Plastics

Exposing Their Climate Impacts

What we know, what we need to know, & recommendations for research and policy

May 2025

Plastics & Climate

ENVIRONMENTAL LAW • INSTITUTE

Monterey Bay Aquarium

UNIVERSITY OF WOLLONGONG AUSTRALIA

This report is dedicated to Rose Hoffman and all of our elders who taught us to protect nature, and to Amara Mien Rose Kaufman and the current and future generations for whom we must restore it.

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ABOUT THE PLASTICS & CLIMATE PROJECT

The Plastics & Climate Project's goals are to fully account for all the climate impacts of plastics and to help estimate the extent to which plastics contribute to global average temperature rise. The initiative has identified the vast gaps in data that need to be filled in order to achieve these goals. The Project has also recommended a research agenda and action items to generate the necessary data and to include climate-relevant plastic impacts in greenhouse gas accounting and climate models. In addition, the Project fosters communication among other researchers and institutions working on complementary aspects of the plastics and climate nexus.

Please support the Project's ongoing work by sharing the findings and recommendations in this report, adding to the Project's publicly available online library of resources on the connections between plastics and climate, and promoting the necessary scientific research. You can also contribute here, or contact the Project directors through The Plastics & Climate Project website. The Plastics & Climate Project is a fiscally-sponsored project of the Social Good Fund, a California non-profit corporation and registered 501(c)(3) organization.

GLOSSARY

Albedo	The percentage of incoming (incident) solar radiation (i.e., energy from the Sun) that is reflected from a surface.
Biological carbon pump	The mechanism by which the ocean stores carbon on the order of centuries, through the mixing, gravitational, and migrant pumps that transport carbon to the deep ocean.
Carbon budget	The amount of carbon dioxide equivalent (CO_2e) that can still be emitted while limiting global average temperature rise to a specific temperature target (e.g., 1.5°C or 2°C above pre-industrial levels). It takes into account the capacity of carbon sinks to absorb greenhouse gases.
Carbon cycle	The biological, chemical, and physical processes that govern how carbon moves and is stored throughout different parts of the planet, such as the atmosphere, land, and ocean.
Carbon sink	A place of long-term storage of carbon, such as the ocean or soils, which slows the rise of carbon dioxide (CO_2) levels in the atmosphere.
Chemical recycling	The process by which plastic waste is broken down into its molecular constituents using chemical reactions, often employing high temperatures, enzymes, and/or harsh solvents. Chemical (or "advanced") recycling depolymerizes plastics into monomers or other substances. The products derived from chemical recycling, including gases and liquids, are used as feedstocks for the production of new polymers, chemicals, or fuels.
Climate change	Human-induced changes in the climate occurring in recent decades on top of natural variability, encompassing greater severity and frequency of extreme weather events, increases in global average surface temperature, changes in precipitation patterns, and a multitude of other adverse effects on ecosystems, wildlife, and human welfare.
Coastal blue carbon ecosystems	Coastal ecosystems, particularly salt marshes, seagrasses, and mangroves, that account for a relatively small area globally but play a major role in carbon sequestration.
Conventional plastics	A variety of synthetic polymers which are produced from petrochemical feedstocks. They nearly always contain chemical additives, including plasticizers, flame retardants, and pigments.
Earth's radiation budget	The balance of incoming radiation towards the Earth's surface and outgoing radiation away from the Earth's surface, which helps maintain the Earth's surface temperature.
Endpoint	For the purposes of this report, a way in which plastics impact the carbon cycle or the Earth's radiation budget, such as impacts to soil biota or albedo.

Global warming	The increase in Earth's average surface temperature as a result of human activities.
Incineration	The burning of waste material at high temperatures in a controlled environment.
Landfilling	The disposal of waste material in a dedicated location, usually lined with barriers to help prevent contamination of the surrounding landscape.
Macroplastics	Plastic particles accumulating in the environment which are greater than 5 millimeters (mm) in diameter.
Marine ecosystems	Habitats in the global ocean and the animals and plants in those habitats.
Mechanical recycling	The shredding, grinding, washing, drying, and re-pelletizing of plastic waste for conversion into secondary raw materials without significantly altering their chemical structure.
Microfibers	Fibers of anthropogenic origin, including plastic and cellulose-based fibers, accumulating in the environment which are 1 micrometer (μm) to 5 mm in diameter.
Microplastics	Plastic particles accumulating in the environment which are 1 μm to 5 mm in diameter.
Monomer	Molecules that form the building blocks of plastics. They are linked together repeatedly to form long polymer chains.
Nanoplastics	Plastic particles accumulating in the environment which are less than 1 μm in diameter.
Open burning	The burning of waste material outdoors, resulting in the direct release of greenhouse gases, volatile organic compounds, and toxic compounds into the atmosphere and surroundings.
Open dumping	The disposal of waste in areas not designed to handle it, including on land or in water, with consequences including air, soil, and water pollution. Open dumping of waste is a form of waste management, but the waste automatically transforms into an unmanaged state when this waste management strategy is deployed.
Plastic debris	Pieces of plastic that have infiltrated into the environment.
Plastic pollution	The introduction of plastics and the chemicals in them into the ecosphere (i.e., into the system of living and non-living components, including humans). Plastic pollution occurs throughout the plastics lifecycle.
Plastic waste	Unwanted or unusable plastic material that remains after its intended use.
Polymer	Long chains of monomers linked together by chemical bonds, which can be natural or synthetic. Plastics are examples of synthetic polymers.

Terrestrial ecosystems	Land-based habitats, excluding coastal blue carbon ecosystems, and the animals and plants in those habitats.
Tonne	A unit that is equivalent to a metric ton (1000 kg).
Unmanaged waste	Waste that has escaped collection, handling, and processing by waste management systems and entered into the environment.

ACRONYMS

CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
EPCRA	Emergency Planning and Community Right-to-Know Act
GHG	Greenhouse gas
HDPE	High-density polyethylene
LLDPE	Linear low-density polyethylene
LDPE	Low-density polyethylene
MNP	Micro- and nano-plastic
NDC	Nationally determined contribution
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PU	Polyurethane
PVC	Polyvinyl chloride
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals regulation
SAN & ABS	Styrene acrylonitrile & Acrylonitrile butadiene styrene
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act

FOREWORD

The genesis of The Plastics & Climate Project was a realization that plastics and the petrochemicals in them had climate impacts, but little data existed to show where in the plastics lifecycle most of those impacts came from, their extent, or their significance in contributing to climate change.

