Conversion of Waste to Energy

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Waste and waste management

- Waste is any unwanted material or substance that results from human activity or process
- Waste management is collection, transportation, recovery, recycling or disposal and monitoring & analysis of waste, in an effort to reduce their effect on human health and ecosystem

Classification of wastes by source

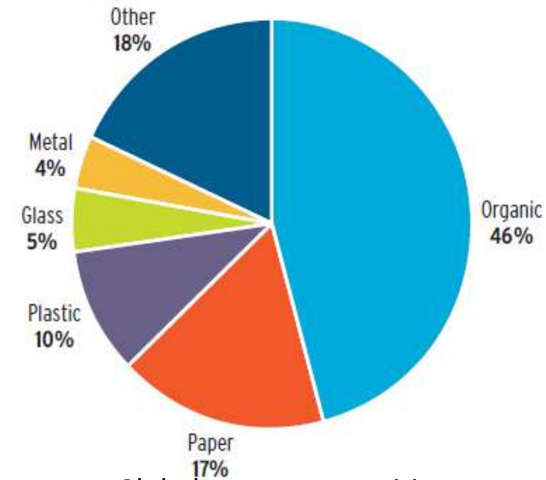
Source	Wastes
Residential	• Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, e-wastes
Industrial	• Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, special wastes
Commercial	• Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes, e-wastes
Municipal services	• Street sweepings; landscape and tree trimmings • General wastes from parks, beaches, & other recreational areas, sludge
Construction and Demolition(C&D)	• Wood, steel, concrete, dirt, bricks, tiles
Medical waste	• Infectious wastes, hazardous wastes , radioactive waste from cancer therapies, pharmaceutical waste
Agricultural	• Spoiled food wastes, agricultural wastes (e.g., rice husks, cotton stalks, coconut shells, coffee waste), hazardous wastes (pesticides)

Municipal Solid Waste(MSW) generally encompasses residential, industrial, commercial, municipal and C&D wastes

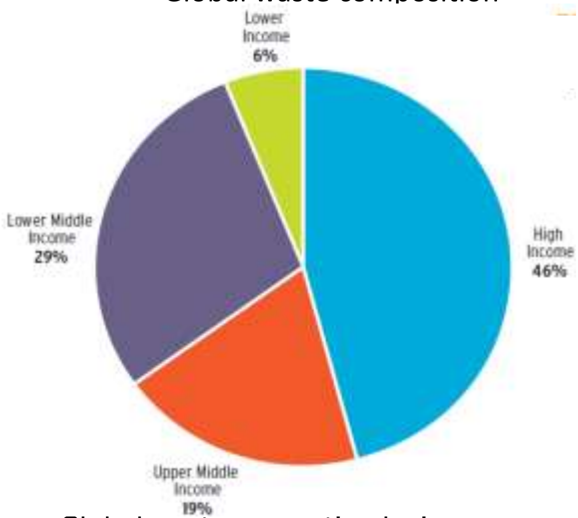
Ref : What a waste, The World Bank, March 2012, No. 15

Global solid waste scenario

- Global solid waste generation is more than 1.3 billion tonnes per year
- Expected to increase waste generation to approximately 2.2 billion tonnes per year by 2025
- Major fraction of solid waste is organic
- Developed countries generate 572 million tonnes of waste per year which is almost half of the world's waste
- Land filling and thermal treatment are the most common methods for disposal of waste in high income countries
- Middle income countries dispose their waste in open dumps



Global waste composition

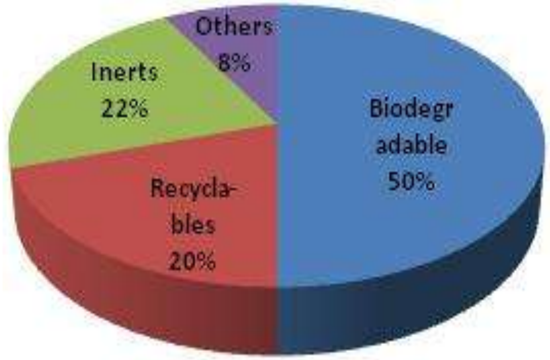


Global waste generation by income

High income countries dispose their waste by land filling and thermal treatment, while middle and low income countries dispose by open dumping

India's solid waste scenario

- Solid waste management is a major concern in India's urban areas
- Around 62 million tonnes of waste is being generated annually in India
- Approximately 68% of generated waste collected, while only 28% of collected waste processed/treated
- Remaining solid waste being disposed through land filling / open dumps
- Projected waste generation by 2033 is 165 MMTPA



Composition of waste

Expected increase in waste generation (@5% annual growth rate)

Indiscriminate disposal of waste at dump yards in unhygienic manner is leading to health related problems and environmental degradation

Ref : CPCB annual report, 2013-14

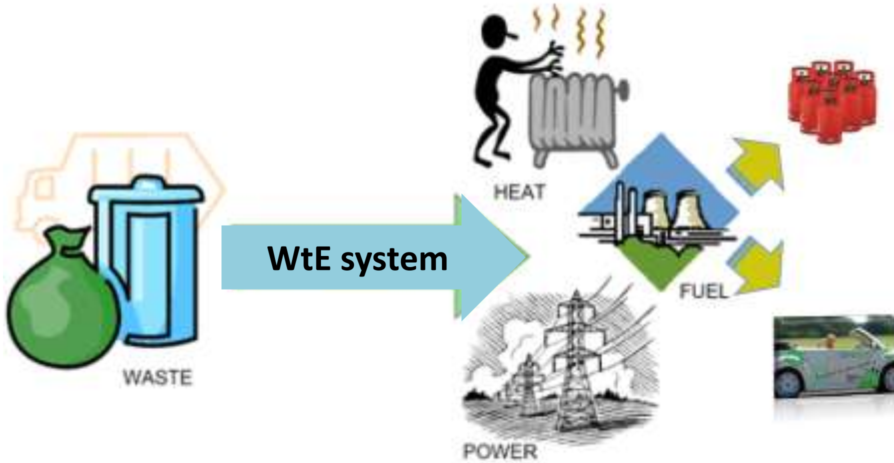
Impacts of waste land filling

Major problems with land filling are

- Air pollution due to release of GHG from land fills
- Soil acidity surrounding the land fill
- Ground and surface water contamination by leachate generated by waste dump
- Health related issues such as dengue, malaria, intestinal problems etc.

