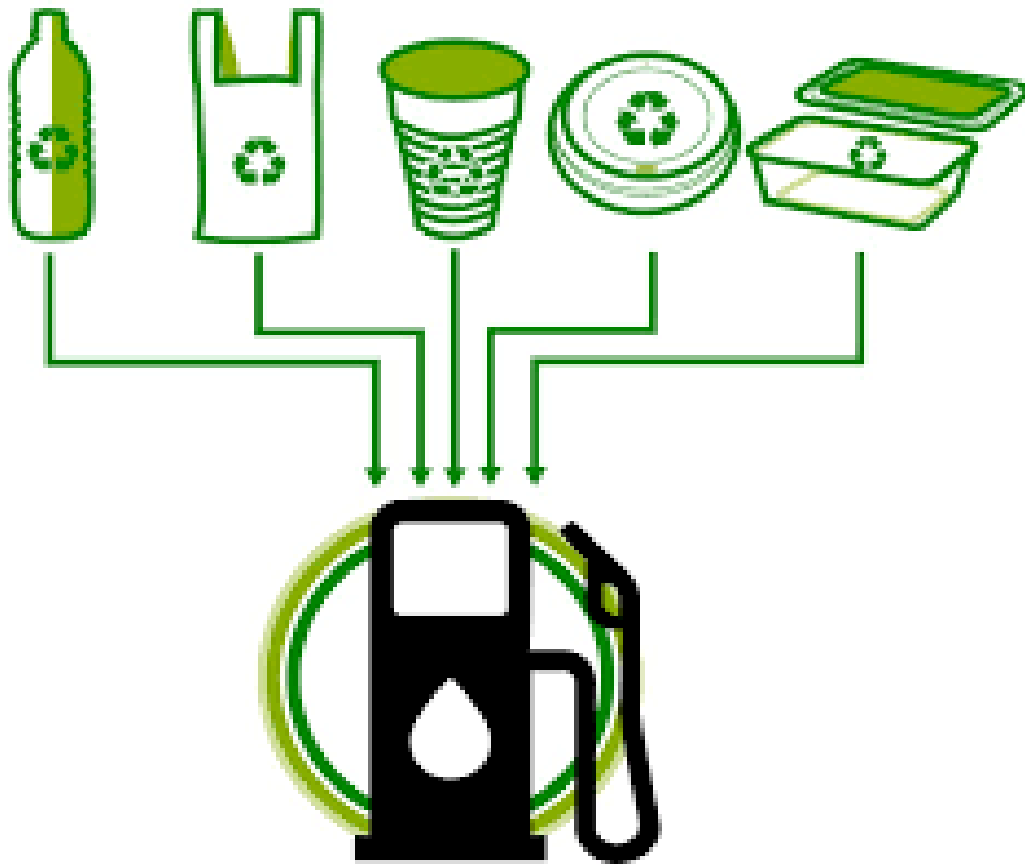


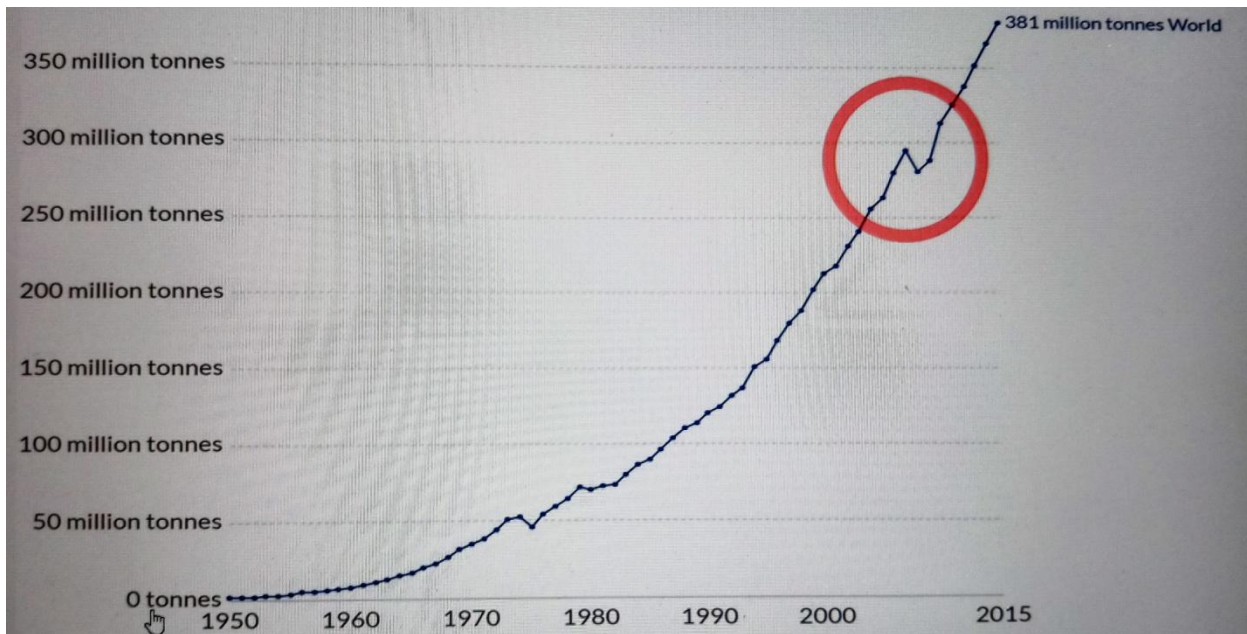
# Plastic to fuel



## Introduction

The issue of plastic pollution has been making the rounds in the news lately but what can we do about it and what is being done about it now in this we'll take a look at the drastic amounts of plastic pollution particularly in the ocean the effects that it's having on our bodies and the environment

from grocery bags to plastic straws to tiny micro beads and everything from soap to make up the earth is swamped in plastic and will remain so for generations to come so how much plastic is there well there's been around a 6.3 billion tons of plastic produced worldwide since the 1950s



**Fig: Growth in plastic production**

looking at this graph you can see the clear uptrend in plastic production but interestingly the effect of the 2008 financial crisis can also be seen of this an estimated 8 million tonnes of plastic wind up in the oceans every year and is pervasive the World Economic Forum predicts that by 2050 if things continue at the current rate the oceans will hold more plastic waste than fish at the bottom of the 11 kilometer deep Mariana Trench the deepest part of the explored ocean plastic waste has been found three times one of the most personal examples of plastic waste in the ocean is the Great Pacific Garbage Patch it's a collection of plastic and floating trash which mainly comes from countries in Asia there's an estimated 1.8 trillion pieces of plastic here there's also a North Atlantic Garbage Patch which is also growing all of this isn't to mention the effect that is having on wildlife already this isn't great but it gets worse a recent study found that we're eating our own plastic waste in fact every week we eat enough plastic to make a credit card annually we eat about 250 grams this study was carried out by the University of Newcastle

and they stayed that the most common source of plastic consumption is drinking water this includes tap water or bottled water fish unsurprisingly was another source but interestingly the other two biggest culprits were salt and beer a lot is unknown about plastic consumption and its effects in humans but a certain chemical found in some plastics called BPA has been shown to reduce sperm count apart from all of this the main problem with plastic is that it just doesn't break down it's estimated that a foam plastic carp will take 50 years a disposable nappy 450 years and a fishing line 600 years to degrade so don't lose hope yet will soon take a look at what's being done about this issue towards the end of the but first we should take a look at who exactly are the biggest plastic polluters and where exactly is the source of all this plastic waste coming from let's take a look at the data so the question must be asked who is the biggest contributor to plastic waste so looking at this chart we can see who the biggest polluters number one is China number two Indonesia number three the Philippines number four Vietnam and number five sri-lanka but note that this was in 2010 just as china was starting their transformation into an industrial economic superpower from this time China's industrial output has grown exponentially it said that in this expansion Chinese does much concrete as the United States did during the entire 20th century but anyway overall the situation is a bit more complex as the United States consumes a lot of goods produced in the East so one can't really exist without the other in some good news China is now making strides to solve these issues and has reported a 66% drop in the amount of plastic bags used in the past year about 40 billion bags weren't used so what are the areas that this plastic waste is coming from well according to a 2017 study about 90 percent of all plastic pollution comes from just ten rivers eight in Asia and two in Africa so what sectors are producing the most plastic well by far and away its packaging packaging leaves by two times the next biggest category which is building and construction ok so this sounds all pretty bad but let's get to the good news about how we can fix this problem so slowly was started taking a look at this chart in 1980 about a hundred percent of plastics was discarded as waste and then in the early 1980s incinerating started to become practice then in the late 1980s recycling was brought into the picture and today about 45 percent of old plastic waste is either recycled or incinerated not perfect but it's better than ending up in the ocean in terms of our recycling rate which is one of the key parts of this entire debate because in theory if we could successfully recycle our plastics and we wouldn't have a plastic problem a lot of experts I talked to insists that we don't have a plastic problem we have a waste problem as shown by this graphic compared to the sheer amount of plastic produced it seems that our recycling efforts may just not be enough to solve this problem in a timely manner we could demand legislation to curb the production of plastics but we could also look to

technology to help one team of engineers took this task seriously and developed a massive cleaning device to take on the great Garbage Patch in the ocean that I talked about earlier unfortunately in January 2019 the device did break down and had to be repaired but it's being relaunched later this year perhaps it's better to engineer projects on a smaller scale these can have an impact on a smaller localized area - rubbish sucking sea bins were recently installed in Sydney Harbor the devices suck in water trapping rubbish in a mesh bag and recirculate the water back into the environment there are 450 C bins in 26 countries around the world collecting around 4 kilograms a day or 1.4 tonnes a year another small ocean cleaner known as mr. trash will is making a difference in the United States as the wheel turns it collects litter from the harbor and stores it in the barge later for removal they're also legislative actions being taken we all know about straws being banned in places and a lot of store outlets have banned single-use plastic bags in May of 2019 a new model of collecting packages from consumers began it's called loop some big name partners include Procter & Gamble Nestle PepsiCo Unilever The Body Shop coca-cola and other firms but what if we could do even more than all of this what if we could turn plastic waste into fuel and here we come to our featured story a research group led by the Washington State University has found a way to turn daily plastic waste into jet fuel in a new paper published in the Journal of Applied energy the scientists melted plastic waste at high temperatures with activated carbon basically processed carbon with increased surface area and the end result was jet fuel so here's how it works in the experiment the scientists ground down waste plastic products like water bottles milk bottles and plastic bags down to about three millimeters or about the size of a grain of rice the plastic granules were then placed on top of activated carbon and achieve reactor at a high temperature of about 571 degrees Celsius the carbon is a catalyst or a substance that speeds up the chemical reaction without being consumed by the reaction itself project lead and associate professor Henry Lee speaks quote plastic is hard to break down you have to add a catalyst to help break the chemical bonds there's a lot of hydrogen and plastics which is a key component for fuel unquote once the carbon catalyst has done its work it can be separated out in the next batch of waste plastic conversion the catalysts can also be regenerated after losing its activity after testing several different catalysts at different temperatures the best results they obtained was a mixture of 85% jet fuel and 15% diesel fuel Lee speaks again quote we can recover almost a hundred percent of the energy from plastic we tested the fuel is very good quality and the byproduct gas is produced a high quality and useful as well unquote he goes on to say that this process is easily scalable it can work at a large facility or even on farms where farmers could turn their own plastic waste into diesel Lee speaks again quote waste plastic is a huge problem worldwide this is a

very good and relatively simple way to recycle these use plastics unquote another research team at Purdue University has invented a way to convert 90% of plastic waste into many different products including pure polymers and fuels Linda Wang professor at the school of chemical engineering at Purdue University speaks quote our strategy is to create a driving force for recycling by converting plastic waste into a wide range of valuable products including polymers or clean fuels our conversion technology has the potential to boost the profits of the recycling industry and shrink the world's plastic waste stock encode so going back to the jet fuel story it's not perfect it's burning fuel will of course result in greenhouse gases but it's a big step above what we have now for those countries who don't have the environmental awareness and don't see much issue with throwing plastic in the ocean it all comes down to the profit motivation aspect of the equation if money can be made by producing plastic waste based fuels this could be a financial incentive for government and private companies alike too heavily recycle and put in place better methods than landfill



Before world can produce environment-friendly plastic, we should continue re-applying this important product. Filling landfills is not a sustainable solution. Plastic to Fuel conversion plants will help us to keep enjoying the benefits of plastic without hurting the environment. Being a bonus, they make revenue and build jobs.

## **REVIEW OF LITERATURE:**

### **HISTORY AND GENERAL INTRODUCTION OF PLASTIC**

According to the Oxford Dictionary word “Plastic” was coined in the mid of 17th century and derived from French *plastique*, Latin *plasticus* or from Greek *plastikos* *plassein*. Meaning of all these cognates is able to be moulded into different shapes” Joel, 1995.



