CLEAN-SEAS
a Clean Vision Corporation company

WASTE PLASTIC

Global Environmental Challenge & Clean Fuel Manufacturing Opportunity

A Clean-Seas, Inc. Whitepaper

January 2022

PART I: Converting Plastic Waste to Valuable Energy

Photo Credit: GGIE

Pyrolysis Fuel Manufacturing

To realize its corporate mission, Clean-Seas has identified advanced pyrolysis technology as the most sustainable option for profitably remediating plastic waste in many markets.

Producing renewable refined fuels like diesel, jet fuel, kerosene, and hydrogen as well as industrial/lubricants, and carbon black char - all products of the pyrolysis manufacturing process - is an effective way to keep a portion of the carbon content of the plastic waste from entering the atmosphere as a greenhouse gas, which less efficient processes like incineration struggle to achieve.

The advanced pyrolysis manufacturing process can contribute to climate change mitigation by not only limiting the release of greenhouse gases into the atmosphere from waste plastic, but also by reducing the need for additional fossil fuel extraction, methane gas flaring and transport of crude oil to refineries.

What is Pyrolysis?

Using pyrolysis, plastic waste is heated in the absence of oxygen, causing a thermal breakdown of the carbonaceous waste into syngas and a high carbon purity char. The pyrolysis process has similarities to gasification, but operates at a lower temperature (350 C – 1000 C), producing refined diesel, jet fuel, kerosene, or hydrogen, as well as industrial oils and lubricants from the condensable portion of the generated syngas.

In addition, the non-condensable portion of the syngas may be combusted in a boiler or CHP engine to produce heat and electricity. Compared to other fuel manufacturing systems, pyrolysis is lower cost, produces far less CO_2 and is more efficient when both electricity and refined fuels/industrial oils are produced in a “hybrid” mode.

Pyrolysis:

- Lowers the strain on air scrubbers & air pollution control devices compared to other traditional manufacturing and refining processes
- Reduces production costs of finished goods
- Has a lower - and thus more energy efficient - operating temperature than gasification
- Has a more efficient material recovery outcome; electricity, heat, pyrolysis oil and syngas
- Energy recovery efficiency up to 60% (hybrid mode - oil and electricity) and 30% - 35% (pure electricity or diesel only mode)

What goes into the pyrolysis manufacturing process?

The inputs of the pyrolysis process for mixed plastic waste are:

1. The sorted, shredded and cut pieces of mixed plastic waste with ~ 15% moisture content and less than 10 mm in particle size
2. Process heat in the absence of oxygen (could be supplied by the combustion of syngas after initial startup by Liquefied Natural Gas (LNG) from an onsite storage tank)

What are the results of the pyrolysis manufacturing process?

The outputs of the pyrolysis process for mixed plastic waste are:

1. Non-condensable syngas (CO, H_2, N_2, CH_4, C_2H_2, C_2H_4, C_2H_6, C_3H_8, C_4H_{10}) – 9% by weight
2. Pyrolysis oil (long chain hydrocarbons that are a precursor to producing different types of plastic, diesel, jet fuel, kerosene, industrial oils, and lubricants) – 51% by weight
3. Char (high purity carbon) – 7.5% - 10% by weight
4. Possibility of combusting some of the syngas to generate electricity to meet consumer demand
5. High temperature and pressure steam – 15% by weight (used for hydrogenation in later stages of the fuel refinement process)
6. Ash (inert material made up of metallic oxides, carbonates, and phosphates) - < 0.0125% by weight that can be used in construction
7. Glass/metal and other inert debris stuck to the mixed plastic waste that can end up as a residue on the floor of the pyrolysis chamber (can be recycled or safely landfilled) – 10% – 15% by weight.

How is pyrolysis fuel synthesis from plastic preferable to crude oil refining?

The crude oil business is high volume and enjoys economies of scale in the production of refined fuels, industrial oils, and lubricants. Nevertheless, it takes large quantities of refined fuels to energize the large collection and refining systems that are used in crude oil extraction from the earth and pumping it to refineries for processing. This not only adds to the cost of producing the refined fuels and industrial oils/lubricants, but it also introduces a significant carbon-footprint in the supply chain of fossil fuels.

Additionally, crude oil includes sulfur that produces SO_2 from combustion. SO_2 is a harmful atmospheric pollutant. While it is not directly a greenhouse gas, SO_2 combines with water vapor in the atmosphere to form sulfuric acid which adversely affects life and material surfaces when it falls as acid rain.

Pyrolysis of mixed plastic waste can eliminate the energy required to extract the crude oil and pump it to the refinery, it avoids the carbon footprint associated with flaring of methane gas at the oil well and avoids the buildup of SO_2 in the atmosphere.