Well-researched estimates existed for greenhouse gas (GHG) emissions produced during some of the early stages of the plastics lifecycle (i.e., production and manufacturing), as well as from some types of waste treatment late in the lifecycle — but even for those stages, some data were missing or inadequate, or only covered certain feedstocks or polymers. Little to no data were available for the stages across the lifecycle of plastics, including the usage phase. There was ample speculation about how micro- and nanoplastics (MNPs) may be harming zooplankton, other organisms, and other processes in water and on land that help sequester carbon, but little hard evidence on how much this might be affecting the carbon cycle or global temperatures. Similarly, practically no data existed about how plastics alter Earth's radiation budget — whether all the tiny bits of plastic that now cover every surface on the planet and circulate in the air and clouds affect how warm or cool the planet gets.

Despite these gaps, enough data exist to demonstrate that **plastics are affecting the climate, and the impacts — be they warming or cooling in nature — are undercounted or unaccounted for**, including in most climate models, GHG inventories, and emissions scenarios.

As Project founders, we undertook an extensive review of the existing peer-reviewed scientific literature to identify currently available data (as of 2023) regarding the impacts of **GHG emissions from the entire plastics lifecycle, carbon cycling impacts, and radiative impacts**. We also assessed what that data showed and what data are still needed. The findings from our review and analysis are presented in our scientific paper, "The knowns and unknowns in our understanding of how plastics impact climate change: A systematic review", which was published in April 2025 in *Frontiers of Environmental Science.*

This report is intended to summarize for non-technical audiences the findings and implications of the scientific paper (referred to as "the *Frontiers* paper" in this report). The paper and this report also present recommendations for the scientific research needed to fill data gaps, as well as recommendations for policies and other actions needed at different levels to support research and ensure the full inclusion of the climate impacts of plastics in emissions scenarios, inventories, and climate models across geographies and sectors. (All of the references for data in this report are included in the *Frontiers* paper, except where we have included links here to additional reports that did not undergo a formal scientific review process.)

As our work and the work of many others demonstrate, **plastics are not just a "waste" problem**, where visible trash continues to pile up in ocean gyres and garbage dumps, continually leaching harmful chemicals and shedding micro- and nano-plastic particles including fragments, foams, and fibers. **Plastics are also a climate problem**, emitting greenhouse gases and altering planetary systems.[1] Plastics' climate impacts are expected to increase significantly, as global plastic production is projected to triple by 2060. By then, the greenhouse gas emissions from plastic production (even just the emissions that are currently counted) will exceed those from trucks, aviation, and shipping combined. Even if all plastic production stopped today, some of the climate impacts would continue to increase.

Solving the various environmental and health problems that plastics cause is challenging. A multitude of suggestions have been put forward, including reducing plastics production and use, bolstering circularity, reuse and refill systems, changing the ingredients that go into plastics, and using cleaner energy to produce plastics. Some of these suggestions can help, depending on how they are implemented, but they will not fully address the problems, including the climate challenges.

Solving all of the problems that plastics present, however, is not the purpose of our *Frontiers* paper or this report, critical as that is. Instead, our hope here is that our findings and recommendations prompt the necessary scientific research on the climate impacts of plastics, and the inclusion of those impacts where they need to be accounted for. We also aim to raise awareness among policymakers, industry, brands, investors, educators, and others about the links between plastics and climate and the importance of taking action to address these (and related) intertwined challenges. The world will benefit from optimizing rather than diminishing human health and the health of the biosphere that sustains all commerce — and life.

~ **Holly Kaufman & Dr. Xia (Alice) Zhu**
Co-founders & Directors, The Plastics & Climate Project

1 For more on plastics' impacts on planetary systems (climate and beyond), see Villarrubia-Gómez et al, Plastics pollution exacerbates the impacts of all planetary boundaries, One Earth, December 2024.

EXECUTIVE SUMMARY

Existing scientific data clearly show that plastics affect the climate. However, there are significant gaps and shortcomings in the data, which preclude a complete understanding of how plastics affect the climate and to what extent. This report summarizes the findings of a recently published systematic review of the scientific literature on the plastics-climate nexus in *Frontiers in Environmental Science*. This review highlighted what is and is not known about the impact of plastics on the climate. The *Frontiers* paper outlined a research agenda to fill these knowledge gaps, and it included general policy and other recommendations to support that research and promote the incorporation of plastics' climate impacts in scenarios, inventories, models, analyses, and assessment reports related to plastics, climate, or both. This report synthesizes and elaborates on the *Frontiers* paper to help these issues reach an audience beyond the scientific community.

While conventional plastics and the petrochemicals in them are part of the fossil fuel industry, those fossil fuels are used as feedstocks, not combusted. Nevertheless, the *Frontiers* paper identified and evaluated **three main ways that plastics can influence the climate**.

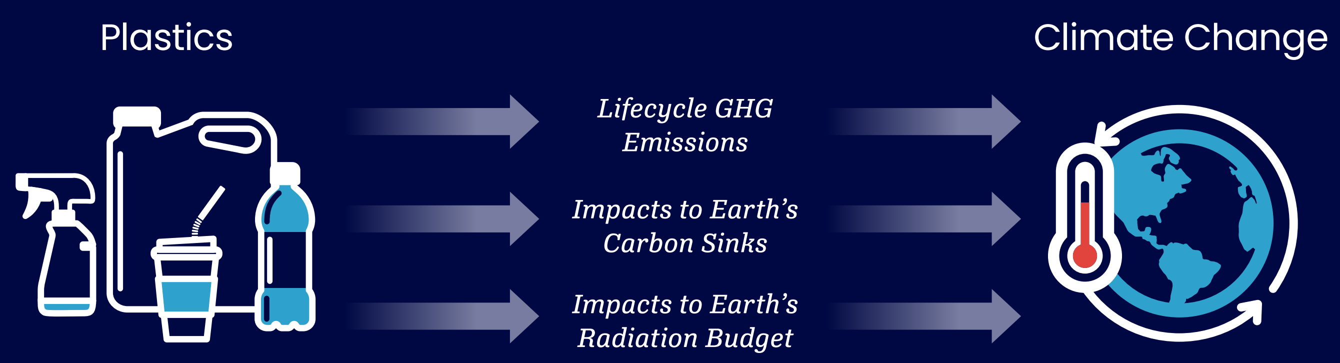
First, all phases of the plastics lifecycle — primary production (including extraction of raw materials), product manufacturing, transportation, consumption (i.e., use), and waste — generate **greenhouse gas (GHG) emissions**, increasing atmospheric GHG concentrations and accelerating global warming. To date, studies have mostly focused on GHG emissions from the two ends of the plastics lifecycle (primary production and waste management) and have given much less attention to the other phases. These and other data gaps make it difficult to discern the full extent of GHGs emitted across the entire plastics lifecycle. The existing data indicate that the plastics lifecycle is responsible for roughly 4% of total global GHG emissions at present, though the data gaps mean it is almost certainly higher (i.e., the plastics sector may be consuming more of the remaining carbon budget than currently assumed).

