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PLASTIC WASTE TO FUEL CONVERSION AS ENERGY SOURCE FOR TOMORROW

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ABSTRACT

This review article aims on the suitable and useful study on the production of fuel from waste plastic. As in everyday life, plastics play a major role in society due to its abundance, less weight and durability. Its consumption and production are increasing day by day with increment in the human population. Since depletion of various fossil fuels such as natural gas, crude oil, coal, so as an alternative, wastes plastic can be converted into fuel using various technologies like pyrolysis, thermal pyrolysis, gasification, liquefaction, etc. Different types of plastics like Poly-ethylene-terephthalate (PET), Polyethylene (PE), Polystyrene (PS), Polypropylene (PP) have taken for the conversion into fuel. The waste is non-biodegradable hence facing the problem of recycling which is a threat to the environment. Municipal Solid Waste Management (MSWM) founds one of the most vital health and environmental problems fronting authorities. The waste is managed by this authority. Hence, this paper focuses on the various conversion technologies of fuel conversion. How plastic waste is threatful for the environment, what are they causes, which process is best suited, etc. So, dealing with all these issues, this paper presents a useful data on the different parameters and technologies used for fuel conversion from various types of plastic wastes. Author has also concluded that the demand of plastics reaches to 2,524.215 kilotonnes in the year of 2025-2026.

Keywords: *Waste Plastic, Fuel Conversion Technology, MSWM.*

Introduction

Current economic growth is unmanageable without saving fossil fuels such as oil, natural gas or coal. There are various substitutes to fossil fuels such as biomass, hydropower, and wind power. In addition, the right waste management strategy is another an important aspect.

Development and innovation have resulted in a significant growth in the production of all types of fundamental items, which produce trash in an indirect manner.[1]. Due to their versatility and inexpensive cost, plastics are one of the materials with a wide range of applications. Primary, secondary, tertiary, and quaternary recycling are the four categories of recycling.

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Increased use of plastic products as a result of rising living standards has a substantial environmental impact. Plastic has become an indispensable material, with demand continually increasing as a result of its numerous and appealing applications in both households and business. Thermoplastic polymers, in particular, have a high waste percentage, which is increasing globally. As a result, thermoplastics are not biodegradable for a long time, and plastic garbage, due to its vast volume and disposal issues, causes major environmental difficulties.[2]

In 2007, the global capacity for plastic materials production reached 260 million tonnes, up from 80 million tonnes in 1990. Plastics manufacturing is predicted to be increasing at a rate of roughly 5% per year over the world. It could be utilised to produce chemicals and energy at a low cost. The production of hazardous chemicals such dioxins, hydrogen chloride, airborne particles, and carbon dioxide from polymer combustion causes major air pollution problems. Landfilling is also unpopular because of its high cost and lack of biodegradability.[3]

The plastics industry has made important contributions to the nation's economic development as well as the expansion of critical sectors such as consumer durables, healthcare, and others. The sector utilises around 3,000 processing units and employs over 40 lakh people directly or indirectly. Plastic is a vital component of the Indian economy, serving as a facilitator for a wide range of sectors. It continues to expand. It generates a lot of jobs. Plastic use per capita is 11 kilogrammes, compared to a global average of 28 kg. According to the Ministry of Petroleum and Natural Gas, India's yearly per capita consumption will reach 20 kilogrammes by 2022.[4,5]

The global plastic market was valued at USD 568.9 billion in 2019, according to Grandview research.com, and is predicted to increase at a CAGR of 3.2 percent from 2020 to 2027. Over the forecast period, the market for plastic is expected to be driven by rising plastic use in the construction, automotive, electrical, and electronics industries. 39 During 2018 and 2019, the construction industry in emerging markets such as Brazil, China, India, and Mexico played a key role in driving plastics demand.

Hence, the aim of this article is to discuss the different technologies of fuel conversion using plastic waste. How different instrumental characteristics techniques used, various methods used to obtain different procedures and present a compendium of different applications of fuel conversion technology. The rest of the organized is as follows.

Plastic Waste: A Severe Problem

In today’s world, plastics play a vital and important role in the modern lives. The mostly used material is plastic because of its light weight, its durability and versatility. Its consumption and production are increasing day by day as increment in the human population which also leads to increase in the economic growth. In early 1950s, the world’s annual consumption of plastics were 5 million tons but currently its consumption is 311 million tons, which means in past 60 years, the production increased by 62 times to the current production rate. Without having a doubt that plastics made the modern lives easier but it is a big threat to the environment just because of its recycling rate.[3] Recycling of plastic material is expected to be the most difficult task for regeneration and utilization. Globally, around 300 million tons of plastic waste generated as such which is of no use.