The collective benefit from pyrolysis is that using a modest capital expense of ~ US$20M, a 40-metric ton per day plant pyrolyzing mixed plastic waste can generate up to 48 MWh of electricity, 17,000 liters of diesel fuel per day, 3,600 liters of industrial oils/lubricants, and 3 metric tons of soil remediating biochar per day. A plant of this size can realize an infrastructure ROI of under 3 years.

The pyrolysis plant operates without using crude oil, the utility electric grid or large quantities of external water. Having a distributed source of refined fuels, industrial oils/lubricants, and char with a local supply chain (from waste to product) ensures high reliability and resilience for the host communities. In a time of climate change and high impact weather events, distributed pyrolysis manufacturing of advanced fuels from plastic waste can avoid the global supply chains interruptions of traditional crude oil extraction, transportation, and refining

The carbon credit from a 40-metric ton per day pyrolysis plant for mixed plastic waste can be as high as 35,000 metric tons per year based on savings from crude oil extraction, pumping to refinery site and the avoidance of methane gas flaring at oil wells and greenhouse gas release from waste incineration.

Economic Feasibility

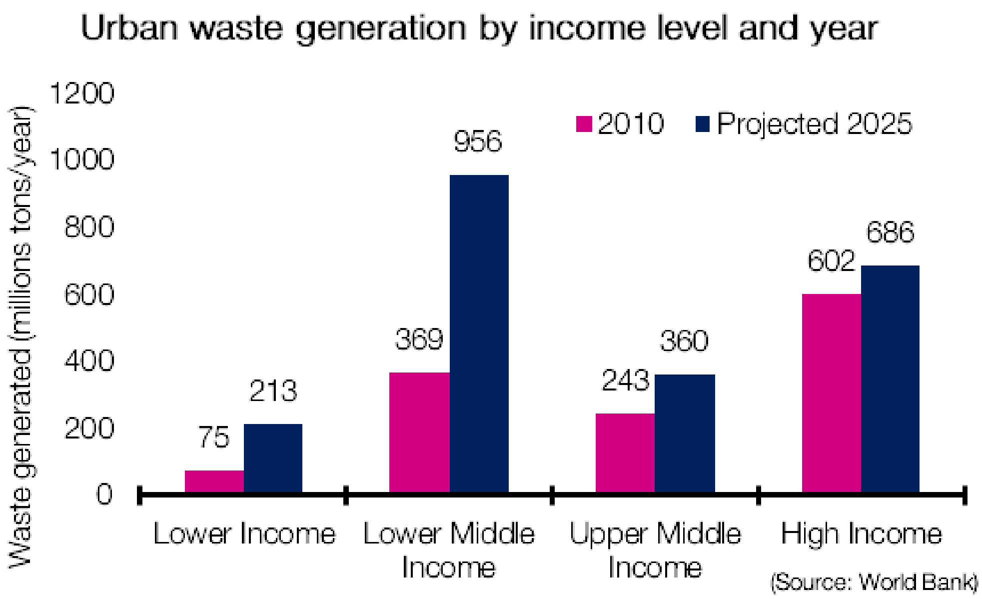
A 40-dry metric ton per day mixed plastic waste plant can deliver an infrastructure ROI of 2.07 years .

# Of modules	**1**
Module capacity per day (metric tons/day)	40
Plant daily capacity (metric tons/day)	**40**
Annual days of operation	350
Total plastic waste processed annually (metric tons)	14,000
Plant size (square meters)	**2,500**
Syngas yield by weight % of total waste	60%
Syngas weight % used by pyrolysis modules	15%
Syngas weight % converted to condensable oil	85%
Diesel/jet fuel yield by weight % of condensable oil	85%
Industrial oil/lubricant yield by weight % of condensable oil	15%
Char yield by weight % of total waste	7.5%
Daily diesel/jet fuel output (metric tons)	17.34
Density of diesel/jet fuel (Kg/liter)	0.78
Daily diesel/jet fuel output (liters)	22,231
Annual diesel/jet fuel output (liters)	7,780,769
Daily industrial oil output (metric tons)	3.06
Density of industrial oil (Kg/liter)	0.856
Daily industrial oil output (liters)	3,575
Annual industrial oil output (liters)	1,251,168
Daily char output (metric tons)	3
Annual char/scrap metal output (metric tons)	1,050
Total daily plant ash production (Kg)	5
Total annual ash production (metric tons)	1.75
Annual carbon credit per module (metric tons)	35,000

