Vellore Institute of Technology
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WASTE TO ENERGY WITH EMPHASIS ON ORGANIC WASTE

School of Civil Engineering

CLE-2020 SOLID WASTE MANAGEMENT

J COMPONENT PROJECT

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CERTIFICATE

This is to certify that the project work entitled "Waste to Energy with Emphasis on Organic Waste" that is submitted for Solid Waste Management (CLE2020) is a record of bonafide work done under my supervision. The contents of this project work, in full or in parts have neither been taken from any other source nor have been submitted for any other course.

Place: Vellore

Date: 28th April, 2022

Signature of the faculty

Mahindrakar Amit Baburao

ACKNOWLEDGEMENT

We would like to express our heartfelt gratitude and we are very thankful to our teacher Dr. Mahindrakar Amit Baburao for guiding us immensely throughout the course of the project. His constructive advice and constant motivation have been responsible for the successful completion of the project. We are grateful that we got an opportunity to explore practical field of this course with this project.

Contents:

Objectives:

The main objectives of this project are:

• To collect the current situation of organic waste collection in the study area.

• To study about the ways to solve major environmental issues namely pollution caused due to organic waste accumulation.

• To find proper methods to reduce the organic wastes by converting waste to energy, it considerably reduces the amount of waste entering landfills, which can save valuable land.

• To provide a safe, technologically advanced means for conversion of organic wastes to energy that reduces greenhouse gases, generates clean energy and recycles useful materials.

• To study the ways to improve the economic status of the people by the use of the technology selected.

• To study about the different types of waste to energy processes for organic wastes.

• To study about the theoretical and actual energy generation of energy from the solid wastes

• To study about the issues and challenges in waste to energy conversion

• Scope of Waste to Energy conversion

Introduction:

• Due to unmanaged solid waste, there is huge increase in air pollution, water pollution and land pollution and it also cause many diseases

• Thus, to control this solid waste as well as to get benefit from this, a new concept known as waste to energy is introduced with the help of which we can be able to reduce the solid wastes by converting into a form of energy

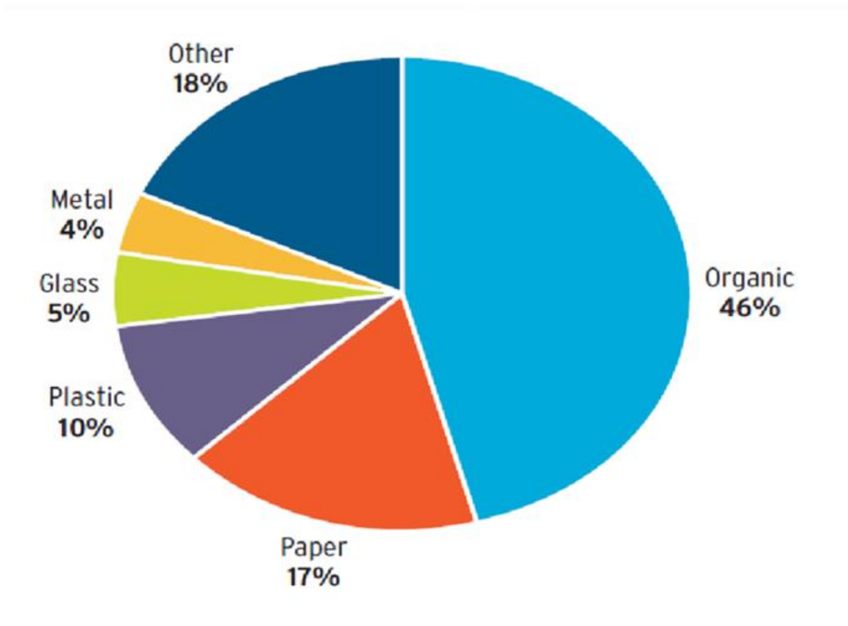


Fig: Global Solid Waste Composition

Source: Global solid waste composition. | Download Scientific Diagram (researchgate.net)

Why to focus more on organic wastes for energy conversion?

1. The major fractions of Global Solid Waste consists of Organic Wastes (As can be seen in the graph, nearly half of the produced waste from society is organic)

2. Sustainable energy can be obtained from organic waste.

Bio-organic waste has immense potential for green energy recovery

3. The cost of organic waste to energy conversion is relatively less than inorganic waste and the conversion process is eco friendly

4. People are using this conversion from the past itself. So, it will be easier. E.g., Biogas from organic waste was started from the time of our forefathers.

Introduction of waste to energy technologies in several countries

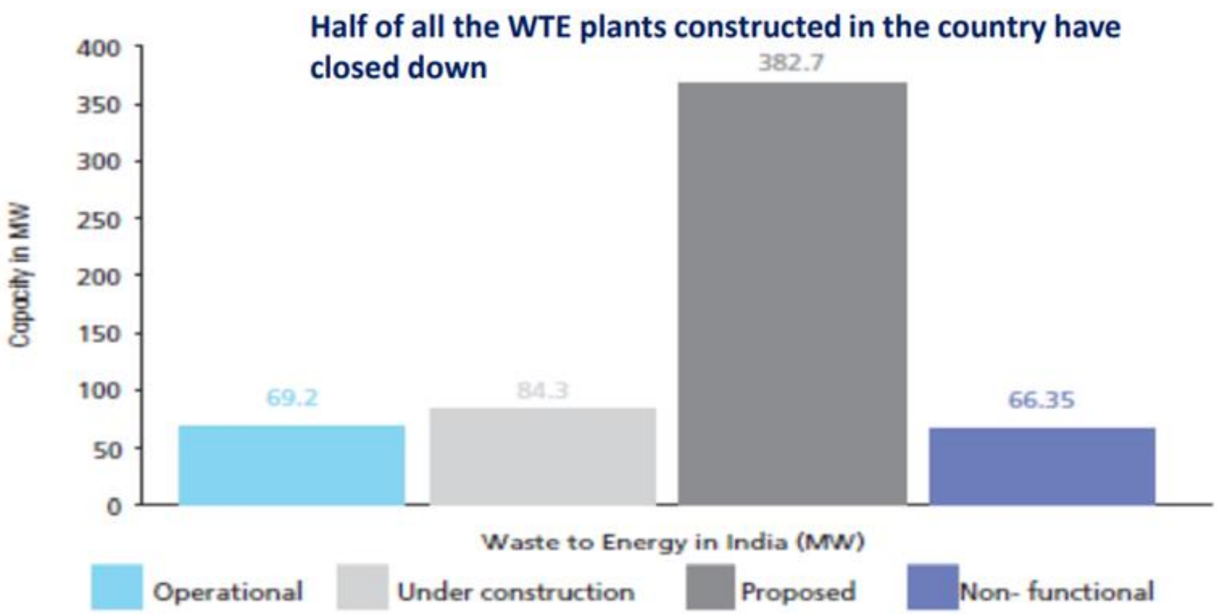
• New York has delivered 550,000 tons of waste to several waste to energy plants in other corners of the state. 25 percent of waste goes to such plants while the rest is sent to landfills, a better average compared to the national average of just 10% of waste sent to waste-to-energy plants.

• Norway's Klemetsrud plant is another notable waste to energy plant that delivers electricity and heat, emitting over 330,700 tons of CO_2 annually from municipal solid waste. Recent tests concluded the plant is able to stop 90 percent of CO_2 from entering the atmosphere.

• In Europe, waste to energy has also co-existed with recycling. Sweden, Denmark and the Netherlands boast of large scale waste to energy facilities, and even drive the highest recycling rates.

• In the U.S., waste to energy accounted for just 12 percent of municipal solid waste in 2013. Landfilling is still viewed as an economical option in many parts of the U.S.,

Indian Scenario



Source: CSE,2018

The total estimated energy generation potential from urban and industrial organic waste in India is approximately 5690 MW.

Niti Aayog has set a target of constructing 511 MW of WTE plants by for under the Swachh Bharat Mission (SBM).

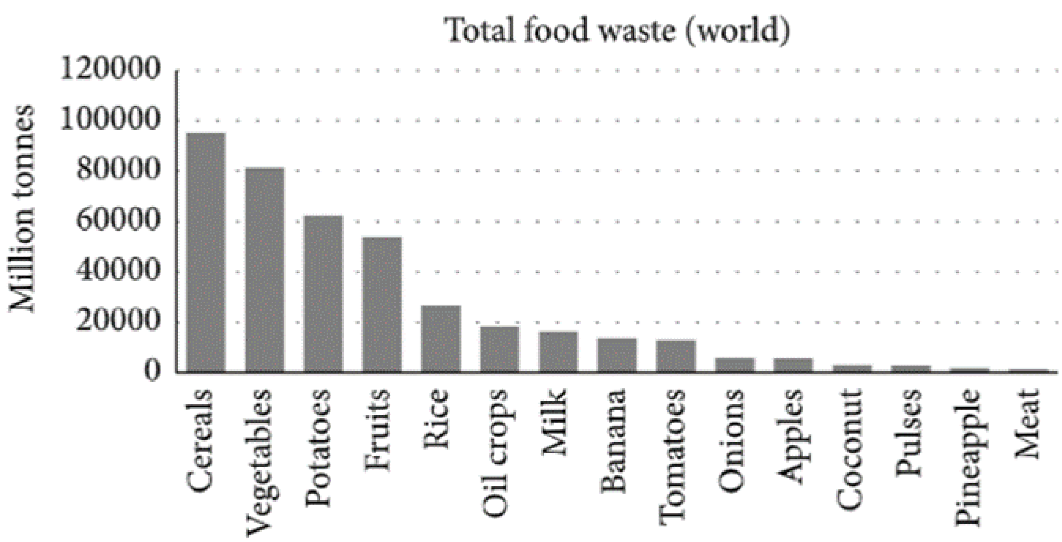
S.No.	State	Project/Under Trial	Installed Capacity (MW)
1.	Delhi	M/s Ramky Group, Narela-Bawana	24.0
2.	Delhi	M/s Jindal Urban Infrastructure Pvt Ltd., Okhla	16.0
3.	Delhi	M/s IL&FS Environment Infrastructure and Services Ltd., Ghazipur	12.0
4.	Madhya Pradesh	M/s Essel Infra at Jabalpur	9.0
5.	Maharashtra	M/s Solapur Bio-energy Systems Pvt. Ltd., Solapur	3.0
6	Himachal Pradesh	M/s Elephant Energy Private Ltd., Shimla	1.75

Table: Electricity from municipal solid waste [Source: MNRE, 2018]

Concept of Organic Waste to Energy Conversion

• Organic waste represents a significantly fraction of municipal solid waste. Proper management and recycling of huge volumes of organic waste are required to reduce its environmental burdens and to minimize risks to human health. Organic waste is indeed an untapped resource with great potential for energy production. Utilization of organic waste for energy conversion currently represents a challenge due to various reasons

• Organic Waste to Energy is a form of energy recovery where input is Organic waste and we can expect the output to be in the form of energy.