Most plastic wastes are categorized into some categories for the recycling purpose such as PET (Polyethylene Terephthalate), low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), polystyrene (PS) and polyvinyl chloride (PVC). [6]

The plastic wastes causing environment severely and countries with higher rate of consumption of waste plastic facing serious environmental challenges like soil and water pollution, heavy metal pollution, water blockages, injuries and deaths of aquatic animals especially, blockages of sewages and drains, etc. These are some causes mentioned here which is due to the inappropriate disposing of plastic waste. Every year an increment up to 4% in plastic waste generation is noted. Since plastic material is non- biodegradable cannot recycle properly and also a big threat to the environment.[7]. Hence, the lifespan of plastics material ends only at their waste disposal. This plastic waste system managed under the system of MSWM (Municipal Solid Waste Management). There are many methods and techniques for the disposal of plastics like landfills, incineration, chemical recovery, etc. But the main question is still arising that which is suitable and best treatment for plastic wastes, keeping all the energetical, economic, environmental and political aspects together.[8]

From the above recent information, it is clear that since plastics are harming the environment and today’s modern lives cannot be run without the use of plastics. So, keeping the demand for energy of the countries or an alternative resource of fossil fuels which are limited as of now. Like other alternatives

such as biomass, hydropower, plastic waste also can be used as an alternative to the fossil fuels with the help of various conversion technologies which are discussed in next section of this paper. So, waste plastic can be used as a fuel which economically is good for the environment purpose and as of now it receives most of the attention because of its high abundance and especially for the environment benefits.

Different Plastic Consumption and Waste Production

From past centuries, the whole world was not even paying attention on the huge impact of increasing and fast growth of use of plastics in day-to-day life, which led to the accumulation of different types of plastics as waste which entered the environment and damage to it. Since plastics use in day-to-day life, but most of the plastic used as packaging materials in domestic as well as industrial applications. Plastics used in packaging account for half of all plastic garbage[9]. Food packaging is becoming more popular as a result of changing lifestyles, which has resulted in a significant increase in plastic waste generation. As a result, food packaging materials are in high demand. As a result, plastics are now found in large quantities in every aspect of the environment, including land, water, and, most importantly, the food chain. However, a world without plastics appears to be improbable today.[10].

Since the 1950s, the globe has created more than 8.4 billion tonnes of plastic. Between the early 1950s and 2017, worldwide plastic output grew dramatically. In 1950, it was around 0.35 million tonnes, while in 2017, it was around 348 million tonnes. Since the 1950s, China has been the world's leading manufacturer of plastic, followed by a slew of other countries with varying levels of production and use.

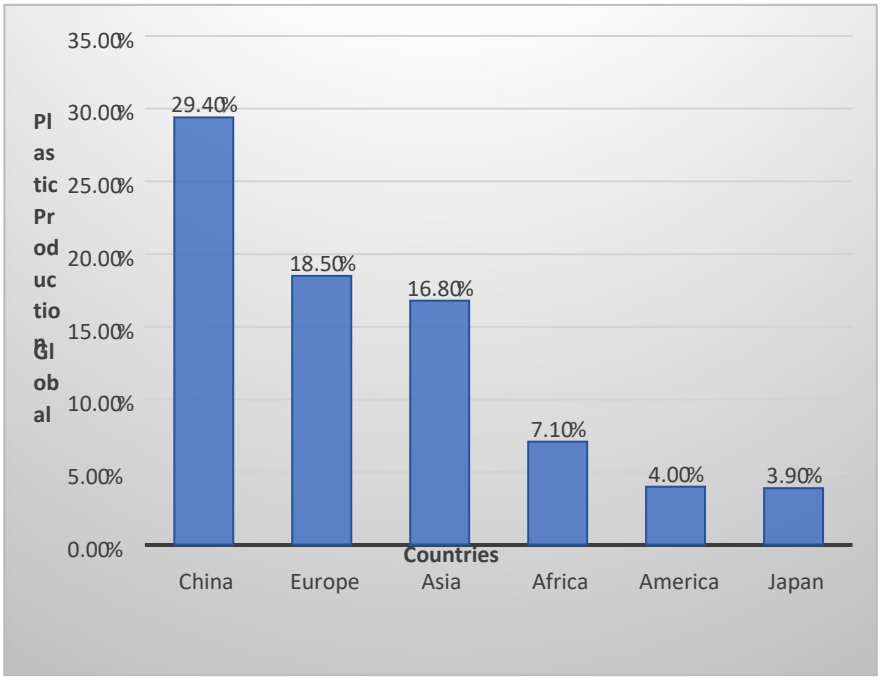

Figure 1: Global Production of Different Countries in Year 2017[11]

It has also been found that there is a large production of resins and polymers including fibres and some additives. Up till 2017, it is predicted that 8300 million metric tonnes of plastics were manufactured. Around 6300 million metric tonnes of waste were generated in 2015, with around 9% going through the recycling process, 12% going via incineration, and 78-79 percent ending up in landfills. Also, it is estimated that by the year 2050, around 12,000 million metric tons will be in the landfills or in the natural environment, which obviously the big threat to the environment as most of the plastic wastes are non- biodegradable[12]**.**

If taken the case of production of plastics in India, it was about 9.4 million tons in the year 2019. As compared with the global production, it was about 380 million metric tons in 2019 from the year 2017. From which India's contribution in plastic waste generation was about 3.1% of the global production and 40-42% are consumed in packaging sector and 15-17% in construction sector[10]**.**