The first man-made plastic, a modification of cellulose, was created by Alexander Parkes in 1862 and called Parkesine”. In 1868 John Wesley Hyatt invented Celluloid, derived from cellulose and alcoholized camphor that could be molded with heat and pressure into a durable shape. By 1900, movie film was an exploding market for celluloid Harris, 1981. Plastic, from the time of their origin have become an indispensable part of our life and in modern society. Synthetic plastics are extensively used in packaging of products like food, pharmaceuticals, cosmetics, detergents and many products manufactured from plastics are a boon to public health, e g. disposable syringes and intravenous bags

Halden, 2010. This utilization is still expanding at a high rate of 12% per annum Sabir, 2004 and has replaced paper and other cellulose-based products for packaging because of their better physical and chemical properties viz. strength, lightness, resistance to microorganisms Shah et al., 2008 and favorable mechanical/thermal properties, stability and durability Rivard et al., 1995. With time, stability and durability of plastics have been improved continuously, hence this group of materials is now considered as a synonym for the materials being resistant to many environmental influences Joel, 1995. Plastic is inert i.e. resistant to biodegradation, durable, hygienic, lightweight, cheap, and malleable Mohee and Unmar, 2007. It has been proven that polyolefins especially low density polyethylene LDPE, are resistant against degradation and microorganism attacks Mahmood and Reza, 2004. These are manmade long chain polymeric molecules Scott, 1999. The basic materials used for making plastics are extracted from oil, coal and natural gas that comprise inorganic and organic raw materials, such as carbon, silicon, hydrogen, nitrogen, oxygen and chloride Seymour, 1989. Petroleum-based synthetic polymers are introduced in the ecosystem as industrial waste products that generate several problems e.g. visual pollution, blockage of gutters and drains, livestock deaths and threat to aquatic life Shimao, 2001.

## **PLASTIC STATISTICS OF THE WORLD**

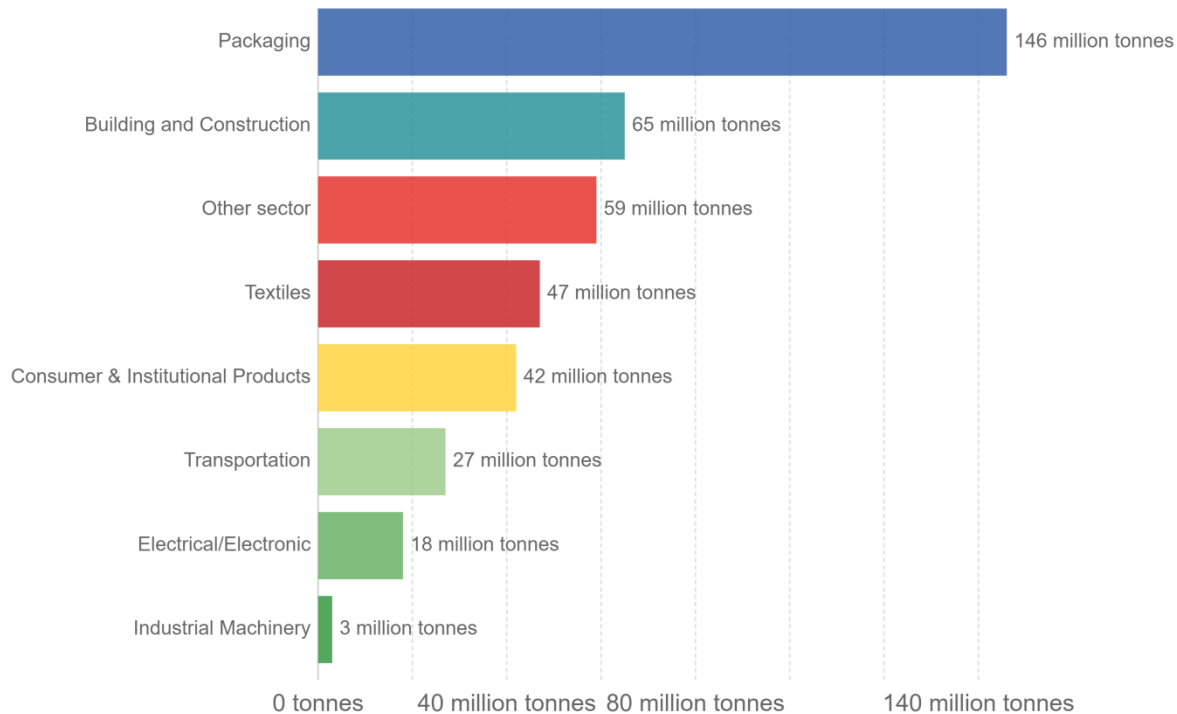
Production of plastic has increased from 0.5 million tonnes in 1950 to 260 million tonnes in 2007. This increase in usage, especially disposable items of packaging, makes up 9.37% of all the plastic produced Plastic Europe, 2008. Packaging utility is the biggest field where polythene and its kind material are used. It is estimated that 41% of plastics are used in packaging, and that almost half of that volume is used to pack food products O'Brine and Thompson, 2010. Low density polyethylene is the most applied polyolefin in packaging, horticulture and agricultural utilizations Bastioli et al., 1991. As population is increasing so the consumption of synthetic plastic is increasing, only in a span of one year 1996-95 shipments from the Canadian Plastic Industry increased by 10.6% Charron, 2001. In Australia about 1 million tones of plastic materials are produced each year and a further 587,000 tonnes are imported Australian Academy of Science, 2002. In European countries on an average 100kg of plastic is used per person each year Mulder, 1998.

The bags, with a typical thickness of 16 microns and weight of 7-8 gm are provided free of charge in Israeli stores and supermarkets Ayalon et al., 2009. In Mauritius, plastic wastes constitute around 8% by weight or 100 tonnes of the total solid waste generated daily. The amount of plastic carry-bags disposed

at the landfill is approximately 1000 tonnes annually, while the local plastic industries generate around 250–300 million plastic carry bags per annum Mohee and Unmar, 2007. In Israel, 2 billion HDPE carrier bags are manufactured every year. The total amount of these bags is 30,000 tons/year. At the end

### Primary plastic production by industrial sector, 2015

Primary global plastic production by industrial sector allocation, measured in tonnes per year.



Source: Geyer et al. (2017)

CC BY

of

2007, there were 2,007,300 households in Israel. It means that the consumption in Israel per household is 1000 bags /yr, 2.

Every person in Israel uses an average of 300 bags /yr, similar to other countries such as Ireland, where before introduction of the levy, a yearly average was of 330 bags per person Ayalon et al., 2009. The estimated figure of plastic waste generation across the Pakistan was 1.32 million tons per annum Sabir, 2004. The plastic industry in Pakistan was reported to be growing at an average annual growth rate of 15% Shah et al., 2008.

## PLASTIC STATISTICS OF INDIA

In India, plastic consumption grew exponentially in the 1990s. In the decade 1990 - 2000, total consumption of plastics grew twice 12% /yr as fast as the gross domestic product growth rate based on



purchasing power parities 6% /yr. The current growth rate in Indian polymer consumption is higher than that in China and many other key Asian countries. The average Indian consumption of virgin plastics per capita reached 3.2 kg in 2000/2001 5 kg if recycled material is included from a mere 0.8 kg in 1990/1991 that is only one-fourth of the consumption in China 12 kg/capita, 1998 and one sixth of the world average i.e.18 kg/capita Muthaa et al., 2006.



Source: Central Pollution Control Board

NDTV.com

This consumption led to more than 5400 tonnes of plastics waste being generated per day in 2000/2001 and the percentage of plastics in municipal solid waste MSW has also increased significantly from 0.7% in 1971 to 4% in 1995 TERI,1998. Polyolefin account for about 60% of the total plastics consumption, followed by PVC and polystyrene. Together, the commodity plastics PE, PP, PVC and PS accounted for 83% of the total plastics consumption in India in 2000/2001. Between 1990 and 2000, LLDPE was the material with the strongest growth rate of 20% /yr, followed by PP 16% /yr, HDPE 14% /yr, PVC 12% /yr, PS 10% /yr and LDPE Muthaa et al., 2006. Polyolefin account for the major share of 60% in the total plastics consumption in India. Packaging is the major plastics consuming sector, with 42% of the total consumption, followed by consumer products and the construction

industry. This is similar to the situation in Western Europe where packaging accounts for 37- 40% of the total plastics consumption APME, 2002; SGCCI, 2000; VKE, 2002. In the year 2000-01, the share of recycling accounted for 47% of the total volume of waste generated including primary, secondary and tertiary recycling Muthaa et al., 2006. According to ICPE 2005 the per capita consumption of the plastic is 4 kg in India whereas in china it accounts 18 kg while 20 kg in the other developed nations. Recycling is highest in India that is 60 % while it comes only 20 % for the rest of the world. Further, according to Muthaa et al. 2006 the consumption of plastics will increase about six-fold between 2000 and 2030 and LLDPE, HDPE, PP will dominate in India due to their versatility and cost benefits. PVC will grow very slowly because it will be replaced by PP and HDPE. Due to the increasing share of long-life products in the economy, and consequently in the volume of waste generated, the share of recycling will decrease to 35% over the next three decades. The total waste available for disposal will increase at least 10- fold up to the year 2030 from its current level of 1.3 million tonnes. This model result assumes that the plastics recycling rates will remain at the current level for the next three decades. However higher recycling rate improved waste management system still a strong regulatory discipline is required in India because volumes of plastic waste will clearly rise in the future as the per capita consumption of plastic products increases. Plastics waste management, therefore, needs continued policy attention from both stakeholders: Government and Industry. Some initiative examples are; Plastics Waste Management Task Force established the Ministry of Environment and Forests in 1997 and the Indian Centre for Plastics and Environment ICPE that was established by the Indian plastics industry in 1999 Muthaa et al., 2006. Recently, Ministry of Environment and Forests issued a new gazette of rules 4th Feb, 2011 known as Plastic Waste Management and Handling Rules, 2011. Some salient features of these rules are; a No person shall use carry bags made of recycled plastics or compostable plastics for storing, carrying, dispensing or packaging food stuffs. b No person shall manufacture, stock, distribute or sell any carry bag made of virgin or recycled or compostable plastic, which is less than 40 microns in thickness. c Sachets using plastic material shall not be used for storing, packing or selling gutkha, tobacco and pan masala.

## **ISSUES RELATED WITH PLASTIC BAGS**

Plastic grocery bags have been a part of daily life in developed countries since their introduction in 1977 and in more recent years, their use has spread to many developing countries as well (Williamson, 2003). Countless numbers of bags filling landfills and spilling over every surface of the Earth (Chauhan, 2003; Thier et al., 2003). This prevalence results in several critical environmental and social impacts associated with their use and immediate disposal. Plastic bags are also problematic in terms of the loss of agricultural potential and impacts on tourism, in addition to the high cost of cleanup that falls to local and national governments. In these regions, plastic bags are found everywhere, from remote tourist destinations to city streets where they can clog drain pipes, contributing to massive flooding that has already cost thousands of lives. In 2005, city Mumbai, India experienced massive monsoon flooding, resulting in at least 1,000 deaths, with additional people suffering injuries (The Asian News, 2005). City officials blamed the destructive floods on plastic bags that clogged gutters and drains, preventing the rainwater from leaving the city through underground systems. Similar flooding happened in 1988 and 1998 in Bangladesh that led to the banning of plastic bags in 2002 (World Watch, 2004). By clogging sewer pipes, plastic grocery bags also create stagnant water that produces the ideal habitat for mosquitoes and other parasites that have the potential to spread a large number of diseases, such as encephalitis and dengue fever, but most notably malaria (Edwards, 2000; World Watch, 2004). Plastic also has the potential to leach their chemical components and toxins into soil and water sources that can be passed on to humans, resulting in health dangers such as neurological problems and cancers (Butte Environmental Council, 2001; Lane, 2003). Plastic bags are mistakenly eaten by animals, leading to suffocation or blockage of digestive tracts, and eventually death. South Africa, Kenya, Somaliland, and India are four nations that report high levels of these problems, with as many as 100 cows dying per day in India (World Watch, 2004; Edwards, 2000). Due to their propensity to be carried away on a breeze and become attached to tree branches, fill roadside ditches or end up in public waterways, rivers or oceans. In one instance, Cape Town, South Africa, had more than 3000 plastic grocery bags that covered each kilometre of road (Ryan and Rice, 1996). In this century, an estimated 12 46,000 pieces of plastic are floating in every square kilometre of ocean worldwide (Baker, 2002). According to Williamson (2003) about 96 % of all grocery bags are thrown into landfills. A bag can last up to 1000 years, inhibiting the breakdown of biodegradable materials around or in it (Stevens, 2001). According to Matlack (2001) problems of air and water pollution become more intensive in several countries with few environmental regulations over plastic shopping bags that results in even greater impacts on the environment and human health. The ecological footprint of the plastic bag grows with each increasing statistic. Australia

alone imports 4 billion bags annually Australian Bureau of Statistics, 2004. Container ships used to transport these bags to each consumer country use fuels that produce high levels of pollutants, such as sulphur Long and Wagner, 2000. To illustrate, of the estimated 4 to 5 trillion plastic bags produced per year, North America and Western Europe account for nearly 80 %, with the U. S. that throwing away 100 billion plastic grocery bags annually Geographical, 2005; Murphy, 2005. Australia uses 7 billion plastic bags annually, of that 53 per cent come from supermarkets Australian Bureau of Statistics, 2004; Brown, 2003. The United Kingdom consumes between eight and 10 billion bags annually and in Taiwan this number rises to 20 billion Geographical, 2005.