[Source : Food Waste to Energy: An Overview of Sustainable Approaches for Food Waste Management and Nutrient Recycling (hindawi.com)]

Around 100000 Million tonnes of food waste is generated globally
So, we can imagine how much it will benefit us if we are able to convert this much food waste to energy

Methodology

- This project synthesizes the current knowledge available in the use of technologies for organic waste to energy conversion involving biological (e.g., composting, fermentation and anaerobic digestion), thermal, thermochemical technologies (e.g., incineration, pyrolysis, gasification) and importance of Material Recover Facility (MRF) for organic waste to energy conversion is discussed.

- The competitive advantages of these technologies as well as case studies associated with them are discussed. In addition, the future directions for more effective utilization of organic waste for renewable energy generation are suggested from an interdisciplinary perspective.

For this project, in review 2, we will select a study area and do the research about what are the Waste to Energy methods done in that area for organic wastes and calculate the amount of energy that can be obtained from that study area from the organic wastes. The Methodology we will follow is:

1. Study the amount of organic waste generation in that study area

2. Categorize the different types of organic wastes and find out which of the above methods will be the best for conversion of that particular Organic waste to Energy

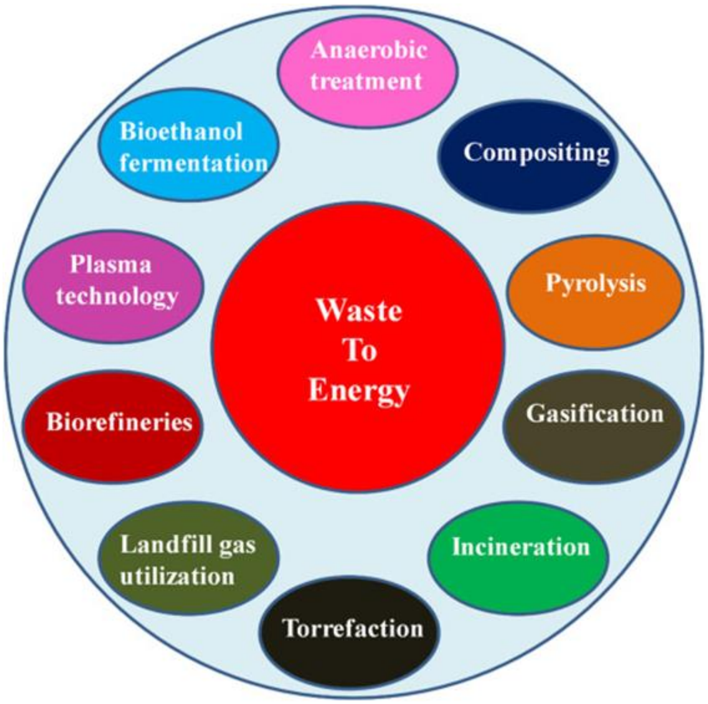
3. Calculate the rough estimation of Energy that can be obtained from the organic wastes

4. List out the issues that can arise for the conversion process

5. To do the research on the strategies and necessary activities to be carried out for the effective conversion of organic wastes to energy in that area

For now, we will discuss about the Methods used for the effective conversion of organic waste to energy and discuss about the rough estimation of the Energy that can be obtained from that Method with the help of the values obtained from the test conducted and also, see a case study where organic waste is converted to energy for household works in the form of bio gas in Chhattisgarh (India).

Methods of converting organic wastes to energy



Different methods to convert waste to energy

Source : Modalities for conversion of waste to energy — Challenges and perspectives - ScienceDirect

• To convert Organic Wastes into Energy, there are many methods
Most of the methods can be used to covert both the organic and inorganic wastes to Energy whereas there are also some of the methods which can be used to convert only Organic wastes (like composting).

• As our main objective is to convert Organic Wastes to Energy, we can use both the methods after separating the organic and inorganic wastes from the Mixed wastes.

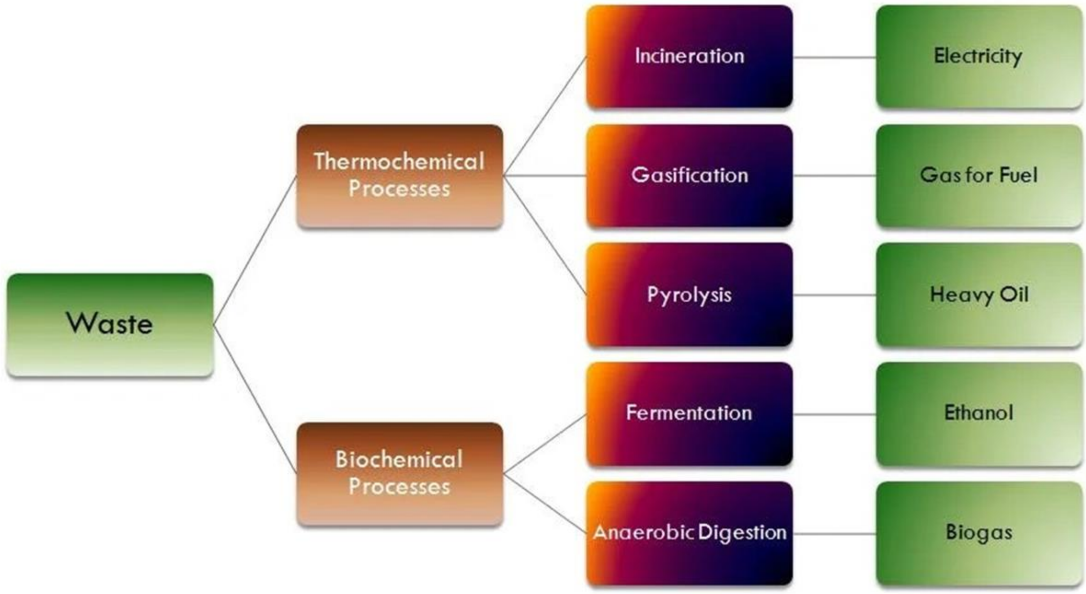
• A detailed explanation about some of the widely used ways/methods by which we can convert any waste into Energy is given in the table below:

Technology	Main Input	Main Output
Composting Fermentation	Organic waste	Fertilizer and Heat Liquid Fuels
Anaerobic Digestion(AD)	Organic waste	Biogas and/or digestate
Material Recovery Facility (MRF)	Mixed waste	RDF, recyclables, organics, inerts
Incineration with energy recovery	Mixed waste	Electricity, Leachate, Bottom ash and fly ash, Treated flue gas
Pryolysis and gasification	Pre-treated mixed waste	Synthetic gas, char, tar or ash

As, we are trying to convert waste to energy with emphasis on organic waste, so the Technologies that will be discussed for this project for out study area for the conversion are:

1. Composting/Bio-Drying and Fermentation
2. Anaerobic Digestion (AD)
3. Pryolysis and gasification for organic wastes
4. Material Recovery Facility (MRF) for organic wastes
5. Incineration with energy recovery for organic wastes

Note: Incineration is not a good approach to follow for the conversion of organic wastes to energy as it causes pollution as smoke is introduced into the air. Our main goal is to reduce the organic waste by converting it into energy by protecting the environment, so instead of incineration, other methods are preferred more. When waste is burned in incineration facilities it produces hazardous air pollutants including particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide, acid gases, nitrogen oxides and cancer-causing dioxins.



Source: [Know About Popular Waste to Energy Conversion Routes (bioenergyconsult.com)]

Composting:

Can composting help for energy recovery?

well, yes.. compost produces heat as a byproduct of decomposition. As such, this is just one of a myriad of ways we can capture heat and use it to generate electricity and heat your home.

Findings:

Reuse of Compost Heat as a Source of Renewable Energy

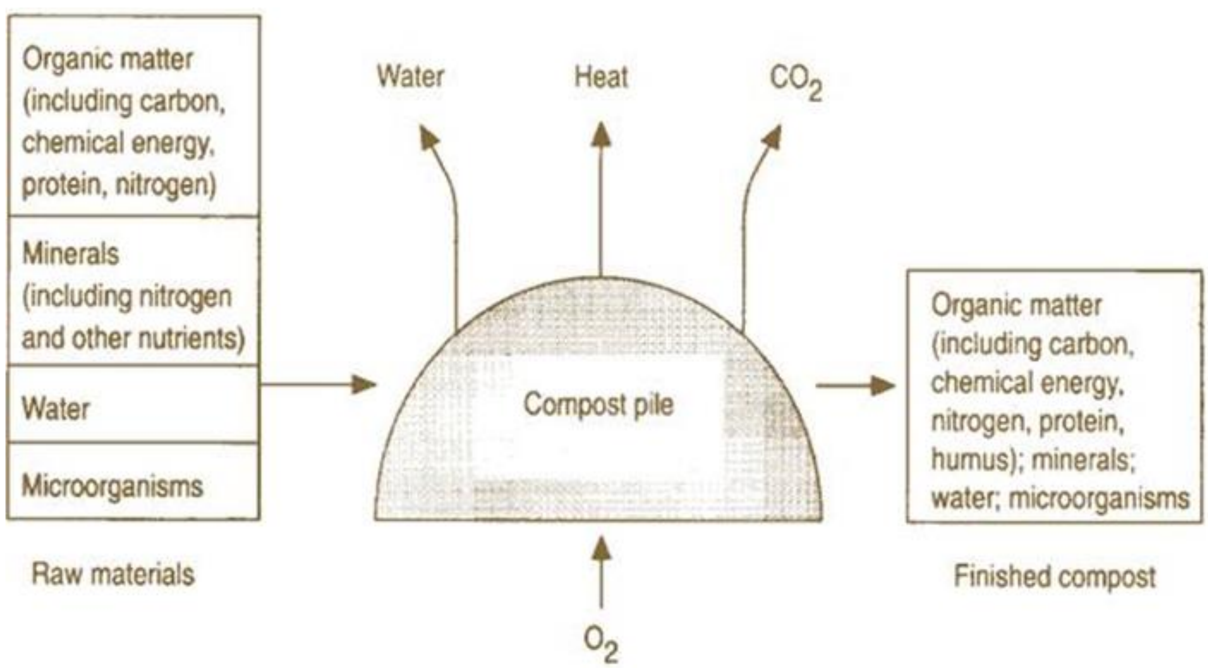
• As of recent study report, during high-temperature phases (around 60 degree C) of municipal waste composting, on average 1136 kJ kg^{-1} of heat was released

• Similarly, values (961 kJ kg^{-1}) have been reported earlier with an average compost moisture content of 52.7%

• Heat produced during the composting of wheat straw and poultry droppings was approximately 17.06 MJ kg^{-1} and 12.8 MJ kg^{-1}, respectively

• From the above values, it is fully justified to investigate the potential reuse of compost heat as a source of renewable energy

• So, composting can be a good method to convert organic wastes to energy. It is eco-friendly and helps a lot to reduce the solid wastes.