Second, the various forms of plastic pollution (including macroplastics, microfibers, other microplastics, nanoplastics, and the chemicals in plastics) affect a range of organisms and ecosystems that are vital to the planet's **carbon cycle**, altering the way that carbon is absorbed from the atmosphere and stored in plants, soils, the ocean, and other carbon sinks. The less carbon stored in sinks, the more remains in the atmosphere, which leads to global warming and worsens climate change. Existing data indicate that plastics are adversely impacting the oceans' ability to remove carbon from surface waters and store it in the deep ocean, are harming the health of microscopic marine plants that use carbon dioxide for photosynthesis (and thus act as carbon sinks), and are increasing the release of carbon dioxide from soils. The data for some other metrics relevant to the carbon cycle are not always clear (and are sometimes contradictory), but studies generally find that plastics impact the carbon cycle in ways that increase warming.

Third, plastic particles may physically affect the **Earth's radiation budget**, changing how the planet reflects, absorbs, traps, and moves energy in the atmosphere and on the surface of the Earth. This is still a relatively new area of research, and only a few scientific studies have performed actual tests. Still, the indications are that plastic particles on the surface may increase reflectivity, which would have a cooling effect, and that plastic particles in the atmosphere may directly affect energy exchange between the surface and the atmosphere in ways that would also produce a cooling effect. However, because this area of research is so new and few tests have been done, much remains unknown.

The available science indicates a strong linkage between plastics and climate impacts and points to key areas of further research needed to better understand and quantify those impacts. Because numerous knowledge gaps, unclear results, and methodological shortcomings limit understanding of how plastics affect climate change, the *Frontiers* paper identified specific areas for research attention going forward in each of the three categories of impacts:

- **GHG emissions:** there is a need for more studies that estimate GHG emissions and GHG emissions intensities across the entire plastics lifecycle, particularly for lifecycle stages with little to no existing data and for a broader range of plastic types. In addition to global-scale studies on the plastics lifecycle, more national-level studies are needed to address the fact that the scientific literature is missing GHG data from the plastics lifecycle for most countries. This category of impacts is expected to contribute most to global warming, and filling in the unknowns in this category is a priority.
- **Carbon cycle:** more experiments and modeling efforts are needed that focus on Earth's terrestrial, marine, and coastal ecosystems. More data are needed on ecosystems and natural processes that have received inadequate study and/or where studies have produced conflicting results about plastics' effects on carbon sinks.
- **Radiation budget:** this is the area that is least well understood. More experiments and studies are needed to fill in the knowledge gaps in this category, including research to elucidate the quantities and types of plastics that are infiltrating clouds, the direct and indirect impacts of atmospheric plastic debris, and the effect of plastic particles on the reflectivity of the planet's surface and the melting rate of ice and snow.



Entities in both the public and private sectors, from the international to the local levels, should take steps to support filling in these data gaps and to promote the inclusion of plastics' impacts on climate in carbon accounting, GHG emissions inventories and scenarios, climate models, and any relevant evaluations of plastics' impacts. Only by enhancing understanding of how these two global challenges are intertwined will it be possible to address the impacts of each issue effectively, through science, policy, technology, multi-sector engagement, public awareness raising, investment, and other levers of change.

SCIENTIFIC FINDINGS ON THE CLIMATE IMPACTS OF PLASTICS

Introduction

Conventional plastics and the petrochemicals in them are made from fossil fuels, but those fuels are used as feedstocks, not combusted. Nevertheless, there are clear linkages between plastics and climate. The number of peer-reviewed studies exploring the links between plastics and climate has grown considerably over the last decade (Fig. 1). The systematic review published in *Frontiers of Environmental Science* broke these down into **three impact categories**: the **greenhouse gas (GHG) emissions of the plastics lifecycle**, the **impact of plastics on the carbon cycle**, and the **physical impact of plastics on the exchange of energy** into and out of Earth's atmosphere (i.e., Earth's radiation budget).

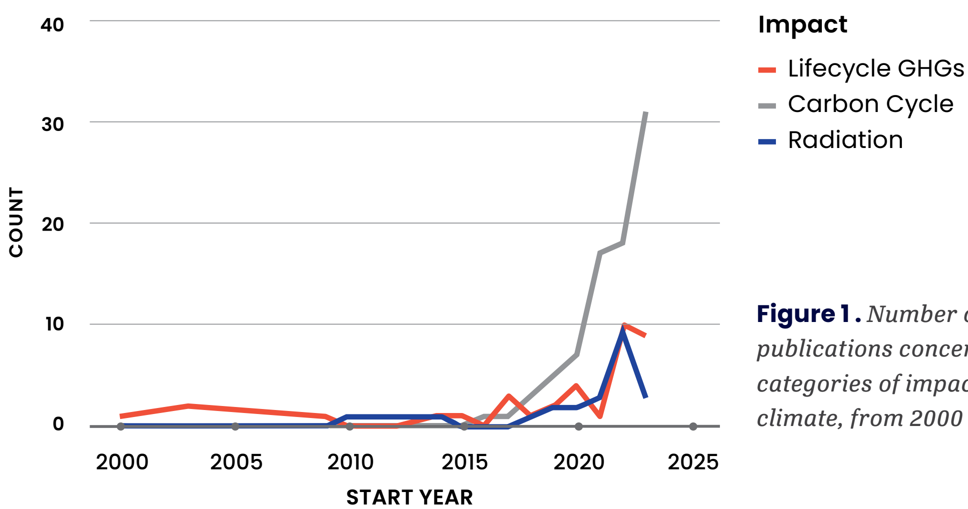


Figure 1. *Number of peer-reviewed publications concerned with the three categories of impacts of plastics on climate, from 2000 to 2023.*

It is clear, and perhaps unsurprising, that the intersection of these two pressing environmental challenges has attracted growing scientific attention. The sections below summarize some of the main scientific findings in each of the three impact categories, supplemented by findings from substantive reports. These findings provide context for the discussion in the next section on the need for a research agenda to fill in knowledge gaps.

Summary of Evidence: GHG Emissions of the Plastics Lifecycle

In both the scientific and policy literature, plastics and the pollution they cause are often discussed in terms of the plastics lifecycle. Here, following the *Frontiers* paper's synthesis of 36 peer-reviewed scientific studies, the plastics lifecycle is divided into four stages: **primary production** of plastics (which includes fossil fuel extraction and refinement, as well as plastic monomer and pellet formation); **manufacturing** of plastic products; **transportation and consumption (use)** of those products; and **after-use waste and waste management strategies** such as recycling and landfilling.

