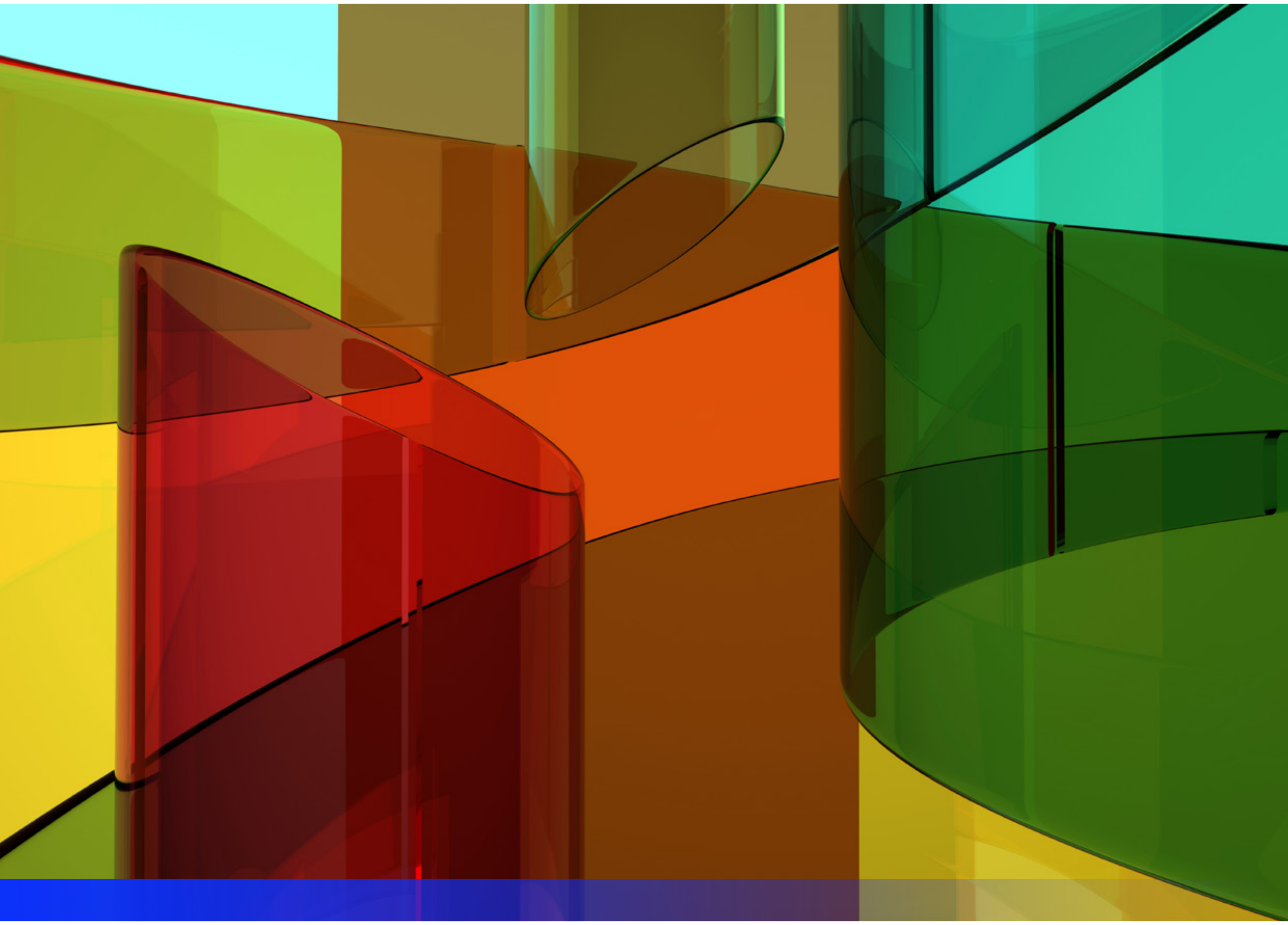


Plastics

BRIEFING NOTE (SMI)

Summary

- Plastics bring many advantages, including environmental.
- But they generate significant GHG emissions throughout their life cycle; and damage the environment.
- Much of this plastics ‘tragedy of the commons’ stems from poor waste management.
- Contamination causes economic and societal damage, and threatens earth’s ecosystem and biodiversity.

