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Review Article

Gasification – A Process for Energy Recovery and Disposal of Municipal Solid Waste

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Abstract: The paper offers an outline of Gasification technology, starting from basic aspects of the process and arriving to a comparative examination of Gasification and Incineration and the environmental applications of Gasification technology for Municipal Solid Waste management (MSW) and also considered limitations of Gasification Technology. Gasification is waste to energy technology that is able to convert a variety of waste materials into renewable and alternative energy products. The technology can process nearly any carbonaceous material, transforming it into forms of usable energy that can be consumed or sold easily. This review paper indicates that Gasification technology can help the world both manage its waste and produce the energy and products needed to fuel economic growth. It is able to meet existing emission limits and can have a remarkable effect on reduction of landfill disposal option.

Keywords: Waste-to-Energy, Gasification, Municipal Solid Waste, Syngas, Incineration

1. Introduction

The growth of energy demand in India is not balanced with the availability of energy. Currently, energy needs in India continue to rise. In India alone, 300 million people lack any access to power and another 400 million Indians have limited access to power. India is on economic growth, and energy needs to provision electricity continue to rise, while we obtain the energy we need in a variety of ways, ranging from the conversion of light and radiant heat from the sun into a usable form to the use of nuclear energy. Perhaps the most familiar release of energy is the combustion of fossil fuels. Fossil energy can no longer dependable as a source of energy major in pushing economic growth in the future, besides fossil energy also produces emission takes damage the environment. On the other side India has renewable energy source very large, as MSW.

According to repot of Central Pollution Control Board, Government of India that 1, 83,765 MT of MSW was generated daily in the country. Out of this only 75- 80% of the municipal waste gets collected. Out of this, only 22-28% is processed and treated, remaining disposed of indiscriminately at dump yards. [12, 13]

As given in table 1, current practice of dumping on landfills without treatment will need 3, 40,000 cubic meter of landfill space every day and 1240 hectare per year. Considering the projected waste generation of 165 million tons by 2031, the requirement of land for setting up landfill for 20 years (considering 10 meter high waste pile) could be as high as 66,000 hectare.

Table 1. *Waste generation scenario in India and future projection.*

S. No.	Parameters	Present Scenario 2011 Census	Projected for 2031
1	GDP Growth Rate	5.54%	8%
2	Manufacturing Rate	4%	7%
3	Urban Population	377 Million	600 Million
4	Waste Generation	62 Million TPA	165 Million TPA
5	Land for Disposal	1240 hectare/year	66,000 hectare/ year

In addition to increasing waste generation, the global demand for energy will increase by 56 percent between 2010 and 2040, with the greatest demand in the developing world.

According to the World Bank, there are currently 1.2 billion people (20% of the world's population) without access to electricity. [14]

2. Gasification Technology

Gasification technology turns variety of low-value feedstock into high-value products, it can converts any carbon-containing material into a synthesis gas (syngas). The syngas is a combustible gas mixture and it typically contains carbon monoxide, hydrogen, nitrogen, carbon dioxide and methane. The syngas can be used as a fuel to generate electricity or steam. Alternatively, it can be converted into electricity and valuable products. [2] With Gasification, MSW and wastes are no longer useless, but they become feedstock for a gasifier. Instead of paying to dispose of and manage the waste for years in a landfill, using it as a feedstock for Gasification reduces disposal costs and landfill space, and converts those wastes into valuable electricity, fuels, chemicals or fertilizers. [1]

The overall thermal efficiency of Gasification process is more than 75%. Gasification can accommodate a wide variety of gaseous, liquid, and solid feedstock and it has been widely used in commercial applications for more than 50 years in the production of fuels and chemicals. [3] Conventional fuels such as coal and oil, as well as low- or negative-value materials and wastes such as petroleum coke, heavy refinery residuals, secondary oil-bearing refinery materials, municipal sewage sludge, hydrocarbon contaminated soils, and chlorinated hydrocarbon byproducts have all been used successfully in Gasification operations.