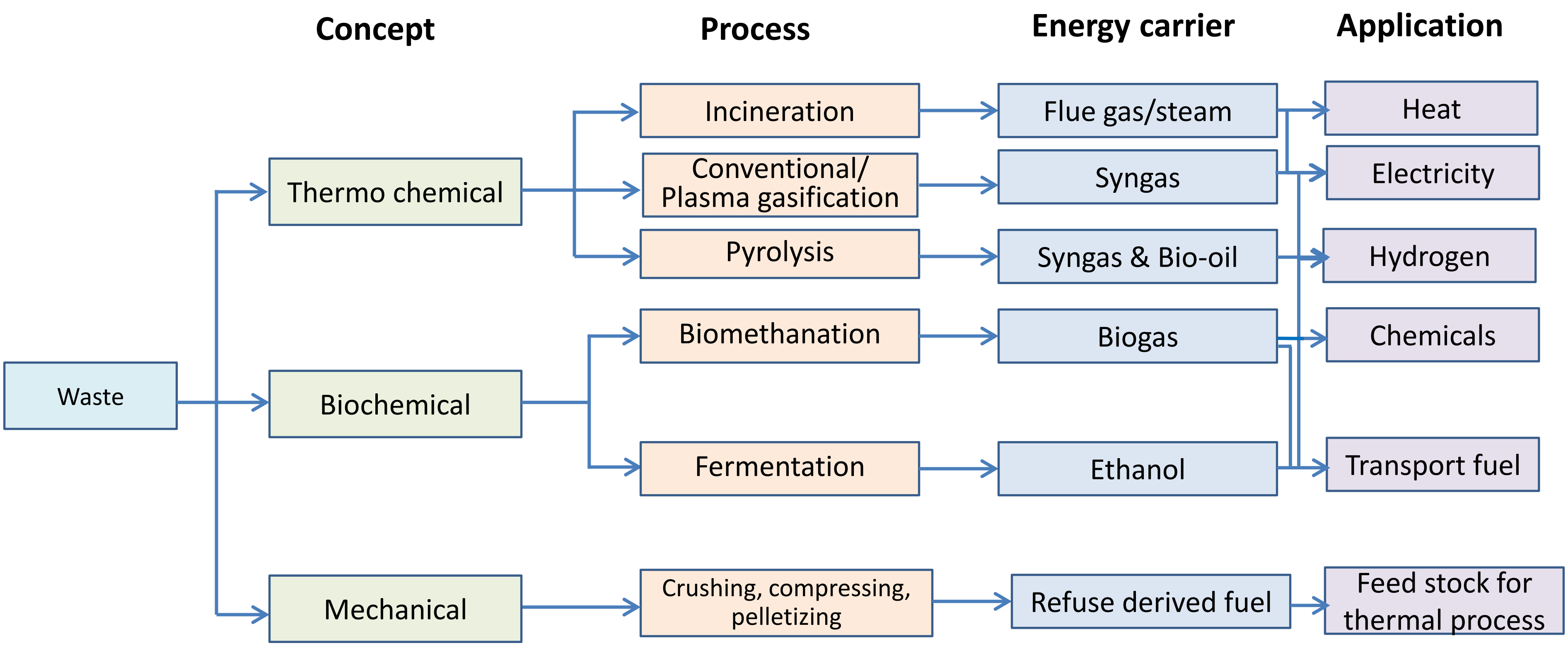
Drivers for waste to energy

- Due to rising urbanization and change in life style, expected solid waste generation going to increase rapidly
- Existing land filling are neither well equipped nor well managed
- Improper land filling adversely affect human health and environment
- At the projected waste generation of 165 MMPA by 2033, required land for land filling for 20 years (considering 10 meter high waste pile) is 66 thousand hectares
- Waste to energy systems uses waste as renewable fuel and generates energy
- WtE systems reduces waste volume by 90% and the remaining residue can be safely disposed off in land fills



WtE systems collects and process the waste scientifically and converts waste into inert non-leachable ash while generating energy

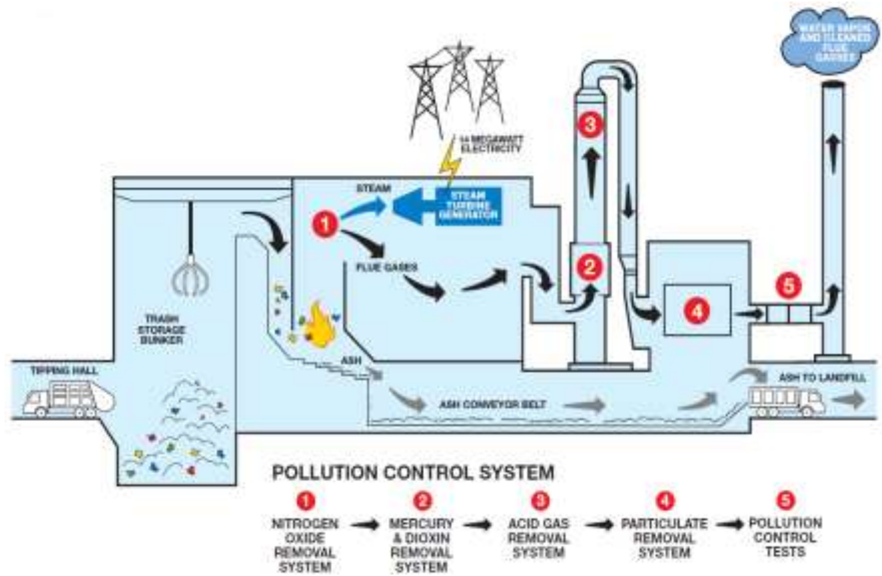
Technologies for conversion of WtE



Waste to energy technologies recover energy from organic fraction of waste using either biochemical or thermo chemical processes