Introduction

A plastic material is an organic solid, essentially a polymer, i.e. a chain of several thousand repeating molecular units of monomers, or combination of polymers. The monomers of plastic are either natural or synthetic organic compounds. The term ‘resin’ is sometimes used as a synonym for a commercial polymer.[1]

There are many different types of plastics, but they can be grouped into two main polymer families:

- **Thermoplastics,** which soften when warmed and harden again on cooling; and
- **Thermosets,** which never soften once they have been moulded.[2,3]

Plastics confer myriad advantages over other materials, and are widely used across numerous areas.

So great are these advantages that plastics production growth over the past 65 years or so has substantially outpaced that of any other manufactured material. Production has risen from just 2 million tonnes in 1950 to some 400 million tonnes per year today. Between 1950 and 2015, an estimated 8,300 million metric tons (Mt) of virgin plastics have been produced.

Most plastics contain hydrocarbons,[4] which poses two problems. The first is that plastic is intrinsically toxic, and the second is that, when it biodegrades, it produces CO_2 and methane.

Advantages of plastics

Plastics are an important component of economic activity, and have a wide range functionalities, including lightness, robustness, malleability, and durability. They are also fairly cheap.

- **Plastic packaging delivers direct economic benefits, and also contributes to resource productivity.**
  - The ‘environmental cost’ of using plastic is complicated to assess and difficult to estimate with precision: that said, it has been estimated that the cost of using plastic in consumer goods is only around one-quarter that of using alternative materials.[5]
    - For example, a typical plastic soft drink bottle contains 30 grams of plastic. Were it to be replaced by a weighted average mix of alternative materials currently used in the market, such as glass, tin or aluminium, an equivalent capacity bottle would require 141 grams of alternative materials.
  - Extrapolating to the entire consumer goods sector, replacing the 84 million metric tons (Mt) of plastic used in consumer products and packaging annually could well require around 350 million metric tons (Mt) of alternative materials.[6]

- **Plastic packaging can also benefit the environment.** Its low density reduces fuel consumption in transportation, relative to other packaging materials, and its barrier properties keep food fresh longer, thereby reducing food waste.[7]
  - Trucost estimates that replacing plastic components in passenger vehicles currently sold in the North America by alternative materials would increase lifetime fuel demand for those vehicles by over 336 million litres of gasoline and diesel, at an 'environmental cost' of $2.3 billion. This equates to an 'environmental cost' increase of $169 per gasoline or diesel passenger car sold in North America.[8]
- **Today's plastic products have enabled energy savings equivalent to 53 million tonnes of fossil fuel.** Were all plastics solutions available on the market actually used today, this would save 12 tonnes of CO_2 for each tonne of CO_2 emitted during plastics production (a 12:1 ratio of use over production).[9]
- **Plastics are also key enabling materials for many manufacturing industries.**

Problems with continued growth in the mass use of plastics

Despite their many advantages, he wide usage, and continued growth, of plastics is problematic, for four primary reasons:

1. **Plastics production and manufacture uses considerable energy.** Much of this comes from the burning of fossil fuels, thereby directly generating greenhouse gas emissions (GHGs).
   - In the United States, China and Europe, petrochemical production is not deemed sufficiently energy intensive and is exempt from carbon regulation.[10]
2. **Recycling is both technically challenging and energy intensive.** Much of this energy too is supplied by the burning of fossil fuels.
3. **Vast amounts of plastic waste are mismanaged.** Much is discarded or ends up in landfill, and some is incinerated.
4. **Serious consequences result.** Plastic leaks into the environment, enters the food chain, and damages life. Incinerated plastic releases GHGs and often toxic materials too.