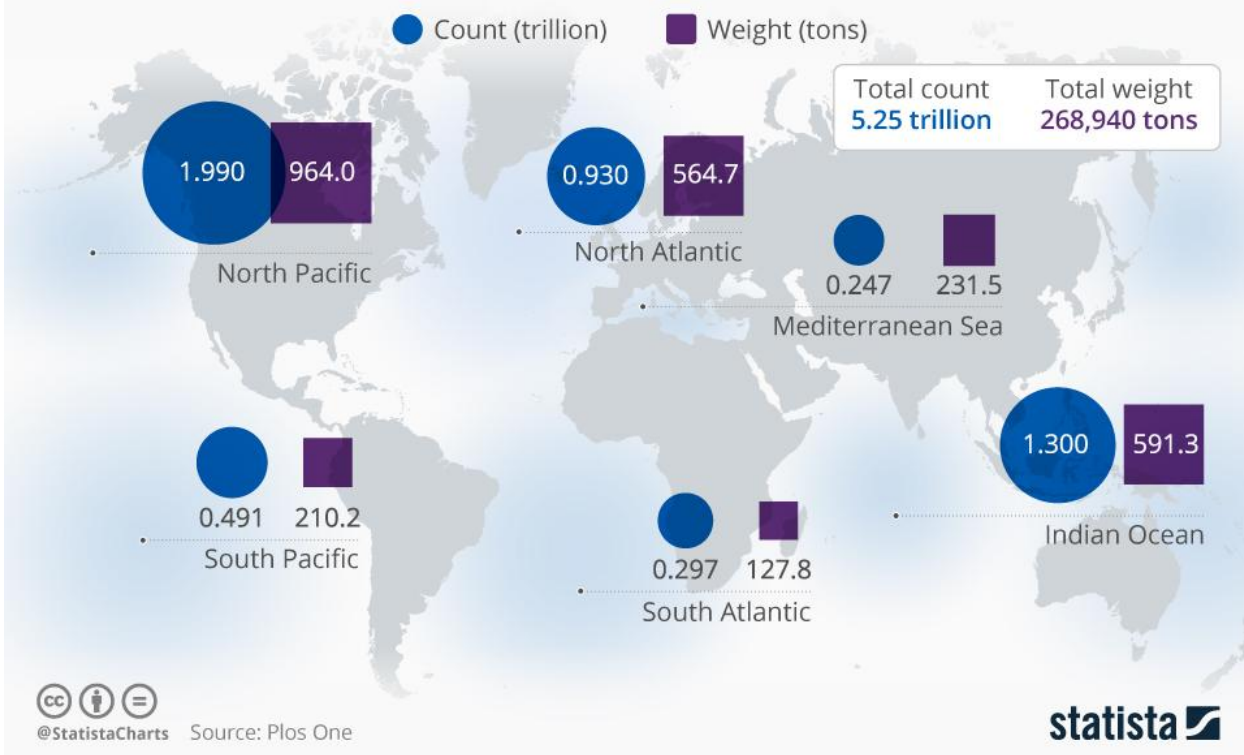
## **PLASTIC FOOTPRINTS IN OCEANS AND IMPACT ON MARINE LIFE**

Human activities are responsible for a major decline of the world's biological diversity, and the problem is so critical that combined human impacts could have accelerated present extinction rates to 1000–10,000 times the natural rate Lovejoy, 1997. One particular form of human impact constitutes a major threat to marine life: the pollution by plastic debris. Plastics are synthetic organic polymers, and though they have only existed for just over a century Gorman, 1993. These threats to marine life are primarily mechanical due to ingestion of plastic debris and entanglement in packaging bands viz. synthetic ropes and lines, or drift nets Broken or discarded fishing gear, pellets, scrubbers, microplastics, films and flakes Gregory, 2009; Mallory et al., 2006; Thompson et al., 2004; Derraik, 2002; Moore et al., 2001; Baird and Hooker, 2000; Blight and Burger, 1997; Laist, 1987, 1997; Quayle, 1992; Colton et al., 1974; Rothstein, 1973; Carpenter and Smith, 1972. Plastic fragments on beaches are derived either 1 from inland sources and are transported to coasts by rivers, wind, man-made drainage systems or human activity, or 2 directly from the oceans where low density floating varieties accumulate and are transported across great distances. Corcoran et al., 2009 Floating plastic fragments in the world's oceans have been reported since the early 1970's e.g. Carpenter and Smith, 1972; Colton et al., 1974, with the amount of debris showing a documented exponential increase Ryan and Moloney, 1993. The majority of these items are non-biodegradable and can attract encrusting organisms as drift plastics Minchin, 1996; Gregory, 1983; Winston, 1982. Types and amounts of plastic debris on beaches are controlled mainly by topography, current and storm activity, proximity to litter sources and extent of beach use Storrier et al., 2007. Surveys carried out in South African beaches, showed that the densities of all plastic debris have increased substantially Ryan and Moloney, 1990. In Panama, experimentally cleared beaches regained about 50% of their original debris load after just 3 months Garrity and

Levings, 1993. Plastic pellets can be found across the Southwest Pacific in surprisingly high quantities for remote and non-industrialised places such as Tonga, Rarotonga and Fiji Gregory, 1999. In New Zealand beaches they are found in quite considerable amounts, in counts of over 100,000 raw plastic granules per meter of coast Gregory, 1989, with greatest concentration near important industrial centers Gregory, 1977. Their durability in the marine environment is still uncertain but they seem to last from 3 to 10 years, and additives can probably extend this period to 30–50 years Gregory, 1978. Since they are also buoyant, an increasing load of plastic debris is being dispersed over long distances in marine environments and beaches across the globe are littered with plastic debris. Items of plastic have been reported from the poles to the equator 60–80 percent of marine litter being plastic Oigman-Pszczol and Creed, 2007; Storrier et al., 2007; Thompson et al., 2004; Derraik, 2002, Gregory and Ryan, 1997. Even far and remote beaches Subantarctic islands and South Pacific are becoming increasingly affected by plastic debris, especially fishinglines Walker et al., 1997; Benton, 1995 In 1975 the world's fishing fleet alone dumped into the sea approximately 135,400 tons of plastic fishing gear and 23,600 tons of synthetic packaging material DOC, 1990; Cawthorn, 1989. Horsman 1982 estimated that merchant ships dump 639,000 plastic containers each day around the world and ships are therefore, a major source of plastic debris Shaw, 1977; Shaw and Mapes, 1979.

# The World's Oceans Are Infested With Plastic

Number and weight of plastic pieces afloat at sea



Recreational fishing and boats are also responsible for dumping a considerable amount of marine debris, and according to the US Coast Guard they dispose approximately 52% of all rubbish dumped in US waters UNESCO, 1994. Unfortunately, plastics do not degrade rapidly through mineralization, and may remain in microscopic form indefinitely Corcoran et al., 2009. Conventional plastics show high resistance to aging and minimal biological degradation O'Brine and Thompson, 2010 and when they finally settle in sediments they may persist for centuries Goldberg, 1995, 1997; Hansen, 1990; Ryan, 1987. According to Kanehiro et al., 1995 plastics made up 80–85% 14 of the seabed debris in Tokyo Bay. The accumulation of such debris can inhibit the gas exchange resulting hypoxia or anoxia in the benthos that can interfere with the normal ecosystem functioning Goldberg, 1994. In addition, chemicals including phthalates, PCB's and organochlorine pesticides, reported in plastic fragments may present a toxicological hazard Teuten et al., 2009, 2007; Mato et al., 2001; Andrady et al., 1993. Dispersal of aggressive alien and invasive species by these mechanisms leads one to reflect on the possibilities that ensuing invasions could endanger sensitive or at-risk coastal environments both marine and terrestrial far from their native habitats Tourinho et al., 2010. This plastic can affect marine wildlife in two

important ways: by entangling creatures, and by being eaten. However, the impact of plastic bags does not end with the death of one animal; when a bird or mammal dies in such a manner and subsequently decomposes, the plastic bag will be released into the environment to be ingested again by another animal Derraik, 2002. The problem may be highly underestimated as most victims are likely to go undiscovered over vast ocean areas, as they either sink or are eaten by predators Wolfe, 1987. Marine debris are affecting at least 267 species worldwide, including 86% of all sea turtle species, 44% of all seabird species, and 43% of all marine mammal species Laist, 1997. Some representative examples typifying the global spread of plastic ingestion behaviour are red phalaropes Connors and Smith 1982; 15 species of sea birds, Gough Island, South Atlantic Ocean Furness ,1985; Wilsons storm-petrels, Antarctica Van Franeker and Bell 1988; storm-petrels Blight and Burger 1997; short-tailed shearwaters, Bering Sea Vlietstra and Parga 2002; southern giant petrels, Southern Atlantic Ocean Copello and Quintana, 2003; northern fulmars, Nunavut, Davis Strait Mallory et al.,2006. Most distressing, over a billion seabirds and mammals die annually from ingestion of plastics Baker, 2002. Brown 2003 mentioned that in Newfoundland 100,000 marine mammals are killed each year by ingesting plastic.

## **ISSUES RELATED TO PLASTIC PRODUCTS MANUFACTURING**

The manufacturing of plastic bags accounts for 4 per cent of the world's total oil production Greenfeet, 2004. The energy used to make one high-density polyethylene HDPE plastic bag is 0.48 mega-joules. To give this figure perspective, a car driving one kilometre is the equivalent of manufacturing 8.7 plastic bags Australian Bureau of Statistics, 2004. If a country such as Ireland, with approximately 1.23 million shoppers, switched 50 per cent of plastic bag users to cotton, 15,100 tonnes of CO<sub>2</sub> emissions would be saved per annum. This is equivalent to one person driving around the world 1,800 times Simmons, 2005. Two plastic bags require 990 kJ kilojoules of natural gas, 240 kJ of petroleum, and 15 160 kJ of coal ILEA, 1990. Additionally, there are large amounts of energy used to acquire oil, such as the large, fuel-burning heavy machinery, and most of the electricity used in the process of manufacturing the actual bags comes from coal-fired power plants Greenfeet, 2004. Manufacturing process of plastic bags contribute to air pollution i.e. acid rain, smog etc. Other harmful effects associated with the use of petroleum, coal, and natural gas, such as health conditions of coal miners and environmental impacts associated with natural gas and petroleum retrieval is a significant environmental impact. Additionally, the manufacturing of plastic grocery bags produces waterborne waste, that has the capability of disrupting associated ecosystems, such as waterways and the life that

they support Environmental Literacy Council, 2005; ILEA, 1990; NPBWG, 2002. Toxic chemicals that are most frequently released during the production of plastics include trichloroethane, acetone, methylene chloride, methyl ethyl ketone, styrene, 3 toluene, and benzene IFC, 2009. Other major emissions are sulfur oxides, nitrous oxides, methanol, ethylene oxide and volatile organic compounds NSEPB, 1987. Benzene is believed to be extremely toxic while a cause of cancer. Sulfur oxides are known to harm the respiratory system, nitrous oxides adversely affect the nervous system and child behavioral development and ethylene oxides harm the male and female reproductive capacity Xiao and Levin, 2000; IARC. 1998; Schaumburg, and Spencer, 1978; Seppäläinen and Tolonen 1974.