Source : NC State Extension Publications - NC State University

Fermentation:

- Fermenting to Make Fuel: Organisms use the metabolic process of fermentation to convert sugars into acids, gases or alcohol

$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$

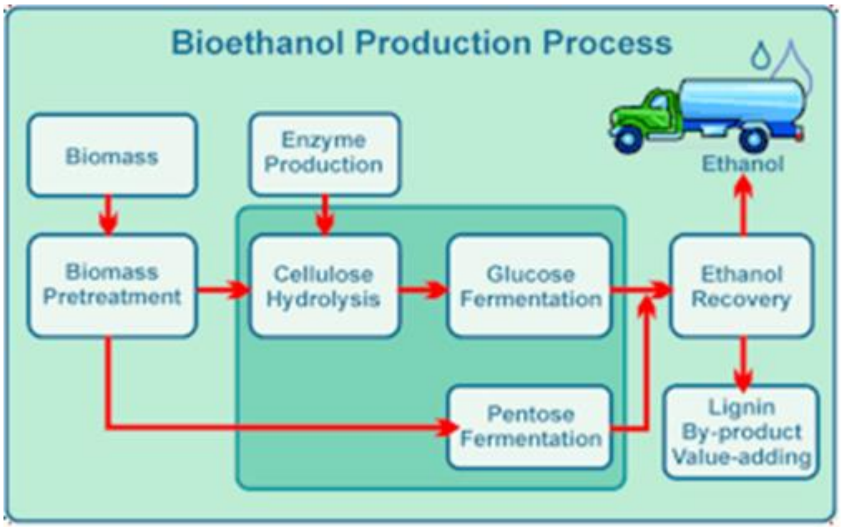
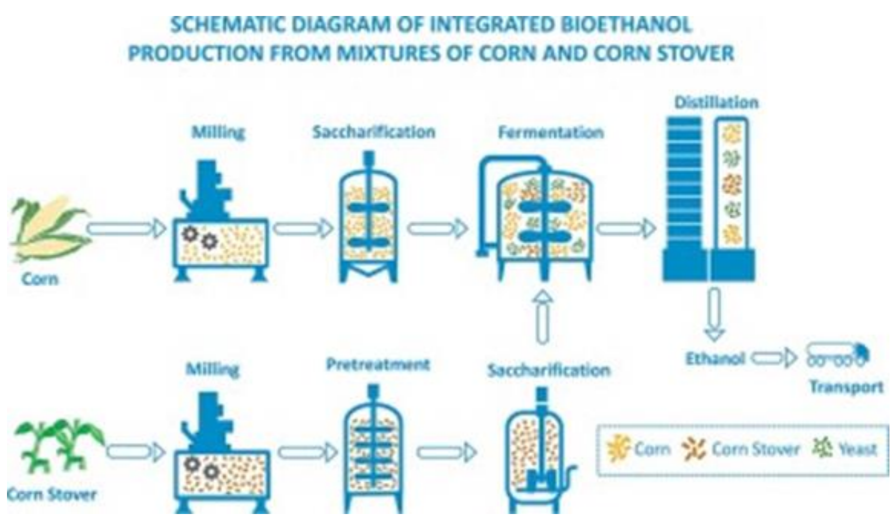


Fig: Biochemical Method for Ethanol Production

Source: Fermentation | BioEnergy Consult



Findings

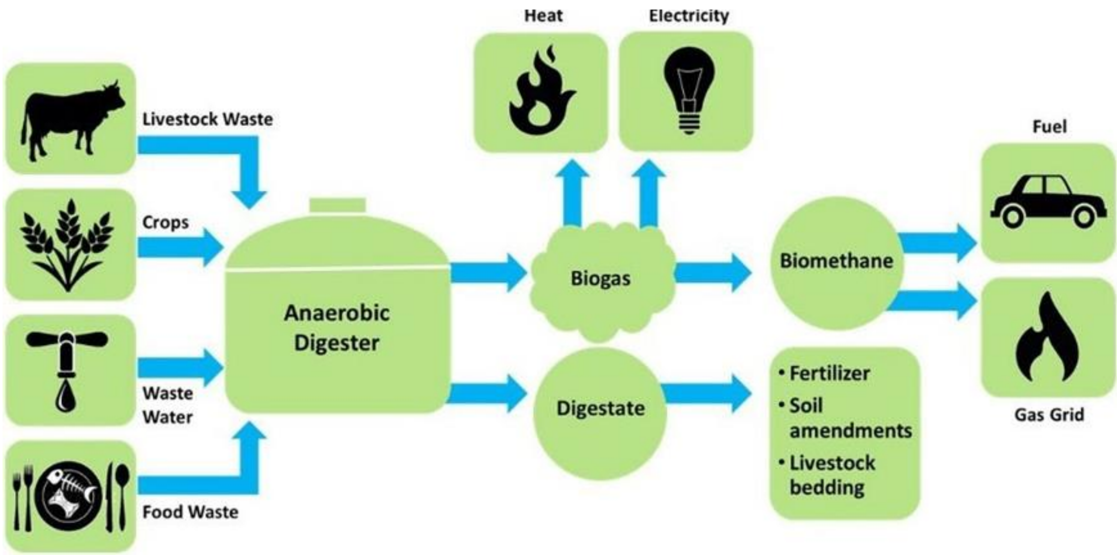
Mixture of alkali pretreated CS and corn at solids loadings of 10% and 20%, respectively, resulted in 92.30 g/L ethanol

Source : Integrated bioethanol production from mixtures of corn and corn stover - ScienceDirect

Anaerobic Digester (Biogas plant):

It is one of the most used methods to convert organic wastes to energy.

The principle it works on is that microorganisms break down organic waste and produce gas [Mostly methane and carbon dioxide]



Findings:

How much energy can be produced from canteen food waste?

• A laboratory scale of Biochemical Methane Potential (BMP) test was carried out under controlled and batch condition.

• The calculation of theoretical methane potential was carried out using Buswell Equation. Electricity energy potential was also calculated. The characterization analysis found that canteen food waste has higher organic material content, mainly carbohydrate, protein and lipid.

• This indicating its potential to be used as feedstock for biogas/methane production.

• The measured methane potential was found at value of 0.191 m3 /kg VS, which was lower than theoretical methane potential of 0.300 m3 /kg VS. The estimation of electricity potential found that 473.8 kWh of electricity can be generated per ton fresh canteen food waste.

Case Study: Biogas Plants in Chhattisgarh (India)

This is a case study of biogas plants in Chhattisgarh, as mentioned above, Biogas Plant is one of the best methods to convert organic wastes to energy and even people from non-technical background or with little knowledge can use/operate it

This case study briefly explains about the number of wastes required and how much Energy is obtained from the waste and what is the energy efficiency of the Biogas Plant

The data and methods are well explained
Also, relevant formulas and equations were used for the calculations.

- In Chhattisgarh, use of biogas is limited to only cooking purpose
- The total numbers of biogas plants installed by CREDA in the Chhattisgarh state were found to be 30,376 till year 2010. And on an average more than three thousand (3375) plants are added annually
- Animal excreta and other agricultural wastes are used to produce biogas through anaerobic digestion

Material and Methods:

A survey was conducted randomly in each district of Chhattisgarh plains. It was conducted by visiting the biogas plant and collecting feedback from the operator / owners. The major objectives of biogas plants are to achieve higher gas generation efficiency, uniformity in application and maintaining the input raw materials to increase the performance of plants. For collecting the important data required for technical knowledge, dung fed % to required dung, plant efficiency, repair and maintenance; for each and every randomly selected plant, collection of relevant data were detailly studied considering the technical knowledge required to collect the data, climatology data for the temperature and status of biogas plant in Chhattisgarh plain.

Performance of Biogas Plants

• The theoretical gas generation was worked out 0.04 m^3 gas per kg fresh dung per day. Burner diameter, dung fed in kg and gas consumption time are noted at the site of plants. Therefore, theoretical gas produced was calculated by multiplying dung fed with 0.04. Therefore, plant use or presently working efficiency was calculated as below.

$$\text{Gas genration efficiency} = \frac{\text{Actual gas consum.}}{\text{Theo. gas genration efficiency}} \times 100$$

This equation is used to calculate the Gas generation efficiency The datas obtained from the calculation can be found in Table below

Capacity Wise Performance of Biogas Plant

By survey in Chhattisgarh Plains, the size of plants was found 1- 6 m^3/day. As per standard practice, the required dung for different size of plants is given as below

The capacity wise performance of biogas plants is calculated as given below:

$$\text{Over all plant's efficiency} = \frac{\text{Actual gas consum.} \times \text{Dung fed \%}}{100}$$

Capacity wise Dung Feeding

S.N.	Plant's capacity, m^3	Required dung per day	Dung fed, %
1	1	25	NA
2	2	50	95.87
3	3	75	83.95
4	4	100	62.77
5	6	150	61.44
6	8	200	47.50

$$\text{Dung fed per cent of total required dung} = \frac{\text{Dung fed per day} \times 100}{25(\text{kg/m}^3) \times \text{plant capacity } (\text{m}^3)}$$

Results and discussions of this case study

1	**Raipur**	**76.11**	**78.77**	**4.35**	**59.95**
2	Mahasamund	83.50	98.60	4.30	82.30
3	Dhamtari	72.00	101.66	3.03	73.20
4	Durg	80.81	56.29	6.04	45.49
5	Rajnandgaon	71.60	94.94	3.60	67.97
6	Kawrdha	76.70	87.90	3.17	67.41
7	Bilaspur	72.23	81.00	2.70	58.50
8	Korba	75.20	88.00	3.90	66.18
9	Raigarh	71.73	73.10	3.17	52.43
10	JanjgirChampa	78.00	85.00	3.90	66.30
11	Kanker	75.20	96.00	3.10	72.20
	Average	75.93	85.51	3.75	64.78
	SD	4.23	13.25	0.93	10.07

Table a: District-wise performances of biogas plants in CG plain

• It is revealed that the average gas generation efficiency in the biogas plants was found maximum in the district Mahasamund (83.5 %) followed by Durg (80.81 %) and minimum plant gas generation efficiency was found in district Rajnandgaon (71.6 %) followed by Raigarh (73.10 %).

• On an average the overall gas generation efficiency of biogas plants in the Chhattisgarh plain was found to be 75.73 %. However, the mean plant gas generation efficiency did not differ significantly.

• It was observed that the gas generation efficiency is highly dependent on feeding and maintenance practices followed by owners.