1. Production and manufacture

High dependency on virgin fossil fuels

Plastics are traditionally derived from fossil sources, mainly oil and gas: currently these account for more than 90% of the feedstock. Often referred to as conventional plastics, fossil-based plastic, most often used for packaging, is generally long lived, durable, and non-biodegradable.[11] Around half of the hydrocarbon use is for the energy required in the manufacturing process; the other half is used as feedstock.[12]

Today, plastic is associated with about 4% to 8% of total annual global oil consumption.[13] This oil consumption is equivalent to that of the global aviation sector, and is in addition to the natural gas used as material feedstock and fuel.[14] If this reliance on plastics persists (i.e. if recent trends are maintained), by 2050 plastics will account for around 20% of global oil consumption.[15]

Plastics can be made from renewable resources of biological origin,[16] including biomass, plant-based sources (e.g. starch, cellulose, oils,[17] lignin organic waste and residues),[18] as well as gaseous effluents (e.g. CO_2).[19] Thus the term 'bio-based' refers to the source from which the plastic is made, not how the material will function.[20] Bio-based polymers can be used to make plastic packaging that, like fossil-based plastics, is durable and long-lived.[21]

Whether fossil-based or bio-based plastics should be regarded as the more sustainable alternative depends not only on their origin from renewable materials and their carbon balance, but also a broad range of environmental aspects, including land use, water use, eutrophication,[22] and potential toxicity impacts, e.g. due to pesticides.[23]

Most importantly however, regardless of whether plastic is produced from fossil fuels or from 'cleaner' alternatives such as green hydrogen, today's plastics are composed of hydrocarbons, with all their inherent problems.

GHG emissions

Industrial sources are responsible for some 40 percent of global GHG emissions (2014). Just four sectors—steel, plastic, cement, and aluminium – account for fully three-quarters of these emissions.

- In 2012, the production process of plastics alone accounted for approximately 390 million tonnes of CO_2 emissions[24]
- All told, (in 2015) plastics, over their entire lifecycle, accounted for emissions equivalent to 1.8 billion metric tons of CO_2.[25]

Global demand for plastics is projected to increase by some 22% over the coming five years.[26] On this course, emissions from plastics will reach 17% of the 1.5^{0}C global carbon budget by 2050, and emissions will need to be reduced by 18% just to break even.[27]

Recycling and reuse of plastics

Low recycling rates

Much of the world's plastic production has been, and continues to be, poorly managed after use.

Of the plastic produced from 1950 to 2015, it has been estimated that **only about 6 percent has been recycled**. And, of that which was recycled, only one-fifth is still in use, three-fifths having ended up in landfill, and one-fifth having been incinerated.[28]

Today, around 95% of plastic packaging material value, some $80–120 bn annually, is lost to the economy after a short first-use.[29,30]

- More than 40 years after the launch of the well-known recycling symbol, plastic recycling rates remain low, at between 14–18% as a global average. This compare with recycling rates exceeding 50% for steel, aluminium, copper and paper.[31]
- When additional value losses in sorting and reprocessing are factored in, only around 5% of material value is retained for a subsequent use.[32]
- Plastics that do get recycled are mostly recycled into lower-value applications, and are not again recyclable.[33]

Around 70% of plastic packaging is not recovered at all: 40% is consigned to landfill, and around 30% leaks out of the collection system — that is, either it is not collected at all, or it is collected but then illegally dumped or otherwise mismanaged.[34]

The complexities of plastics and their recycling

Low re-use rates are attributable in part to the complexities and intricacies of the myriad types of plastic in use.

Plastics are resistant to biodegradation; but it can be done.[35] These 'bioplastics' are decomposed by microorganisms, into water, carbon dioxide (CO_2) and methane (CH_4), and biomass (e.g. new microbial cellular constituents).

That a plastic is described as biodegradable does not however mean that it should thereby be released freely into the environment. But plastics that meet an appropriate standard can be **composted**, variously in industrial or even home composting systems.