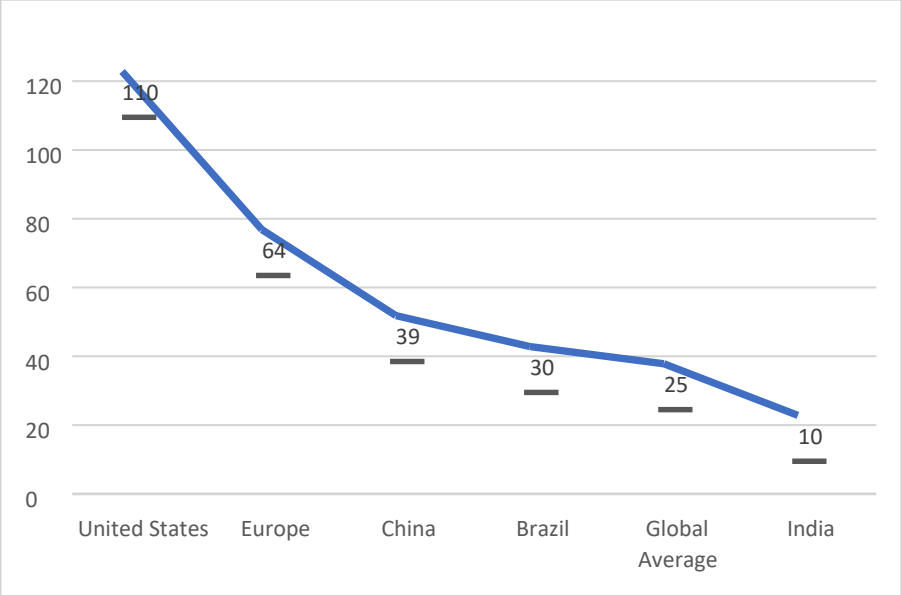

Figure 2: Plastics per unit Consumption of Different Countries [10]

As a result, given the widespread usage of plastics in today's society, it's difficult to picture a future without them. Therefore, number of steps are required to effectively manage garbage produced by human activity, such as collecting of plastics, transportation, sorting, disposal, or treatment, so that it does not harm the environment or human health.[11]

Plastic Waste Management

Mainly plastic materials are usually divided into two categories i.e., thermosets and thermoplastics. Thermosets plastics are those which have high linked cross structures with excessive mechanical and physical strength with heat stability. Some thermosets are epoxy, phenolic resins, polyurethanes, etc. Whereas, thermoplastics are linear and branched chains of intermolecular interactions such as polyvinylchloride (PVC), polyethylene (PE), etc.[11]

In today's scenario, with the high demand of plastics in domestic and industrial sector, food packaging industries plays a major role in plastic world. Food packaging demand is on the rise.[9] These industries operate single use of plastic material that are dumped in a short span of time. Therefore, food industry always encouraged to make use of 3R's i.e., reduce, reuse and recycle. Plastics are required in the food industry since it serves quick food, ready meals, on-the-go beverages, and snacks. In 2019, it was estimated that by 2050, global need of food supplies in plastic packaging materials will increase by 50% with increasing human population which demands for more food production. Primary packaging, secondary packaging, and tertiary packaging are the three basic types of food packaging that employ plastics.

Primary packaging is that which is acquainted with the product handled by the person by its own. Secondary packaging mainly used for transportation purposes. And tertiary packaging is utilized for the storage and handling of secondary packaging materials. Since with the production of these packaging materials, there is a huge amount of waste produced by these materials which entered the environment causes pollution. Sometimes it becomes hard to manage the produced waste leads to the damage of environment. Only 13-14 percent of single-use plastics collected for recycling and only 5% of plastic recycled to generate new plastic are recycled globally for packaging industries. These plastics are disposed of, recycled, or burnt once the product has been used. According to a 2015 assessment, 6300 million tonnes of plastic garbage were produced, of which 9% was recycled, 12% was burnt, and 79% was disposed of in landfills. With these occurring problems of plastic waste many policies and schemes were introduced for the proper management of plastic waste. For recycling the major steps are collecting and sorting of the wastes in different categories.[9]

Since other developed countries have better options, policies and schemes for plastic waste management as compared with India's scenario.

Table 1: Comparison of Plastic Waste Management of India and other Developed Countries[9]

Other Developed Countries	India
Organized source separation	Unorganized source separation
High waste collection efficiency	Low waste collection efficiency
Technologies for waste treatment	Inefficient transportation
Incineration	Recycling
Engineered landfilling	Unsecured landfilling

In India, SBA (Swachh Bharat Abhiyaan) policy was started in the year 2014, for controlling and managing the plastic waste produced. The main process is recycling which consists of 5 steps which is source, collection, pre-processing, recycling and other treatments.

Many other policies like PWM (Plastic Waste Management rules) started in 2016 were implemented for well organized of plastic waste in categories. Various authorities amend some acts for the implementation and monitoring of produced plastic waste proposed by the Central and State Government organization of India.

Hence, various technologies are introduced for the plastic waste which can be used for various purposes like fuel conversion from it[10].

