Technology Routes for Biomass Conversion

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- Biomass characteristics relevant to conversion
- Biomethanation – Biogas
- Producer gas
- Liquid Fuels – Non-edible oil from trees

  Alcohols from sugarcane and biomass

  Pyrolitic oil through fast pyrolisis.
- Reciprocating engines and gas turbines with liquid fuels, biogas and producer gas – the differences

Biomass Features

Sugars

Oils

Starch

Biomass

Cellulose

Hemi-cellulose

Lignin

Leafy biomass – Mostly cellulosic + some starch + some lignin

Woody biomass – 50 % cellulose + 25 % hemi-cellulose + 25 % lignin

Seeds – Starch and/or oils

Sugars + starch ◊ easily digested by bacteria (without or with air)

Vegetable and leafy wastes ◊ digested by bacteria even though not so completely or easily (time requirement) again, without or with air.

Woody wastes ◊ difficult to be digested by bacteria

Lignin requires fungi for digestion

We exclude those meant for human/animal consumption – wastes and rejects are acceptable.

Kitchen wastes – fruits/vegetables/some starchy stuff

Market wastes – similar to the above - Contain large amount of sugars/starch.

Sewage – contains starch/more complex biodegradable matter.

Urban solid wastes – contains some biodegradable matter and a larger amount of matter that can be converted only by thermo chemical means (lignaceous, plastics, etc)

Agricultural wastes – contains a large amount of matter that can be converted by thermo-chemical means.

Plantation residues – same as above

Biomethanation Route

Biomethanation route (under anaerobic operating conditions) has two operating temperatures depending on the bacteria available for conversion.

Mesophyllic bacteria operate at 37 C or less with progressively deteriorate in performance with decrease in temperature.

Thermophyllic bacteria operate between 52 to 55 C Operating the reactors calls for pH control since both acidic (pH ~ 3 to 5) and near neutral conditions (pH ~ 6.5 to 7.5)prevail in the two segments of the conversion process – acidification and methanogenic action .

Biomethanation route is well known for bovine dung and both China and India have vary large number of plants for domestic and community applications, The design is simple - a feed system and a extraction system – hydraulic residence time of 30 to 40 days at ambient temperature. This functions well at tropical conditions with liquid temperatures ~ 20 to 30 C.

At lower temperatures, performance goes down.

High rate Biomethanation techniques (35 and 55 C operations) can improve the performance. These have not been attempted with bovine dung since the market cannot sustain the capital investment costs.

In the above cases the solids content is about 10 %. For MSW (Municipal solid waste treatment using Biomethanation, There are several processes with some of them working with solids content as large as 20 % (like the DRy ANaerobic COmposting – DRANCO process). Most of these have been developed in Europe.

1 kg of solids with 4 to 9 times the water will produce about 50 20 gms (30 to 70 liters) of gas.

The composition of the gas is: 50 to 55 % Methane, ~ 1000 to 5000 ppm Hydrogen sulfide and the remaining amount ~ 47 % Carbondioxide.

For distillery effluents one uses anaerobic digestion technique to reduce the BOD/COD of the effluent. These plants use generally high rate biomethanation processes.

The composition of the gas is 60 to 65 % Methane, 2 to 5 % Hydrogen sulfide and remaining ~ 33 % CO2.

The gas has a calorific value of 18 to 22 MJ/m3.

The air-to-gas ratio for complete combustion is 9 to 12 (volumetric or mass measure is not very different) depending on the methane fraction in the gas [as a reference, for Methane, the air to fuel ratio is 17 by mass measure and 10 by volume measure].

It can be used to generate electricity via reciprocating engines/gas turbines. The Hydrogen sulfide content has to be brought down to less than 1000 ppm for sure and desirably to a few ppm.

The total installation cost of the Biomethanation plant and power generation system will be around 2.5 to 3 million US $/MWe.

Thermochemical conversion Technologies

Use combustion process – on a grate – to provide hot gases to be used to raise high pressure steam and then extract power from steam turbine – generator route (standard).

The calorific value of dry biomass is 16 MJ/kg.

The air-to-biomass ratio at stoichiometry is about 6.

(note for reference, the calorific value of fossil fuels is about 42 MJ/kg and the stoichiometric air-to-fuel ratio is 15)

The cost of the power generation system is 0.8 to 1 million US $/MWe. Economical at power levels more than 3 MWe. At lower power levels, the cost goes up to 1.5 to 2 million US $/ MWe.