- **Non-biodegradable packaging plastics can be recycled,** if collected and sorted into separate material reprocessing streams. The route for recycling or disposal must not compromise other recycling routes.
- **Non-biodegradable plastics entering the composting processes can contaminate** the final product.[36]
- **Biodegradable plastic cannot be recycled in the same way as non-biodegradable plastic.** It must be separated from non-biodegradable plastic streams and dealt with separately.[37]
- **Compostable plastics.** It is vital that only compostable plastics are sent to these routes as non-compostable plastics can contaminate the final compost produced.[38]

Although it is estimated that over 80% of all product-related environmental impacts are determined during the design phase of a product, currently, **there is no agreed definition of design for recyclability.**[39]

- Design for increased recyclability is currently facing several obstacles that are linked to the production processes, habits, and a lack of dialogue across the value chain and between different actors.[40]
- There may be some plastic items that, taken in isolation, are recyclable but not suitable for recycling if occurring in low quantities and mingled with other, often incompatible, plastic materials.[41]

Moreover, although recycling is technically possible, it is often not at present economically viable.[42]

  - Plastics contain a main polymer, and bespoke additives. Some of these additives cause problems during the recycling phase, or may be directly hazardous.[43]
  - Many additives cannot be removed by traditional mechanical recycling methods; but if some of those additives are not removed, they may remain in the recycled plastics and occur as legacy substances in recyclates, thereby degrading their quality and, in certain cases, presenting safety issues.[44]
  - Incentives are inadequate. Most secondary plastic materials created from recycled plastic are of inferior quality to virgin plastic, and therefore command only a lower price.[45]

Waste management: discarding, landfill and incineration

Around 55% of the plastic produced from 1950 to 2015 (excluding that which was first recycled and then incinerated) has gone to landfill or been discarded. About 8 percent has been incinerated.

Today, an estimated 56%% of plastic waste is disposed of in landfills, but the proportion incinerated has risen to around 25%.

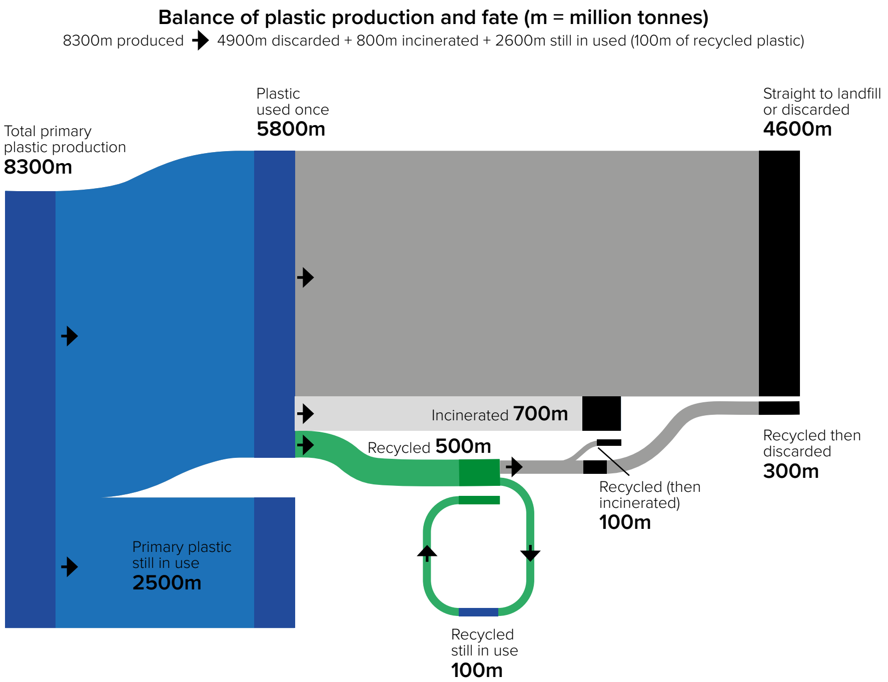
The carbon footprint of plastics continues even after disposal: dumping, incinerating, recycling and composting (for certain plastics) all release carbon dioxide and methane.[46,47]