### **PLASTIC WASTE SCENARIO (QUANTITY AND COMPOSITION)**

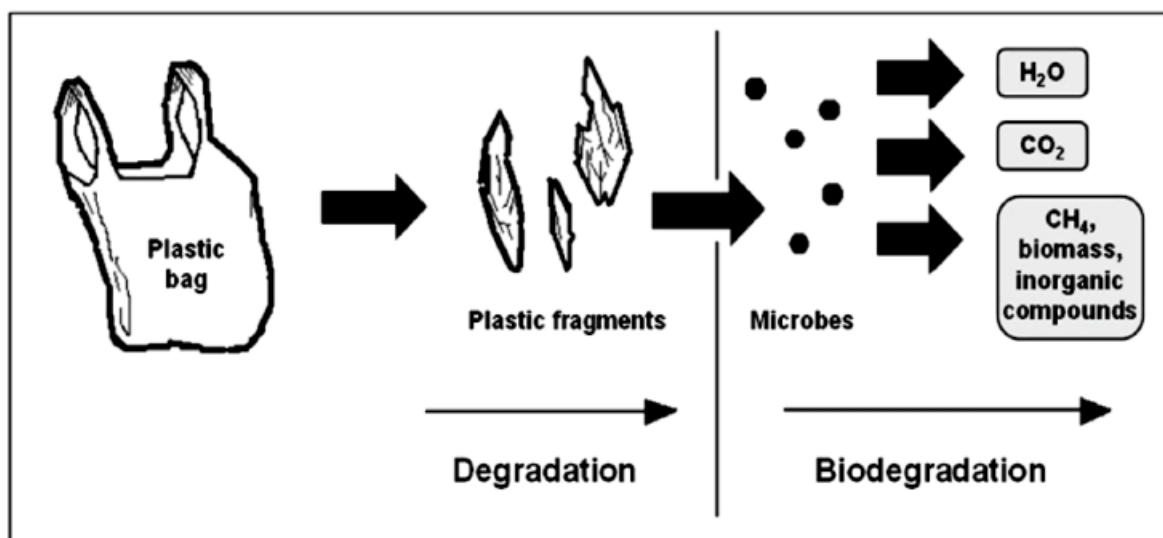
The dramatic increase in production and lack of biodegradability of commercial polymers, particularly commodity plastics used in packaging (e.g. fast food), industry and agriculture, focused public attention on a potentially huge environmental accumulation and pollution problem that could persist for centuries (Albertsson et al., 1987). Moreover, the problem of wastes cannot be solved by landfilling and incineration, because suitable and safe depots are expensive, and incineration stimulates the growing emission of harmful, greenhouse gases, e.g. NO<sub>x</sub>, SO<sub>x</sub>, CO<sub>x</sub>, etc. (Miskolczia et al., 2004). The same as in wealthy countries, light-weight and dirty plastics products (e.g. packaging films) are disposed of in India together with the normal household waste (without reimbursement). The major part of this waste stream is either dumped on landfill sites or remains in the environment where it is the main contributor to littering. A minor part of this light-weight and dirty plastics waste is suitable for recycling and is collected in various stages via various middlemen; it ultimately finds its way to the preprocessors (Muthaa et al., 2006) 16 Since they are also buoyant, an increasing load of plastic debris is being dispersed over long distances, and when they finally settle in sediments they may persist for centuries (Goldberg, 1995, 1997; Hansen, 1990; Ryan, 1987). Clearly indicates the predominance of plastics amongst the marine litter, and its proportion consistently varies between 60% and 80% of the total marine debris (Gregory and Ryan, 1997). Kikuchi et al. (2006) reported following statistic data of composition of post-user plastic wastes (municipal waste and industrial waste) in Europe; 32.9% low density polyethylene (LDPE), 14.1% high density polyethylene (HDPE), 11.6% polypropylene (PP), 11.0% polyvinyl chloride (PVC), 8.7% polystyrene (PS), 5.7% polyurethane (PU), 3.6% polyethylene terephthalate (PET), 2.5% acrylonitrile butadiene styrene (ABS) and others. Environmental health costs associated with a plastic product life cycle could reveal the true costs of plastic bag consumption.



Western nations have infrastructures that are able to deal well with waste and recycling; generally do not feel the same effects of plastic bags in the environment like underdeveloped countries (Spivey, 2003). However, this is far from the case in developing nations where waste management is not well established or is non-existent (Environmental Literacy Council, 2005). The effects of plastic bags are most severely felt in poor and rural areas, where shopping bags are dispensed and used widely but not disposed off properly (Reynolds, 2002). The footprint of plastic grocery bags also includes high civic costs to governments, most of that are incurred through clean-up efforts. Plastic bags can litter roads, sewers and waterways, making litter collection and disposal difficult and costly (NPBWG, 2002; Reynolds, 2002; Ryan and Rice, 1996; World Watch, 2004). High costs are being shouldered by governments and taxpayers that result in the loss of funds from other services offered by the government. Because of this myriad of problems, many governments have banned plastic grocery bags entirely or imposed levies on their use (The Asian News, 2005; Environmental Literacy Council, 2005; World Watch, 2004).

## **DEGRADATION OF PLASTIC**

A degradable material breaks down completely by natural processes so that the basic building blocks can be used again by nature to make a new life form (Gautam, 2009). Plastics made from petrochemicals are not a product of nature and cannot be broken down by natural processes. Also, there is no data presented about complete biodegradability within the one growing season/one year time period. It is assumed that the breakdown products will eventually biodegrade. In the meanwhile, these degraded, hydrophobic, high surface area plastic residues migrate into the water table and other compartments of the ecosystem causing irreparable harm to the environment (Gautam, 2009).



PE is a synthetic polymer with  $\text{-CH}_2\text{-CH}_2\text{-}$  repeating units in the polymer backbone. Among different types of synthetic polymers, PE is considered to be highly resistant to biodegradation. Several features of PE have been identified to make it resistant to biodegradation: (1) highly stable C-C and C-H covalent bonds, (2) higher molecular weight (MW) of PE polymer, that makes them too big to penetrate cell walls of microbes, (3) lack of readily oxidizable and/or hydrolyzable carbonyl, amide, and C=C double bond groups etc. in the polymer backbone, (4) lack of chromophores that can act as catalysts for synergistic photo and biodegradation, and (5) highly hydrophobic nature. Because of these features, PE has been considered almost inert to biodegradation and a literature review revealed differing views among authors regarding whether to consider PE as a biodegradable polymer or not (Gautam et al., 2007). Some plastic articles may take 500 years to decompose (Gorman, 1993; UNESCO, 1994). Due to the long-life of plastics on marine ecosystems, it is imperative that severe measures are taken to address the problem at both international and national levels, since even if the production and disposal of plastics suddenly stopped, the existing debris would continue to harm marine life for many decades (Derraik, 2002). Synthetic polyolefins are inert materials whose backbones consist of only long carbon chains. The characteristic structure makes polyolefins non-susceptible to degradation by microorganisms. It takes several centuries until it is efficiently degraded (except when exposed to UV from sunlight) (Yamada et al., 2001). Introduction of microorganisms for the specific digestion of polymer materials is another more intensive approach that ultimately costs more but it circumvents the use of renewable resources as biopolymer feed-stocks. Although microorganisms are researched to target and breakdown petroleum based plastics but this method only reduces the volume of waste and

does not help in the preservation of non-renewable resources (Andreopoulos, 1994). According to Yamada et al. (2001) degradation always follows photo degradation and chemical degradation. Otake et al. (1995) reported the changes like whitening of the degraded area and small holes on the surface of PE film after soil burial for 32 years. Biodegradation of LDPE film was also reported as 0.2% weight loss in 10 years (Albertsson, 1980). Polyvinyl chloride (PVC) is a strong plastic that resists abrasion and chemicals and has low moisture absorption. There are many studies about thermal and photodegradation of PVC (Braun and Bazdadea, 1986, Owen, 1984) but there only few reports available on biodegradation of PVC. 18 In Europe, some countries allow the addition of paper and biodegradable polymers to the bio-waste fraction (Venelampi et al., 2003). Wilde and Boelens (1997) have proposed three characteristics of bioplastics and/or paper that would render them suitable for use in composting and organic recovery. These characteristics are: biodegradation, disintegration and no effect on compost quality. When plastics are exposed to UVB radiation in sunlight and the oxidative and hydrolytic properties of the atmosphere and seawater, polymers can be oxidized, forming hydroperoxides that lead to polymer chain scission (Billingham et al., 2000). However, these would require further degradation before they would become bioavailable. The mineralization rate from long-term biodegradation experiments of both UV irradiated samples (Albertsson and Karlsson, 1988), In addition, the burning of polyvinylchloride (PVC) plastics produces persistent organic pollutants (POPs) known as furans and dioxins (Jayasekara et al., 2005). On the other hand, it is important to have comparable international standard methods of determining the extent of biodegradation. Unfortunately, the current standards have not, so far, been equated to each other and tend to be used in the countries where they originated [e.g. ASTM (USA), DIN (Germany), JIS (Japan), ISO (international standards), CEN (Europe)]. Many, that are otherwise harmonious, differ in the fine details of the testing. There is an urgent need to standardize all details so that researchers may know that they have all worked to the same parameters (Shah et al., 2008).

## **PROBLEMS IN RECYCLING AND INCINERATION OF PLASTIC GARBAGE**

According to conventional economics, recycling does economically efficient if it costs more to recycle materials than to send them to landfills or incinerators. Many critics also point out that recycling is often not needed to save landfill space because many areas are not running out of it (Tierney, 1996). It is hard to understand why recycling is held to a different standard and thus forced to cover its own costs. As well, the lower charges for depositing wastes in landfills in North America and the lower prices paid

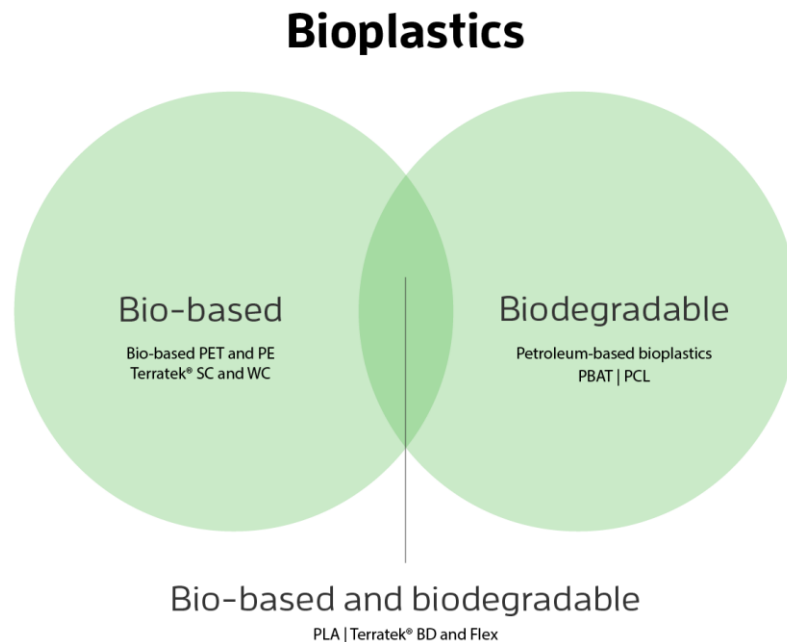
for recycled plastic shows that recycling is not a priority for most governments, businesses and individuals, causing grave consequences around the globe (Porter, 2000). An ecoprofile analysis shows that the incineration of plastics with heat recovery is the most environmentally friendly and resource compatible process if it is not technically and economically easy to sort different types of plastic material (Kikuchi et al., 2008). McKinney and Schoch (2003) discussed three reasons that affect the recycling rates of plastic bags. First, plastics are made from many different resins, and because they cannot be mixed, they must be sorted and processed separately. Such labour-intensive processing is expensive in high-wage countries like the United States and Canada. Most plastics also contain stabilizers and other chemicals that must be removed before recycling. Second, recovering individual plastic resins does not yield much material because only small amounts of any given resin are used per product. Third, the price of oil used to produce petrochemicals for making plastic resins is so low that the cost of virgin plastic resins is much lower than that of recycled resins (Miller, 2005). Hence, recycling is not a simple solution to lessen the ecological footprint of the plastic encroachment. Recycling can be divided into further important categories, such as mechanical recycling and chemical recycling. Chemical recycling is virtually a thermal method that yields a liquid with high sulphur and nitrogen content. This is a disadvantageous property for further utilization (Miskolczia et al., 2004). However, with used thin films, recovery is often not economically feasible, more oil being used to provide the energy for collection and sorting from other refuse than is saved by the recovery of the plastics material (Philip et al., 1993). Although it is important to individually separate various types of waste plastic with a high accuracy, it must also be environmentally helpful to sort mixed waste plastics according to their final destination (waste-to-energy application or landfilling) by a simple approach. Without proper measures, there may be no alternative but to dump them at a landfill. The plastic densities change with the order  $PVC > PET > PU > PS > ABS > PE > PP$ . The number of floatable plastics increases with an increase in the liquid density. After pre-sorting by the current process, the mixed waste plastics contain 2.2% Cl. If these plastics are combined with a waste-to-energy project the Cl content is too great for the same (Kikuchi et al., 2008). However, mechanical recycling has some limitations. Firstly, the recycled plastics lose their properties steadily and their final appearance is different. Besides, small contaminations by other polymers give low quality plastics because of the material incompatibility, and therefore they can only be used in lower-quality applications. Finally, mechanical recycling is limited to thermoplastics (Aguado et al., 2006). However, recycling appeared to be a viable way to reduce pollution and environmental damage when it was first introduced as a waste

reduction technique but use of plastics that are compostable or easily degraded must be encouraged to reduce toxic emissions when plastic material is recycled or decomposed (Kolybaba et al., 2003). With regard to recycling the situation is very specific in India since the percentage of plastics recycling is much higher than that in most developed and in many developing countries e.g. China 10%, South Africa 16%, compared to ~ 47% in India (Muthaa et al., 2006). The recycling sector in India has developed autonomously because of the particularly low cost of labour and on account of the fairly large market for second-grade (lower-quality) 20 products. Recycled products are available at a 20–40% lower price than the same products manufactured from virgin plastics. The cost per hour in India (according to report issued by the Plast India Foundation) is 35 times less than in Germany, 19 times less than in the United States and 6 times less than in Taiwan (NetPEM, 2001). The pollution that occurs in the disposal stage is largely during incineration. A large amount of plastic wastes is burnt in incinerators and burning of these chlorine-containing substances releases toxic heavy metals and emits noxious gasses like dioxins and furans. The latter two are two of the most toxic and poisonous substances on earth and can cause a variety of health problems including damage to the reproductive and immune system, respiratory difficulties and cancer. In fact, dioxin has been shown to have hormonal activity and is an endocrine disrupt or disruptor (Hicks et al., 2005). On the other hand Incineration coupled with energy recovery, that has received great support from the industry and Government in India, could minimize the immediate waste disposal problems in India; but this could also aggravate pollution problems if strict standards are not enforced. Further there are huge costs associated with incineration, if it has to be profitable and carried out in an environmentally friendly manner. Another key aspect is composition of municipal solid waste in India. The waste has a very low calorific value and additional fuel is required to carry out incineration effectively. This would further add to the costs associated with incineration. Another important complication arising from introduction of incineration in India is that it may adversely affect the recycling industry.