Studies on the GHG emissions associated with the plastics lifecycle (or a specific stage of it) report data in terms of the **quantity of emissions** and/or **emissions intensity** (i.e., GHG emissions per a particular amount/weight of plastic).

To date, studies have mostly focused on GHG emissions from the two ends of the plastics lifecycle, specifically primary production and waste management strategies. Fewer studies have investigated GHGs emitted during the manufacturing, transportation (including import, export, and trade activities), and consumption stages of plastics; the same holds true for GHGs emitted by unmanaged plastic waste.

Some scientific studies, plus a handful of reports outside of the scientific literature, have examined the cumulative GHG emissions across the entire plastics lifecycle. Some have also explored the emissions of specific polymers. At present, **data gaps make it difficult to discern the full extent of GHGs emitted by the plastics lifecycle, but existing data indicate that plastics emit about 2 billion metric tons of carbon dioxide equivalent (CO_2e) every year, roughly 4% of current total global emissions.** This is approximately equal to the CO_2e emissions from over 400 five-hundred-megawatt coal power plants operating at full capacity.[2] According to The New Coal: Plastics & Climate Change report from Beyond Plastics, if the plastics industry were a country, it would be the fifth highest emitter. These emissions are expected to increase, given that plastic production is set to triple by 2060.

Scientific studies conducted at the global scale show that the highest GHG emissions are produced during the primary production stage (Fig. 2). Annual global emissions estimates for this stage range from 1085-1700 million tonnes of CO_2e — or about the same as the annual CO_2 emissions of roughly 241-378 five-hundred-megawatt coal power plants operating at full capacity.[2] As for emissions intensity, the range of estimates for the primary production stage is wide. However, the GHG emissions intensity for the production stage could be as high as 12.9 kilograms (kg) of CO_2e per kg of plastic. This estimate is more than 5.5x the emissions intensity of burning coal and more than double the highest-end estimate for any other plastics lifecycle stage.[3]

2 A five-hundred-megawatt coal power plant operating at full capacity is expected to emit roughly 4.5 million metric tons of CO_2e as reported by the Center for International Environmental Law.

3 The coal comparison was calculated by converting carbon dioxide emissions coefficients published by the U.S. Energy Information Administration from five types of coal (anthracite, bituminous, subbituminous, lignite, and coke) to CO_2 emissions per kg coal, and then taking the average of those five. Emissions intensities for burning individual types of coal range from about 1.5 to 3.6 kg CO_2/kg coal.

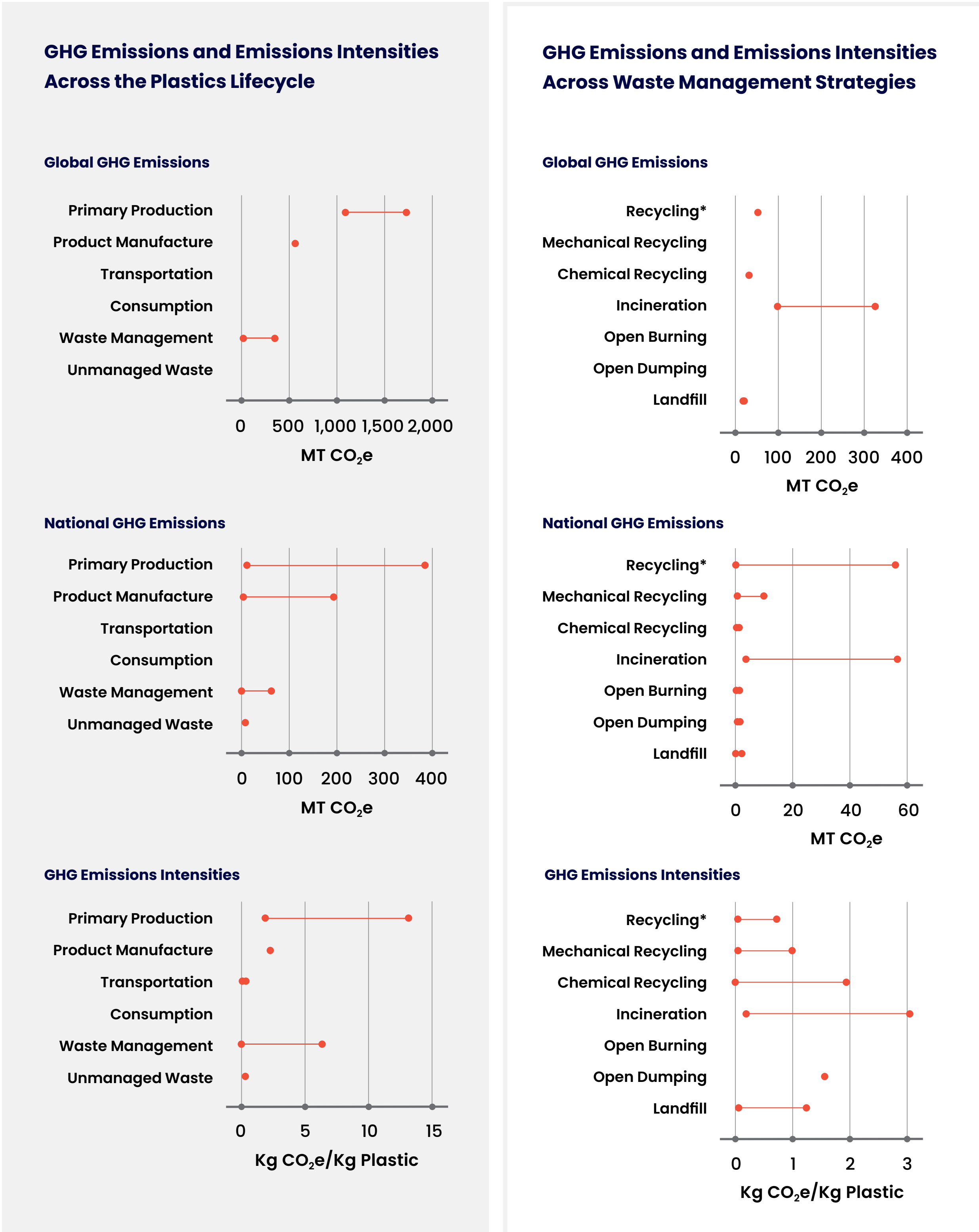


Figure 2. *GHG emissions and GHG emissions intensity estimate ranges from the peer-reviewed scientific literature. *Recycling refers to an unspecified recycling type (can be mechanical or chemical). Note that studies of GHG emissions from the plastics lifecycle at the "national" scale have only been conducted in 14 countries.*

The scientific studies' finding of high emissions and emissions intensities during the primary production phase compared to other plastics lifecycle stages is consistent with the findings of a report from Lawrence Berkeley National Lab that investigated polymer-specific emissions at the global level (Fig. 3) and a report from a group of non-governmental organizations on Australia's plastics-derived emissions (Fig. 4).