Overall Plant Efficiency in the Districts

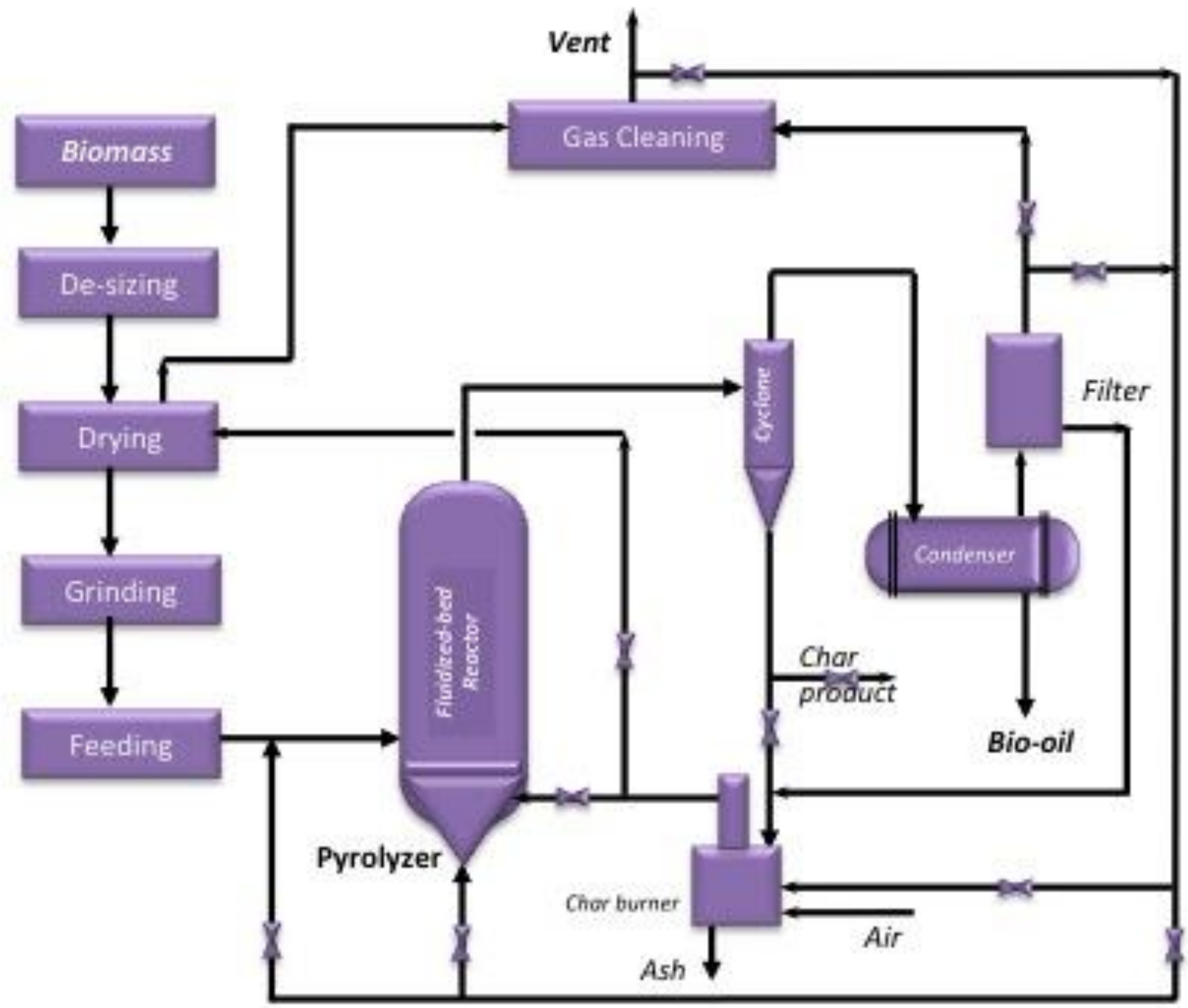
• The overall plant efficiency of each district of Chhattisgarh plains is presented in the previous tables. The overall district wise plant efficiency of biogas plants of C.G plain was found 64.72 %, which varied district to district from 46-82 %. The maximum overall plant efficiency was recorded in district Mahasamund (82.3 %) followed by Dhamtari (73.2 %).

S.N.	Plant capacity ,m^3	Under working Nos.	Non- working Nos.	Total sample, Nos.	Working / gas generation efficiency,%	Dung fed, %	Over all plant's efficiency %
1	2	62	10	72	76.60	95.87	73.44
2	3	08	01	09	77.25	83.95	64.85
3	4	13	01	14	71.08	62.77	44.62
4	6	14	05	19	75.86	61.14	46.38
5	8	02	01	03	81.75	50	40.87
Total		99	18	117	-	-	-
Average					76.51	70.75	54.00

Table b: Capacity-wise status and performance of biogas plants

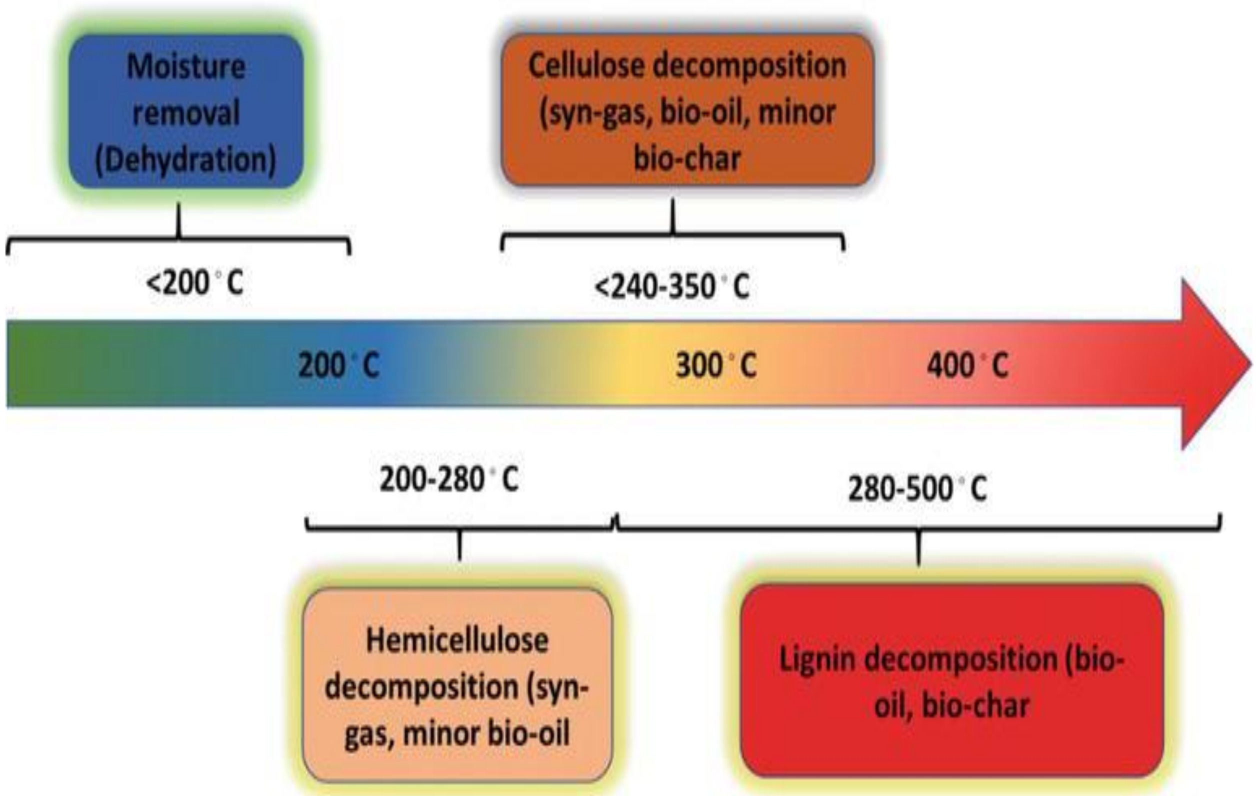
Pyrolysis for organic wastes

- Pyrolysis is the thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen or any halogen.
- An external heat source is provided to maintain the temperature (For MSW 300-850 degrees centigrade)
- Fast pyrolysis of biomass is becoming increasingly important in many countries
- The eventual objective of pyrolysis is to yield high-value energy products for contending with and gradually supplanting non-renewable fossil fuels.



Pyrolysis Principle, End products

- Takes place in the absence of oxygen under inert atmosphere(Ar and N2 gases flow as inert atmosphere)
- Breaks down organic materials in the absence of oxygen to produce liquid (bio-oil), gaseous (syngas), and solid (biochar) products
- Emits mainly methane, hydrogen, carbon monoxide and carbon dioxide