Technologies used for Plastic Waste to Fuel Conversion

As discussed earlier, plastics have negative impact on the environment. To manage the plastic waste, various methods performed to convert several plastics like PET, PE, PS and PP into oil or fuel. Pyrolysis is the most efficient process for converting plastic waste to gasoline.[13] Earlier traditional treatment of thermal pyrolysis was performed. Material was first recycled, landfilled or incinerated. Since there are many problems associated with these two methods. Due of the scarcity of land and the availability and durability of plastics, landfilled plastics pose a risk. In addition, insufficient incineration might result in the production of hazardous chemicals, resulting in major health consequences.

Other techniques such as gasification and liquefaction or bio-conversion are used for organic materials. So, converting plastic waste into oil or fuel using this method is known as thermolysis.[2]

Pyrolysis is a process in which plastics are thermally broken due to rapid and rapid heating in the absence of oxygen, resulting in the conversion of long polymer chains into small hydrocarbon chains. Initiation, transfer, decomposition, and termination are the four steps of the pyrolysis process, which culminate in the creation of char and vapours, which include both condensable and non-condensable gases. The given process used to perform in the fluidized bed reactor using ZSM-5 catalyst. Firstly, the various types of plastics have been separated, cleaned, dried and size reduced, after which process starts. Yogurt tubs, cleaning product containers, and bottles all include HDPE. Food and mouthwash containers are used to make PET. Food storage containers are used to collect PP. PS can be found in a variety of items, including packing materials and disposable containers.[14]

These plastics are then shredded or cutted into the small pieces just to reduce its volume before sending to the reactor. The reactor depends on various parameters but temperature plays a major role which lies between 450-650℃ also depends on the rate of heating and type of plastics. On completion of the process, the product called fuel collected in the chamber that is impure which must be wax, grease or other impurity. These will be filtered afterwards for the collection of pure fuel or oil.

Waste plastics can be converted to bio-oil, synthesis gas, char, or wax using the pyrolysis process, depending on the conversion method. Temperature, heating rate, plastic type, concentration, reactor type, and catalyst are all important aspects in the conversion process.[8]

Hence, all these various methods are discussed in detail in next section.

Pyrolysis

Thermal deterioration is another name for this phenomenon. Pyrolysis is the process of a material's heat breakdown in the absence of oxygen. Plastic is fed into a cylindrical chamber, and the pyrolytic gases are condensed in a specially designed condenser system to produce a hydrocarbon distillate containing straight and branched chain aliphatic, cyclic aliphatic, and aromatic hydrocarbons, which is then separated from the liquid using fractional distillation to produce liquid fuel products. At 370–420°C, the plastic is pyrolyzed.

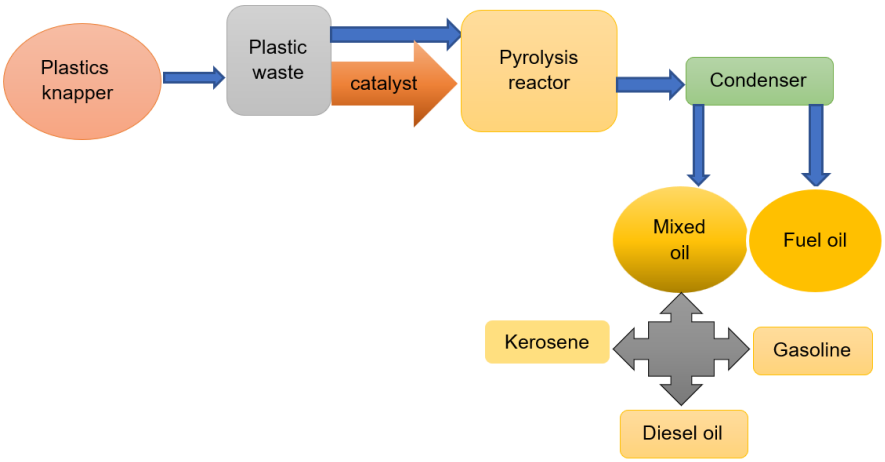

Figure 3: Pyrolysis Method for Converting Waste Plastics into Useful Fuel Products[15]

There are numerous types of pyrolysis processes, such as traditional or slow pyrolysis, which uses a low heating rate of 0.1- 1 K/s to produce solid, liquid, and gaseous products in varied parts at a pyrolysis temperature of 550- 900 K with particle sizes of 5- 50 mm. This is an old charcoal-making method. The second type is fast pyrolysis. It is associated with tar at temperature 850- 1250 K with particle size less than 1 mm and at heating rate of 10- 200 K/s. The other process is flash pyrolysis process. This process proceeds under a higher heating rate of more than 1000 K/s having a high temperature of 1050- 1300 K and with particle size of less than 0.2 mm. Fast or flash pyrolysis at high temperatures with a short residence period is currently the preferred method. Fast pyrolysis, also known as thermolysis, is a more precise way of rapidly heating a material, such as biomass, to a higher temperature in the absence of oxygen.[15]

- **Properties of Extracted Oil**

After the completion of pyrolysis process, two types of oil are extracted from the condenser i.e., mixed oil and fuel oil. Mixed oil is divided into three categories that is gas, gasoline and diesel oil. Whereas, fuel oil is categorized in heavy oils and petroleum. Following are some properties of these extracted oil.