Incineration

- Incineration involves combustion of waste at very high temperatures in the presence of excess oxygen
- Results in the production of ash, flue gas and heat energy
- Incineration is feasible for unprocessed or minimum processed refuse besides for the segregated fraction of the high calorific waste



Advantages

- Immediate reduction in volume and weight by about 90% and 75% respectively
- Stabilization of waste
- Energy recovery

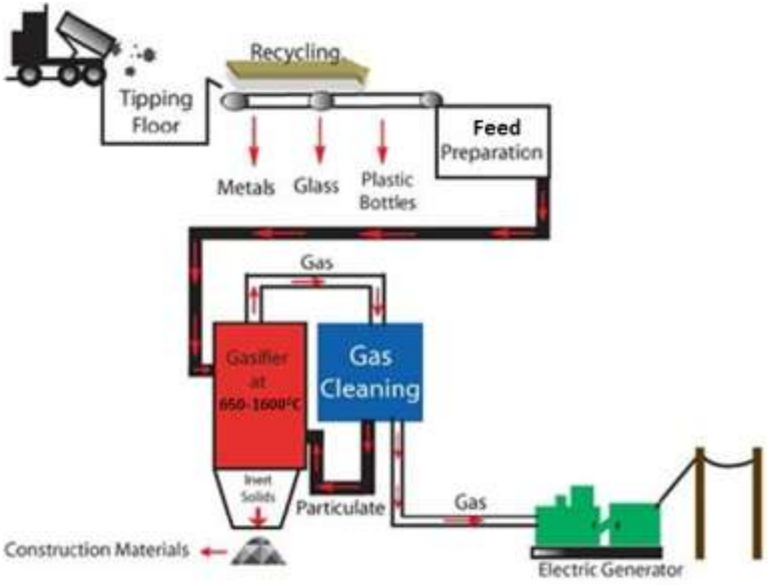
Challenges

- Management of dioxins and furans formed in incineration

Incineration is a maturated technology for processing and energy recovery from waste

Gasification

- Gasification is thermo chemical conversion of carbonaceous fraction of waste into syngas (CO, H_2, CH_4 and CO_2) in oxygen deficient environment and at high temperatures (650-1600°C)
- Inorganic fractions present in the waste converted to ash and can be safely land filled
- Syngas can be used for variety of applications such as generation electricity, FT fuels, chemicals, hydrogen



Advantages

- Immediate reduction in volume and weight
- Environment friendly
- Energy efficient

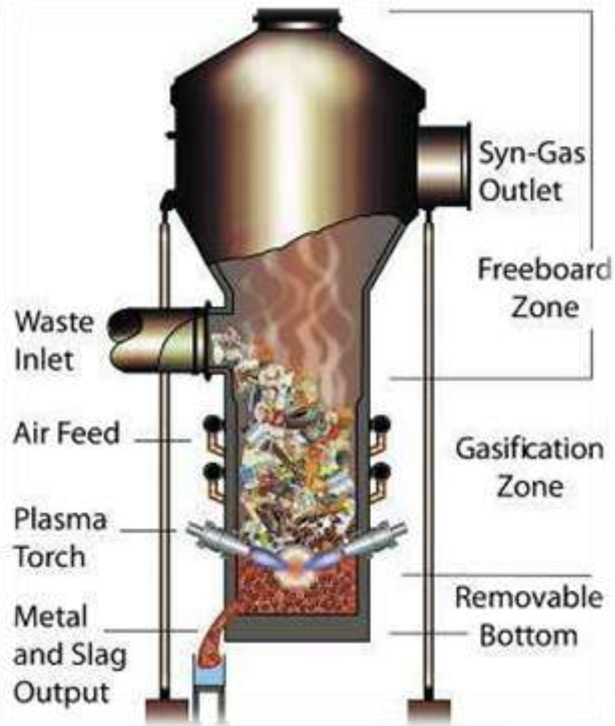
Challenges

- Higher initial cost compared to incineration
- Skilled labour is required

Gasification is more efficient and environmental friendly technology than incineration for conversion waste into energy

Plasma gasification

- Plasma is an ionized gas where the atoms of the gas have lost one or more electrons and have become electrically charged
- Waste introduced into the plasma field, where intense heat breaks down the waste molecules into simple compounds
- Waste converted into fuel gases with high calorific value and inert solid slag in the temperature range 1200 – 2000 ^{0}C



Advantages

- Immediate reduction in volume and weight
- Converts waste to inert vitrified slag
- Suitable for low calorific value waste

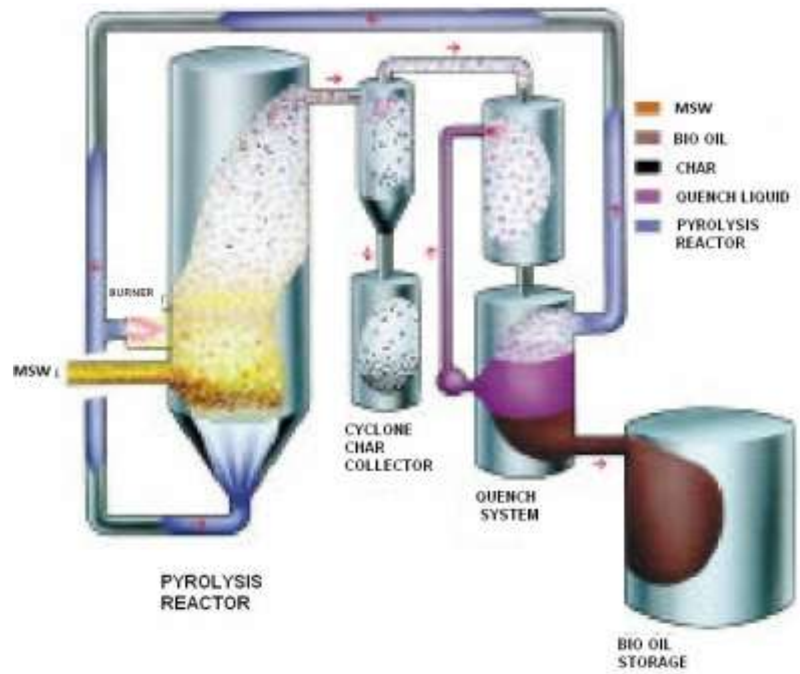
Challenges

- Expensive compared to conventional gasification
- Skilled labor is required

Plasma gasification is an emerging waste to energy technology for processing of variety of waste such as MSW, medical waste, agro waste etc.