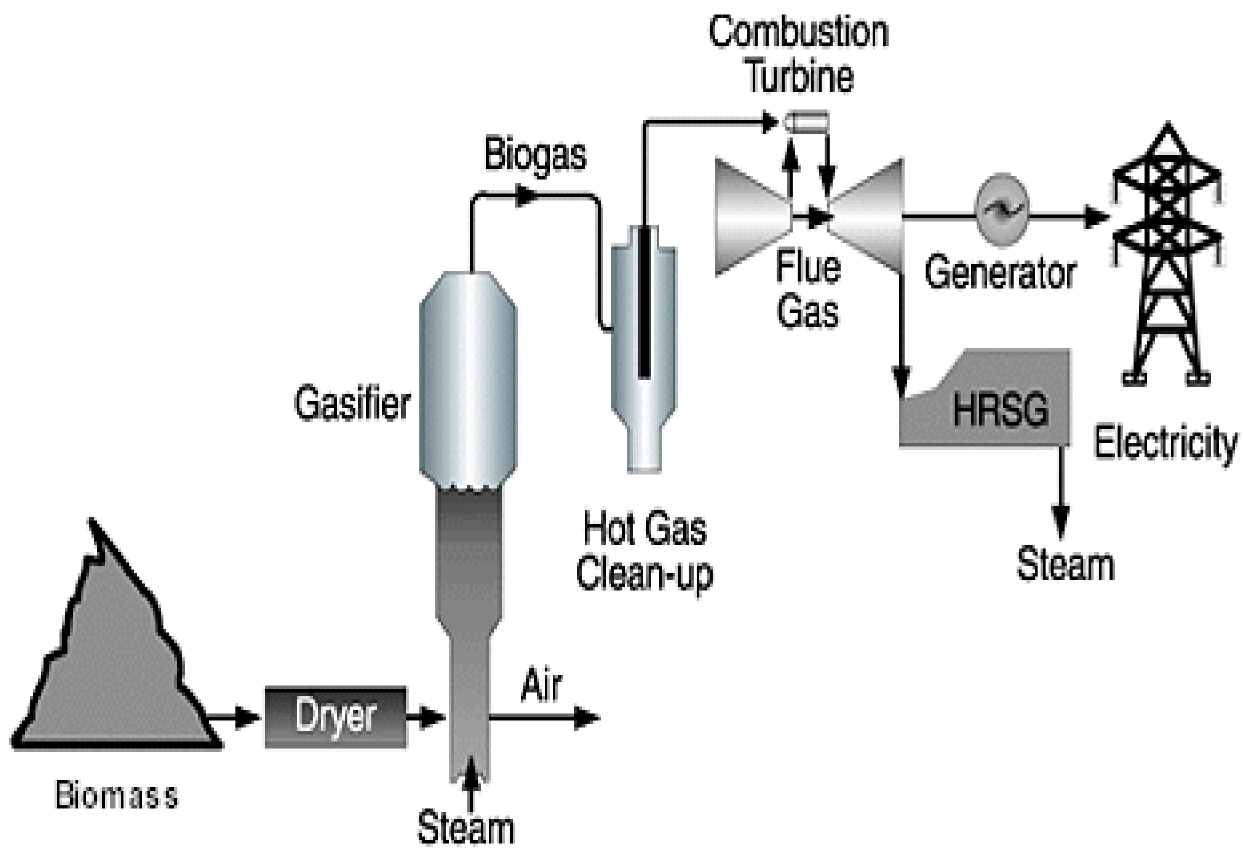


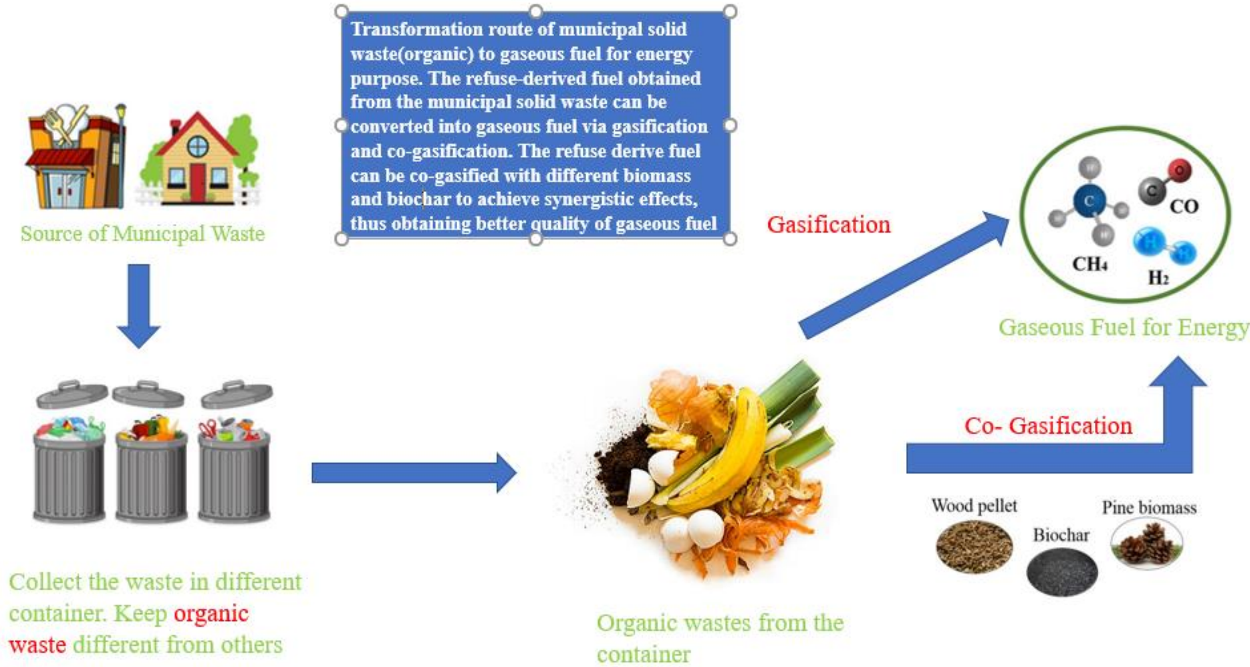
Use of end products

- Biochar can be utilized as solid fuel in boilers. After catalytic pre-treatment, it can be used to produce activated carbon, carbon nanotubes and gaseous fractions, etc.
- Syngas from pyrolysis is a combustible gas and can be used for the production of power in many types of equipment, from steam cycles through gas engines and turbines.
- Pyrolysis oil is used for combustion in boilers, fueling in engines and turbines, upgrading to transportation fuels or as a renewable feedstock for chemicals and materials.

Gasification for Organic Wastes- Biomass Gasification

- Biomass Gasification is basically a thermochemical process which converts biomass materials such as forest and agriculture waste into gaseous components that can be used in various applications
- Reaction between fuel and gasification agents take place and syngas (producer gas) is produced. Syngas is mainly composed of CO, H2, N2, CO2 and some hydrocarbons and small amounts of H2S, NH3.
- The producer gas, which has a calorific value of 1200 to 1500 kcal/m3, can be combusted for thermal energy or used to operate gas turbines or internal combustion engine for mechanical and electrical power.





Case study of waste to energy concept

Study Area: Kathmandu Metropolitan City(KMC)

Energy potential from Organic Wastes at Teku transfer station

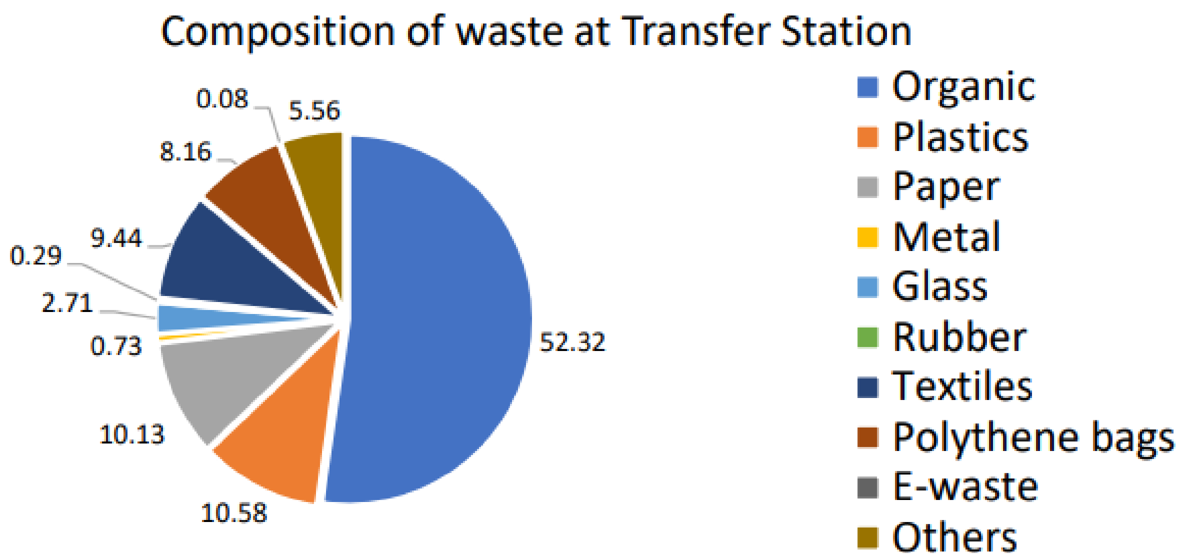
- KMC solely operates the transfer station at Teku where the waste collected by the municipality is first hauled and then transferred to Sisdol landfill site

- To collect the data of Total wastes generated per day and percentage of organic wastes, we visited the teku transfer station.

- Then we estimated how much energy we can obtain from the wastes

Findings

- An average of 106 metric tons of waste is collected daily



52.32% of the total waste collected daily at Teku transfer station is Organic

So, Total Organic Wastes generated per day = (52.32/100) * 106

= 55.5 MT

- The Organic Waste thus generated can be used as a fuel to the biogas plant, which in turn can produce Biogas as an Output of anaerobic digestion of organic wastes.
- Approximately, from 1 metric ton of organic wastes, 240 m^3 of biogas is produced
- Organic waste has approximate 60% water content and in order to have quality production of biogas 80% water content has to be maintained. So, 20% water is to be added.

- Therefore,
- Total weight of input slurry = 55.55 + (20/100)*55.55 = <u>66.66 MT</u>
- Thus, Bigas generated from 66.66 MT = 66.66*240 = <u>15998 m^3/day</u>
- 1 m^3 = 1000 liter of biogas

- ∴ Per day 15998000 liter of Biogas can be generated(potential)
- The average methane content in biogas produced due to the organic waste is 53% of total gas produced.
- The average methane content in biogas produced due to the organic waste is 53% of total gas produced.
- Also, as per Calorific value comparison, 1m^3 of Biogas is equal to 0.433kg of Butane.
- So, 15998 m^3 of Biogas = 15998 × 0.433 = <u>6927 kg</u>
- As, One Cylinder of LPG is 14.2 kg of Butane ∴
- 6927 kg = 487.8 ~ <u>488 Cylinders</u>
- The current Cost of 1 LPG cylinder is Rs. 1500 in Nepal ($12.5)
- We have 488 Cylinder Equivalent per day = 12.5 × 488
    - = $ 6100

- Thus, in one month,
- 6100*30 = $183000 can be generated
- So, instead of throwing the organic wastes into landfill, if we apply waste to energy concept to convert the organic wastes to energy(biofuel), the mass of wastes going to landfill can be reduced as well as money can be generated from the waste.

If we are able to convert the organic wastes to electricity with the help of biomass gasification or pyrolysis, then the amount of electricity produced per month will be:

- The energy content of a fuel is measured in terms of its calorific value (CV), expressed as Joules per kilogram

  - The average energy content of organic wastes is around <u>15 MJ/kg</u> in dry basis

- <u>3.6 MJ heat produces 1KWH of Electricity for 100% plant efficiency</u>

  - But the efficiency is never 100 %, considering electricity conversion efficiency is 40%