## **BIODEGRADABLE POLYMERS AND BIO-PLASTIC**

Sustainability requires that a degradable material breaks down completely by natural processes so that the basic building blocks can be used again by nature to make a new life form. Plastics made from petrochemicals are not a product of nature and cannot be broken down by natural processes hence the use of biodegradable is the need of the hour to implement immediate application for biodegradable plastics (Gautam, 2009). Marlet (2004) has shown that plastic bags are preferable to paper bags

throughout their life cycle due to lower energy needs for production and environmental pollution. Hill (2005) was unable to show significant advantages or disadvantages of bags produced from one type of plastic over those made from other kinds of plastic, including recyclable material (Ayalon et al., 2009). Furthermore, comparison with the paper bag alternative, which is accepted by the public as the „greener” choice, reveals that the paper bag uses almost 10 times as much material as that needed to produce a single-use plastic bag. The production process also requires the use of cellulose derived from trees an important environmental resource for<sup>21</sup> sequestering greenhouse gasses. Moreover, the process of producing paper bags demands the use of larger volumes of water than plastic bags and the degradation process of paper bags in landfills releases greenhouse gasses.



No difference was found between plastic and biodegradable bags in reference to the problems associated with a whole life cycle, and both these alternatives are preferable to the paper bag alternative (DEHA, 2002). The great advantage of bioplastic is the conservation of fossil resources and reduction in CO<sub>2</sub> emissions. It makes them one of the most important innovations for sustainable development. Plastics, with their current global consumption of more than 250 million tonnes consume 5% crude oil. This consumption may appear comparatively small, however it does emphasise how dependent the plastics industry is on oil. Making, disposal and recovery of bioplastics have the additional advantage of using renewable resources. According to IBAW (2004), the use of biodegradable plastics has doubled

between 2001 and 2003 to 40,000 tonnes. So far the paper and board sector has been by far the largest bio-polymer producer. Its world-wide production amounted to approximately 365 million metric tonnes (Mt) in 2006 (FAO, 2008). Non-food starch (excluding starch for fuel ethanol), cellulose polymer and alkyd resins are also important bio-polymers but they are much smaller in terms of production volumes. In total, they account for approximately 20 Mt /yr, of that non-food starch takes the lion's share (75% or 15 Mt), followed by cellulose polymers (20% or 4 Mt, excluding paper) and alkyd resin (5% or 1 Mt) (Shen et al., 2009). Bioplastics (Biopolymers) obtained from growth of microorganisms or from plants that are genetically-engineered to produce such polymers are likely to replace currently used plastics at least in some of the fields (Lee, 1996). The global interest in PHAs is high as it is used in different packaging materials, medical devices, disposable personal hygiene and also agricultural applications as a substitute for synthetic polymers like polypropylene, polyethylene etc. (Ojumu et al., 2004).

### **Why should we turn plastic to fuel?**

Estimates show that less than 5% of the plastic manufactured each year is recycled, with production of the material set to increase by 3.8% every year until 2030, adding to the 6.3 billion tonnes churned out since production began 60 years ago. The majority ends up in our oceans, posing a disruption to marine ecosystems, which researchers predict would take a minimum of 450 years to biodegrade, if ever.

The solution of plastics-to-fuel holds promise in not only curbing such pervasive pollution but also providing a significant economic benefit to regions. The American Chemistry Council estimates plastic-to-fuel facilities in the US alone would create nearly 39,000 jobs and almost \$ Plastic-derived fuels are also capable of producing a cleaner burning fuel than traditional sources due to their low sulphur content, considering the majority of developing nations use sulphur-heavy diesel.

## **PYROLYSIS**

Pyrolysis is a process which involves thermochemical decomposition of organic matter at high temperature ( $>370^{\circ}\text{C}$ ) in the absence of oxygen. Products of this process are Pyrolysis Oil, Carbon Black, and Hydrocarbons. This review paper is focusing the most efficient and widely used method of converting plastics to fuels: 'Pyrolysis' and its effectiveness on resolving the both issues of waste plastic management and the requirement of a good alternative fuel for use. **KEYWORDS:** Pyrolysis,

Decomposition, Plastic Waste, Green Technology, Waste Management In the world a total of over 100 million tonnes of plastic is manufactured to meet global plastic demand. This much production and consumption of plastic is a threat to environment as it takes several years to decompose naturally. According to ASTM (American Society for Testing and Materials) , plastic recycling methods are of four types on the basis of final products. The tertiary or chemical recycling degradation is one of the categories. From this method of chemical degradation, liquid fuels and high value added chemicals are produced by waste plastic fragments. One of tertiary recycling method is pyrolysis. Pyrolysis Pyrolysis is a process of decomposing plastics by heating in absence of oxygen generating gaseous and liquids products which can be utilized as fuels. This process can be thermal or catalytic and is an alternative that allows the conversion of polymers into gas and liquid hydrocarbons. The plastic waste is processed to produce petrochemical compounds.

1.1 Thermal Pyrolysis The temperature of pyrolysis ranges from 350°C to 900°C and generally following products are derived.

- Non condensable gases
- Liquid fraction (paraffin, olefins, naphthenes, and aromatics)

From liquid fraction following range products are obtained,

- Gasoline range
- Diesel Range
- Kerosene Range
- Motor Oil Range
- Solid waste

1.2 Catalytic Pyrolysis: The homogeneous catalysts used are Lewis acids, as  $AlCl_3$ , fused metal tetrachloro-aluminates ( $M(AlCl_4)_n$ ), where the metal may be lithium, sodium, potassium, magnesium, calcium or barium and n can be 1 or 2). Heterogeneous catalysts used are conventional solids like zeolites, silicaalumina, alumina and catalysts for fluid bed and fluidized bed Catalytic Cracking, mesostructured catalysts (such as MCM-41 etc.), and Nano crystalline zeolites (such as

**PLASTIC WASTE MANAGEMENT**

In India, during the period 2010-11 on general a total of over 3500 tonnes per day of plastic waste was generated in sixty major cities only. Industrial and domestic Plastic waste management: Mostly it is done by recycling the waste and when it becomes unsuitable for recycling it is used for pyrolysis. Marine Plastic Waste Management: Marine waste commonly known as Marine Debris or Marine Litters is generally non-repairable/out of use products of shipping industries. Every year about 10,000 containers are accidentally been lost in the sea because of storms. These types of waste kept floating in sea until it gets settled on a seashore. About 8.8 million metric tons of waste plastic is dumped in the oceans every year . Mass concentrations of marine debris in high seas ‘sink’ areas, such as the equatorial convergence zone, are of particular concern. In some such areas, ‘rafts’ of assorted debris, including various plastics, ropes, fishing nets, cargo-associated wastes such as dunnage, pallets, wires and plastic covers, drums and shipping containers can be seen spreading widely . In India ship-breaking operations are carried out over a distance of about -10 km on the beaches of Alang in



Gujarat – one of the largest and busiest ship-breaking yards in the world. When a ship is dismantled it results in release of pollution causing components like Asbestos, PCB's, PVC and PBB's, which are directly dumped into the sea . All the recyclable plastic is sent to recycling units.

### 2.3 Tyre Waste Management:

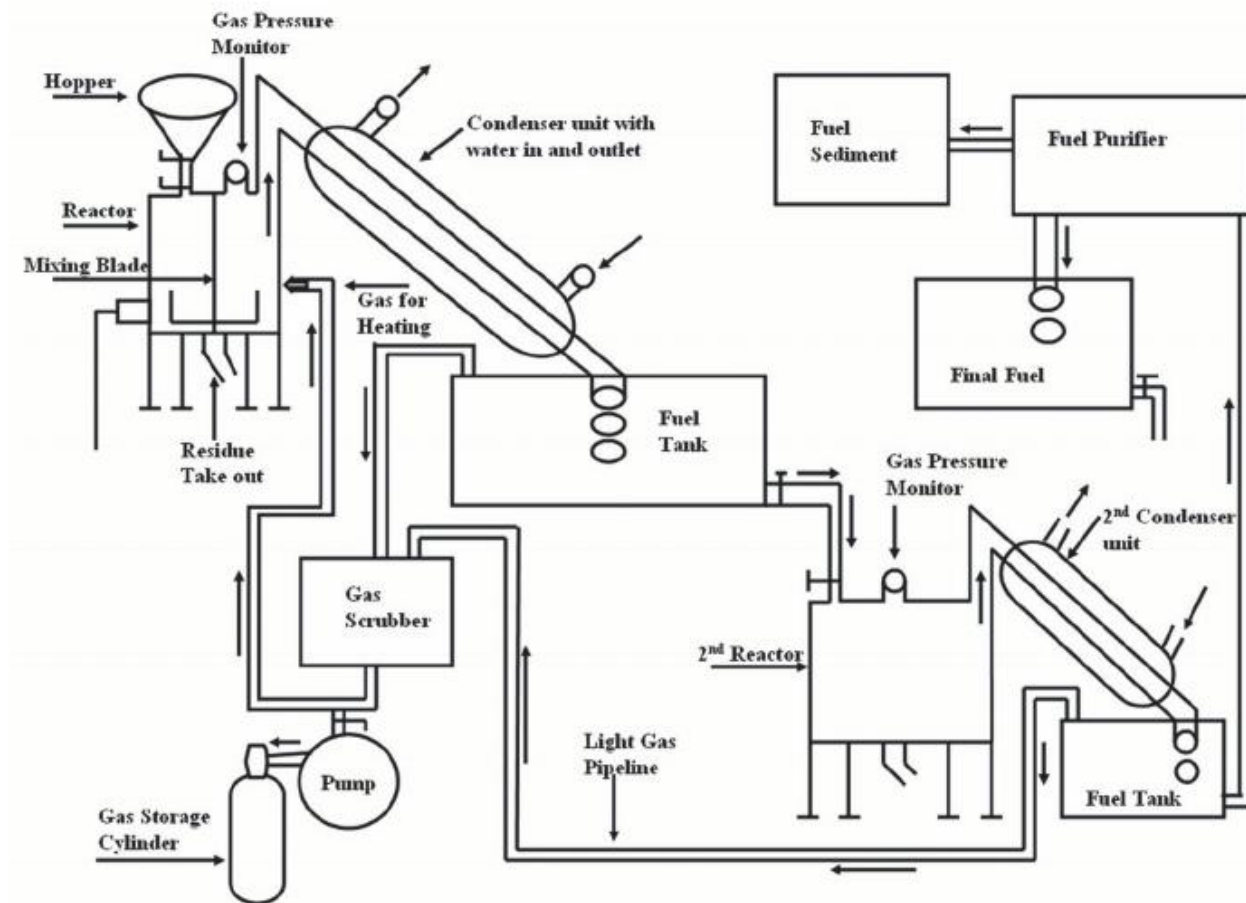
Tyre consists of vulcanized rubbers (including styrene butadiene (SBR), natural rubber (NR) and polybutadiene (BR)), carbon black, steel, textile cord and small amount of other additives. The disposal of waste tyres is one of the important environmental concern throughout the world. More than  $3.4 \times 10^6$  tonnes of end-of-life tyres are generated annually in European Union,  $2.5 \times 10^6$  tonnes in North America and  $1 \times 10^6$  tonnes in Japan. India had over 100 million vehicles registered on its roads in the year 2008. Pyrolysis of tires can produce oils, chars, and gases. Oil obtained from pyrolysis have high gross calorific value (GCV) of around 41-44 MJ/kg. In addition to fuels, these oils can be used as source of light aromatics such as benzene, toluene and xylene. Active carbon also can be prepared from tires. Carbon Black obtained from this can also be used as additive for road bitumen. It is being found that pyrolysis gas fraction contains high concentrations of methane, ethane, butadiene and other hydrocarbon gases with a GCV of approximately 37 MJ/m<sup>3</sup> . Different procedures can be used to obtain oils from tires like fixed-bed reactors, fluidized-bed pyrolysis units, vacuum pyrolysis units, spouted-bed reactors, etc. Dr. L Nageshwara Rao and team has performed an experiment for detecting the properties of the pyrolysis oil. A mixture of 1 ton of plastic waste is subjected to produce oil. The process involves washing of waste for several time to ensure dust elimination. After which the waste is dried up to room temperature to remove moisture content. The reaction is carried out in presence of catalyst 'Aluminum silicate'. The volume of catalyst is kept to 2.5% of the mass of waste. The mixture is heated at 603-723K. As a result of this pyrolysis, three products are obtained Pyrolysis Oil (60- 70%), Gas (15-20%) and Carbon Black (20-30%). Further various mixture containing 40% oil+60% petrol, 10% oil + 90% diesel, 30% oil + 70% diesel and 50% oil + 50% diesel are subjected to various characteristic tests and are found similar to that of pure fuel oils the process of pyrolysis by using microwave oven. This system generates microwaves in continuous cycles. The setup is gravity feed and nitrogen is used to prevent oxygen to enter in the process. The plastic is heated by microwaves at a specified temperature. The product of the heating is then transferred to condenser where vapors are converted into liquid oil. Pyrolysis oil was obtained as product. the process of pyrolysis in preparing fuel from the plastics waste generated from electric and electronics equipment. This type of waste consist of acrylonitrile butadiene styrene, polypropylene, polystyrene, polyethylene, polycarbonate, etc. Two-stages of pyrolysis catalyst reaction system was used to convert low density polyethylene into fuel. In