- **GASOLINE**

Gasoline, often known as petrol, is a clear flammable liquid that is used to power most spark-ignited engines. It is mostly made up of organic components that are converted to petroleum through fractional distillation and the addition of a range of additives. Gasoline has a specific gravity of 0.71 to 0.77, with higher densities having a higher volume component of aromatics. Because gasoline floats on water due to its low density, water cannot be utilised to extinguish a gasoline fire unless administered in a thin mist. Gasoline of good grade may readily be kept for six months. If it stored for over time, it breaks down slowly due to the separation of components. It has a calorific value of 11,110 kcal/kg. Gasoline molecular weight range is 60-150 g/mol. Gasoline with 50-100 octane number has flashpoint of about -49°F.[16]

Figure 4: Gasoline[16]

- **Diesel Oil**

Diesel oil is also called diesel oil which specifically designed for usage in diesel engines. Basically, it is a liquid fuel which requires good ignition characteristics. Most of the diesel fuels like biodiesel, Petro diesel freezes at winter temperatures where temperature vary. Petro diesel freezes at around -8.1℃ whereas biodiesel freezes at 2℃. As temperature decreases its viscosity kept increasing which changes into a gel at temperature -19℃ which cannot used as a fuel further. Diesel fuels vaporise at temperatures ranging from 149°C to 371°C. It has a flash point ranging from 52 to 95°C, making it safer than gasoline but not ideal for spark-ignited engines. It has a density of 0.85kg/l. It's often used in farming equipment, military transport, off-road vehicles, mining and logging equipment, and for fueling generators because it's often more efficient than gasoline when it comes to large weights.[17]

Figure 5: Diesel Oil[18]

- **Kerosene**

Kerosene, often known as paraffin or paraffin oil, is a type of kerosene. It's a flammable hydrocarbon liquid that's mostly employed as a source of energy. It's a clear, colourless liquid with a lovely aroma. It is generated from petroleum and is mostly utilised as an aviation fuel as well as for domestic usage. This fuel can be used for a variety of functions, including heating and lighting, cooking (in portable stoves), engines, and so on.

Kerosene is a low viscosity liquid which is obtained from the fractional distillation of petroleum at temperature between 150 and 275℃. It has a density about 0.78-0.81g/cm^3. It is miscible in petroleum but immiscible in water. The flash point of kerosene is between 37 and 65℃ and its autoignition temperature is 220℃. Its freezing point depends on the grades of kerosene if it is used as an aviation fuel, then its freezing point is -47℃. Its lower and higher heating values are 43.1 MJ/kg and 46.2 MJ/kg respectively.[19]

Figure 6: Kerosene Oil[20]

The following are some of the benefits of the pyrolysis process:

- The waste volume is greatly decreased.
- Solid, liquid, and gaseous fuels can be easily made from waste plastic.
- This method can produce transportation fuel or chemical feedstock.
- The environmental problem has been alleviated.
- Desirable method because energy is derived from renewable sources such as municipal solid waste or sewage sludge, and capital costs are lower.[15]

Catalytic Degradation

The cracking process is carried out using an appropriate catalyst in this manner. The reaction temperature and time are reduced when a catalyst is present. At lower temperatures, the procedure produces a substantially smaller product distribution of carbon atom number. To make the process more appealing from an economic standpoint, the cost should be cut further. This technique can be improved by reusing catalysts and using effective catalysts in smaller quantities. This technology could be evolved into a commercial polymer recycling process to address the urgent environmental challenge of plastic waste disposal. It also has a stronger plastic cracking ability and a reduced solid residue content in the product.[21]

Gasification Process

The initial step of this process involves partial burning of biomass to create gas and char, followed by reduction of the resultant gases, mostly CO2 and H2O, by the charcoal into CO and H2. The process can also produce methane and other higher hydrocarbons, depending on the reactor's design and operating circumstances. The thermochemical conversion of a solid or liquid carbon-based substance into a combustible gaseous product by the addition of a gasification agent is known as gasification. The gasification agent enables the feedstock to be turned into gas fast through a variety of heterogeneous processes. A gasification system consists of three basic components: (1) the gasifier, which aids in the production of combustible gas; (2) the gas clean-up system, which removes hazardous substances from the combustible gas; and (3) the energy recovery system. The system is completed with appropriate subsystems that aid in the regulation of environmental impacts such as air pollution and solid waste management, among other things. For the thermal treatment of homogeneous carbon-based waste and pre-treated heterogeneous waste, the gasification process represents a future alternative to the trash incinerator.[22,23]