The cost of energy is about 0.12 cents (US) per MJ for biomass and 0.75 cents (US) for fossil fuels (in India)

For power levels less than 2 MWe, the cost can be cut down by using gasification technologies and using the gas in reciprocating engines.

Gasification of solid biomass occurs because of thermo-chemical reactions at sub-stoichiometric conditions.

One gets a gas: CO = 20 %, H_2 = 18 %, CH_4 = 2 %, CO_2 = 12 %, H_2O = 2 %, Rest = N_2

This gasification process captures between 78 to 82 % of the energy in Biomass. Every kg of dry biomass generates 2.8 m^3 of gas. The gas has a calorific value of 4.5 to 5 MJ/m^3. The stoichiometric air-to-fuel ratio is 1.4 [note: 1 kg biomass needs 6 kg of air for combustion. This is the same as the above calculation as follows: Biomass requires 1.8 kg air for gasification. The gas whose magnitude is 2.8 kg requires 2.8 times 1.4 kg air = 3.92 kg air – thus the total air required for combustion is 1.8 + 3.92 = 5.72, a value close to 6.0]

When used in dual fuel mode in diesel engines, the dry biomass and diesel required are about 0.9 to 1 kg and 60 to 75 ml per kWh.

When used in producer gas engines, the dry biomass required is about 1.0 to 1.3 kg/kWh.

Liquid Fuels – Non-edible oil from trees

Alcohols from sugarcane and biomass

Pyrolitic oil through process

A large number of trees store in their seeds, starch or oils. Some of these are non-edible. They can be used for power generation.

These are Rape seed oil, Jatropha, Jojoba, Mohua, Sal, Pongemia, Cashew, Neem, Anderouba, Soumarouba.

The seeds should be dried, used in an oil expeller to extract the oil, filter the oil, esterifies by adding methyl or ethyl alcohol (depending on what is cheaper and available) – about 5 %; this also reduces the emissions when used in engines.

The oils have a calorific value about 5 to 10 % lower than diesel. They work very well in compression ignition engines. The amount required for producing electricity is 275 to 330 ml/kWh in comparison to 250 to 300 ml/kWh for diesel. Many of the oil- bearing trees are hardy and grow in semi-arid climates as well. They are the cheapest means for sustainable diesel-like fuel for the entire world when fossil fuels get exhausted.

Alcohols are produced from sugar juice through the process of fermentation. They have about 60 % energy compared to fossil fuels and non-sooty in combustion since the oxidizing element – O is in the molecular structure itself – CH_3OH or C_2H_5OH.

Some attempts are being made to derive alcohol from biomass. This process is likely to be more expensive.

A technique called fast pyrolisis in which the biomass is heated at about 1000 C/s so that it releases gases which contain a high amount of condensable combustibles leading to the generation of liquid fuel. This process requires that the biomass be reduced in size to small particles so that high heating rates can be achieved. The liquid fuel that is generated from this technique has 20 to 30 % non-separable water, , and acidic components to a degree to require all ducting to be made resistant to acid attack. Its calorific value is about 20 MJ/kg. It has difficulties in ignition and when used in reciprocating engines, poses serious problems. It can be used with greater convenience in gas turbine engines (since the combustion process is continuous).

Reciprocating engines and gas turbines with liquid fuels, biogas and producer gas – the differences

Reciprocating engines are built in large numbers compared to gas turbine engines. They are built for clean liquid and gaseous fuels – Diesel, gasoline and natural gas. They are built for not-so clean fuels – Light diesel oil (LDO), Low sulphur heavy stock (LSHS) and Furnace oil; in terms of gases, biogas (largely natural gas + carbon dioxide) is a familiar fuel;

Compression ignition (CI) engines that can take diesel oil can also handle non-edible oils with some alcohol or with no alcohol. CI engines dealing with furnace oil can very conveniently accept non-edible oils. In dual-fuel mode, they can take producer gas as well to replace even up to 75 % fossil fuel.

Spark ignition engines can take gasoline with or without blends with alcohols, and alcohols alone.

Gas turbine engines demand fuels that are much cleaner compared to reciprocating engines. This is because the turbine blades rotating at high speed tend to erode with impingement of particulate matter and corrode in the presence of sulphur oxides in the hot gas. Gas turbine installation becomes economical only at high power.

Reciprocating engines are relatively cheaper. Recent trends in the development of high power reciprocating engines (~ 3 MWe class) has shown that one can get very high efficiencies comparable to combined cycle operation (~ 42 %)

These show future trends in the utilization of bio-resources for energy generation.