the first stage of the process the sample was heated the sample of plastic waste to a temperature of 5000C at a rate of 100C/min. The product is then sent to second stage i.e. second reactor where the catalytic temperature is 5000C is maintained and it is held for 30 minutes. Pyrolysis oil obtained was further tested for its properties. Seo et al. studied Catalytic degradation of HDPE using a batch reactor at a temperature of 450°C. As shown in table 1, the pyrolysis performed with the catalyst zeolite ZSM-5 had higher yield of the gaseous fraction and smaller yield of liquid fraction when compared with thermal cracking explained by the properties of the catalyst. Most zeolites, including ZSM-5, showed excellent catalytic efficiency in cracking, isomerization and aromatization due to its strong acidic property and its micro porous crystalline structure. The ZSM-5 zeolite has a three-dimensional pore channel structure with pore size of  $5.4 \times 5.6 \text{ \AA}$  which allows an increased cracking of larger molecules, beyond the high Si / Al ratio which leads to an increase in thermal stability and acidity. Table 1. Yield in thermal and catalytic pyrolysis of HDPE with ZSM-5

Product	Yield (% wt.) Thermal Pyrolysis	Yield (% wt.) Catalytic Pyrolysis
Gas Fraction	13.0	63.5
Liquid Fraction	84.0	35.0
Total	97.0	98.5
C6-C12	56.55	99.92
C13-C23	37.79	0.08
>C23	5.66	0.0
Solid Fraction	3.0	1.5

Zhang et al. studied the conversion of LDPE into the jet fuel . The catalytic microwave degradation was carried out at 375°C with catalyst to feed mass ratio of 0.1 or 0.2 to produce different proportions of aliphatic and cyclic hydrocarbons. It is found that in catalytic microwave degradation of LDPE carbon yields were found 66.18% and 56.32% respectively. For obtaining optimal conditions for the production of fuels different parameters were changed in hydrogenation process. More catalyst loading could facilitate rate of catalytic cracking to form gaseous compounds. The gas was primarily composed of ethylene, ethane, hydrogen, and methane because of the large extent of catalytic cracking and oligomerization reactions. By the process of Pyrolysis, plastics can be converted into fuel and in most scenarios three major products are obtained at the end of the process. These products are namely Pyrolysis Oil, Carbon Black and a Gaseous mixture. All these three are arranged in order of their composition in the product. The properties of pyrolysis oil can be improved by hydrogenation. The pyrolysis oil is a good substitute of conventional fuel and in various test run by Dr. Rao and team it is found that the oil when blended with conventional fuel like petrol & diesel, shows same characteristics as pure fuel dose. It is worth mention to notify that not only pure plastics but also plastics in which additives were used can be treated to form equally good oil [9]. Thermal and catalytic pyrolysis has their own yield aspects for different products. It has been found that can be opted thermal pyrolysis for Liquid products and to catalytic pyrolysis can be preferred for Gaseous products . In the light of addressing solution for energy and environmental issues. Pyrolysis

has been found the most effective technique of conversion of waste plastic to fuels. It is noticeable that the fuel obtained by Pyrolysis is cleaner than conventional fuels.



## Plastic to hydrogen

Most recently, researchers from Swansea University have discovered a means of converting plastic waste into hydrogen fuel, which they say could one day be used to power cars. The team added a light-absorbing photo catalyst to plastic products, a material that absorbs sunlight and transforms it into chemical energy in a process called 'photo reforming'. The plastic and catalyst combination was then left in an alkaline solution exposed to sunlight, breaking down the material and producing bubbles of hydrogen gas in the process.

The new method would be a cheaper than current recycling options, as any plastic can be used without needing to be cleaned. According to The Balance Small Business, it currently costs around \$4,000 to recycle a tonne of plastic bags, which often leads to plastic waste being burned or thrown in landfill to avoid expenses.

Dr Moritz Kuehnel, from the university's chemistry department, said: "There's a lot of plastic used every year – billions of tonnes – and only a fraction of it is being recycled. We are trying to find a use for what is not being recycled.

The beauty of this process is that it's not very picky. It can degrade all sorts of waste."

The team is now looking to scale up the process from current milligrams of plastic to use the photo reforming process on more sizeable pieces.

While it may be years before this plastic-to-fuel process can be rolled out on an industrial level, its development would work well in tandem with the advent of hydrogen vehicles. Currently, no such cars exist on our roads, though a number of companies have big plans in the pipeline. For instance, Toyota has stated its aim to sell one million electric and fuel cars worldwide by 2030, while it is also due to launch a fuel cell-powered bus in 2020.

## **Plastic to diesel**

Chemists from the University of California, Irvine (UC), in collaboration with researchers from the Shanghai Institute of Organic Chemistry, have devised a plastic recycling method that allows them to dissolve the bonds of polyethylene plastic to create petroleum and other fuel products.

While untreated polyethylene can be broken down, it requires either a significant amount of heat or reactive, toxic chemicals, and results in the atomic bonds breaking in an unusable way. By contrast, the process developed by the researchers uses far less heat and allows the final product to be transformed into a new fuel source.

The team, led by UC Irvine chemist Zhibin Guan, used a type of hydrocarbon molecule known as alkanes, which are typically used to produce polymers, though they were here harnessed to break down polymers. In a gradual process of removing and adding bonds between the carbon and hydrogen atoms

within the material, the team were able to restructure the polyethylene into a liquid fuel that can be used in cars or other industrial purposes.

The catalysts used are also compatible with various types of polyolefin additives, meaning plastic waste such as bottles, bags and film can all be converted into chemical feedstocks without the need for any pre-treatment.

### **Plastic to crude oil**

In 2016, Illinois Sustainable Technology Center researchers B.K. Sharma and Kishore Rajagopalan, in collaboration with the US Department of Agriculture, successfully converted plastic bags into fuel.

The team used high-density polyethylene bags sourced from local retailers and fed them into a pyrolysis unit, creating plastic crude oil (PCO) in the process. They then distilled the PCO to make gasoline and two types of diesel. Following the addition of antioxidants, the resulting materials proved superior to conventional diesel fuels in terms of lubricity and derived cetane number, which demonstrates ignition quality.

### **Plastic to sulphur**

US firm Plastic2Oil works to turn waste plastic into sulphur fuel, using the discarded material as feedstock to create an 'ultra-low sulphur diesel' that contains 15ppm or lower sulphur content.

Currently, ultra-low sulphur diesel is primarily produced from petroleum, though Plastic2Oil provides a viable alternative with its plastic-derived fuel. The firm's processor accepts unwashed and unsorted plastic, generating around one gallon of fuel from 8.3 pounds of the material. The processor uses its own off-gases as fuel (approximately 10%-12% of process output), meaning minimal energy is required to run the machine. The fuel produced can also be refined and separated without the cost of a distillation tower.



**Product types of some plastics pyrolysis**

<b>Main products</b>	<b>Type of plastics</b>	<b>Feedstock of liquid fuel</b>
<b>Liquid hydrocarbons</b>	<b>Polyethylene (PE)</b>	<b>Allowed.</b>
	<b>Polypropylene (PP)</b>	<b>Allowed.</b>
	<b>Polystyrene (PS)</b>	<b>Allowed.</b>
	<b>Polymethyl metacrylate (PMMA)</b>	<b>Allowed.</b>
<b>Liquid hydrocarbons</b>	<b>Acrylonitrile-Butadiene-Styrene</b>	<b>Allowed. But not suitable.</b>
	<b>copolymer (ABS)</b>	<b>Nitrogen-containing fuel is obtained. Special attention required to cyanide in oil-</b>
<b>No hydrocarbons suitable for fuel</b>	<b>Polyvinyl alcohol (PVA)</b>	<b>Not suitable, formation of water and alcohol.</b>
	<b>Polyoxymethylene (POM)</b>	<b>Not suitable. Formation of formaldehyde.</b>
<b>Solid products</b>	<b>Polyethylene terephthalate (PET)</b>	<b>Not suitable. Formation of terephthalic acid and benzoic acid.</b>
<b>Carbonous products</b>	<b>Polyurethane (PUR)</b>	<b>Not suitable.</b>
	<b>Phenol resin (PF)</b>	<b>Not suitable.</b>
<b>Hydrogen chloride and carbonous products</b>	<b>Polyvinyl chloride (PVC)</b>	<b>Not allowed.</b>
	<b>Polyvinylidene chloride (PVDC)</b>	<b>Not allowed.</b>

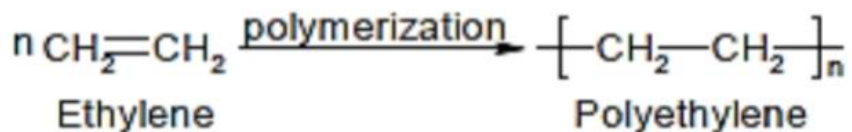
## FACTORS AFFECTING PLASTIC PYROLYSIS

The major factors influencing the plastic pyrolysis process and pyrolysis product molecular distribution include chemical composition of the feedstock, cracking temperature and heating rate, operation pressure, reactor type, residence time and application of catalyst

These factors are summarized in this sections as follows.

### Chemical composition of feedstock

The pyrolysis products are directly related to the chemical composition and chemical structure of the plastics to be pyrolyzed. In addition, the chemical composition of the feedstock also affects the pyrolysis processes. In reality, waste plastics are possibly contaminated before recycling which could also have effects on the pyrolysis process and products. PE, PP and selected as the investigated materials in this study. Polyethylene is formed from ethylene through chain polymerization which is shown in Formula PS are most commonly used polymeric hydrocarbons and were selected as the investigated materials in this study. Polyethylene is formed from ethylene through chain polymerization which is shown in Formula-

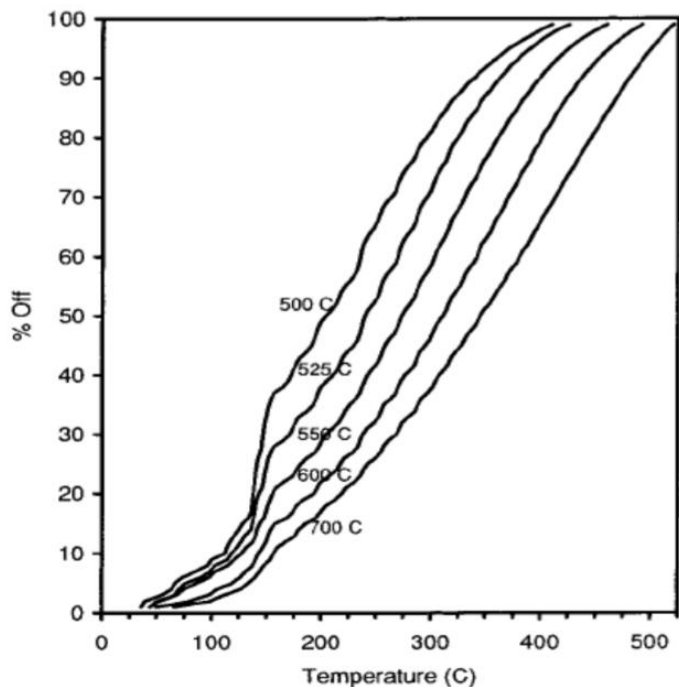


## CRACKING TEMPERATURE AND HEATING RATE

Temperature is one of the most important operating variable, since the temperature dominates the cracking reaction of the polymer materials. Not all of the polymer materials can be cracked by increasing the temperature. Van der Waals force is the force between the molecules, which attracts molecules together and prevents the collapse of molecules. When the vibration of molecules is great enough, the molecules will evaporate from the surface of the object. However, the carbon chain will be broken if energy induced by van der Waals force along the polymer chains is greater than the enthalpy of the C-C bond in the chain.