Thus, 3.6/0.4 = 9MJ of heat produces 1KWH of electricity

Thus, 1 kg of organic wastes will produce 15/9 = 1.667 KWH of electricity

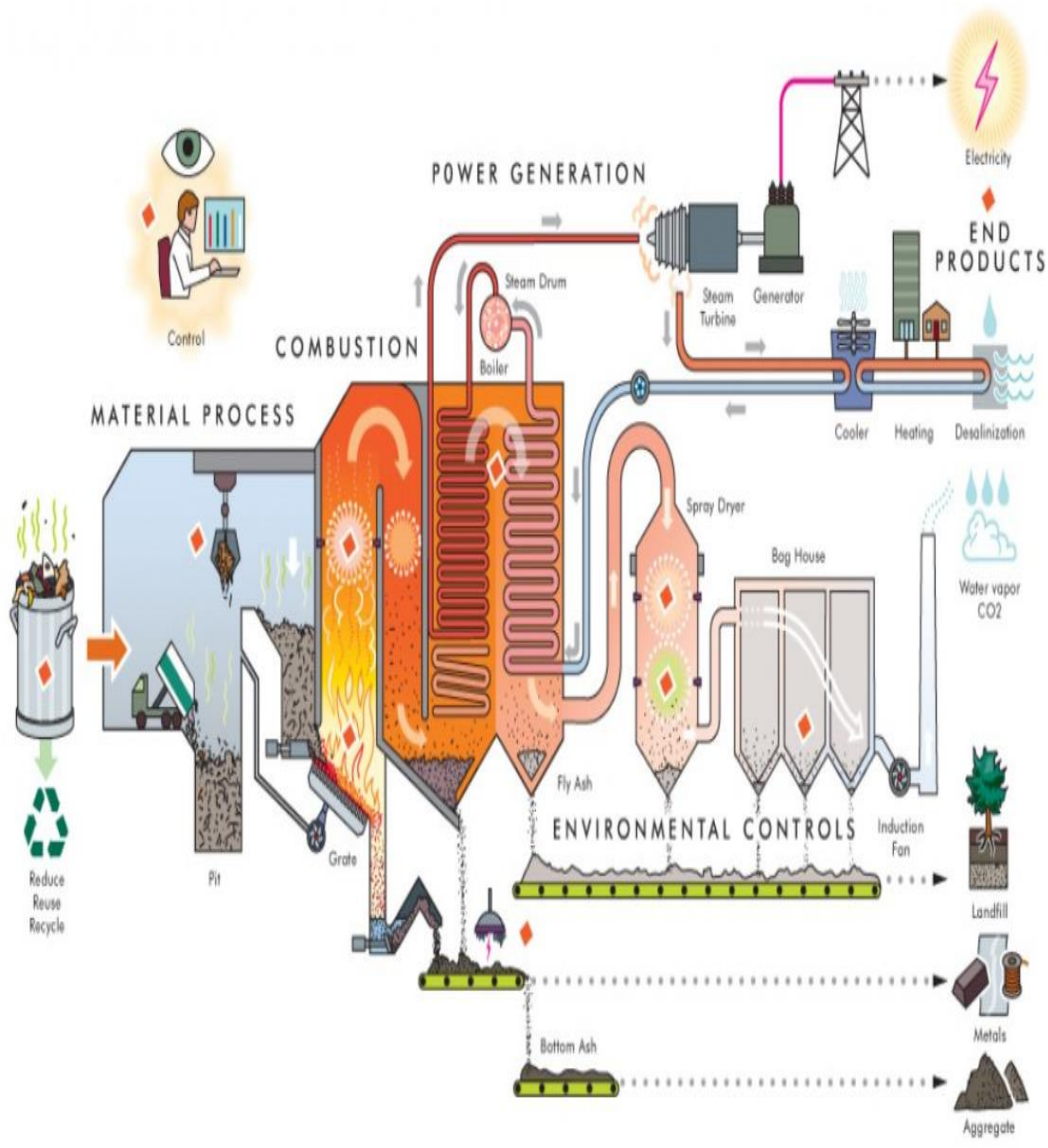
Now, 66.66 * 10^3 kg of dry waste would produce = 66.66 * 10^3 * 1.667 = 111122 kwh/day

Per month electricity production = 111122 * 30 = 3333660 kwh/month

Thus, 3999600 kwh of electricity can be produced in one month if the organic wastes are converted to electricity.

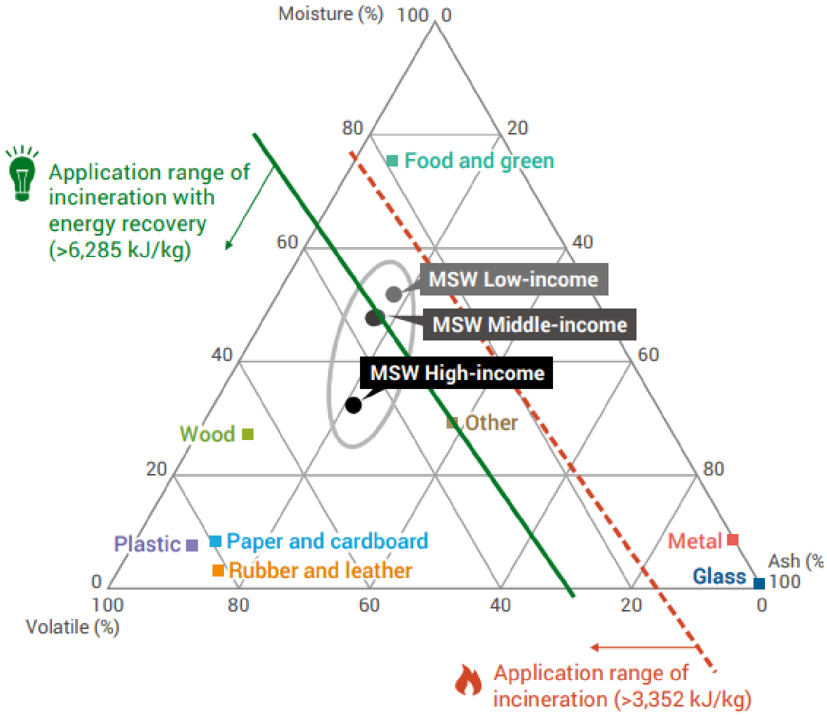
Incineration for Organic Wastes

For effective incineration of Organic Wastes, we should focus on source separation and reducing the moisture content of food and kitchen waste. Incineration with energy recovery refers to the combustion of waste under controlled conditions to generate electricity and/or heat



Is Incineration the best method for WTE conversion for Organic Wastes?

- Food waste is composed of about 70% water, and burning it requires considerable energy
- Incineration facilities in cities with a high level of food and organic waste in their waste stream – which is common in Global South cities – often require additional fuel to be added to the waste to enable the burning process, adding to costs and making waste incineration even less efficient.
- The Energy content of organic waste is less than the energy content of inorganic wastes making. So, it is not the best method for Organic wastes as for same amount, organic wastes generate less energy.



Waste	Energy(MJ/kg)
Food Waste	4.65
Plastics	32.60

Case Study

Biogas from Organic Waste and potential energy in the form of electricity can be generated from the organic wastes. The potential energy generated from organic wastes has numerous use in human life.

- Using biomass to generate energy is one such option that has lately gained popularity as a clean and sustainable source of energy around the world.
- Waste treatment plants that produce biofuel and electricity are common in many countries. This paper studies an AD biogas plant from Norway to investigate its development potential. The operation of the plant was monitored over a period of two years and data on production of biogas, energy and bio-rest was gathered. An energy and environmental balance were performed and parameters for optimization of the plant were discussed.

Study Area: Norway

• In this case study, the development possibilities of an AD biogas plant from Norway were studied. Over the course of two years, the plant's operation was monitored, and data on biogas, energy, and bio-rest production was collected. The plant's energy and environmental balances were calculated, and parameters for plant improvement were reviewed.

Plant Specifications

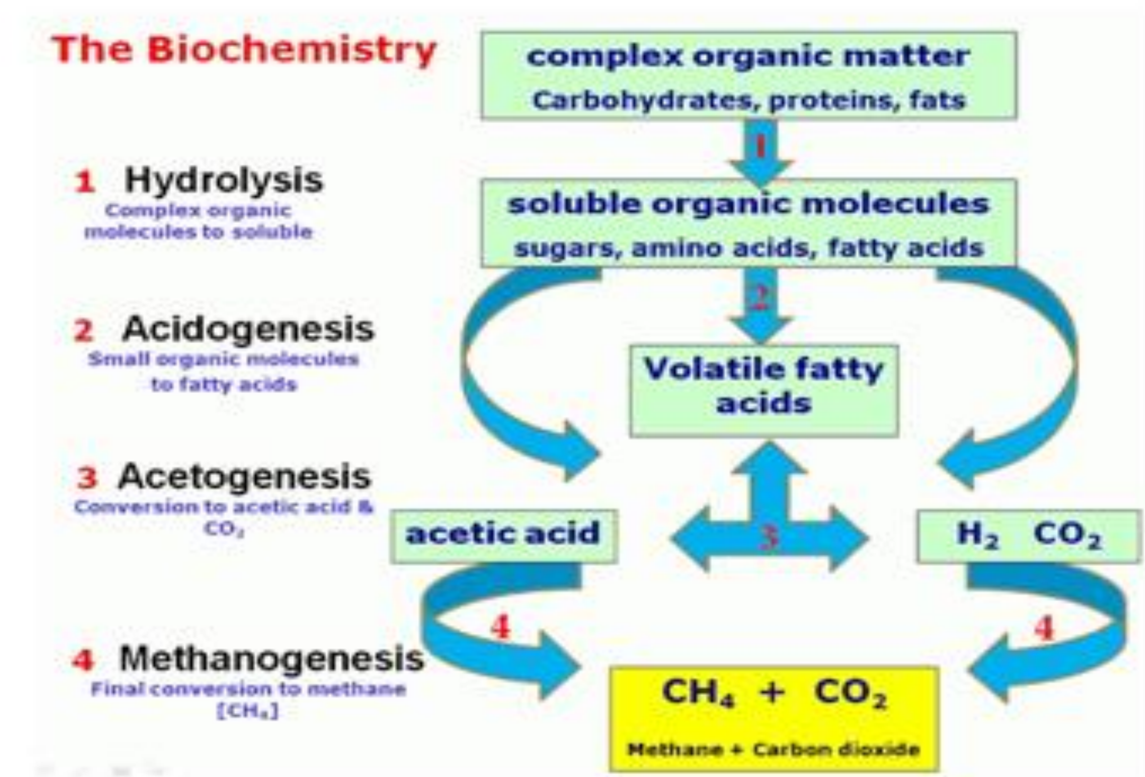
- The plant considered in this study is located in Nord Trøndelag County in central Norway.
- Its current "waste-zone" comprises 98200 km2 and has a population of 230000 people.
- The plant treats three organic substrates: organic household trash, wastewater sludge, and a small amount of ensilage waste from fish farms.
- The plant has a total capacity of 30000 to 45000 tons of organic waste.

Working

Biogas is a product of biodegradation of refuse in the AD process. It contains primarily methane (CH_4) and carbon dioxide (CO_2), with trace amounts of non-methane organic compounds

(NMOC). Anaerobic digestion, which is also known as biomethanation or methane fermentation can be divided into four stages:

1. Hydrolysis or fermentation
2. Acidogenesis or formation of organic acids
3. Acetogenesis
4. Methanogenesis



1. Acetogenesis

$$C_6H_{12}O_6 \xrightarrow{yields} 2C_2H_5OH + 2CO_2$$

2. Methanogenesis

$$CH_3COOH \xrightarrow{yields} CH_4 + CO$$

$$CO_2 + 4H_2 \xrightarrow{yields} CH_4 + 2H_2O$$

The maximum amount of natural gas that may be generated during anaerobic decomposition can be determined from the approximate, simplified molecular formula.

$$C_6H_{10}O_4 + 1.5H_2O = 3.25CH_4 + 2.75CO_2$$

From the equation , ignoring other minor constituents such as moisture and inorganic particles, the molar ratios of CO2 and CH4 in the product are 54% and 46% respectively. However, a different formula in which the molar amounts of CO2 and CH4 in the product are equal is shown in the equation:

$$C_nH_aO_b + \left(n - \frac{a}{4} - \frac{b}{2}\right) H_2O \xrightarrow{yields} \left(\frac{n}{2} + \frac{a}{8} - \frac{b}{4}\right) CH_4 + \left(\frac{n}{2} + \frac{a}{8} - \frac{b}{4}\right) CO_2$$

• Ratio between CO2 and CH4 depends on the oxidation state of the carbon present in the organic material, which means that the more reduced the organic carbon content is, the more CH4 will be produced.