Pyrolysis

- Pyrolysis is thermal decomposition of organic fraction of waste in the absence of oxygen
- Pyrolysis is an endothermic process and usually required heat is generated by burning of some of the product gas in separate heater
- Pyrolysis produces three components:
  - ✓ Fuel gas: A mixture of fuel gases
  - ✓ Fuel oil: Consisting of tar, pitch, light oil etc.
  - ✓ Char along with the inert materials in the waste feed



Advantages

- Immediate reduction in volume and weight & less space requirement
- Stabilization of waste
- Easy to operate

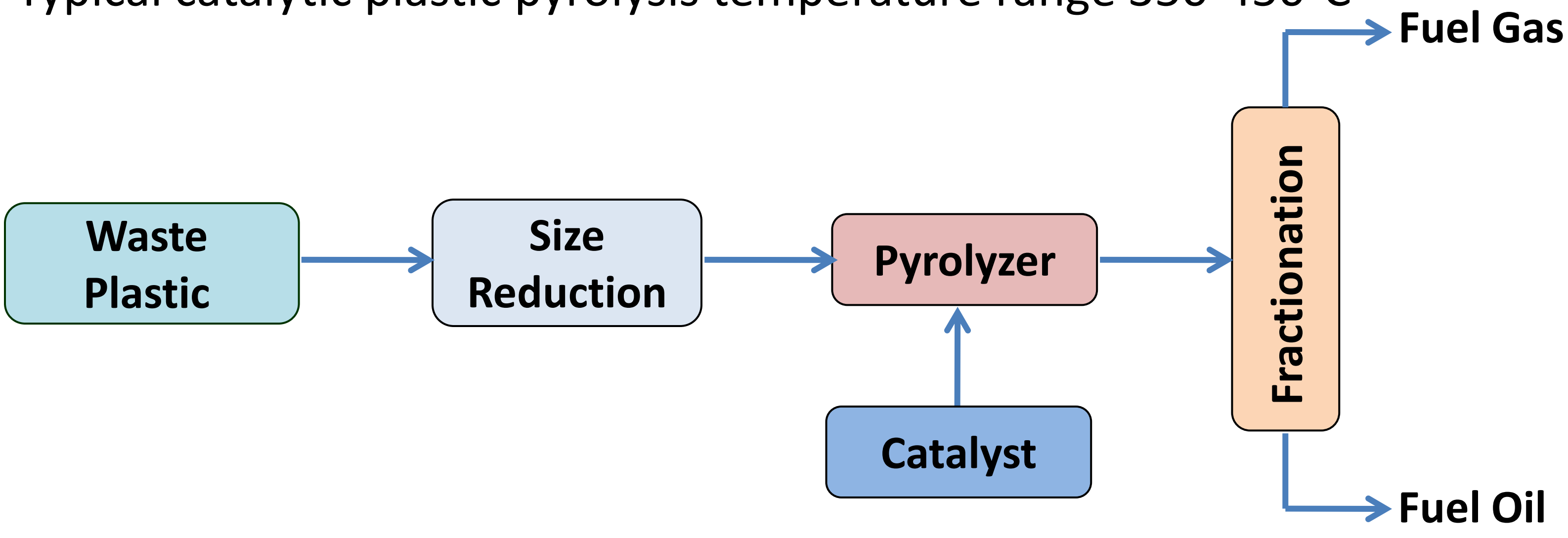
Challenges

- Pyrolysis oil is unstable & needs further processing
- Energy is distributed in 3 fractions

Pyrolysis of waste plastics is an upcoming technology for conversion plastics to either liquid fuels or chemicals

Conversion of plastics to fuel oil

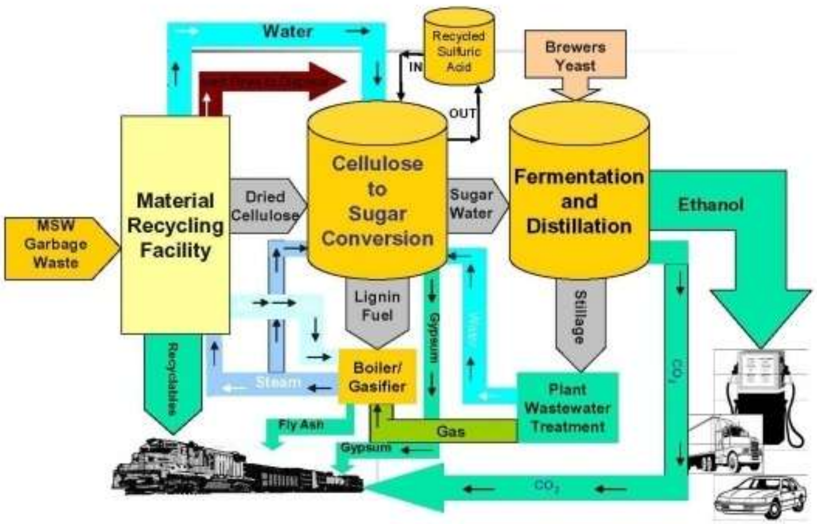
- Catalytic pyrolysis is used for conversion of non-recyclable waste plastics to fuel oil
- Converts plastics into fuels, monomers and other valuable materials by thermal and catalytic cracking process
- Temperature of pyrolysis and catalyst used determines final product
- Typical catalytic plastic pyrolysis temperature range 350-450^{0}C



By changing the catalyst and process parameters, catalytic pyrolysis can produce either gasoline or diesel or petrochemicals

Hydrolysis and fermentation

- First step in conversion of cellulosic fractions of waste to ethanol is hydrolysis of cellulose and hemicellulose into simple sugars using chemicals / enzymes
- Second step is fermentation of sugars into ethanol followed by distillation
- Lignin is by a product in this process



Advantages

- Generation of drop-in bio-fuels
- Stabilization of waste
- Energy recovery

Challenges

- High capital and O & M Cost
- Convert only cellulosic and hemi cellulosic fractions
- Conversion of polysaccharides to sugars is complex