- Incineration leads to extremely high emissions, and is the primary driver of emissions from plastic waste management.[48]
  - In 2016, U.S. waste incinerators alone released the equivalent of 12 million tons of carbon dioxide, more than half of which came from plastics.[49]
- Landfilling emits the least GHG gases on an absolute level, although it presents significant other risks.[50]
- Recycling too results in some emissions; but to the extent that it displaces new virgin plastic, it reduces overall emissions.[51]

The full life cycle for plastic is shown in figure below:

Figure 1 : Global plastic production to final fate over the period 1950 to 2015[52]

Global production of polymer resins, synthetic fibres and additives, and its journey through to its ultimate fate (still in use, recuycled, incinerated or discarded). Figures below represent the cumulative mass of plastics over the period 1950-2015, measured in million tonnes.



Source: baed on Geyer et al. (2017). Production, use and fate of all plastics ever made.

A range of consequences

Today's plastics are 'destined to be toxic from birth to forever': damage to the environment starts from its production, and continues due to its mismanagement after use. The impact can be considered in three component parts: **ecological, social, and economic.**

Ecological

Today there are an estimated 150+ million tonnes of plastics in the world's oceans.[53]

Each year, at least 8 million tonnes of plastics leak into the ocean, with plastic packaging reckoned to account for the bulk of this. This is equivalent to dumping the contents of one garbage truck into the ocean every minute.[54]

- If no action is taken, this is expected to increase to 2 per minute by 2030, and 4 per minute by 2050.[55]
- On present trends, the ocean is likely to contain 1 tonne of plastic for every 3 tonnes of fish by 2025 and, by 2050, more plastics than fish.[56]
- More than 80 percent of ocean plastic apparently comes from land-based sources rather than ocean-based sources such as fisheries and fishing vessels.[57]
    - Of that 80 percent, some three-quarters comes from uncollected waste, the remainder from leaks from within the waste-management system itself.[58]
    - More than half of the plastic leaking into the ocean comes from just five countries: China, Indonesia, the Philippines, Thailand, and Vietnam.[59]

Plastic's resistance to biodegradation results in the presence of microplastics, which have entered oceans and ecosystems (including drinking water and fish). Plastic litter clogging up sewers has amplified the risk of flooding, contamination, and vector-borne diseases.[60]

- Plastics are ubiquitous, showing up in the world's most remote places – Mount Everest, the deepest seas, the highest peaks, Arctic ice – as well as blowing in the wind and in our guts.[61]
- Impacts of marine plastics include the ingestion, suffocation, and entanglement of hundreds of marine species.[62]
    - These also suffer from lacerations, infections, reduced ability to swim, and internal injuries[63]
- Plastic debris is reckoned to kill more than a million seabirds per year, as well as more than 100,000 marine mammals.[64]
- The impacts on aquatic life are generally negative, with the exception of algae and bacteria, where plastic increases the range of habitats available for colonisation, and enables the spread of these species to new areas, thereby increasing their range and abundance.[65]
- Soil and water contamination: Microplastics released during clothes washing, and nano-plastics used in cosmetics, accumulate in wastewater systems.[66]
- Floating plastics also contribute to the spread of invasive marine organisms and bacteria, which disrupt ecosystems.[67]
- Several chemicals used in the production of plastic materials are carcinogenic, and interfere with bodies' endocrine systems, causing developmental, reproductive, neurological, and immune disorders in both humans and wildlife.[68]
- Plastics production and the incineration of plastic waste together give rise globally to an estimated 400 million tonnes of CO_2 per year.[69]
- Microplastic particles can, it is becoming apparent, affect phytoplankton, whose photosynthesis absorbs (or "fixes") nearly half of the CO_2 that is released into the earth's atmosphere. Oceanic primary production (the first step in the food chain) accounts for up to 80% of the planet's total oxygen production.[70]