• Assuming that waste material contains 70% of biomass, and assuming that the dry organics amount to 60% of the biomass. Thus, the total mass of dry organic material(C6H10O4), is equivalent to 420 kg/tonne of waste material.

• The molar mass of C6H10O4 is 146 g/mole, which means that 420 kg of the material is equivalent to 2.56 kmol. From Equations above, a yield of 3.25 moles of CH4 for each mole of C6H10O4 is obtained, in other words, the expected yield of methane is 8.32 kmol per tonne of waste material. In terms of mass, 133.5 kg or 0.1335 tonne of methane per tonne of solid waste is anticipated.

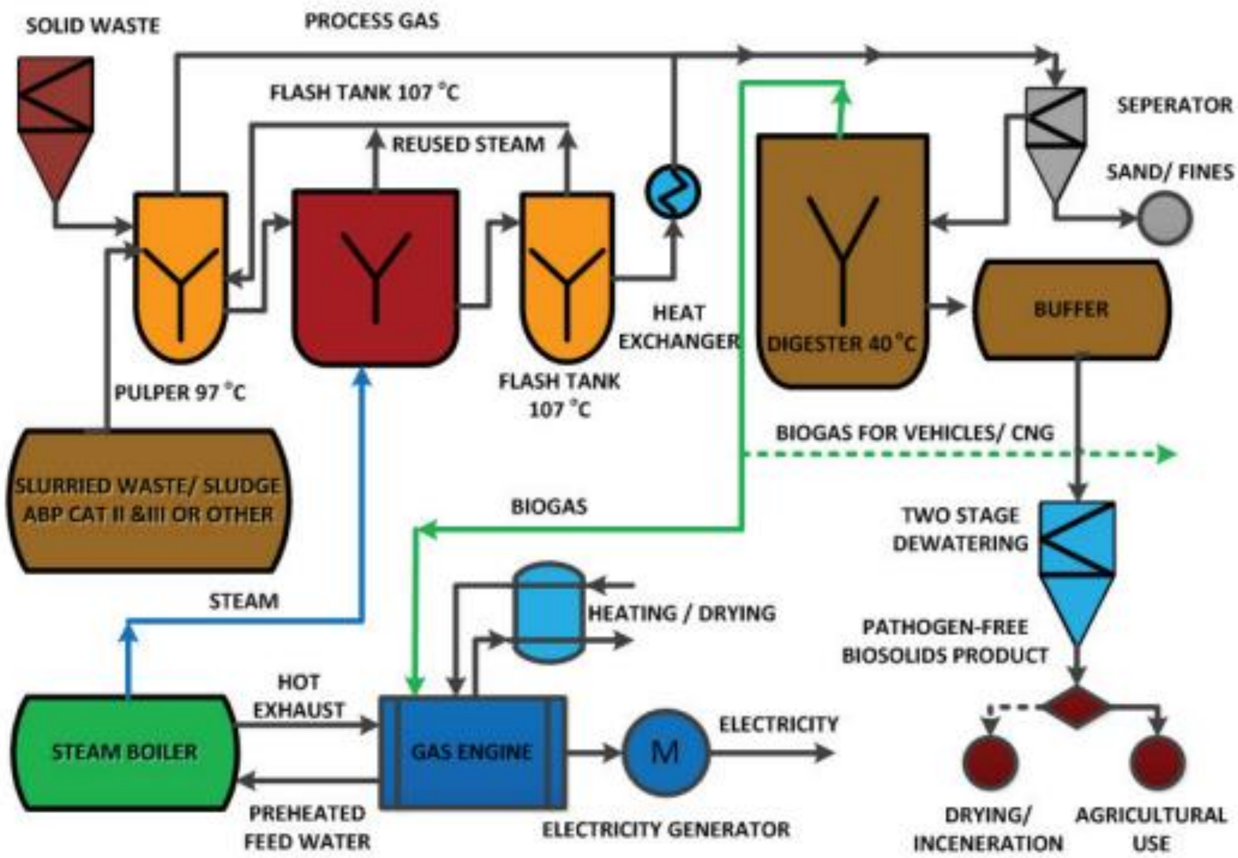
• Assuming that the thermal efficiency of electricity generation at the plant is 25%, and considering the Lower Heating Value (LHV) of methane (which is 50,000 kJ/kg), the total electricity produced per tonne of waste material will be according to equation :

$$133.5(kg/tonne) * 50000(kJ/kg) * 0.25 = 1668750\ kJ/tonne$$

• Hence, the expected theoretical output electricity from the solid waste = 463.5 kWh/tonne

• This analysis is used in this work to evaluate the actual output of the plant against the theoretical expected output to investigate causes of lower productivity and potential for upgrade of outputs.