3. Process of Gasification

Gasifier capture the remaining value from a variety of MSW streams feedstock can include Wood waste, Crops, Agricultural waste, Wastewater treatment plant bio solids, Plastics, Cardboards, Tyres, Animal wastes and blends of the various feedstock's. Generally, the feedstock requires some pre-processing to remove the inorganic materials (such as metals and glass) that cannot be gasified. In addition, the feedstock is typically shredded into very small particles as well as dried before being fed into the gasifier. The feedstock is fed into the gasifier along with a controlled amount of air or oxygen. The temperatures in a gasifier for MSW typically range from 800°C to 1200°C.

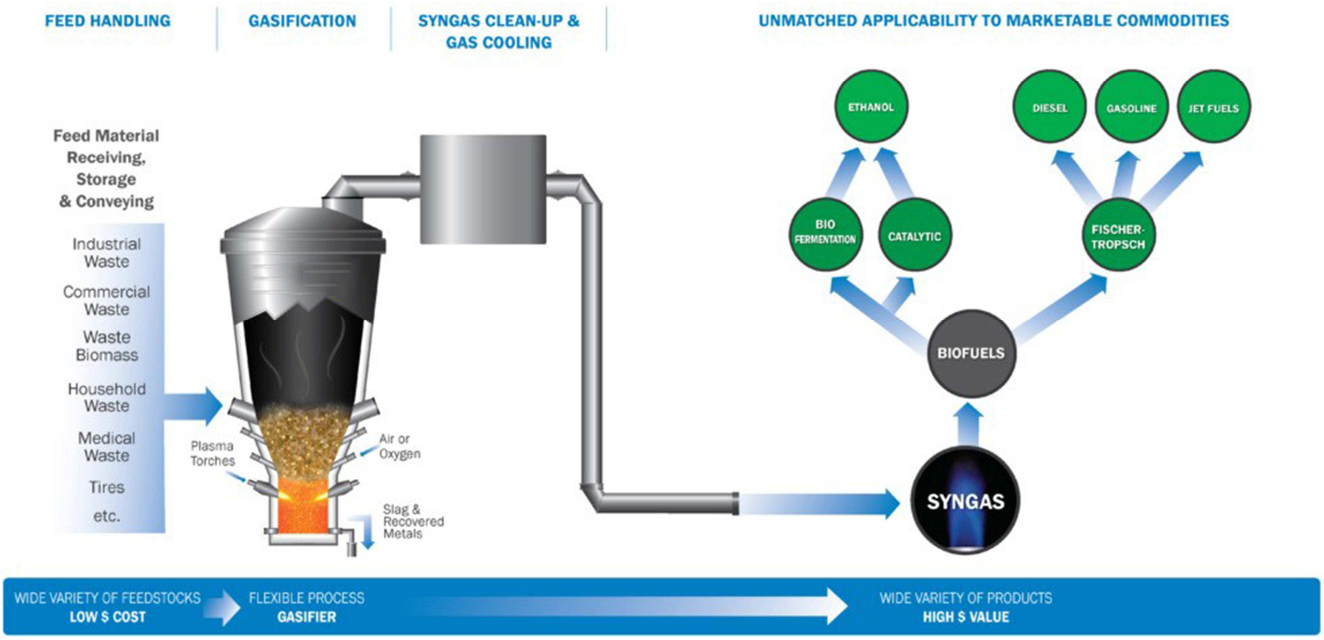

Figure 1. *Schematic process of Gasification.*

As indicated in figure 1, many downstream processes require that the syngas should be cleaned of trace levels of impurities. Trace minerals, particulates, sulfur compounds, mercury and unconverted carbon can be removed to very low levels using processes common to the chemical and refining industries. The clean syngas can then be sent to a boiler, internal combustion engine or gas turbine to generate electricity or further converted into chemicals, fertilizers transportation fuels, or substitute's natural gas. [7]

As shown in figure 2, the chemical reactions in Gasification process take place in the presence of steam in an oxygen-lean, reducing atmosphere. The ratio of oxygen molecules to carbon molecules is far less than one in the Gasification reactor. [5] A portion of the fuel undergoes partial oxidation by precisely controlling the amount of oxygen fed to the gasifier. The heat released in the first reaction provides the necessary energy for the other Gasification reaction to proceed very rapidly. At higher temperatures the endothermic reactions of carbon with steam are favored.