Major challenges in hydrolysis and fermentation are integration of hydrolysis and fermentation into single step, and availability of low cost enzymes

Refuse Derived Fuel(RDF)

- RDF is produced by removing recyclables and noncombustibles from waste and producing a combustible material by shredding, compressing and pelletization of remaining waste
- RDF is easily storable, transportable, and more homogeneous fuel for either steam/ electricity generation or as alternate fuel in industrial furnaces/boilers
- RDF may also be utilized in co-processing in cement kilns, co-combustion in coal fired power plants

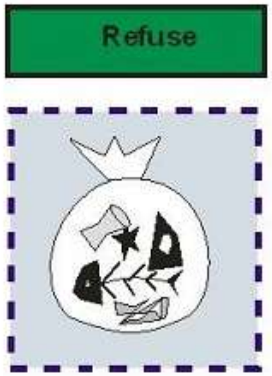
Advantages

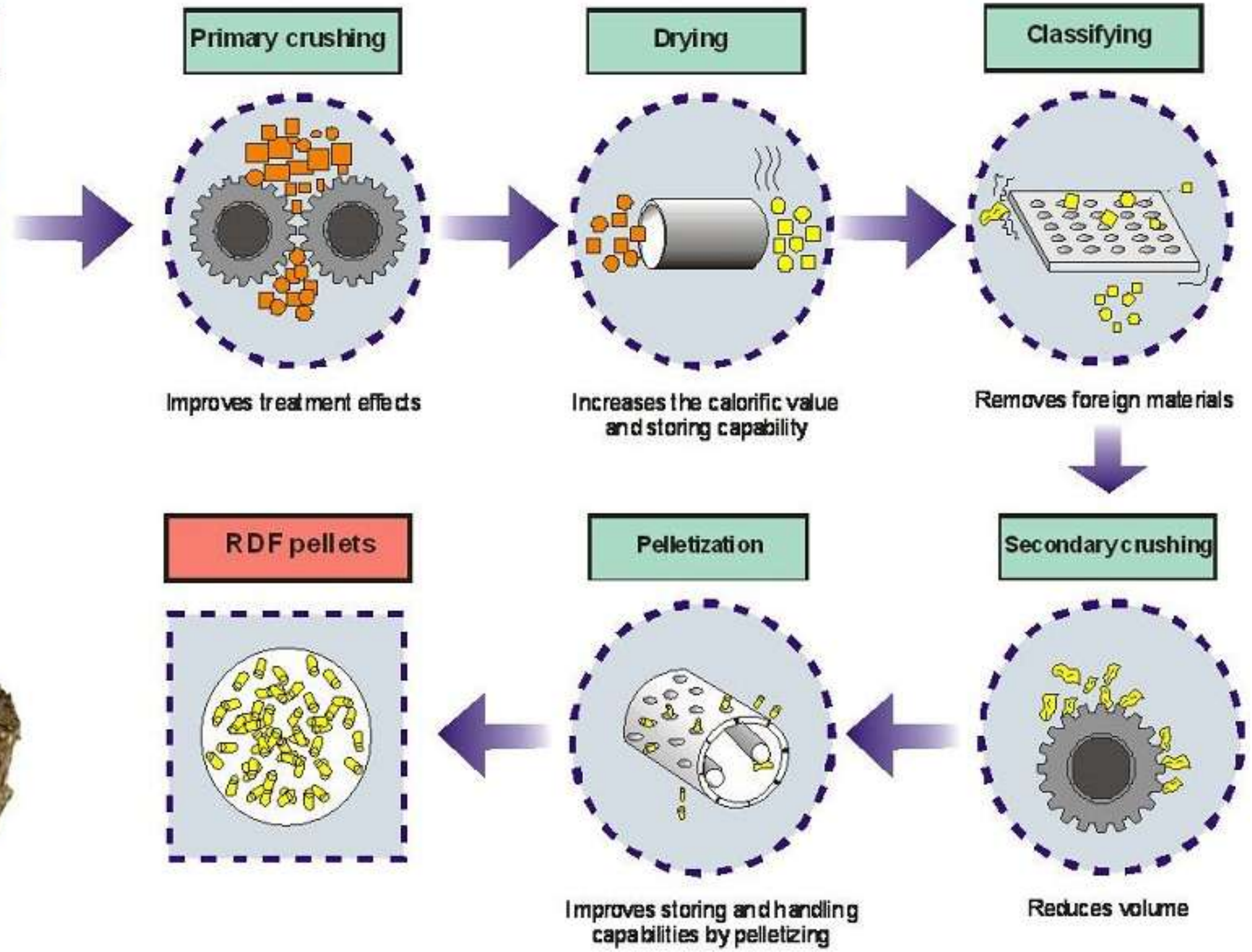
- High calorific value of the waste

Challenges

- Suitable for the areas where large amount of combustible waste is being generated

RDF process flow scheme



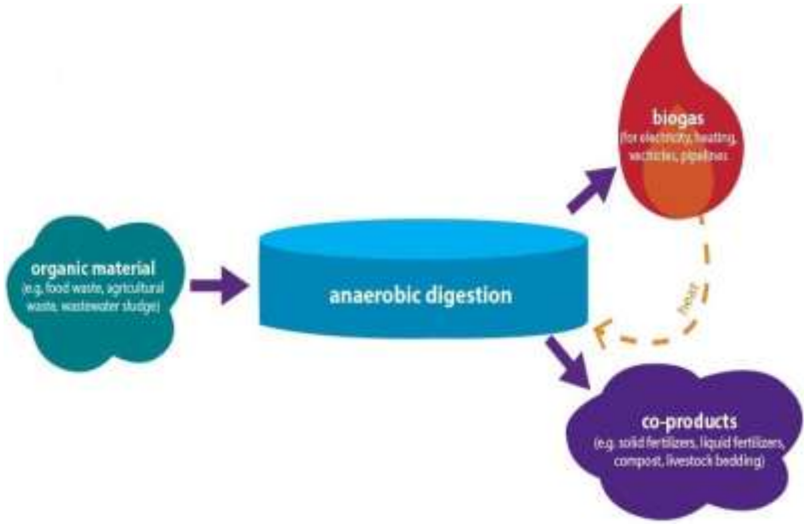


Refuse Derived Fuel (RDF)