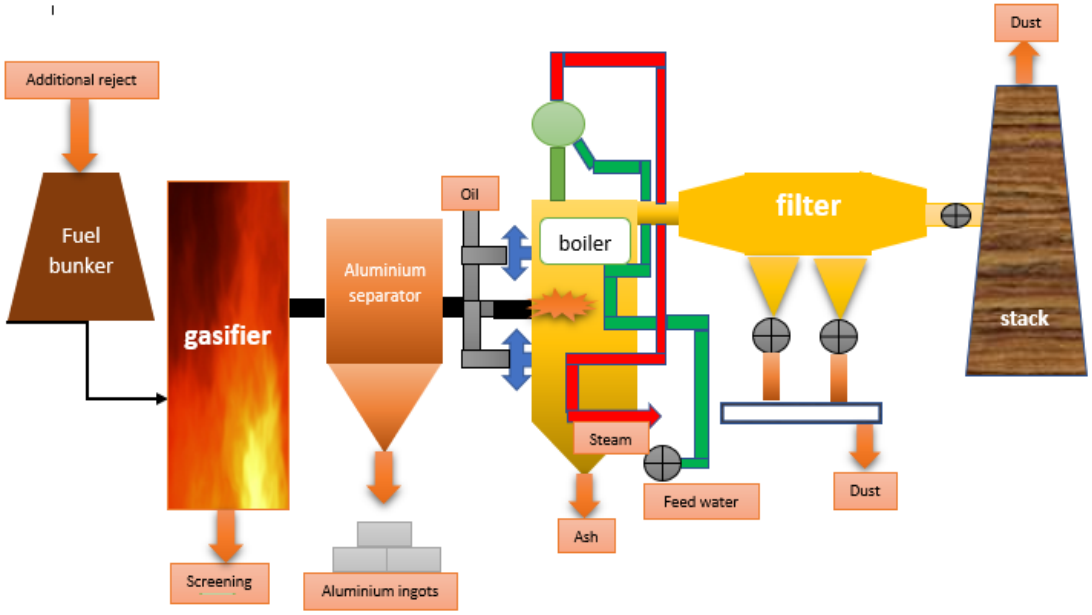

Figure 7: Gasification Process of Plastic Residue[15]

Applications of Extracted Fuel from Waste Plastic

As discussed in previous sections of this paper, fuel can be easily extracted from the waste plastics through different processes. This extracted fuel has many applications in the industrial area. Like,

- Using plastics as binders improves the mechanical and humidity resistance of biomass/plastic briquettes or pellets. In the coal business, plastics are largely utilised as binders. By utilising the tensile physical qualities of plastics, the inclusion of polymers to coal briquettes can improve physical durability.[24]
- Fuel is utilized in heavy oil generators for generating electricity.
- Used in refining factories for additional processing.
- It also serves as heating material in variety of processes.
- This fuel can be used in many types of industries such as ceramic, oil, steel, cement, etc.[25]

Figure 8: Some Major Areas where Extracted Fuel is Used[26]

Advantages of Fuel Converted from Plastic Waste

Nowadays recycling of plastic waste from various processes becomes more important and popular. The extracted fuel has various advantages:

The fuel oil made from plastic waste is a type of heavy oil with a heating value greater than 10000kcal/L, even higher than diesel. Because of its high heating value, it may be used as a diesel, coal, and wood alternative in boilers, cement plants, steel mills, and glass plants, among other places. A steel mill, for example, will consume hundreds of tonnes of fuel oil derived from plastic waste.[26]

Disadvantages of Fuel from Plastic Waste

However, there are several drawbacks to using fuel oil made from plastic waste. The sulphur content of plastic waste fuel oil is higher than that of regular diesel, but this isn't a big deal because many industries have environmental protection devices in place to scrub the smoke produced during the heating process. Aside from that, fuel oil made from plastic waste has a lower flash point. Fuel oil made from plastic waste has a flash point of less than 40 degrees, while regular diesel has a flash point of around 50 degrees. Although the flash point has a significant impact on fuel oil transportation, it has already been demonstrated by a number of customers in various parts of the world that fuel oil transportation is not an issue. Also, with the help of a waste oil distillation machine, the drawbacks of fuel oil made from plastic waste may be greatly reduced. Diesel-like fuel can be recovered from plastic fuel oil after distillation, oil colour and odour reduction, and filtering.[26]

Profile of Plastic Industry in India

- **Production of Plastics in India**

Table 2: Production Data of Plastics in India[4]

Year	Production (in Kilo Tonnes)
2011-2012	1503
2012-2013	1501
2013-2014	1425
2014-2015	1269
2015-2016	1548
2016-2017	1745
2017-2018	2008
2018-2019	2389
2019-2020	2526
2020-2021	2626

Export Data for Plastics

- There are about 2,000 exporters in the industry, which spans the country.
- In August 2020, India exported plastics worth $838 million, with a total of $3.91 billion in April-August 2020.
- The major plastic products that India export are:
  - HDPE sacks/bags for packaging.
  - Films, such as polyester and photo films.
  - Consumer goods, such as toothbrushes, cleaning brushes, hair brushes, nail/cosmetic brushes, combs, and kitchenware, among other things.
  - Pens, ballpoint pens, markers, refills, and other writing instruments
  - Construction - PVC profiles, doors, and windows, among other things
  - Surgical/Medical Disposable Syringes/Urine Bags Laboratory gear

Table 3: Export Data[5]

Year	Export (in Kilo Tonnes)
2011-2012	227
2012-2013	160
2013-2014	99
2014-2015	27
2015-2016	93
2016-2017	143
2017-2018	183
2018-2019	410
2019-2020	460
2020-2021	456