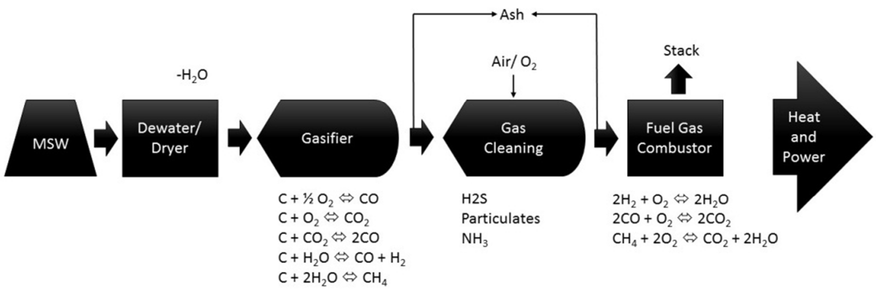

Figure 2. *Chemical Reaction of Gasification.*

Wide variety of carbonaceous feedstock can be used in the Gasification process. Low-BTU wastes may be blended with high-BTU supplementary fuels such as coal or petroleum coke to maintain the desired Gasification temperatures in the reactor. The reducing atmosphere within the Gasification reactor prevents the formation of oxidized species such as SO_x and NO_x which are replaced by H_2S, ammonia, and nitrogen. These species are much easier to scrub from the syngas than their oxidized counterparts before the syngas is utilized for power.

Gasification has been used worldwide on a commercial scale for making gas from coal for heating, lighting and cooking for over centuries. It has been used for more than 80 years by the chemical, refining and fertilizer industries and for more than 35 years by the electric power industry. [4] Gasification is now being adapted for smaller-scale applications to solve the problem of waste disposal and to extract valuable energy from waste.

4. Methodology

In the Gasification process, MSW is not a fuel, but a feedstock for a high chemical conversion process. There's no burning. Gasification can convert MSW that would typically be incinerated into a clean, useful syngas. This clean syngas can then be used to produce energy and valuable products, such as chemicals, transportation fuels, fertilizers, and electricity. Gasification does not compete with recycling; in fact, it enhances it. Metals, glass, and other materials that cannot be gasified are typically segregated from the waste stream prior to being sent into the Gasification process. There are significant environmental benefits of MSW Gasification, including reducing the need for landfill space, decreasing methane emissions from the decomposition of organic materials in the landfill, and reducing the risk of surface water and groundwater contamination from landfills.

5. Gasification Is Not Incineration

While Gasification and incineration are both thermal processes, it is important to point out the advantages of Gasification over incineration. Incineration is simply a mass burn technology with heat recovery to produce steam and/or electricity. It has negative connotations because during the direct combustion of the waste, dangerous carcinogenic compounds such as dioxins and furans are formed, which are discharged into the atmosphere. [8] In contrast, Gasification employs the conversion of waste into syngas, which can then be used for generating steam and/or electricity, for producing chemicals for high-value products, or for producing liquid fuels. The synthesis gas is produced under controlled conditions, and is generated without the formation of impurities associated with incinerator flue gas. Gasification emissions are generally an order of magnitude lower than the emissions from an incinerator. [9]

As shown in table 2, the Gasification process represents significant advances over incineration. In order to understand the advantages of Gasification when compared to incineration, it's important to understand the differences between the two processes:

Incineration literally means to render to ash. Incineration uses MSW as a fuel, burning it with high volumes of air to form carbon dioxide and heat. In a waste-to-energy plant that uses incineration, these hot gases are used to make steam, which is then used to generate electricity.