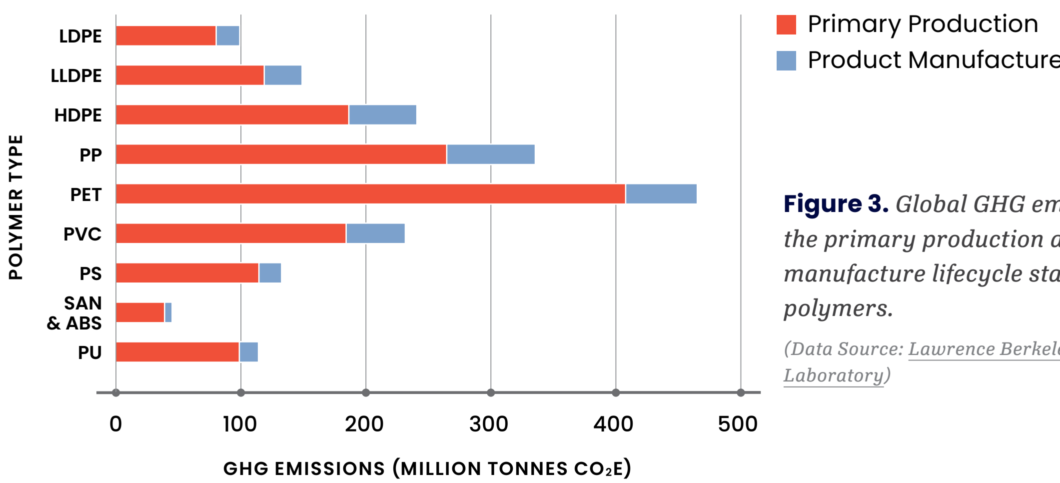


Figure 3. *Global GHG emissions in the primary production and product manufacture lifecycle stages of various polymers.*

(Data Source: Lawrence Berkeley National Laboratory)

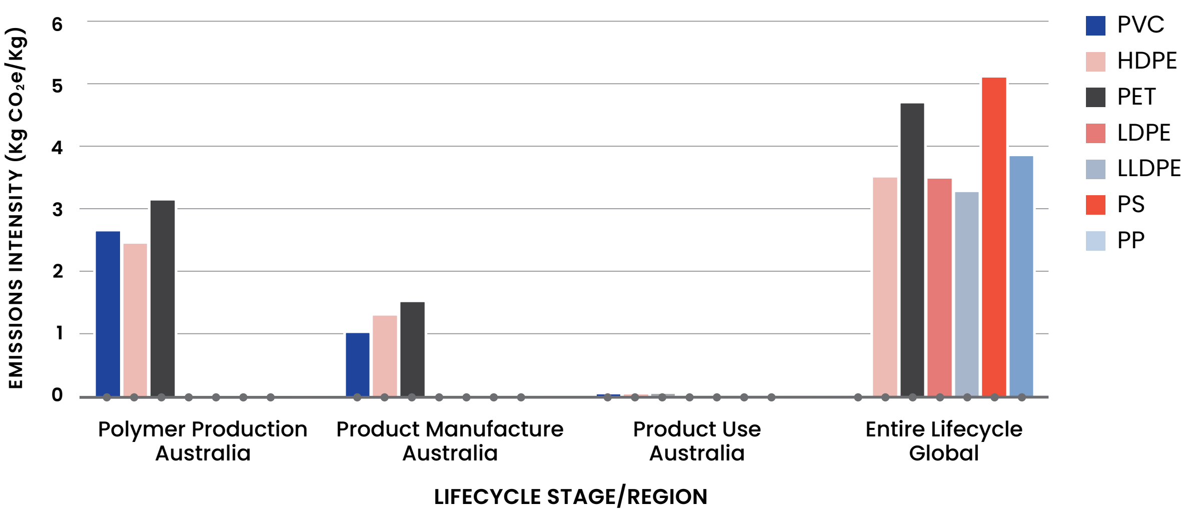


Figure 4. *GHG emissions intensities for select polymers in various lifecycle stages and across the full plastics lifecycle.*

(Data Sources: Minderoo Foundation for global data; Australian Marine Conservation Society, WWF-Australia, and Blue Environment for Australia data)

At the global scale, the available data indicate that plastic product manufacturing emits 535 million tonnes of GHGs yearly, with an emissions intensity of about 2.2 kg CO_2e/kg plastic, although this finding is based on only one study. The report from Lawrence Berkeley National Lab found that polypropylene (PP) emitted the most emissions globally during product manufacturing (Fig. 3), while the Australia report found that product manufacturing involving polyethylene terephthalate (PET), commonly used in everyday packaging and fabrics (among other applications), was the most emissions-intensive in that country. For all polymer types, emissions and emissions intensities from primary production are considerably higher than from the product manufacturing stage (Figs. 3 & 4).

On the other end of the plastics lifecycle, the scientific literature estimates that annual GHG emissions from global plastic waste management range from 16-322 million tonnes of CO_2e, equivalent to about 4-72 five-hundred-megawatt coal power plants operating at full capacity. This range is wide due to the fact that different waste management strategies emit different amounts of GHGs.

Of the waste management strategies for plastics investigated in the scientific literature, incineration was identified as the largest source of emissions globally (Fig. 2), but the emissions estimates vary considerably, and there are waste management strategies for plastics for which GHG emissions have not been quantified at the global scale (for instance, open burning and open dumping). Emissions intensity estimates for incineration also vary widely across the literature, with some studies reporting a negligible intensity and others finding upwards of 3 kg CO_2e/kg plastic. The scientific literature contains wide variations in intensities in most other waste management strategies too, generally ranging from negligible to 2 kg CO_2e/kg plastic (Fig. 2). One study found that open dumping has an emissions intensity of about 1.5 kg CO_2e/kg plastic. The available data indicate that landfilling plastics has a GHG emissions intensity ranging from nearly zero to about 1.2 kg CO_2e/kg plastic, which is generally consistent with the (non-peer-reviewed) Australia report's finding that landfilling has a very low emissions intensity (Fig. 5). The climate impact of landfilling plastics, however, may depend on the type of landfill, such as how well it is designed, contained, and maintained.

The highest-end estimates of emissions intensities for recycling (unspecified types) and mechanical recycling are lower than those of the other plastic waste management approaches.[4] Studies reporting results from unspecified recycling techniques found that emissions can still be substantial, estimating emissions at around 50 million tonnes of CO_2e annually. However, the studies do not specify which aspects of the recycling process or which types of recycling generate the emissions. These studies also may not necessarily consider the potential climate benefits of virgin pellet avoidance if and when realized.