General Process



Details of plant data

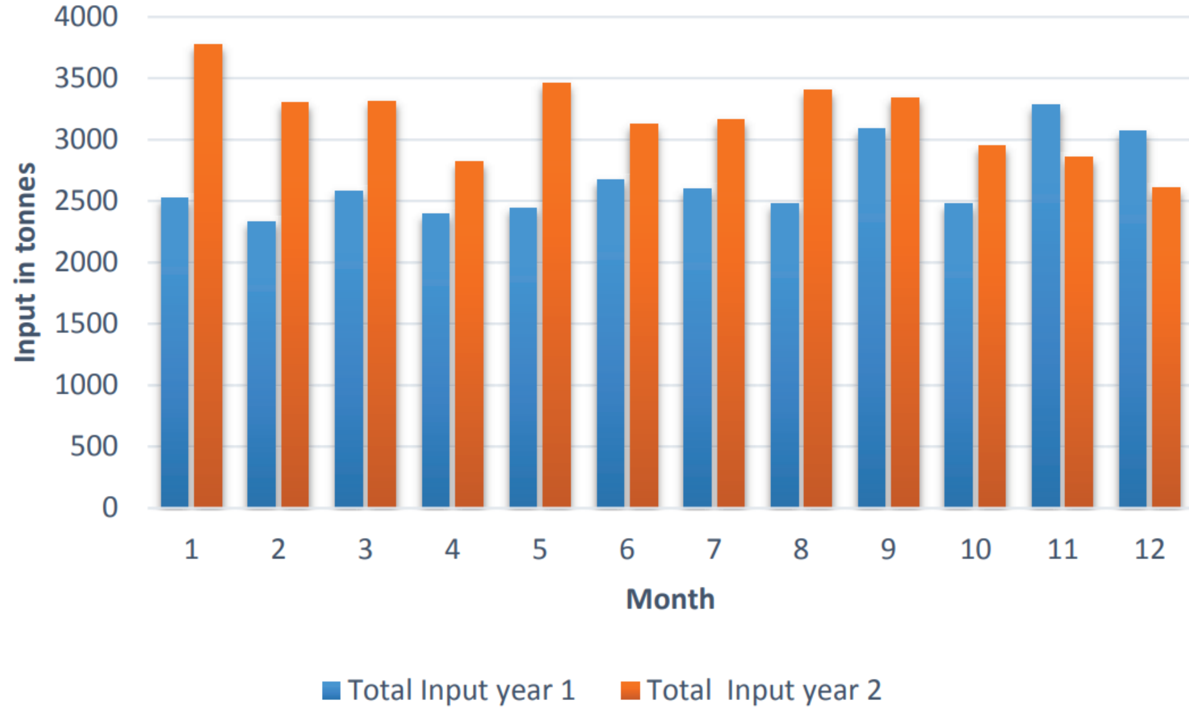


Fig : Total monthly inputs to the plant

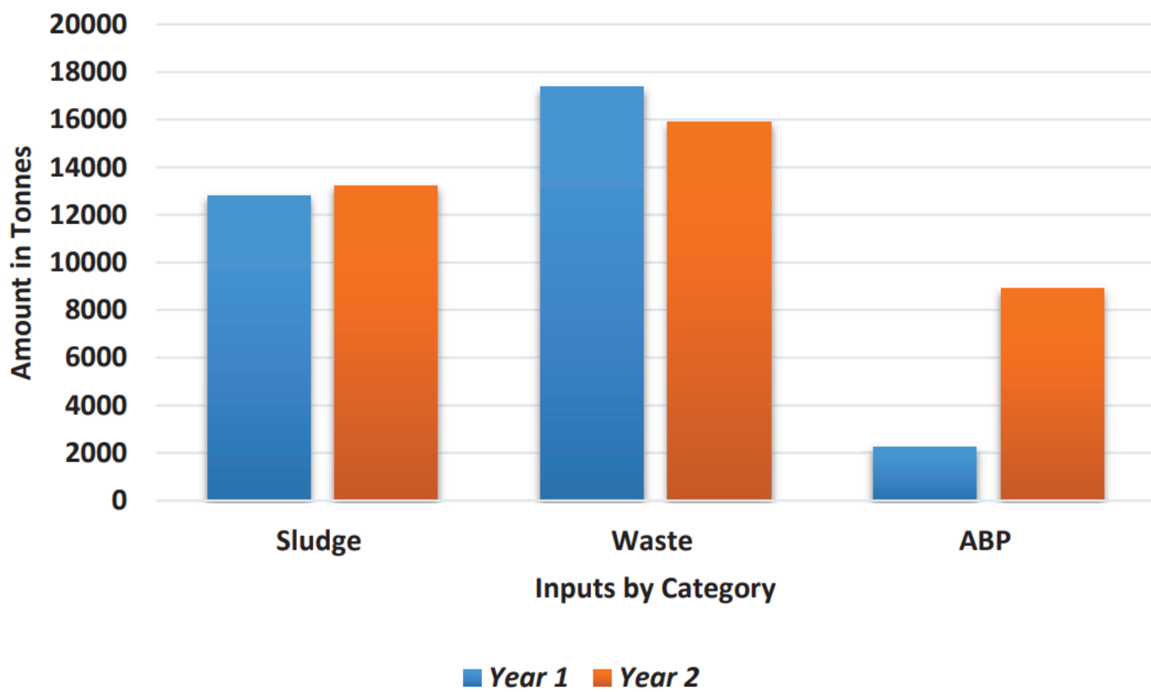


Fig : Comparison of inputs of waste by category in tonnes

Major Outputs of the Plant

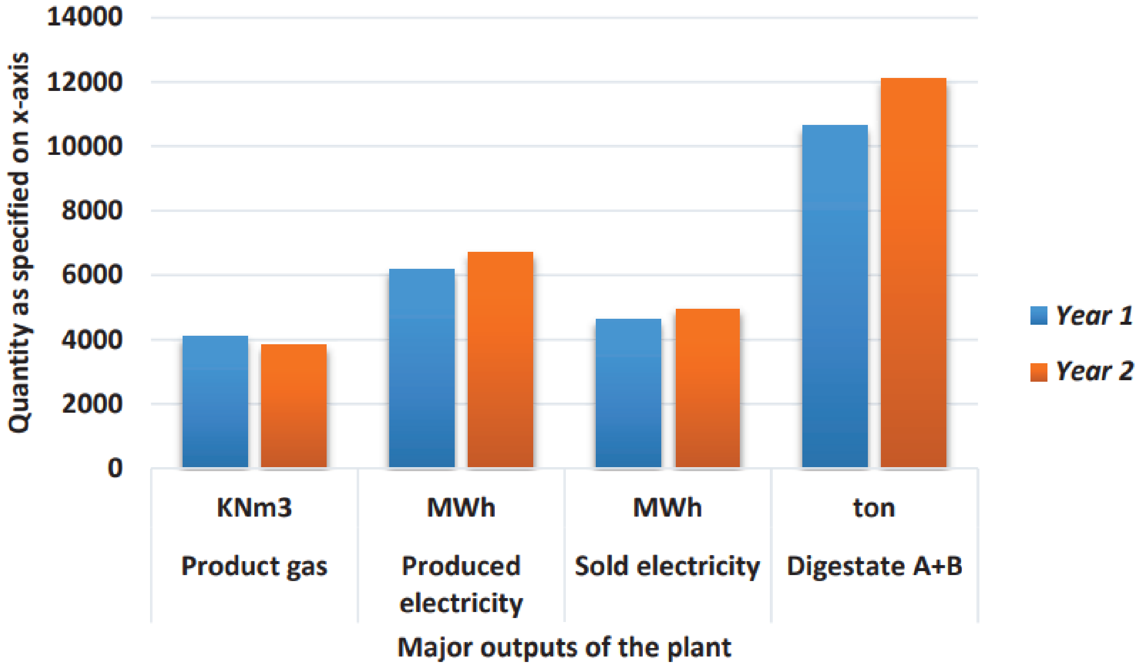


Fig : Comparison of Product gas, produced electricity and sold electricity

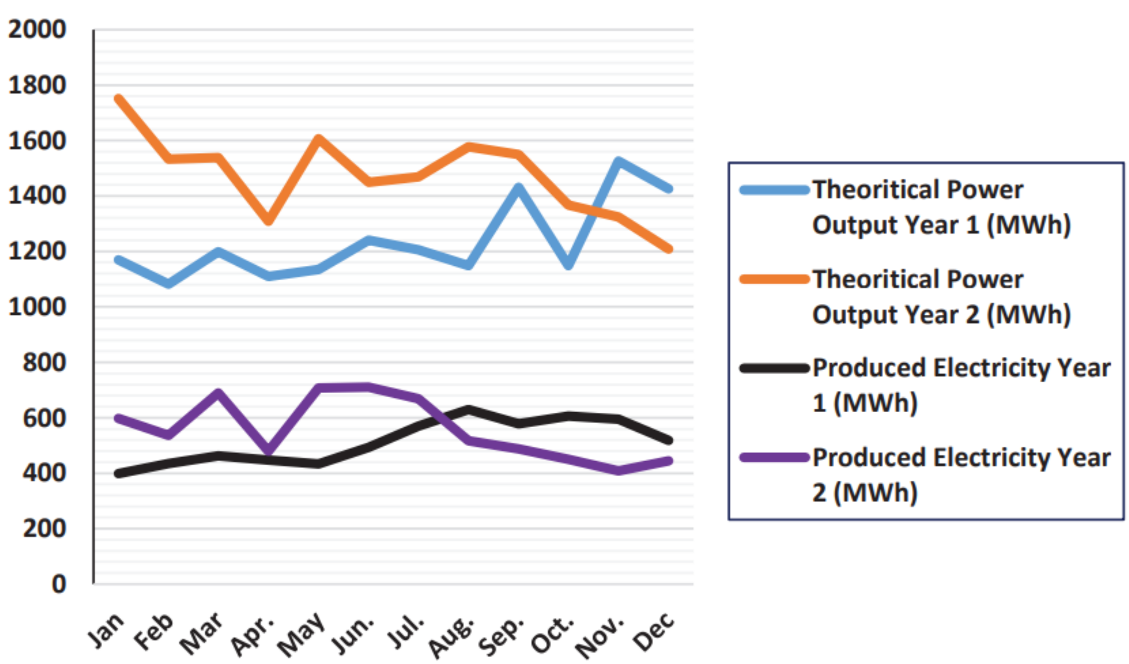


Fig : Theoretical and actual Electricity Generation of the plant for year 1 and year 2

Conclusion

• Actually, produced electricity was around 35% of the theoretical potential, which can be improved by optimizing the process.

• An increased percentage of ABP (Animal By-product) reflects positively on the quality and amount of biogas produced.

• Organic wastes are really helpful for the generation of electricity.

Issues and Challenges with waste-to-energy

1. Same old primitive methods are still at the core of our waste disposal:

In 19th century scientist first thought of utilizing heat from burning of waste as WtE method. More than a hundred years later, those same primitive methods are still at the core of our waste disposal. The problems of waste-to-energy have started to outweigh the benefits. Ashes generated from incineration are not treated properly and dumped into dumping sites which is causing health problems like cancer.

WTE could disincentivize recycling

WTE methods have potential to disincentivize recycling and more sustainable waste management solutions and renewable energy sources. If people, organizations, or governments believe that waste-to-energy is a viable sustainable energy source and waste management technique, they are less likely to engage with or invest in more impactful solutions, such as reduction, reuse, or recycling. It is important that an appropriate balance is struck so that the demand for WTE feedstock does not incentivise the creation of *more* waste.

• For example, a business may relax its waste reduction or recycling efforts if its waste is feeding WTE production to create energy at lower cost

3. Unregulated waste trade

• Developed countries send their waste to developing countries for processing and WTE. They will claim that it is their broader plans of SWM but due to lack of proper regulation those wastes are simply burned or landfilled. Contractors collect waste in the name of WtE but dump them in landfill without even processing.

4. Most WTE are inefficient and cause pollution:

Depending on the feedstock and technology, WTE processes may create air pollution, contaminated water or other residues. Further**,** the transportation of unprocessed organic waste feedstock may pose a biosecurity risk, due to the potential spread of pests and plant disease. There is also a risk that such transportation and the WTE plant itself may also adversely affect amenity, through odour, noise, local transport congestion, dust and vermin, depending on the feedstock and treatment method used.

5. Copying developed countries:

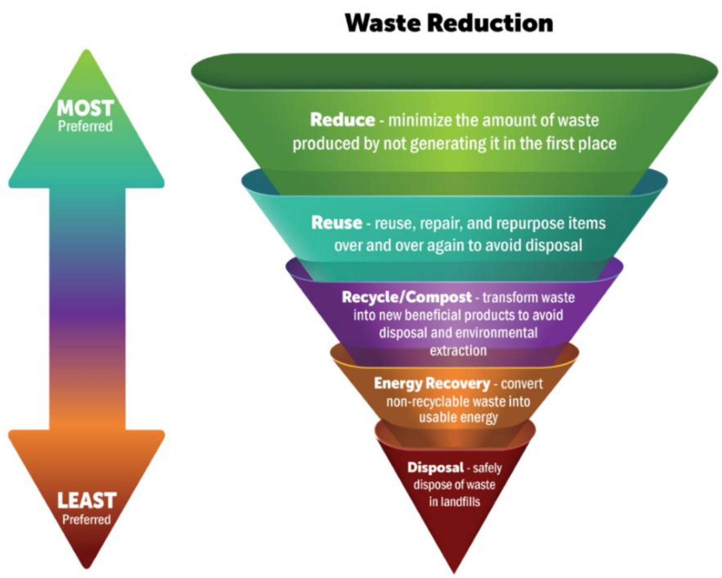
Developed countries are encouraging developing countries to follow their methods for WTE. In most cases, the methods brought are not suitable

• For eg: Incineration WTE plants in India are installed seeing that it is efficient in western countries but those are not efficient in India as the percentage of organic waste in SW in India is very high and there is no practice of segregation of waste at the source in India

Scope of Waste to Energy

Solid waste management and waste to energy concept aims to solve the major environmental issues and need for an alternative fuel source. Future of waste to energy is growing as green technology is steppingstone to waste management. In context of India, the solid waste generated from cities/towns in India has present potential to generate power of approx. 500 MW which can be enhanced to 1075 MW by 2031 and further enhancement too.

Future perspective of Solid Waste Management in India

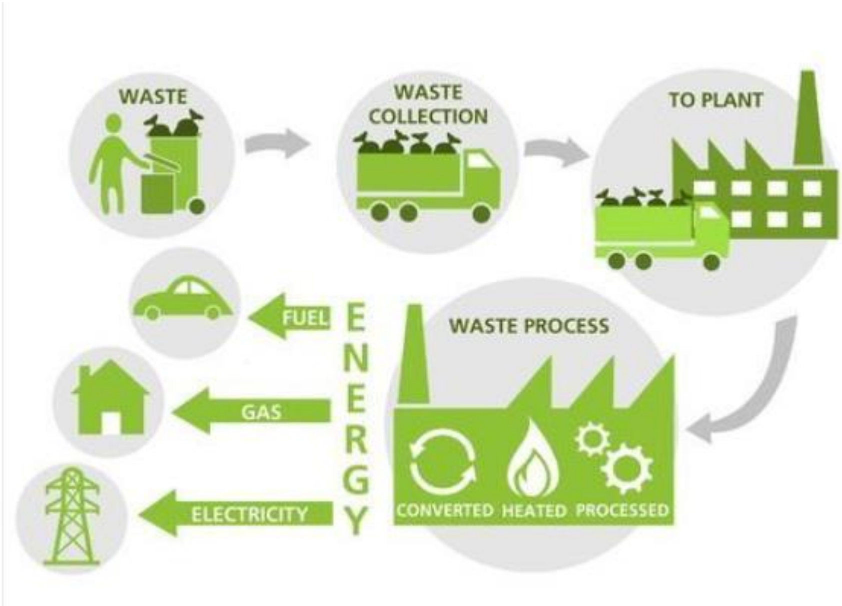


Waste to energy industry is estimated to have 70% growth rate in global market by 2026. With countries looking to decrease their dependence on fossil fuels, there is great potential in waste to energy industry. WTE plants today are far more advanced than trash incinerators of past. Waste-to-energy conversions have potential to reduce 160 million tons of annual greenhouse gas emissions.

• Rise in demand for sustainable energy sources to boost the demand for global market.

• Countries are moving towards achieving zero emission sources bolstering the demand for global waste to energy market.

• Considering the innovative technology and design taking place in waste management industry, it is likely that waste to energy will become more widely utilized in future.



Conclusion

Thus, instead of disposing the organic wastes to landfill, we can convert it to energy and the energy can be used for many purposes.

The ways of converting wastes to energy were discussed and some of the case studies related to the same were also discussed.

The main problem in waste to energy conversion was found out to be in segregation of wastes at the source and also lack of proper technology. There is a great scope of waste to energy conversion in the present context and also in the future context.

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