RDF is usually prepared in the form of pellet/ briquette/ fluff from dry high calorific value combustible wastes

Biomethanation

- Biomethanation is anaerobic digestion of biodegradable organic waste in an enclosed container under controlled conditions of temperature, moisture, pH, etc.
- Organic fractions present in waste undergoes decomposition thereby generating biogas comprising mainly of methane and carbon dioxide
- Remaining material (digestate) is rich in nutrients and can be used as fertilizer



Advantages

- Energy generation
- Reduced land requirement
- Results in stabilized sludge which can be used as a soil conditioner

Challenges

- Suitable for only wet organic waste
- System is sensitive w.r.t. ambient temperature
- Needs efficient O&M to control odor

Biomethanation is well established and matured technology, but suitable only for wet biodegradable wastes

WtE : Technology selection considerations 3 E's

Environment

- Emissions control
- Minimize Landfill

Economy

- Cost Vs. Benefit
- Social & Financial

Energy

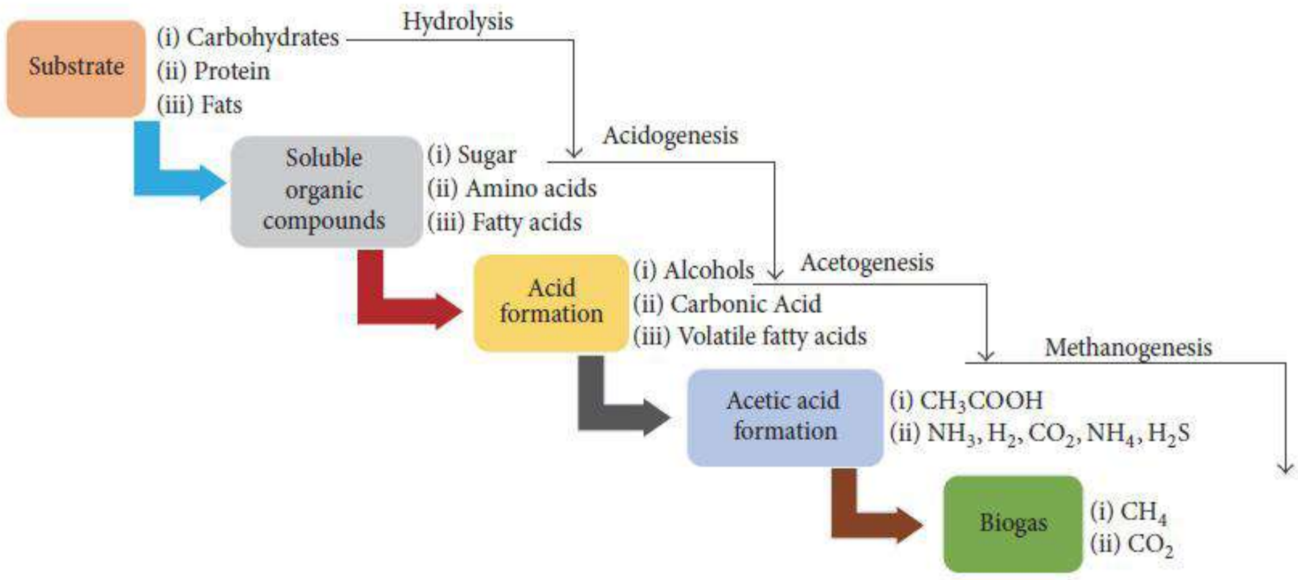
- ✓ Energy recovery
- ✓ Efficiency

Selection of waste to energy technology is based on scale of waste to be processed, existing emission norms, energy recovery and economic factors

IOC R&D initiatives on waste to energy

Biomethanation
Process Steps

- Anaerobic digestion take place in 3 steps
- Hydrolysis - breaks down the organic material into simple molecules such as sugar, fatty acids and amino acids
- Acidogenesis - Conversion of hydrolyzed organic matter into volatile fatty acids(VFAs)
- Methanogenesis - Conversion of VFAs into methane gas



Biomethanation
Feedstocks

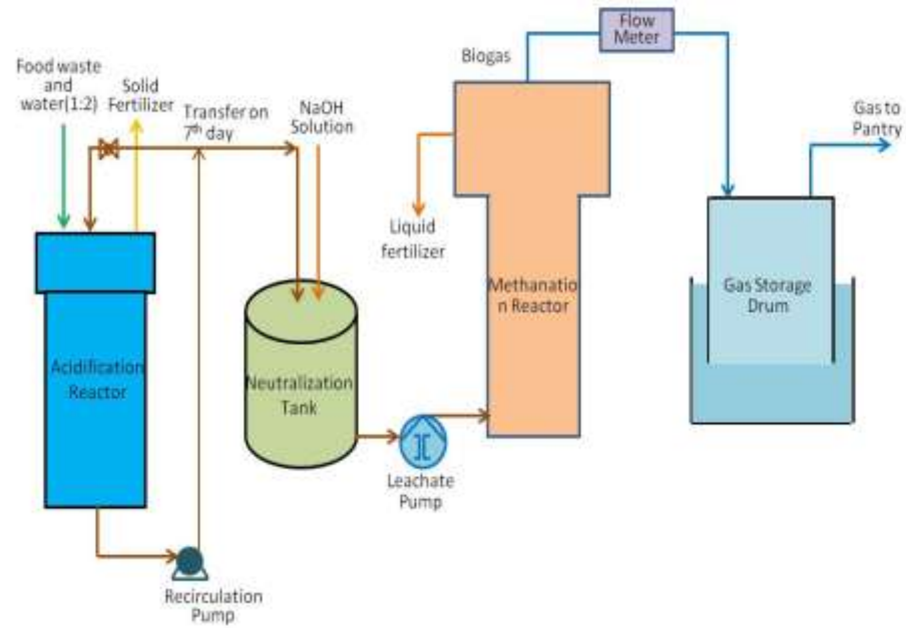
- Food waste (both precooked and leftover) from various sources like food processing industries, households, and hospitality sector
- Horticultural/plant residues
- Animal waste (Cattle dung and Poultry droppings etc)
- Dairy waste
- Municipal Solid Waste (MSW)