Studies that focused on one or more types of chemical recycling (coke oven, pyrolysis, gasification, or gasification-pyrolysis) found that those processes generate approximately 30 million tonnes of annual CO_2e emissions. The data (Fig. 2) indicate that the emissions

4 Mechanical plastics recycling is a form of plastic production and has significant impacts that must be considered. For example, the washing, grinding, and shredding associated with mechanical plastic recycling generates microplastics that can get into the air, water, and soil (e.g., Suzuki et al., 2022).

intensity of chemical recycling could be as high as 2 kg CO_2e/kg plastic — a significantly higher potential intensity than mechanical recycling and unspecified recycling techniques. However, different types of chemical recycling will have different emissions intensities. The Australia report similarly found chemical recycling to be particularly emissions-intensive, producing over 3 kg CO_2e/kg plastic for high-density polyethylene (HDPE) and polypropylene (PP) (Fig. 5).[5]

In contrast to plastic waste management, there are few studies focused on unmanaged plastic waste. One study found unmanaged waste to be a negligible source of GHG emissions with a low GHG emissions intensity, while another study looking at polymer-specific emissions of methane (a potent GHG) identified similarly negligible methane emissions intensities for plastics when exposed to air and immersed in water, though the methane emissions intensity for plastics in open air was greater by two-fold.

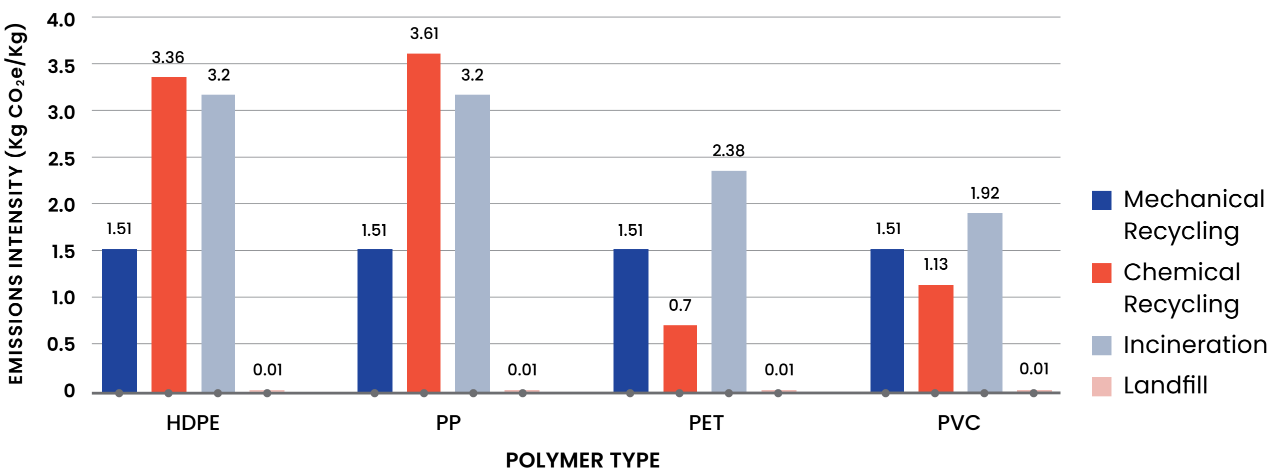


Figure 5. *GHG emissions intensity of managed end-of-life options for various polymers produced in Australia.*

(Data Source: Australian Marine Conservation Society, WWF-Australia, and Blue Environment)

As noted, scientific studies rarely focus on the middle stages (transportation and consumption) of the plastics lifecycle. For the transportation stage, studies have found a relatively low emissions intensity, between about 0.03 and 0.13 kg CO_2e/kg plastic (Fig. 2). Studies thus far have reported emissions intensities for specific transportation processes, including the import, export, and trade of plastics. GHG emissions from plastics during the consumption phase (e.g., plastic windows and doors exposed to sunlight) have not been explored in scientific studies, although the Australia report found fairly negligible emissions intensities from product use across polymer types (Fig. 4). This, however, is only one estimate for one country and might not be representative of larger trends.

5 Chemical recycling generates harmful emissions that affect human health, usually in communities already negatively affected by other industrial processes.

In summary, most of what is currently known about GHG emissions associated with plastics comes from the beginning of the plastics lifecycle (primary production) and from the end (waste management). Even in these areas, however, the range of estimates tends to be very wide, perhaps due in part to a failure to distinguish between different relevant sub-classifications (e.g., mechanical versus chemical recycling or the different types of chemical recycling) and a lack of standardized methodologies. To fill these knowledge gaps, additional and more specific studies are needed at every lifecycle stage, particularly plastic use and unmanaged waste. There is also a need to adopt standardized best practices for measuring GHG emissions within and across the plastics lifecycle so that datasets can be more easily and accurately compared.

Summary of Evidence: Impacts on the Carbon Cycle

Of the three plastics-climate impact categories included in the *Frontiers* paper, the impact of plastic pollution and unmanaged plastic waste on the carbon cycle has received the most scientific attention (Fig. 1), though data are still lacking. The "carbon cycle" refers to the biological, chemical, and physical processes that govern how carbon moves and is stored throughout different parts of the planet, such as the atmosphere, land, and ocean. Carbon can be absorbed from the atmosphere and stored in rocks, soils, the ocean, living organisms, and other carbon "sinks"; it can also be released to the atmosphere through the decay of dead organisms, forest fires, volcanic eruptions, burning fossil fuels, and other means. Carbon storage is an important component of the planet's climate because the more carbon stored, the less there is in the atmosphere to cause warming and worsen climate change.

The *Frontiers* paper identified and categorized scientific studies focusing on three ecosystems in which plastics could affect the movement and storage of carbon: terrestrial ecosystems (land), marine ecosystems (ocean), and coastal "blue carbon" ecosystems (e.g., mangroves) that are known to play an outsized role in carbon storage. (As freshwater ecosystems account for a small fraction of global carbon sequestration, they were not a focus of the *Frontiers* paper or this report.) Of the 83 scientific studies in the *Frontiers* review pertaining to the impact of plastics on carbon storage, over half of them (47) focused on impacts to terrestrial carbon sinks, 30 focused on the impacts on marine carbon sequestration, and just 6 focused on impacts on blue carbon ecosystems. Most of these studies reported results from original research, but there were several instances where effects were speculated rather than tested and demonstrated.