- **Import Data of Plastics**

Table 4: Import Data[5]

Year	Import (in kilo tonnes)
2011-2012	385
2012-2013	440
2013-2014	404
2014-2015	545
2015-2016	568
2016-2017	634
2017-2018	607
2018-2019	533
2019-2020	540
2020-2021	600

- **Demand Data of Plastics**

  Demand = Production + Import – Export

Table 5: Demand Data[27]

Year	Demand (in Kilo Tonnes)
2011-2012	1661
2012-2013	1781
2013-2014	1730
2014-2015	1787
2015-2016	2023
2016-2017	2236
2017-2018	2432
2018-2019	2512
2019-2020	2606
2020-2021	2770

Demand Projection using Simple Exponential Smoothing Method

One of the simplest ways to forecast a time series is to use basic exponential smoothing. It's used to make predictions about the data. The exponential window function is used to smooth time series data in exponential smoothing. Inn this there is more weightage is given to the recent observation.

a=actual value

p=predicted value

ά=constant weight factor

(0 < ά < 1)

D (t, a) =Actual demand at time t

D (t, p) =Actual demand at time t+1

Yellow colour = given data / collected data

Table 6: Demand Projection Data[27]

	D = Production + Import - Export	D (t+1, p) = ά D (t, a) + (1- ά) D (t, p)	
Year	**Demand**	**ά = 0.1**	**ά = 0.2**
2011-2012	1661		
2012-2013	1781	1661	1661
2013-2014	1730	1673	1685.0
2014-2015	1787	1678.7	1694
2015-2016	2023	1689.53	1712.6
2016-2017	2236	1722.877	1774.68
2017-2018	2432	1774.1893	1866.944
2018-2019	2512	1839.9701	1979.9552
2019-2020	2606	1907.17309	2086.36
2020-2021	2770	1977.055781	2190.291
		2056.350203	**2306.28**

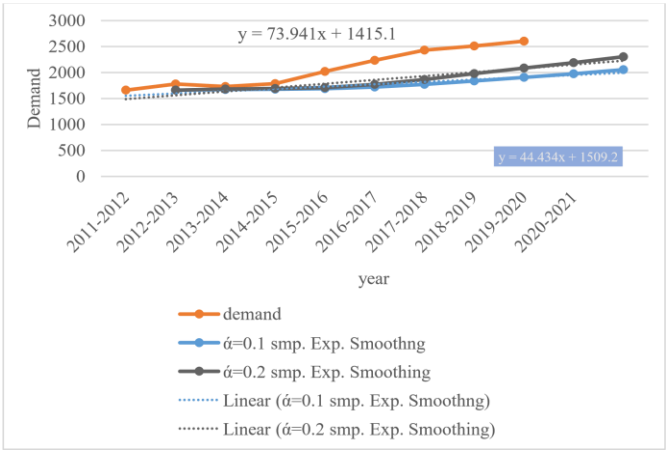

Figure 9: Demand Projection by using Simple Exponential Smoothing Method (SESM) for ά=0.1 and ά=0.2

Table 7: Demand projection for ά=0.1, y = 44.434x + 1509.2 for next 5 years[27]

	BY SESM ά=0.1	By linear fit on MA data: D = = 44.434*t+ 1509.2			
Time (Year)	2021-2022	2022-2023	2023-2024	2024-2025	2025-2026
Demand (KT)	2056.350203	2,042.408	2,086.842	2,131.276	2,175.71

Table 8: Demand Projection for ά =0.2, y = 73.941x + 14151 for next 5 years[27]

Calculation	By SESM ά=o.2	By linear fit on MA data: D=73.941*t + 14151			
Time (Year)	2021-2022	2022-2023	2023-2024	2024-2025	2025-2026
Demand (KT)	2306.28	2,302.392	2,376.333	2,450.274	2,524.215

Here 't' is in number as t=1 for the year 2011-2012, t=2 for the year 2012-2013 and so on…

Discussion

The demand for plastics reached 2770 kilo tonnes in the year 2021. Since its import and export grows rapidly, the industry is expected to grow in the coming years.

The demand for plastics on an involuntary basis continues to grow. Referring to demand data in Table 6, we can infer that the demand mostly kept increasing yearly, but there were several years when there was a downfall in demand.

Conclusion

- Since plastics are believed to be one of the greatest inventions of all time, it has shown to be accurate. Plastic is lightweight, does not rust, and is, most significantly, inexpensive and reusable. For these reasons plastics becomes so popular in the society that it is a part of the daily life and mostly used in every type of product. However, with so many advantages there are lot of subsequent problems which are associated with it. In huge amount of plastic wastes are generated which harms the lives of living beings and creating health problems.
- After lots of research and reviewing it has been found that the generated plastic waste can be turned into a useful innovation i.e., conversion of fuel from plastic wastes using different technologies, so that the issue of depletion of fossil fuels can also be resolved. Since plastics are the most produced material globally for various applications. Its major part has been found in the packaging industry which again consists with the same problem.
- Therefore, various fuels like diesel oil, kerosene, petroleum can be extracted using different technologies and methods from generated plastic waste. Pyrolysis considered being the most effective technique of conversion of plastic wastes to fuels. It has been observed that the fuel obtained from the pyrolysis process is cleaner than other conventional fuels.
- As a result, from both an economic and environmental standpoint, pyrolysis evaluation of plastic waste is critical. It is concluded that the demand of plastics reaches to 2,524.215 kilotonnes in the year of 2025-2026.