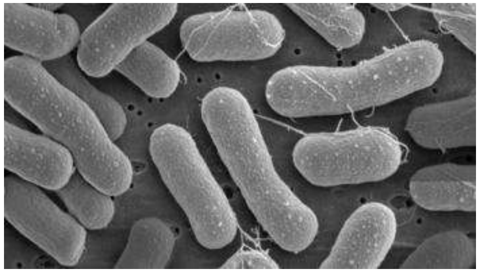
Large Potential of energy recovery from above substrates and treatment & disposal of wastes

Biomethanation of kitchen waste

IOCL R&D Technology

- Developed two stage biomethanation process for conversion of kitchen waste to biogas
- In the first stage biodegradable organic fraction present in waste gets extracted into liquid form
- In second stage organic matter present in liquid is converted into biogas in the presence of high performance bacterial innoculum





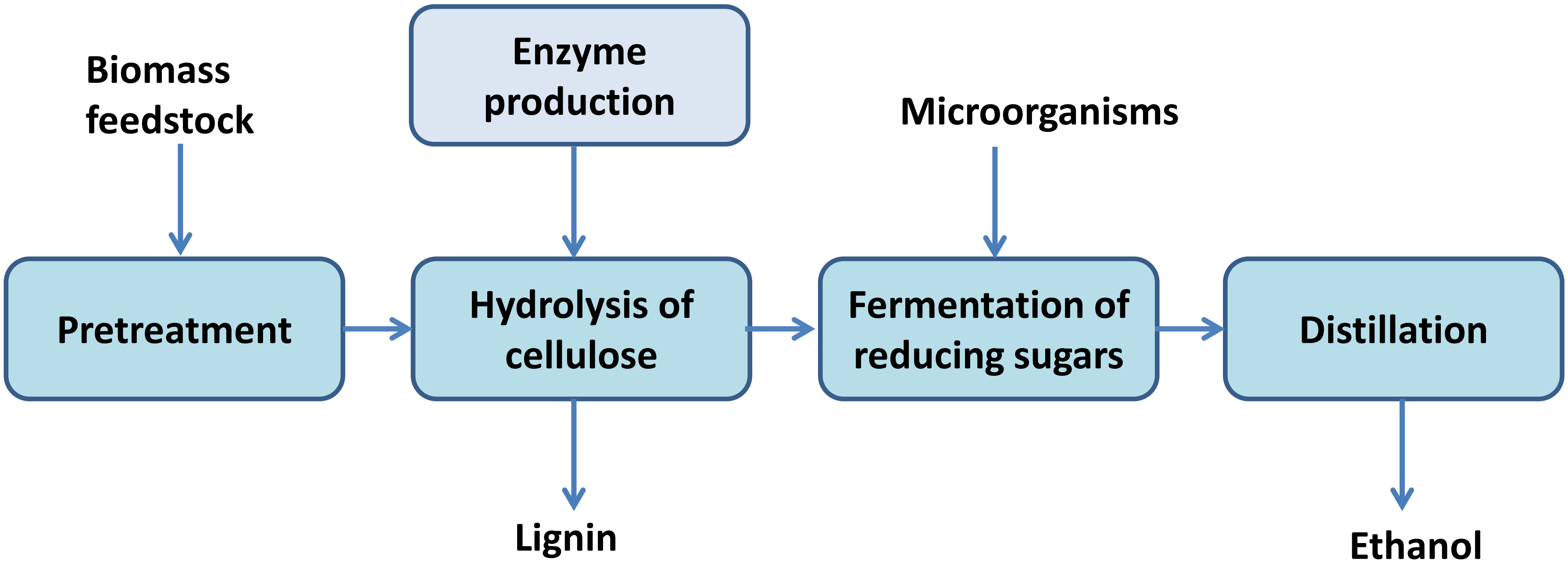
Typical composition of biogas generated

Component	Methane	Carbon dioxide	Nitrogen
Composition (vol%)	80-85%	11-13%	3-5%

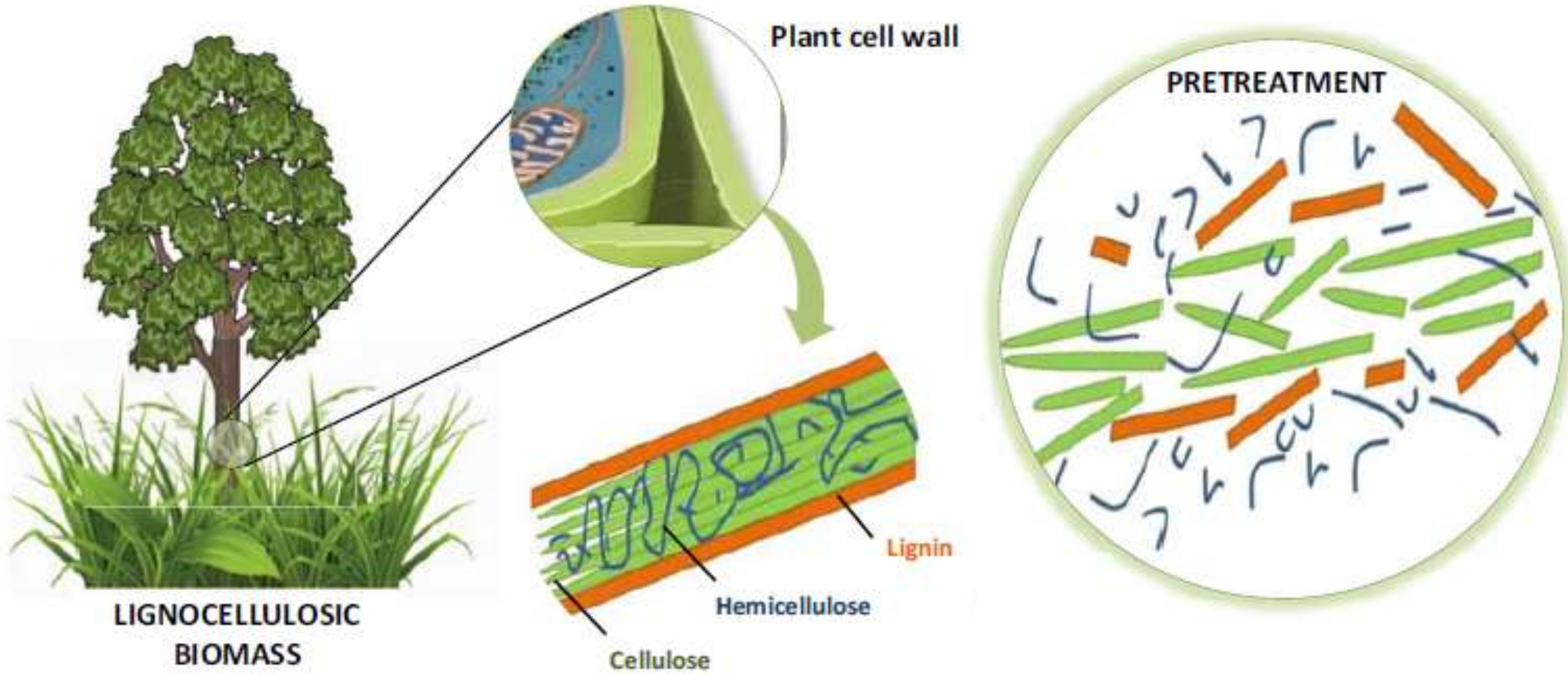
Biomethanation of kitchen waste
IOCL R&D Technology