Gasification converts MSW to a usable synthesis gas, or syngas. It is the production of this intermediate product, syngas, which makes Gasification so different from incineration. In the Gasification process, the MSW is not a fuel, but a feedstock for a high temperature chemical conversion process. Instead of producing just heat and electricity, as is done in a waste-to-energy plant using incineration, the syngas produced by Gasification can be turned into higher value commercial products such as transportation fuels, chemicals, fertilizers, and even substitute natural gas. Incineration cannot achieve this. One of the concerns with incineration of MSW is the formation and reformation of toxic dioxins and furans, especially from PVC-containing plastics.

Table 2. *Incineration vs Gasification.*

Incineration	Gasification
$C + O_2 \rightarrow CO_2$	$C + ½ O_2 \rightarrow CO$ $C + CO_2 \rightarrow 2CO$ $C + H_2O \rightarrow CO + H_2$
A flame is present	Syngas is produced
Incineration is the burning of fuels in an oxygen-rich environment	Require very less oxygen
Dioxins and Furans forms	The oxygen-deficient atmosphere in a gasifier does not provide the surroundings needed for dioxins and furans to form or reform.
Comparatively much space required to perform incineration	Least amount of space required for system
Open System	Completely sealed storage unit

These toxins end up in incinerator exhaust streams by three pathways:

1. By decomposition, as smaller parts of larger molecules;
2. By "re-forming" when smaller molecules combine together; and/or
3. By simply passing through the incinerator without change.

Incineration does not allow control of these processes, and all clean-up occurs after combustion. One of the important advantages of Gasification is that the syngas can be cleaned of contaminants prior to its use, eliminating many of the types of after-the-fact (post-combustion) emission control systems required in incineration plants. The clean syngas can be used in reciprocating engines or turbines to generate electricity or further processed to produce hydrogen, substitute natural gas, chemicals, fertilizers or transportation fuels, such as ethanol.

In the high temperature environment in Gasification, larger molecules such as plastics, are broken down into the valuable components of syngas, which can be cleaned and processed before any further use. Dioxins and furans need sufficient oxygen to form or re-form, and the oxygen-deficient atmosphere in a gasifier does not provide the environment needed for dioxins and furans to form or reform. Dioxins need fine metal particulates in the exhaust to reform; syngas from Gasification is typically cleaned of particulates before being used. [10]

In Gasification facilities that use the syngas to produce downstream products like fuels, chemicals and fertilizers, the syngas is quickly quench-cooled, so that there is not sufficient residence time in the temperature range where dioxins or furans could re-form; and when the syngas is primarily used as a fuel for making heat, it can be cleaned as necessary before combustion; this cannot occur with incineration. [6] The ash produced from Gasification is different from what is produced from an incinerator. While incinerator ash is considered safe for use as alternative daily cover on landfills, there are concerns with its use in commercial products. In high-temperature Gasification, the ash actually flows from the gasifier in a molten form, where it is quench-cooled, forming a glassy, non-leachable slag that can be used for making cement, roofing shingles, as an asphalt filler or for sandblasting. [11] Some gasifier are designed to recover melted metals in a separate stream, further taking advantage of the ability of Gasification technology to enhance recycling.

6. Discussion

Gasification does not compete with recycling. In fact, it enhances recycling programs. Materials can and should be recycled and conservation should be encouraged. However, many materials, such as metals and glass, must be removed from the MSW stream before it is fed into the gasifier. Pre-processing systems are added up-front to accomplish the extraction of metals, glass and inorganic materials, resulting in the increased recycling and utilization of materials. In addition, a wide range of plastics cannot be recycled or cannot be recycled any further, and would otherwise end up in a landfill. Such plastics can be excellent, high energy feedstock for Gasification.

