Dimension Are In Meter

	Biogas Plant Process			General Infrastructure
1	feeding platform		14	controll room
2	aerobic tank		15	generator
3	pre digester		16	pure water tank
4	main digester		17	office room
5	purification system area		18	toilet
6	balloon		19	security room
7	compressor unit		20	Transformer yard
8	gas filling area			
9	slurry storage tank			
10	de-watering machine			
11	water re-circulation tank			
12	mannure platform			
13	sieving machine and mannure storage yard			

Si:no	Net Built up area calculation	length (L)/dia (D)	bredth (B)	Area (sqm)
1	Feeding platform	12	20	240.0
2	Sieving and Mannure storage shed	25	15	375.0
3	Compost platform -1	37.6	13.5	507.6
4	Compost Platform-2	42.5	12.5	531.3
4	Purification & compressor shed	10	25	250.0
5	Gas filling shed	15	15	225.0
6	Control room	6	5	30.0
7	Office room	12	5	60.0
8	DG platform	3	6	18.0
9	Internal Road	185	5.5	1017.5
10	security room	3	3	9.0
11	Leachate tank	4		12.6
12	Feeding tank	8.3		54.1
13	Digester-1	18.2		260.1
14	Digester-2	18.2		260.1
15	Slurry tank	8.3		54.1
16	Water re-circulation tank	5.3		22.1
17	solid liquid seperator	2.3	2.5	5.8
18	Pure water tank	5.3		22.1
19	Balloon platform	12		113.1
			TOTAL	4067.3