Social impact

- Plastic waste from Western countries is poisoning Indonesia (World Economic Forum).[71]
  - The waste is burned as fuel by local communities, the smoke causing respiratory illness and other long-term health problems amongst those who inhale it.
  - Pollutants have also contaminated Indonesia's food chain.[72]
- Incineration facilities are disproportionately located near low-income, marginalized communities.[73]
- Open dumping also pollutes nearby aquifers, water bodies, and settlements.[74]

Economic impact

- Marine plastic can reduce the efficiency and productivity of commercial fisheries and aquaculture through physical entanglement and damage, as well as pose a direct risk to fish stocks.
  - Seafood is the principal source globally of animal protein, and makes up more than 20% of food intake (by weight) for 1.4 billion people (19% of the global population)[75]
  - Commercial shipping vessels are highly sensitive to contact with plastic pollution. The Asia-Pacific Economic Cooperation (APEC) estimated the cost of litter damage to commercial shipping at around $300m per year.[76]
- The economic activities directly affected by marine plastic litter and micro-plastics include shipping, fishing, aquaculture, tourism, and recreation. The associated cost may be of the order of $8bn per year (UNEP, 2016).
- For the EU, costs to the tourism and recreation sector (extrapolated from the costs of cleaning beaches) have been estimated at up to €630m per year; and costs to the fishing industry at up to €.57 million cleaning
- Economic damage from litter on marine industry users has been estimated to be $1.26bn per year to marine industries in the Asia Pacific region. The UN estimates the damage to marine environments globally to be at least $8bn per year.[77]

What should be done

- The numerous issues involved in the current use of plastics considered above Indicate that a range of actions is needed in order progressively to reduce present dependence on plastics.
- The effectiveness of various actions have been assessed by Center for International Environmental Law (CIEL) in the heatmap on the following page.

Recommendations

Strategies	**Greenhouse Gas Emissions** Reduces greenhouse gases or limits emissions growth	**Imapact** Lifecucle approach	**Non-Climate Benefits** Will it have +/- impacts on SDGs	**Feasibility/ Deployability** Feasibility/ is it ready for implementation	**Scalability & Affordability** Can it be implementated cost-effectively at scale
High-impact Interventions to Rduce Greenhouse Gas Emissions from the Plastic Lifecycle					
Stop the production and use of single-use, disposable plastic products	High	High	High	High	High
Stop new and expanded petrochemical and plastic production infrastructure	High	High	High	High	High
Zero-waste communities	High	High	High	High	High
Extended producer responsibility for circular economy	Moderate	High	High	High	Moderate
Set and enforce meaningful emissions limits and monitoring requirements for paint sources	High	Moderate	High	High	Moderate
Medium-Impact Interventions that May Benefit Climate or sustainable Development Goals but Not Both					
Reduce construction of new petrochemical and plastic manufacturing infrastructure	Moderate	Moderate	High	High	Moderate
Reduce new pipeline and well pad constuction	Moderate	Moderate	Moderate	High	Moderate
Identify and fix leaking pipes and tanks	Moderate	Moderate	Moderate	Moderate	Moderate
Beach cleanups	Low	Low	High	High	Moderate
River controls (catchment areas below artificial barriers)	Low	Moderate	High	High	Low
Low-Impact Interventions that Do Little to Safeguard the Climate or the Planet					
Mandate off setting reforestation projects	High	Moderate	Low	Moderate	High
Use renewable energy sources throughout plastic supply chain	High	Low	Moderate	Moderate	Moderate
Ocean plastic recycling	Low	Low	High	Moderate	Low
Maximize energy efficiency throughout plastic supply chain	Low	Low	Moderate	High	Low
Modern landfill	Low	Low	Moderate	High	Low
Mandate capturing gas vs. loss (flaring/venting)	Low	Moderate	Moderate	Moderate	Low
False Solutions					
Biodegradable plastic	Low	Low	Moderate	Moderate	Low
Use bio-feedstocks in petrochemical and plastic manufacturing	Moderate	Low	Low	Moderate	Low
Plastic-eating organisms	Low	Low	Moderate	Moderate	Low
Ocean cleanup	Low	Low	Moderate	Low	Low
Use chemically recycled feedstocks in petrochemical and plastic manufacturing	Low	Low	Low	Moderate	Low
Further integrate petroluem refining, gas processing, petrochemical and plastic manufacturing	Low	Low	Low	Moderate	Low
Waste-to-energy	Low	Low	Low	Moderate	Low