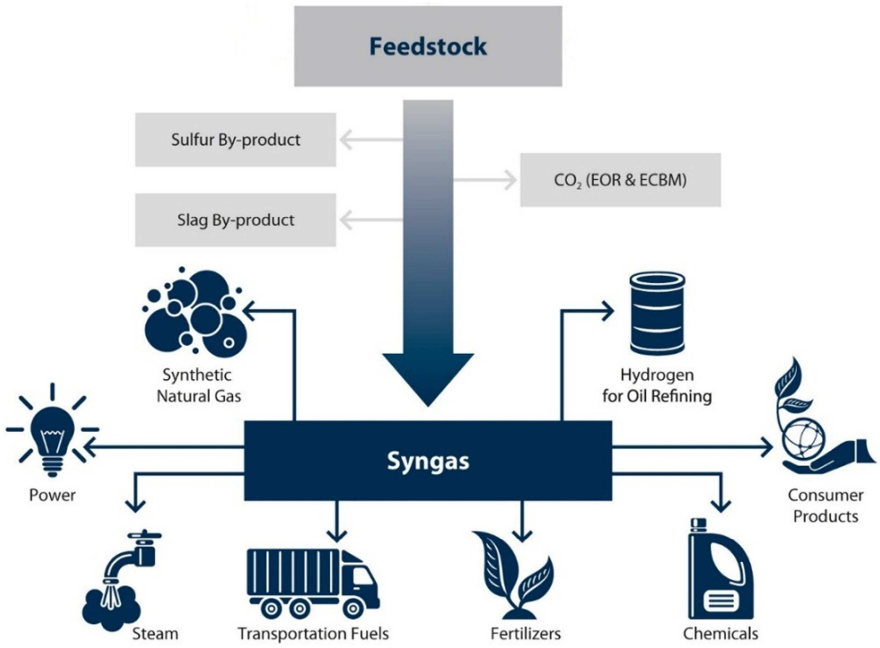

Figure 3. *Gasification – Recycling Products.*

7. Applications of the Process

- Reduces the need for landfill space.
- Decreases methane emissions from decomposition of MSW in landfills.
- Reduces risk of surface water and groundwater contamination from landfills.
- Extracts useable energy from waste that can be used to produce high value products.

- Enhances existing recycling programs.
- Reduces use of virgin materials needed to produce these high value products.
- Reduces transportation costs for waste that no longer needs to be shipped hundreds of miles for disposal.
- Reduces use of fossil fuels.

8. Limitations of Gasification

Biomass Gasification process has some limitations which are given here.

- Gasification is a complex and sensitive process. There exists high level of disagreement about gasification among engineers, researchers, and manufacturers. Several manufacturers claim that their unit can be operated on all kinds of biomass. But it is a questionable fact as physical and chemical properties varies fuel to fuel.
- Gasifiers require at least half an hour or more to start the process. Raw material is bulky and frequent refueling is often required for continuous running of the system. Handling residues such as ash, tarry condensates is time consuming and dirty work. Driving with producer gas fueled vehicles requires much more and frequent attention than gasoline or diesel fueled vehicles.
- Getting the producer gas is not difficult, but obtaining in the proper state is the challenging task. The physical and chemical properties of producer gas such as energy content, gas composition and impurities vary time to time. All the Gasifiers have fairly strict requirements for fuel size, moisture and ash content. Inadequate fuel preparation is an important cause of technical problems with Gasifiers.
- Gasifier is too often thought of as simple device that can generate a combustible gas from any biomass fuel. A hundred years of research has clearly shown that key to successful gasification is gasifier specifically designed for a particular type of fuel. Hence, biomass gasification technology requires hard work and tolerance.
- Major drawbacks are the high amounts of tar and pyrolysis products that occur because the pyrolysis gas does not pass the hearth zone and therefore is not combusted. This is of minor importance if the gas is used for direct heat applications in which the tar is simply burned. But when the gas is used for engines, extensive gas cleaning is required.

9. Conclusion

As the world's population increases, so does the demand for energy and products, and so will the amount of waste generated. This waste represents both a threat to the environment and human health, but also a potential source of energy. Gasification can help address and solve these problems.

Conflict of Interests

The authors have not declared any conflict of interests.

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