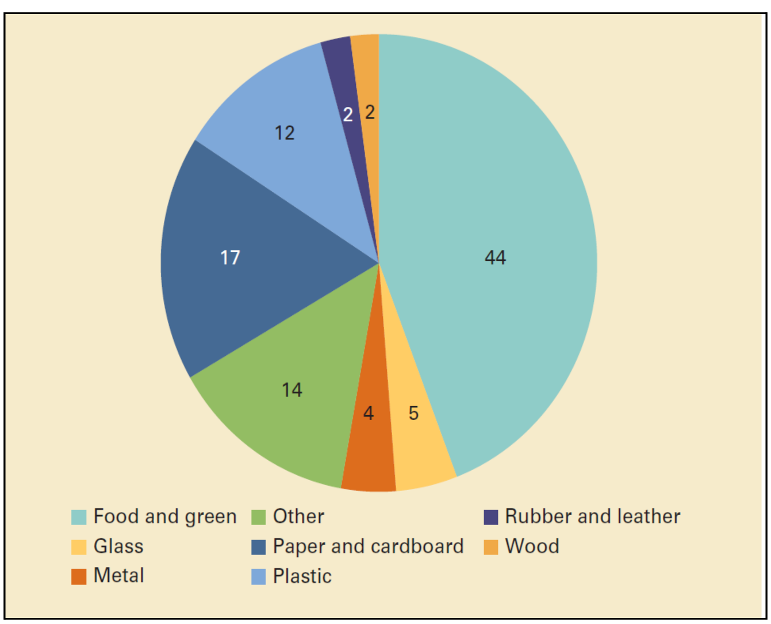
PART II: The Global Plastic Waste Challenge

Growing global population, rapid industrialization of developing countries, increased per capita consumption of processed goods and low rates of recycling are collectively creating a serious environmental challenge posed by plastic waste generation and outdated and inadequate disposal techniques.

Clean-Seas Inc. is a US company whose mission specifically addresses the growing global plastic waste problem. Global MSW generation is forecasted to reach 2.2 billion metric tons per year by 2025:

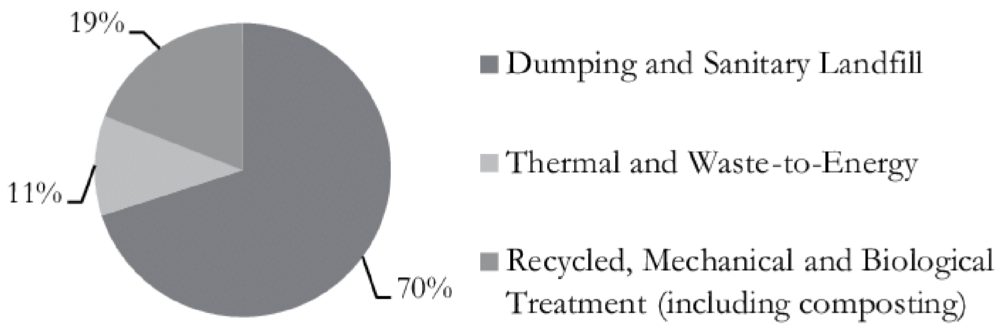


Plastic waste is estimated at 12% of total global MSW:



Global MSW Composition (courtesy World Bank Group)

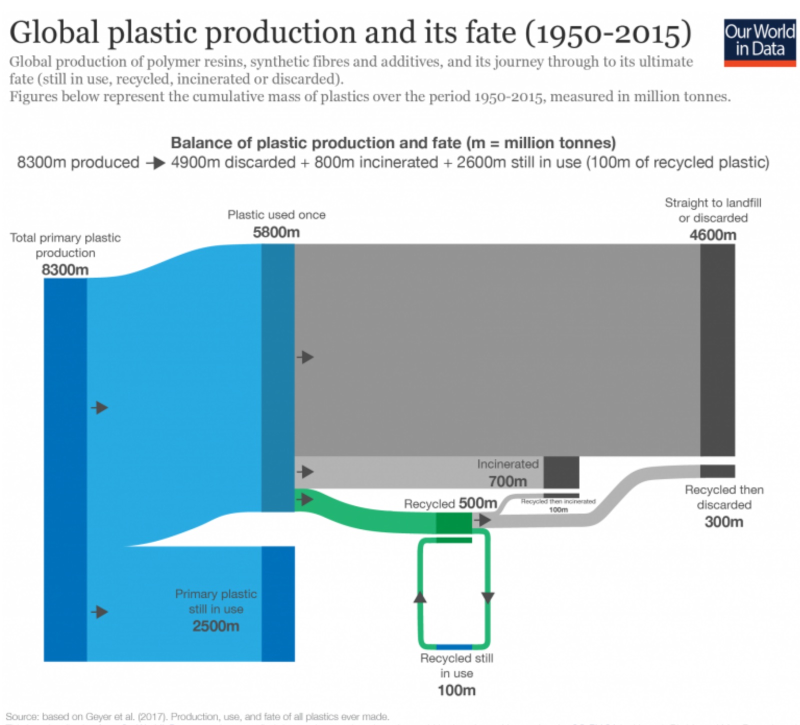
MSW is mostly ending up in landfills:



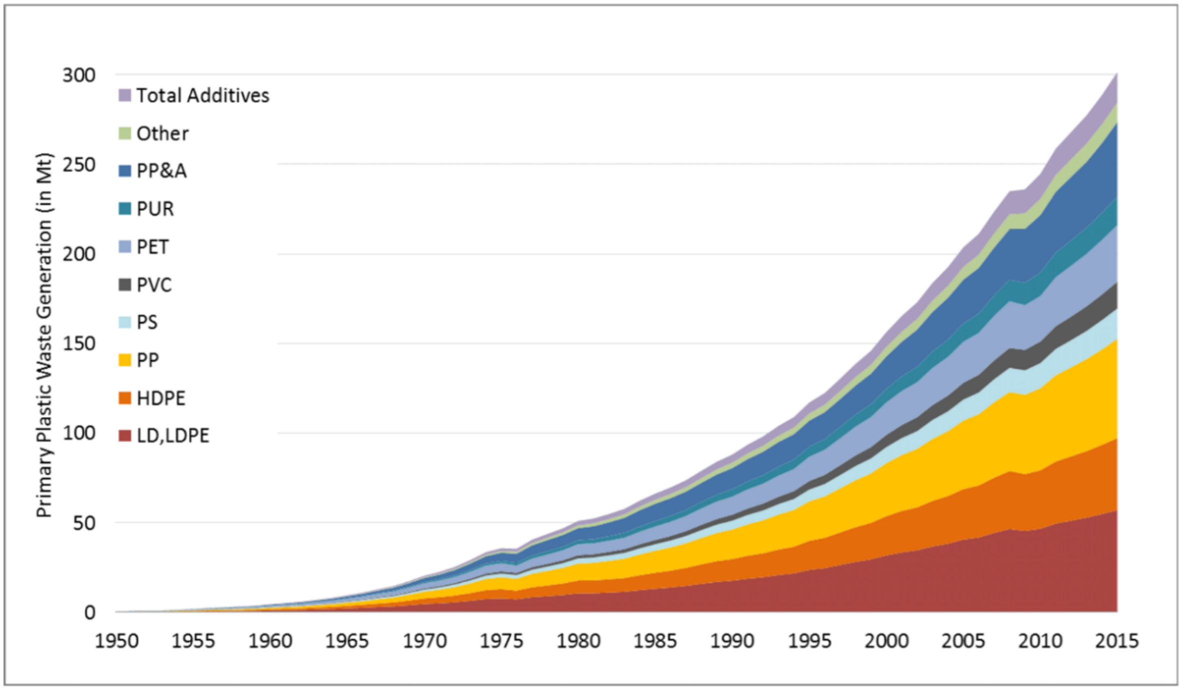
Global MSW Management (courtesy Research Gate)

There is a growing plastic waste problem globally, both on land and in the world's oceans

- Some of the most populous areas of the world also have the largest plastic waste mismanagement problem
- Even countries that are managing their plastic waste are not remediating it in a sustainable way (81% landfilled and incinerated)
- A handful of sectors are consuming and throwing away most of the plastic waste in the world today
- Less than 1/3 of the total plastic produced since 1950 is still being used today (over 1/2 has entered the global waste stream)



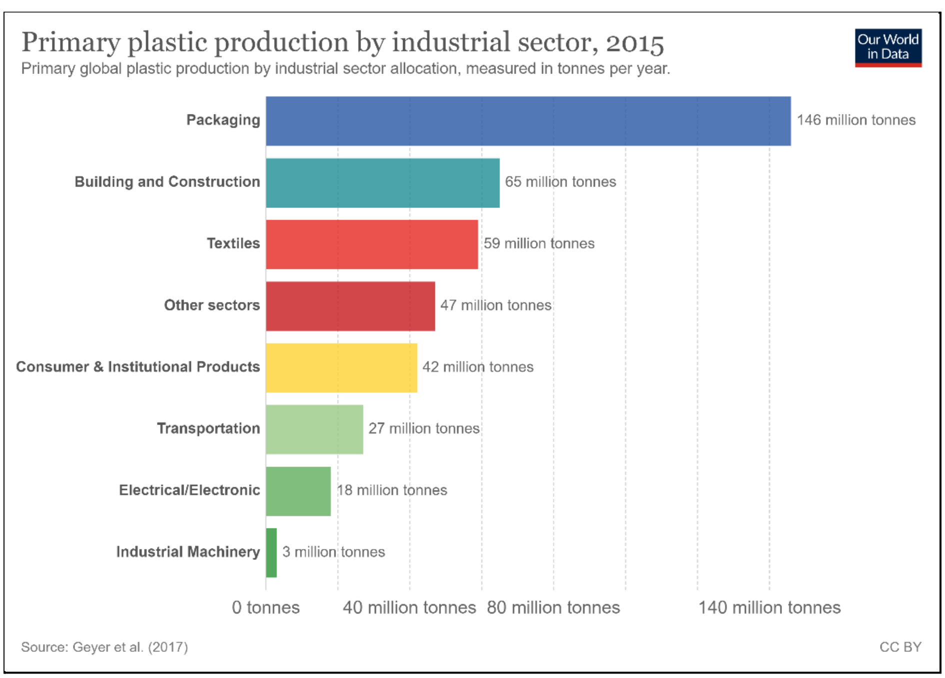
Additionally, industry generates a lot of plastic waste. The growth of plastic waste as a function of time is shown in the diagram below between 1950 and 2015:



Global Plastic Production by Type (courtesy of Cosmos Magazine)

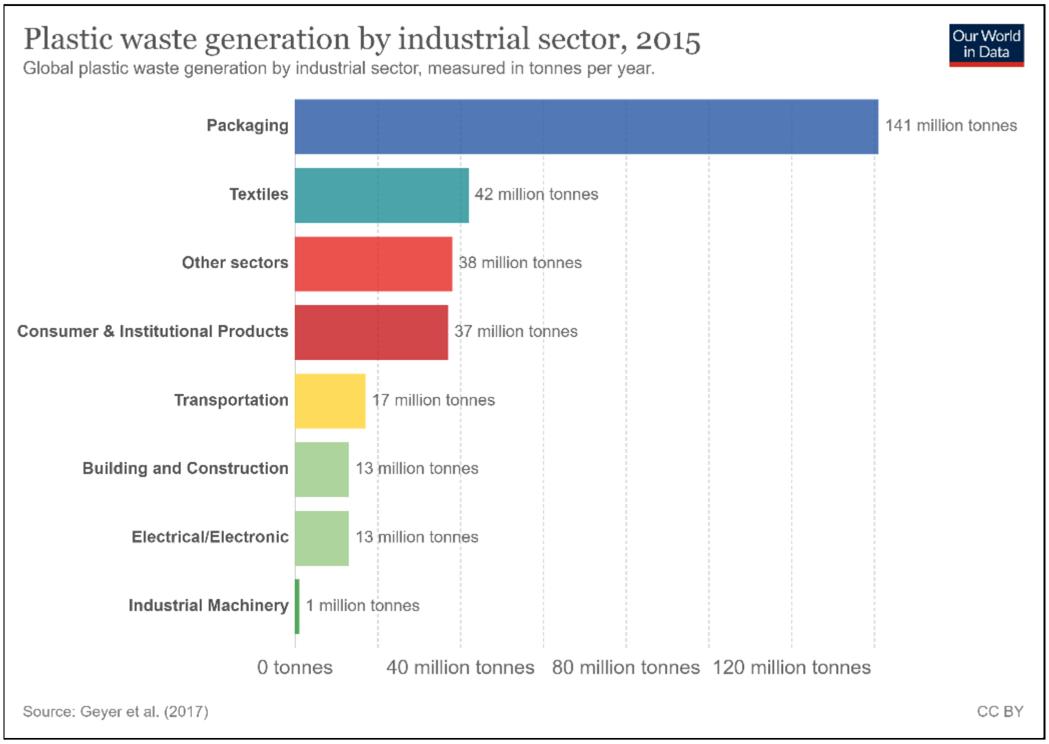
The diagram above shows that we need to have solutions for remediating all types of plastic waste, not just the few types that are recyclable (e.g., PET) to manage plastic waste effectively.

The diagram below shows consumption of plastic by sector:



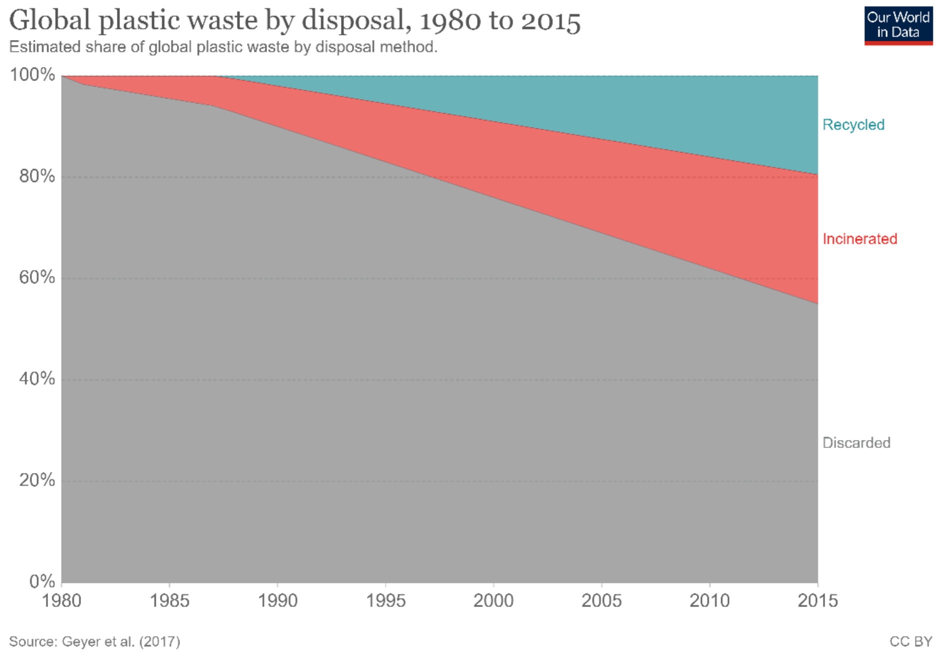
Packaging, building/construction, textiles, and consumers/institutional products consume the most plastic in the world.

The diagram below shows which sectors mismanage their plastic waste the most:



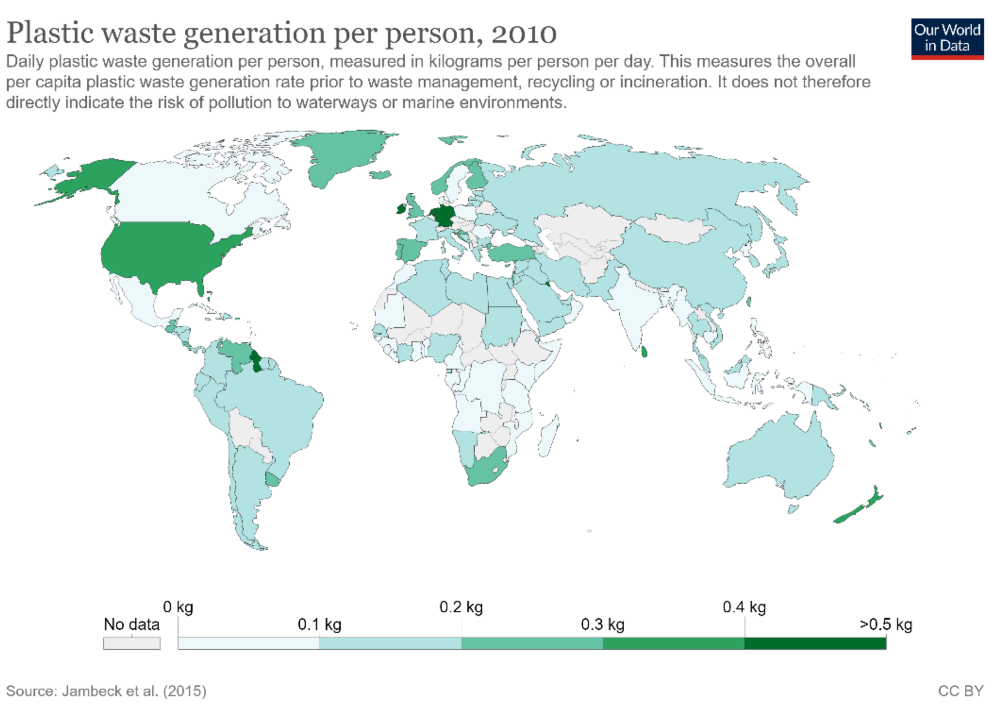
Packaging, textiles, consumer/institutional products are also in the top 5 sectors that mismanage their plastic waste the most.

The diagram below shows what is happening to the plastic waste after it has been picked up from the source:



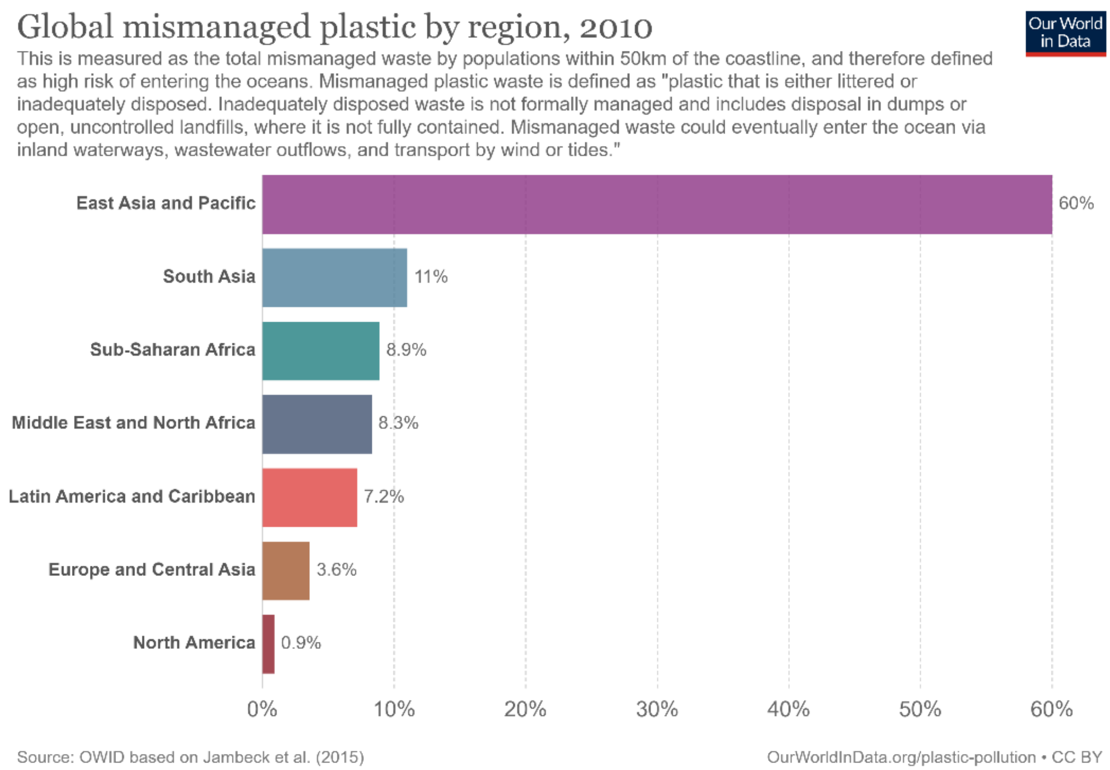
80% of plastic waste is incinerated or landfilled; 20% is recycled. The diagram below provides details about what has happened to the cumulative plastic produced from 1950 – 2015. Most of the plastic waste has been landfilled, about 10% incinerated, less than 1/3 still in use and a little more than 1% recycled.

Looking at plastic waste by regions of the world:

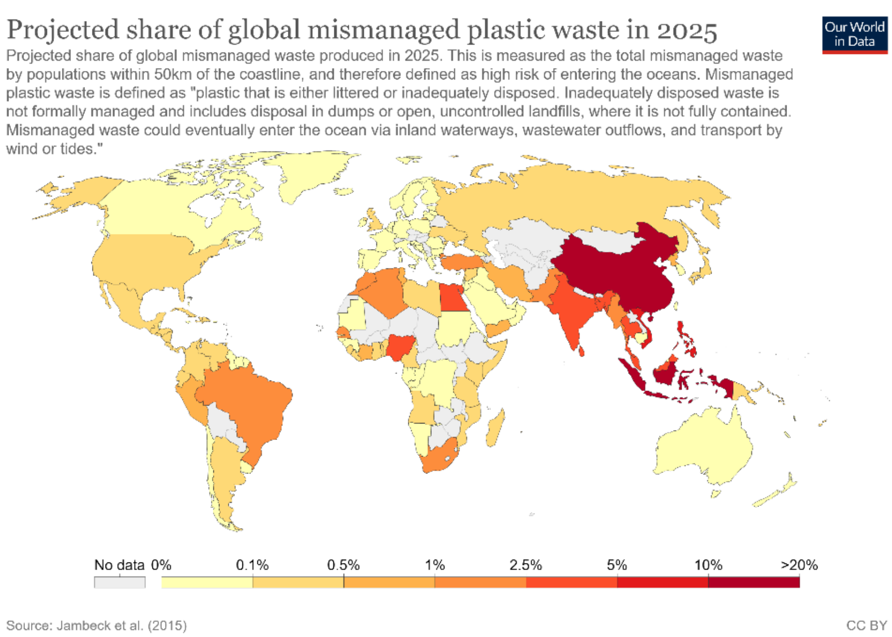


North America, part of Europe, South America and Oceania have the highest per capita production of plastic waste.