- 50 kg /d plant under operation at IOCL R&D
  - Biogas is being used for cooking purpose
- In-house inoculum performance evaluated in 250 kg/d commercial plant at Panipat Refinery
- 250kg/d plant based on in-house design & inoculum is being set up at AOD refinery
- Plans to set up plants in college hostels, Municipal areas, integrated townships etc.

2nd Generation (2G)Ethanol



Lignocellulosic Biomass
Components



Cellulosic ethanol (2G) IOCL R&D Technology

- IOC has developed low Capex, low Opex process at 250 kg/day pilot scale to convert lignocellulosic biomass feedstock such as rice straw, bagasse into ethanol.
- The patented process uses acid pretreatment and novel Simultaneous Saccharification & Co-fermentation (SSCF) process at pilot scale along with in-house developed enzymes
- The process uses low enzyme dosage at high solid loadings to get more ethanol production per ton of Biomass ***(Enzyme cost is major portion in Opex)***
- Life Cycle analysis of each process done and it qualifies as advanced biofuel technology
- 10 TPD Demonstration plant on 2G ethanol technology planned to be commissioned by December 2018
- Data generated shall be used to set up a commercial plants based on indigenous technology

Multi feed/ multi chemical lignocellulosic ethanol pilot plant

Fermenter for Enzyme production

Cellulosic Ethanol
Typical Process Outline

Lignocellulosic Biomass

STEP 1 — Pre-Treatment Step → **Most Complex Step**
High in CAPEX

STEP 2 — Saccharification → **Requires complex enzymes**
High in OPEX

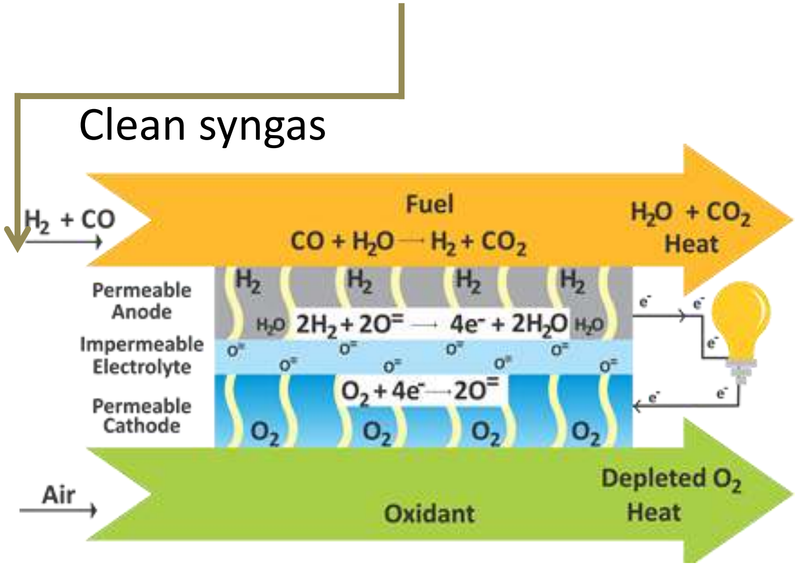
STEP 3 — Fermentation → **Innovations reqd for better Performance & time reduction**

STEP 4 — Separation/Purification → **Alcohol**

Our efforts are directed to reduce cost & process time

Biomass Gasification and Pyrolysis

- Biomass gasification to produce syn gas
- Integration of biomass gasifier with solid oxide fuel cell for electricity generation **(Higher efficiency of fuel cell)**
- Integration of biomass gasifier with gas fermentation technologies for production of ethanol **(economical amongst competing ethanol production technologies)**
- Pyrolysis of agri residues and utilize generated bio-oil for hydrogen generation **(decentralised production)** and co-processing in FCC / delayed coker unit **(value upgradation)**
- Integration of biomass pyrolyser with coal / petcoke gasifier **(reduce oxygen demand in gasifier due to inherent oxygen in Biomass)**



Summary

- Waste is a growing renewable energy source that can be used for generation of energy
- Conversion of waste to energy is not only reduces detrimental effects of land disposal but also avoids GHG emissions associated from fossil fuels combustion
- Incineration of waste is a maturated technology and being extensively used around the world
- Biomethanation is also well established and matured technology, but suitable only for wet biodegradable wastes
- Gasification and pyrolysis are emerging waste to energy conversation technologies
- Selection of waste to energy technology is based on scale of waste to be treated, emission norms, energy recovery and economic factors

Don’t look at Waste as a waste !

Look it as an useful energy source !!

IndianOil R&D The Power of Possibilities

Thank You