This is the reason why high molecular weight polymer is decomposed rather than is boiled when it is heated. In theory, the temperature of thermal breaking the C-C bonds should be constant for a given type of plastic (polymer). However, this temperature has been found to differ in different studies. According to the provided schemes, the most likely reason is the difference in the temperature measurement location where the temperature sensors were located. There was significant temperature gradient along the apparatus in which the melted plastic at the bottom of a fix-bed batch reactor had much lower temperature than that on the top surface of the reactor. It was also found that the space temperature in the pyrolyzer was strongly influenced by the product vapor. Different locations of the temperature sensors in different studies are believed to be one of the most important factors on the different cracking temperature reported.



**Fig: Influence of temperature on product distribution**

## **Use of catalyst**

Homogeneous catalysts used for polyolefin pyrolysis have mostly been classical Lewis acids such as  $\text{AlCl}_3$ . Generally, heterogeneous catalysts are preferred due to their easy separation and recovery from

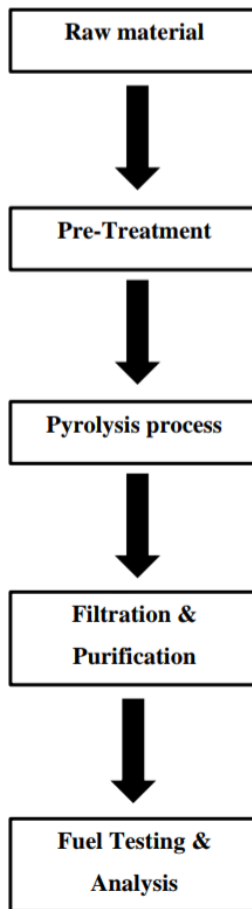
the reacting medium. Heterogeneous catalysts can be summarized as nanocrystalline zeolites, aluminium pillared clays, conventional acid solids, mesostructured catalysts, superacid solids, gallosilicates, metals supported on carbon, and basic oxides. Among the mentioned catalysts, nanocrystalline zeolites have been extensively studied for polyolefin pyrolysis and this type of catalysts will be discussed in more details as follows.

A zeolite is a crystalline aluminosilicate with a three-dimensional framework structure that forms uniform pores of molecular dimensions. Zeolites act as sieves on a molecular scale and exclude molecules that are too large to pass through the pores. The three-dimensional frame structure significantly increases the area of the sieves and absorbs molecules that have similar sizes as the pores. According to the structure of zeolites, 176 zeolite framework types have been confirmed. A three-letter code, such as MFI, is assigned to framework types by the Structure Commission of the International Zeolite Association. The codes are derived from the name of the zeolite, for example, MFI from ZSM-5. The pore openings and sizes are key parameters for the catalytic effect in the plastic pyrolysis, which are determined by the size of single ring and the structure features

## **Process**

The description and classification of pyrolysis reactors are given in Section 2.1 of this thesis and the existing commercial pyrolysis plants use various types of the reactors. Continuous pyrolysis process is applied on most commercial plants with capability to use catalysts in which the plastic retention time is relatively short. Very few of the commercial plants use high pressure operation condition and most of the plants operate at or slightly above atmospheric pressure.

The operating temperature in the reactors varies largely from 250 °C (Mazda fixed-bed catalytic process in Japan) up to 800 °C (Compact Power fixed-bed pyrolysis in United Kingdom) but most of the pyrolysis reactors operate between 400 °C and 550 °C. It must be noted that if the operation temperature is above 800 °C, the process becomes gasification and the products are mainly short chain hydrocarbons which remains as gases under room temperature and atmospheric pressure. All of the commercial plants are fast or flash pyrolysis. Three types of reactors including fixed-bed, fluidized-bed, and rotary kiln can be found in the literature review.



## **METHODOLOGY**

### **Plastic to fuel production in India**

India is also started giving contribution in plastic to fuel project. In 2019 three project were announced

One of which was started by the time. The projects which were announced are as follow

- Plastic to fuel project in pune by Pur O Fuel Pvt ltd
- Waste into low cost project by Vidya and Amaranth maitreya(Chennai)
- Waste plastic to diesel by Indian institute of petroleum (IIP-Dheradun)

## News articles of above projects :



Union minister Harsh Vardhan and CM Trivendra Singh Rawat at the inauguration of the plant



🕒 THIS STORY IS FROM AUGUST 28, 2019

### Plant to convert waste plastic into diesel inaugurated at IIP

KAUTILYA SINGH, TNN • DEHRADUN  
UPDATED 28 AUG, 2019 10:14 AM GMT+05:30

DEHRADUN: Union minister of Science and Technology Harsh Vardhan on Tuesday inaugurated the one tonne per day waste plastic to diesel plant at Dehradun-based Indian Institute of Petroleum (IIP). The IIP team had been working on the project worth Rs 15 crore for the past 10 years.

The Union minister claimed that NGOs would be roped in for collection of waste plastic and through their contribution the “dream of becoming a plastic free society would be realised.”

Vardhan added, “It was very interesting to see the entire process — how the waste is cleaned, broken up into small parts and diesel is made through it. We will start a project in Delhi after we are voted to power there.”

He did not fail to mention that initially the plan was to set up the massive plant in a city area but later the IIP authorities decided to have it within the institute premises. Vardhan claimed that the project will also play a role in strengthening the economy by involving as many people as possible in the process of waste collection and transportation. He added that within a span of three years, the plant would recover its cost.

Vardhan added that efforts were on to set up a retail and research park at IIP to develop renewable source of energy.

CM Trivendra Singh Rawat, who was also present on the occasion, said, “This is a major achievement by IIP. On one end it will help in environment conservation and at the same time, it will be useful in economic growth.”



## Go Green: PMC inaugurates its first plastic-to-fuel project

Civic body launched the plan through corporate social responsibility funds of a private company.

Updated: Sep 11, 2019 16:37 IST

By HT Correspondent, Hindustan Times Pune



Mukta Tilak (green sari), Pune mayor, on Tuesday inaugurated Pune Municipal Corporation's (PMC) first plastic-to-fuel project in the city at Ghole road. (HT PHOTO)

Pune: Mukta Tilak, Pune mayor, on Tuesday inaugurated Pune Municipal Corporation's (PMC) first plastic-to-fuel

Pune: Mukta Tilak, Pune mayor, on Tuesday inaugurated Pune Municipal Corporation's (PMC) first plastic-to-fuel project in the city at Ghole road.

Considering the increased burden of waste generation after merger of additional villages within PMC limits, the civic body in 2018 floated a tender for setting up a plant for generating fuels from plastic waste in the city through corporate social responsibility (CSR) funds of a private company.

Tilak said, "Pur O Fuel Pvt Ltd company invested Rs 3.5 crore in the project, which is indigenous and will promote the 'Make In India' scheme."

The mayor said that Pune is facing a tough task in garbage management as 1,700 to 1,800 metric tonnes of garbage is generated in the city every day. The Maharashtra government had banned the use of plastic items, including carry-bags and thermocol, in June 2018.



## COMPARISON OF DIESEL WITH PLASTIC DERIVED FUELS

The New Zealand diesel regulations have 18 requirements those can be characterized into four groups: thermodynamic properties, flowing properties, component distribution, and performance properties. In the regulation for commercial diesels, one of the most important thermodynamic properties is cetane number or cetane index that can be a substitute as cetane number, which indicates the auto-ignition conditions of the fuel. Cetane index is calculated from fuel density and distillation range which is also listed in the regulation requirements. Therefore, cetane number, density, and distillation range are all important properties to diesel fuel. The next important properties are the fuel flow properties which include viscosity, cloud point, pour point, cold filter plugging point and flash point. The importance of these properties will depend on the extent of known information of fundamental properties mentioned above, e.g., density and distillation range. If all of the fundamental properties are well known, the flow properties are less critical. Miscellaneous properties reflects the effects of the minorities in diesel fuels, including carbon residues, sulphur content, water content, ash content and polycyclic aromatic hydrocarbon content. The carbon residue is fine solid particles in the fuel that may form combustion chamber deposits. The sulphur content in the fuel above a certain level causes high engine wear and poisons catalysts. The water content can contribute to corrosion in tanks and fuel injection equipment whereas the ash content is the solid residue when fuel is burnt off. The polycyclic aromatic hydrocarbon content is used to increase the cetane number due to their low boiling point and high density. The properties of fuel performance consist of colour, particulate, filter blocking tendency, lubricity, oxidation stability and copper corrosion. These properties result from one or more effects of the fundamental and the miscellaneous properties. For example, the copper corrosion is an indicator mainly due to sulphur content in the diesel. Based on the diesel regulation, the fundamental properties of plastic derived fuels are examined in most studies because the diesel fuel is produced from synthetic hydrocarbon polymers that do not contain any other elements except for carbon and hydrogen. Therefore, some of the miscellaneous properties are not important for the diesel from plastic pyrolysis, such as sulphur content and water content. The quality of the liquid fuels from pyrolysis of plastics will vary with pyrolysis operation conditions, pyrolysis reactor type and types of plastic feedstock. The quality of plastic derived fuels varies largely based on the process and the feedstock. The diesel range products in the LDPE derived fuels contain the same linear chain alkanes as those in the fresh diesel. The content of alkene in LDPE derived products is much higher than that in diesel, which decreases the

storage stability of fuel. Compared to naphtha, aromatic compounds, and branched hydrocarbons, linear alkanes have relative higher cloud point with the same carbon number or density. Therefore, many catalysts and processes were used to reduce linear hydrocarbons and increase the proportion of others. It was found that plastic derived diesel contains high proportion of linear alkane that has low solubility in diesel. This can significantly increase the cloud point that is the temperature at which the first crystals appear in diesel. De-waxing, hydrogenation, isomerization and cyclization are normally used in the pyrolysis processes to change the chemical composition in the products. Other properties of plastic derived fuels are controlled in the producing processes such as distillation range and carbon residue in the fuel.

## **Feedstock effects**

In most commercial processes, the raw materials are firstly heated and melted in the feeding system before flowing into the reactor. The air, moisture and other solid materials can be separated from the raw plastic materials in the feeding system. In addition, the pre-treatment may be required for cracking the PVC at 250 °C. In some rotary kiln reactors, solid plastic particles with appropriate sizes can be extruded into the reactor directly. Most feeding systems move the highly viscous melted plastics into reactors by its gravity or by an extruder. However, a required temperature gradient should be maintained from the feeding system to the pyrolyzer although this may not be an issue for the rotary kiln reactors. The required temperature gradient is to prevent plastic cracking before entering the pyrolyzer. For example, the cracking temperature of PS is 420 °C thus any overheating in the feeding system should be avoided. Free-fall feeding system is widely applied in fixed bed and fluidized bed reactors.

## **Scope of liquid fuel**

Liquid fuel within this compendium is defined as plastic- derived liquid hydrocarbons at a normal temperature and pressure. Only several types of thermoplastics undergo thermal decomposition to yield liquid hydrocarbons used as liquid fuel. PE, PP, and PS, are preferred for the feedstock of the production of liquid hydrocarbons. The addition of thermosetting plastics, wood, and paper to feedstock leads to the formation of carbonous substance. It lowers the rate and yields of liquid products. Depending on the components of the waste plastic being used as feedstock for fuel production, the resulting liquid fuel may contain other contaminants such as amines, alcohols, waxy hydrocarbons and some inorganic

substances. Contamination of nitrogen, sulfur and halogens gives flu gas pollution. Unexpected contamination and high water contents may lower the product yields and shorten the lifetime of a reactor for pyrolysis Liquid fuel users require petroleum substitutes such as gasoline, diesel fuel and heavy oil. In these fuels, various additives are often mixed with the liquid hydrocarbons to improve the burner or the engine performance. The fuel properties such as viscosity and ash content should conform to the specifications of the fuel user's burners or engines. No additives would be needed for fuel used in a boiler. A JIS technical specification was proposed for pyrolytic oil generated from waste plastic for use as boiler and diesel generator fuel Skillful operators and a well-equipped facility are required due to the formation of highly flammable liquids and gases

## Fuel testing and analysis

The purified fuel is to be tested to find out its characteristics . In order to interpret the quality and properties of fuel, various tests were carried out in the laborotary under various testing conditions. The tests performed were: Color, Density, Viscosity, Calorific Value, Flash Point,Ash Content, Cloud Point , Pour Point, GC/MS Test, FTIR Test

(GC/MS - Gas chromatography / Mass Spectroscopy)

(FTIR - Fourier Transform Infrared Spectroscopy)

So with these tests, the results were interpreted in the following:

**Table 4.2 FTIR Test Results**

Index	Match	Compound name	Library
38	79.86	POLYPROPYLENE}, SYNDIOTACTIC	Hummel Polymer Sample Library
41	78.07	POLY(PROPYLENE), ATACTIC	Hummel Polymer Sample Library
1106	74.43	Polypropylene	HR Hummel Polymer and Additives
489	73.52	Polypropylene, syndiotactic	HR Hummel Polymer and Additives
383	72.54	Polypropylene, syndiotactic	HR Hummel Polymer and Additives
499	71.60	Polypropylene:ethylene), 83 mol% C3	HR Hummel Polymer and Additives
943	71.11	Polypropylene, atactic	HR Hummel Polymer and Additives
566	67.53	Polypropylene, atactic	HR Hummel Polymer and Additives
942	67.22	Polypropylene, isotactic	HR Hummel Polymer and Additives
1061	66.73	Polypropylene :butenone), 2:1	HR Hummel Polymer and Additives



**Table 4.3 GC/MS Test Results**

S.No	SI	RSI	Compound Name	Probability	M. Formula	M. Wt	Area %
1	536	782	2-(1-Methylheptyl)[1,3>2]dioxaborane	22.59	C10H21BO2	184	1.02
2	693	770	ETHYL-2 METHYL-3 PENTENE-1	12.1	C8H16	112	5.69
3	726	783	(2,4,6-Trimethylcyclohexyl) methanol	11.75	C10H20O	156	1.91
4	639	695	(4E)-7-METHYL-4-UNDECENE #	5.66	C12H24	168	1.84
5	850	857	2-Isopropyl-5-methyl-1-heptanol	11.47	C11H24O	172	18.88
6	769	771	Cyclododecanemethanol	8.79	C13H26O	198	3.49
7	810	826	DECANE, 2,3,5,8-TETRAMETHYL-	7.24	C14H30	198	0.93
8	414	723	Methyl 1-methoxypyrrole-2-carboxylate	10.23	C7H9NO3	155	5.51
9	814	845	2-Hexyl-1-octanol	6.04	C14H30O	214	2.41
10	744	818	(2,4,6-Trimethylcyclohexyl) methanol	6.96	C10H20O	156	3.82
11	479	769	(R)-3-Benzoylox-2-propylpropan-2-ol	24.39	C16H18O2	242	5.1
12	591	878	(3-Cyano-5-fluorophenoxy)amine	6.85	C7H5FN2O	152	4.21
13	781	782	1-Dodecanol, 2-hexyl-	3.77	C18H38O	270	1.42
14	758	772	hydroxymethylcyclododecane	10.45	C13H26O	198	4
15	778	796	Trichloroacetic acid, hexadecyl ester	4.34	C13H33C13O2	386	3.41
16	785	801	Trichloroacetic acid, hexadecyl ester	4.97	C13H33C13O2	386	1.54
17	688	699	11.13-Dimethyl-12-tetradecen-1-ol acetate	10.93	C18H34O2	282	4.42
18	731	741	Neophytadiene	6.39	C20H38	278	0.95
19	681	687	1-Heptadecene (CAS)	3.23	C17H34	238	2.9
20	773	785	Trichloroacetic acid, hexadecyl ester	3.33	C18H33C13O2	386	1.77
21	676	691	11.13-Dimethyl-12-tetradecen-1-ol acetate	21.94	C18H34O2	282	4.53
22	757	961	#A	92.59	C23H22N2O4	390	0.98
23	556	798	1-Methoxy-2-methylsulfinylbenzene	14.46	C8H10O2S	170	2.08
24	751	762	Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)-(CAS)	5.78	C25H48	348	3.85
25	803	803	1-Dodecanol, 2-octyl-	5.94	C20H42O	298	2.7
26	920	921	#B	44.94	C29H25N5O2	475	3.82
27	769	779	1-Dodecanol, 2-octyl-	4.22	C20H42O	298	1.47
28	572	691	PERDEUTERIOBENZYLIDENE-(N-BUTYL)AMINE	5.23	C11H9D6N	161	2.51
29	762	773	Octacosyl trifluoroacetate	3.71	C30H57F3O2	506	1.14
30	749	781	1-Hentetracontanol (CAS)	5.49	C41H84O	592	1.7

## **FINDINGS**

### **Fuel demands**

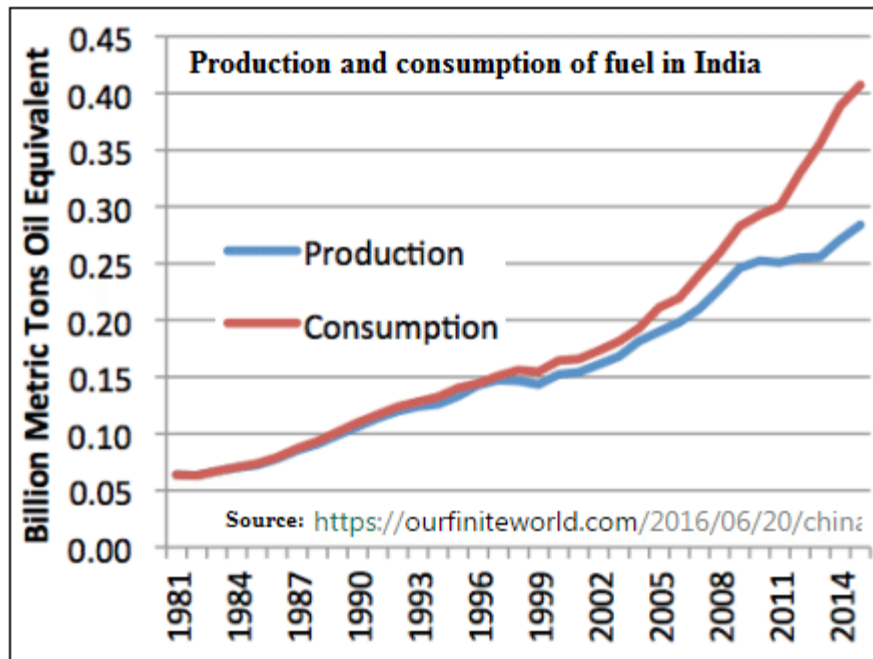
India's dependence on imported fossil fuels rose to 38% in 2012, despite the country having significant domestic fossil fuel resources. India ranked as the fourth-largest energy consumer in the world in 2011, following China, the United States, and Russia. The country's energy demand continues to climb as a result of its dynamic economic growth and modernization. India is the third-largest economy on a purchasing power parity basis and has the world's second-largest population, according to World Bank data. In 2013, India was the fourth-largest consumer and net importer of crude oil and petroleum products in the world after the United States, China, and Japan. India's petroleum product demand reached nearly 3.7 million barrels per day (bbl/d), far above the country's roughly 1 million bbl/d of total liquids production. Most of India's demand is for motor gasoline which is used mainly in the transportation and industrial sectors. Insufficient investment in developing more crude oil and liquids production has caused production to grow at a slower rate than oil demand. Net oil import dependency rose from 43% in 1990 to an estimated 71% in 2012. The Middle East was the major source of crude oil supply to India in 2013, followed by countries in the Americas (mostly Venezuela) and Africa. Conventional sources of the fuel are limited and in future we have to depend on the alternate fuels like bio fuels, ethanol and fuels from the other resources for our survival. Polyfuel is one of the alternative sources for the conventional fuels. Hence we have tried to make the fuel from plastic waste as the generation of waste plastic is very large.

### **Fuel demands in India**

India's fuel demand is expected to rise 1.3% in 2019-20, its slowest pace in six years, with the petroleum ministry on Thursday revising down its initial projections amid a broader economic slowdown. Fuel consumption - a proxy for oil demand - in India is seen at 216 million tonnes in the fiscal year to March 2020, about 3.3 million tonnes lower than initial estimates, the data posted on the Petroleum Planning and Analysis Cell showed.

India, the world's third biggest oil importer, consumed about 213.2 million tonnes of refined fuel in 2018-19. The Indian economy grew at the slowest pace in six years during the July-September quarter.

A sharp reduction in diesel consumption - about two-fifths of overall refined fuel demand, and directly linked to industrial activity - has dragged down the country's overall refined fuel demand in this fiscal year. Local sales of diesel are expected to grow 0.9%, the lowest rate in five years, to 84.3 million tonnes, the data showed. India's diesel demand is also slowing as the country's car fleet shifts predominantly to gasoline, trucks get more efficient and solar pumps displace diesel-fed units across the countryside.



The country's overall industrial output has fallen for three straight months for the first time since the global recession that began in 2008, with electricity demand falling for four consecutive months. Diesel demand is expected to remain subdued until the second half of 2020, when analysts expect various policy measures aimed at stimulating industrial activity to kick in and soak up excess fuel.

## Future scope

The project shows some light on the possibility of manufacturing liquid fuels which could be used as feed stock refinery for further modification or commercial use. By using this technology we could solve the waste plastic problem and also significantly reduce the landfills-which are the cause of infertility of Agriculture land. Waste plastics can also become a very good source of energy and an alternative to fossil fuel which have caused an environment imbalance.

## **Calculations for benefits of plastic to fuel**

Plastic generated in India:- 26000 Tonnes/day OR 9,490,000 Tonnes/year

Total plastic recycled:- 9%

Fuel produced from plastic:- 1000kg Plastic = 800litre Fuel (approx)

(from above values)

*“16.5 million gallons of fuel can be generated”*

*“25000 jobs are provided”*

*“Approx 2million cars can be fuelled every year”*

## **CONCLUSION**

Pyrolysis of hydrocarbon polymers is a very complex process, which consists of hundreds of reactions and products. Several factors have significant effects on the reactions and the products. Based on previous research, this investigated the fundamental plastic processes and reactions. With temperature increasing, plastic will go through glassy state, rubbery state, liquid state, and decomposition. Decomposition of plastic in an inert environment into liquid is called pyrolysis. There are four stages of reactions during the plastic pyrolysis process: initiation, propagation, hydrogen transfer, and termination reactions. It was found that heavy molecular weight hydrocarbons produced from primary cracking can be further cracked into light molecular weight products through a secondary cracking process. This secondary cracking process has significantly influence on the distribution of the product. This process converts heavy hydrocarbons into gas or light liquid product.

## **Cash from trash**

One of the biggest benefits to this approach is that it helps everyone — from businesses to consumers to government — start to value materials that used to be "waste." And when people realize materials have value, everyone starts to think about how this value can be captured and put to work for communities.

Not discarded. Not buried. And certainly not littered. So why do plastics have an intrinsic value as a fuel source? Plastics are created primarily from energy feedstocks, typically natural gas or oil (mostly natural gas in the United States). The hydrocarbons that make up plastics are embodied in the material itself, essentially making plastics a form of stored energy, which can be turned into a liquid fuel source. It makes sense that people are asking how to keep more of this valuable fuel in play, even after plastics are used, and how to keep it out of landfills. One way, of course, is to recycle plastics whenever one can. Today, recycling technologies reprocess many common types of plastics: bottles, containers, cups, caps, lids and so on. Even many flexible plastics, such as bags and wraps, can be recycled at major grocery stores across the United States.

## **Cleaner fuel**

Another potential environmental benefit of plastics-derived fuels is that they can deliver a cleaner-burning fuel, due to the low sulfur content of plastics. Many developing economies currently use diesel with relatively high sulfur content. The main product of fuel from plastic, when refined properly, is a diesel with greatly reduced sulfur content. Using this lower sulfur content fuel for boats, machinery, generators and vehicles can help decrease sulfur-related impacts while reducing non-recycled materials along the way. Plastics-to-fuel technologies are expected to be particularly helpful in island nations where fuel prices are high and landfill options are limited. Communities now have the potential to create some of their own fuel locally, providing economic and environmental benefits, while removing a portion of the waste stream that potentially causes harm to their waterways, reefs, and tourism.

These are just some of the reasons our two organizations — one representing America's plastics makers, the other a nonprofit dedicated to a trash-free ocean — teamed up to create two new tools aimed at helping communities around the globe evaluate their potential to adopt plastics-to-fuel technologies

## **References**

1. [https://en.wikipedia.org/wiki/Plastic\\_pollution](https://en.wikipedia.org/wiki/Plastic_pollution)
2. [www.plasticseurope.org](http://www.plasticseurope.org)
3. <https://auto.economictimes.indiatimes.com/news/oil-and-lubes/indias-fuel-demand-growth-hits-23-month-high-in-november/72488744>

4. [www.eproplasticrecycling.org](http://www.eproplasticrecycling.org)
5. [www.livescience.com](http://www.livescience.com)
6. [www.Iea.org](http://www.Iea.org)
7. <http://www.recoup.org/>
8. [https://www.researchgate.net/publication/323414875\\_Polyfuel\\_-  
\\_A\\_fuel\\_from\\_waste\\_plastics](https://www.researchgate.net/publication/323414875_Polyfuel_-_A_fuel_from_waste_plastics)
9. <https://www.darrinqualman.com/global-plastics-production/>
10. <https://www.power-technology.com/comment/plastic-to-fuel/>