The *Frontiers* paper summarized the results of these studies by looking at different ways (termed "endpoints" here) that plastics could impact the carbon cycle by shifting an ecosystem toward or away from its ability to store carbon. There are a few areas where the carbon cycle endpoints are relatively clear, with most scientific tests revealing an effect and agreeing on whether that effect is warming or cooling in nature (Fig. 6). For example, all four tests that looked at the impact of plastics on the "biological carbon pump" (processes in the ocean that remove carbon from surface waters and store it in the deep ocean on timescales of hundreds of years or more) found an adverse effect. Similarly, out of 28 scientific tests looking at the health of phytoplankton (mostly microscopic marine plants that use carbon dioxide for photosynthesis and, as such, act as carbon sinks), 24 of them (86%) found that plastics caused adverse impacts, with the remaining tests finding no effect. Of the 21 scientific tests that looked at soil respiration (a process in which soil releases CO_2 due to the decomposition of organic matter), 15 of them (71%) found that plastics increased the release of CO_2, with the remaining tests split between finding a decrease and finding no effect. The majority of scientific evidence in the *Frontiers* review thus indicates that **plastics impact these processes involved in the carbon cycle in ways that lead to additional warming.**

As the soil respiration studies indicate, however, scientific tests can come to opposing conclusions, and the results for some other endpoints are decidedly more mixed. For example, out of 48 tests (i.e., model simulations, experimental treatments, field sampling campaigns) looking at the impacts of plastics on the soil microbes that facilitate carbon storage ("carbon sequestering strains" in Fig. 6), 19 (nearly 40%) indicated an adverse impact, 9 (about 19%) arrived at the opposite conclusion, 13 (27%) failed to identify any effect, and 15% reached unclear conclusions. Similar trends were identified in studies looking at the health of living organisms in soil ("soil biota"), with 33 out of 73 tests (45%) showing an adverse impact, 6 (8%) showing a positive impact, 10 (14%) failing to identify an effect, and 24 (33%) with unclear conclusions. Overall, the tests for these two endpoints tend to suggest an adverse impact, but the picture is far from clear.

Interestingly, one mixed result suggested a cooling impact. Out of 153 tests looking at stores of carbon in soils, 73 (48%) found that plastics could increase soil carbon stores, 30 (20%) found the opposite, 48 (31%) found no effect, and 2 (1%) found an unclear effect. The positive indications for soil carbon stores, however, come with two important caveats: first, the "organic matter" considered to be a proxy for carbon in some of these tests is not necessarily a perfect representation of carbon storage, and second, the testing of carbon-containing plastics on soil might cause contamination and inflate the "carbon storage" measured.

While the evidence for the impacts of plastics on carbon cycle endpoints or processes is not always clear, taken as a whole, the **studies generally find that plastics will impact the carbon cycle in ways that increase warming**. Of the total 291 tests across all endpoints, 198 (68%) of them found that plastics will result in additional warming. The magnitude of these effects is not well understood. Still, as the next chapter emphasizes, it will be necessary to gain that understanding to quantify the full climate impacts of plastics.

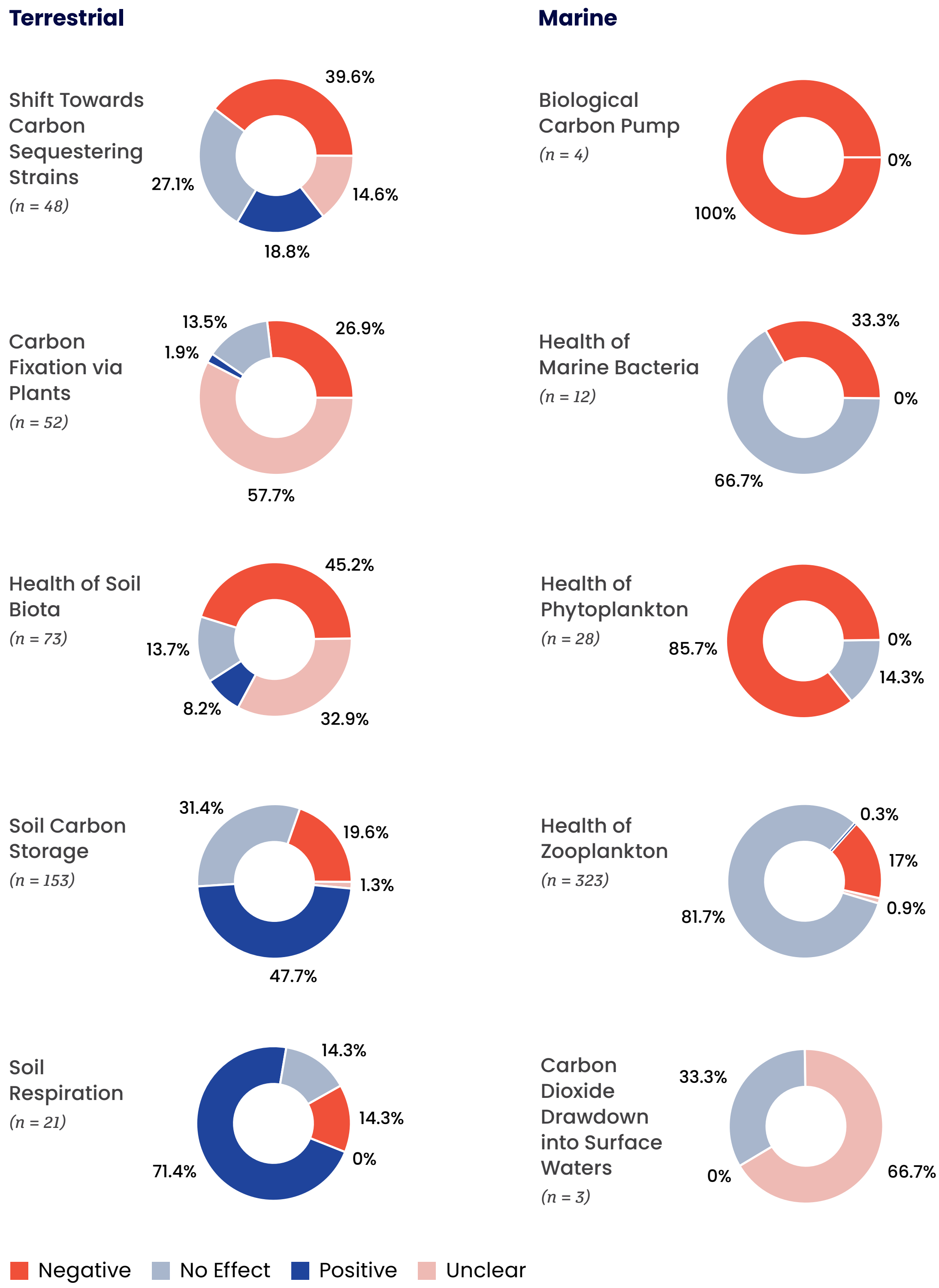


Figure 6. *Impact of plastics on carbon cycle outcomes. Terrestrial includes coastal blue carbon ecosystems. For each pie chart, "n" indicates the number of scientific tests investigated for each outcome. A negative effect on an outcome is synonymous with a warming effect on climate, except for the soil respiration endpoint, where a positive effect is associated with a warming effect on climate.*