■ High ■ Moderate ■ Low

Source: EPA
Full link: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

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[1] Less than 0.1% of global dedicated hydrogen production today comes from water electrolysis. However, with declining costs for renewable electricity, in particular from solar PV and wind, there is growing interest in electrolytic hydrogen

[1] EUROPEAN COMMISSION. 2018.

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[8] Smith, L., 2020.

[9] Vangheluwe, P., 2019.

[10] WWF Report. 2019.

[11] WRAP. 2018.

[12] World Economic Forum. 2016

[13] The remaining carbon is captured in the plastic products themselves, and its release in the form of GHG strongly depends on the products' after-use pathway.

[14] World Economic Forum. 2016

[15] The use of oil by the plastics industry is expected to increase in line with plastics production (growing by 3.5 to 3.8% annually); this is much faster than the growth in overall demand for oil, which is expected to increase by only 0.5% annually. (For more on this topic see WEF, 2016; and Yale Climate Connections. 2019.)

[16] EUROPEAN COMMISSION. 2018.

[17] WRAP. 2018.

[18] EUROPEAN COMMISSION. 2018.

[19] Several companies have stated that in the future alternative feedstocks such as CO2 will be used for plastic polymer production. For the time being, however, more research and innovation is needed to scale up production processes and make this type of feedstock economically viable, (for more see EUROPEAN COMMISSION. 2018.)

[20] WRAP. 2018.

[21] WRAP. 2018.

[22] Excessive richness of nutrients in a lake or other body of water, frequently due to run-off from the land, which causes a dense growth of plant life.

[23] EUROPEAN COMMISSION. 2018.

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[26] Five years from 2019. Of the four industrial sectors steel, cement, plastic, and aluminium: plastic is witnessing the most rapid and sustained growth, and it is projected to have the largest growth in emissions under business-as-usual scenarios.

[27] ScienceDaily. 2019.

[28] Ritchie, H. and Roser, M., 2018.

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[30] World Economic Forum. 2016.

[31] World Economic Forum. 2020. Plastics, The Circular Economy And Global Trade. [online] Available at: <http://www3.weforum.org/docs/WEF_Plastics_the_Circular_Economy_and_Global_Trade_2020.pdf> [Accessed 13 November 2020].

[32] Ellen Macarthur Foundation. 2016.

[33] Ellen Macarthur Foundation. 2016.

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[37] WRAP. 2018.

[38] WRAP. 2018.

[39] EUROPEAN COMMISSION. 2018.

[40] EUROPEAN COMMISSION. 2018.

[41] EUROPEAN COMMISSION. 2018.

[42] EUROPEAN COMMISSION. 2018.

[43] EUROPEAN COMMISSION. 2018.

[44] EUROPEAN COMMISSION. 2018

[45] WWF Report. 2019.

[46] ScienceDaily. 2019.

[47] Ciel.org. 2019.

[48] For plastic packaging, which represents 40 percent of plastic demand, global emissions from incineration of this particular type of plastic waste totalled 16 million metric tons of CO2e in 2015. This estimate does not account for 32 percent of plastic packaging waste that is known to remain unmanaged, open burning of plastic or incineration that occurs without any energy recovery, or practices that are widespread and difficult to quantify. In 2019, the production and incineration of plastic will produce more than 850 million metric tons of greenhouse gases—equal to the emissions from 189 five-hundred-megawatt coal power plants

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