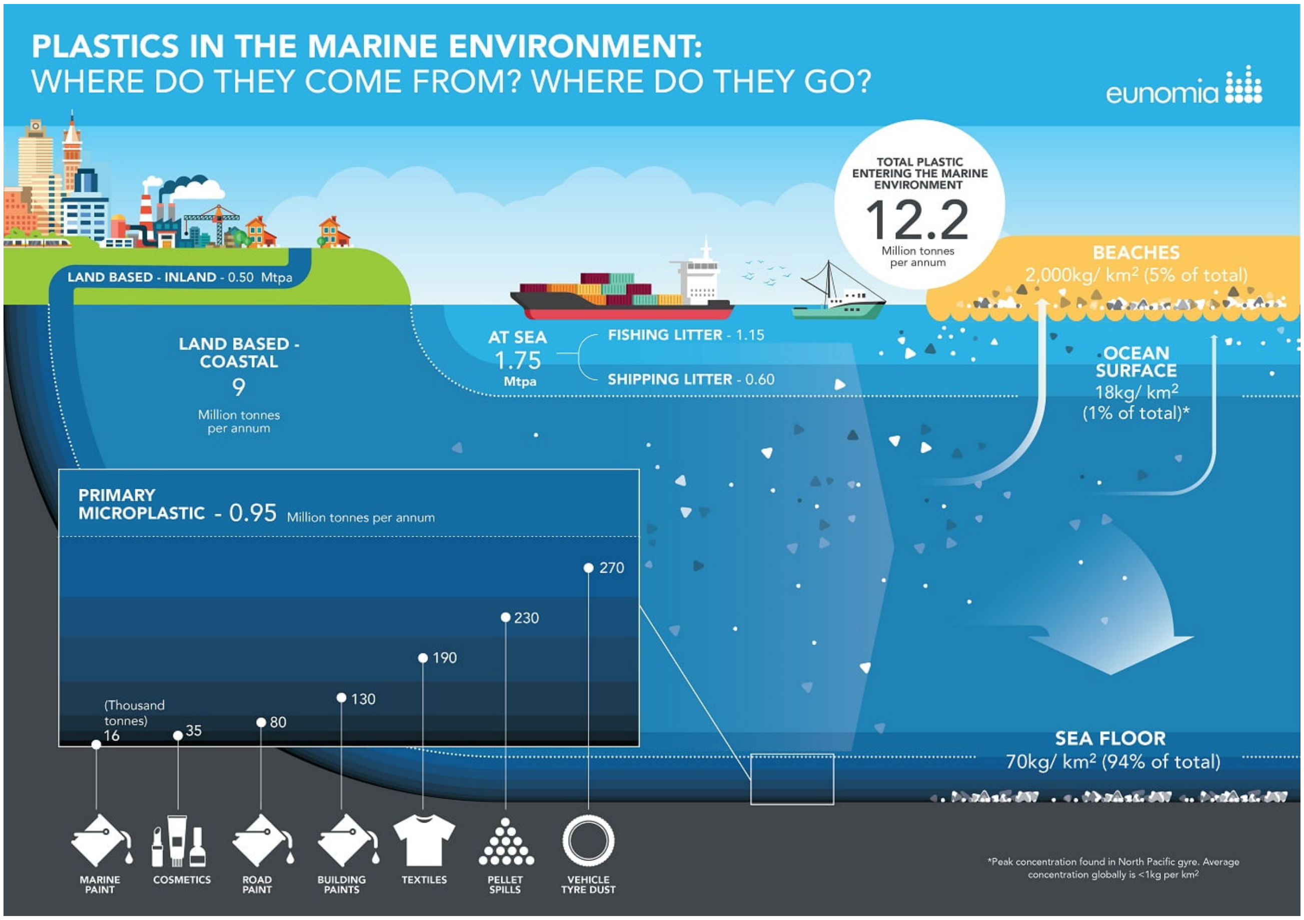
The diagram below shows the amount of mismanaged plastic waste by region of the world:



The bulk of the mismanaged plastic waste can be found in East Asia/Pacific, South Asia, Sub-Saharan Africa, Middle East and North Africa, Latin America, and Caribbean. While Europe and North America consume a lot of plastic, they score low in this chart because the plastic waste from those regions is being landfilled and/or incinerated and therefore not classified as mismanaged. The diagram below shows the same data on a map of the world:



Plastic waste is also creating a problem for the oceans of the world. The diagram below depicts the serious environmental problem of plastic waste entering the oceans of the world:



About Clean-Seas

Clean-Seas Inc. is a wholly-owned subsidiary of Clean Vision Corporation (OTCMKTS: CLNV), headquartered in Manhattan Beach, CA USA, with a Massachusetts registered office and regional offices in Hyderabad, India and Abu Dhabi UAE.

Led by CEO Dan Bates, senior management has a 30+ year record of developing clean energy projects.

Learn more at www.Clean-Seas.com