References

1. Wong, S. L., Ngadi, N., Abdullah, T. A. T., & Inuwa, I. M. (2015). Current state and future prospects of plastic waste as source of fuel: A review. Renewable and sustainable energy reviews, 50, 1167-1180.
2. Nanda, S., & Berruti, F. (2021). Thermochemical conversion of plastic waste to fuels: a review. Environmental Chemistry Letters, 19(1), 123-148.
3. Owusu, P. A., Banadda, N., Zziwa, A., Seay, J., & Kiggundu, N. (2018). Reverse engineering of plastic waste into useful fuel products. Journal of Analytical and Applied Pyrolysis, 130, 285-293.
4. Regulations controlling plastics production, plastic waste and recycling in India, an online report published by chemcai,2014.
5. Export-import bank, ministry of commerce and industry, government of India.
6. Fahim, I., Mohsen, O., & ElKayaly, D. (2021). Production of fuel from plastic waste: a feasible business. Polymers, 13(6), 915.
7. Jha, K. K., & Kannan, T. T. M. (2021). Recycling of plastic waste into fuel by pyrolysis-a review. Materials Today: Proceedings, 37, 3718-3720.

8. Alla, M. M. G., Ahmed, A. I., & Abdalla, B. K. (2014). Conversion of plastic waste to liquid fuel. International Journal of Technical Research and Application, 2(3), 29-31.
9. Ncube, L. K., Ude, A. U., Ogunmuyiwa, E. N., Zulkifli, R., & Beas, I. N. (2021). An overview of plastic waste generation and management in food packaging industries. Recycling, 6(1), 12.
10. Rafey, A., & Siddiqui, F. Z. (2021). A review of plastic waste management in India–challenges and opportunities. International Journal of Environmental Analytical Chemistry, 1-17.
11. Horodytska, O., Cabanes, A., & Fullana, A. (2019). Plastic waste management: current status and weaknesses. In Plastics in the Aquatic Environment-Part I (pp. 289-306). Springer, Cham.
12. Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science advances, 3(7), e1700782.
13. Fivga, A., & Dimitriou, I. (2018). Pyrolysis of plastic waste for production of heavy fuel substitute: A techno-economic assessment. Energy, 149, 865-874.
14. Saxena, A., Sharma, H., & Rathi, G. (2017). Conversion of Waste Plastic to Fuel: Pyrolysis-An Efficient Method: A Review. In International Conference on New and Renewable Energy Resources for Sustainable Future (pp. 3-7).
15. Patni, N., Shah, P., Agarwal, S., & Singhal, P. (2013). Alternate strategies for conversion of waste plastic to fuels. International Scholarly Research Notices, 2013.
16. Osei, A. U. G. U. S. T. I. N. E. (2015). Determination of Attenuation Properties of Some Petroleum Products in Ghana by Gamma Ray Absorption Technique (Doctoral dissertation, University of Ghana).
17. Alleman, T. L., McCormick, R. L., Christensen, E. D., Fioroni, G., Moriarty, K., & Yanowitz, J. (2016). Biodiesel handling and use guide (No. NREL/BK-5400-66521; DOE/GO-102016-4875). National Renewable Energy Lab. (NREL), Golden, CO (United States).
18. https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.indiamart.com%2Fproddetail%2Fsynthetic-diesel-engine-oil-.
19. "Kerosene". Retrieved 10 June 2009.
20. https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.business-standard.com%2Farticle%2Feconomy-policy%2Fgovt-eliminates-subsidy-on-kerosene-through-small-price-hikes-121020201251_1.
21. Panda, A. K., Singh, R. K., & Mishra, D. K. (2010). Thermolysis of waste plastics to liquid fuel: A suitable method for plastic waste management and manufacture of value-added products-A world prospective. Renewable and Sustainable Energy Reviews, 14(1), 233-248.
22. Ram, C., & Kumar, A. (2021). 2 Municipal Solid Waste. Nanobiotechnology for Green Environment, 37.
23. Singh, R. P., Tyagi, V. V., Allen, T., Ibrahim, M. H., & Kothari, R. (2011). An overview for exploring the possibilities of energy generation from municipal solid waste (MSW) in Indian scenario. Renewable and Sustainable Energy Reviews, 15(9), 4797-4808.
24. Song, B., & Hall, P. (2020). Densification of biomass and waste plastic blends as a solid fuel: hazards, advantages, and perspectives. Frontiers in Energy Research, 8, 58.
25. https://www.slideshare.net/SaloniGoyal15/plastic-to-fuel
26. https://m.wastetireoil.com/Pyrolysis_faq/Pyrolysis_Plant/what_are_the_advantages_of_fuel_from_plastic_waste_does_it_have_disadvantages1064.
27. Demand share of plastics across India in financial year 2019, Statista.

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