Summary of Evidence: Impacts on the Radiation Budget

Plastic particles can physically affect the processes directly and indirectly involved in energy exchange between the surface of the planet and the atmosphere. Such impacts manifest across three categories: plastic particles in the atmosphere that influence energy exchange ("direct radiative forcing"), plastic particles in the atmosphere that affect cloud formation and thus indirectly influence energy exchange ("indirect radiative forcing"), and plastic particles on the surface of the planet that alter the Earth's reflectivity ("albedo") and/or impact the integrity of the planet's ice and snow cover. The study of plastics' radiative impacts is a relatively new, but fast growing, area of scientific research, with 19 of the 24 studies identified by the *Frontiers* paper speculating about impacts rather than providing rigorous tests.

Only 5 studies carried out scientific tests. The tests on the impacts of atmospheric plastics on cloud formation and indirect radiative forcing come from a single study, and the results of all 12 of those tests were unclear (Fig. 7). Of the 6 tests that examined albedo, all found that plastics on the planet's surface increase reflectivity ("positive albedo"), which would tend to have a cooling effect. The ability of atmospheric plastics to directly affect energy exchange has been tested the least, with only 3 relevant tests, 2 of which found that plastics in the atmosphere can provide some cooling effect ("negative direct radiative forcing"), with the other test finding no effect.

Large uncertainties exist in this domain of research, partly because it is new and not many tests have been done to date. For example, the findings reported here might not represent all polymer types. Whether plastic particles have a warming or cooling effect depends partly on their color (i.e., light or dark), and researchers have only tested the effects of a limited selection of colors to date. There are also uncertainties surrounding the extent to which plastics are being incorporated into clouds at different altitudes, which play different roles in climate depending on their altitude. Increased knowledge of the interaction of plastics with clouds is important for discerning the impacts of airborne plastic particles on the climate.

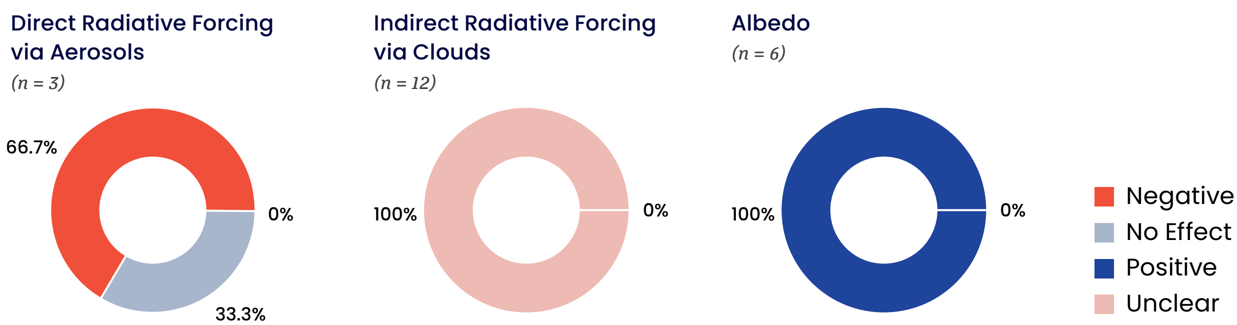


Figure 7. *Impact of plastics on processes relevant to the exchange of energy between the surface of the planet and the atmosphere. A negative effect on direct or indirect radiative forcing translates into a cooling effect on climate, while a negative effect on albedo produces a warming effect on climate.*

Conclusion

The body of available scientific evidence suggests that the **climate impacts of plastics are varied and widespread**. Based on the GHG emissions for which reliable data exist, it appears that the plastics lifecycle emits around 2 billion metric tonnes of CO_2e annually, corresponding to about 4% of the world's total annual GHG emissions. As plastic production increases, it is expected that plastics will consume a greater fraction of Earth's remaining carbon budget. Beyond the emission of GHGs, plastics also affect climate-important processes, such as the carbon cycle and the planet's energy balance. The magnitude of plastics' impacts on climate are unclear, however, due to a lack of research and robust, comparable data. What is most clear from a review of the available science is that more research is required to understand and quantify the full climate impacts of plastics. The next section of this report provides recommendations for specific research efforts to accomplish this task.

PROPOSED SCIENTIFIC RESEARCH AGENDA

Overview

To better understand how plastics are affecting the Earth's climate, several knowledge gaps across the three major impact categories must be filled in. Foremost, there is a need for more estimates of GHG emissions and GHG emissions intensities across the entire plastics lifecycle, in particular for stages with little to no data, for different feedstocks, and across different polymer types. There is also a need for more experiments and modeling efforts that test the impact of plastics on various endpoints that affect how well Earth's natural carbon sinks are working, as well as the effectiveness of restoration measures. In addition, there is a need for more studies that investigate the extent of micro- and nano-plastics (MNP) contamination in the atmosphere and that quantify the extent to which plastics themselves are affecting the radiative balance of the planet. As researchers conduct these future studies, they should utilize methods that reflect real-world conditions, evaluate how emerging bioplastics alternatives may impact climate, and increase specificity and standardization in their reporting of data.

Knowledge Gaps and Proposed Research Agenda

As the previous chapter made clear, the body of evidence regarding the impact of plastics on climate is incomplete. Numerous knowledge gaps, unclear results, and methodological shortcomings limit the ability at present to gain a complete understanding of how plastics could be affecting climate change. The following table describes the main knowledge gaps uncovered by the *Frontiers* paper and proposes future research directions to fill these gaps.

Knowledge Gaps	Research Directions
IMPACT CATEGORY #1 GHG emissions and GHG emissions intensities for the plastics lifecycle	
▪ GHG emissions estimates associated with open burning or open dumping at the global scale are lacking, as are GHG emissions intensity estimates associated with the open burning of plastic waste ▪ Only one study, in Guatemala, has quantified emissions of black carbon (an aerosol with a high warming effect) from the open burning of plastic waste	▪ Prioritize the quantification of GHG emissions associated with open burning and open dumping at the global level, as well as GHG emissions intensities associated with open burning ▪ Quantify emissions of black carbon from the open burning of plastic waste locally and globally
▪ There are no data on GHG emissions for the transportation or consumption stages nationally or globally, including a lack of measurements of GHG emissions from plastic products (e.g., packaging, clothing, infrastructure) while in use ▪ GHG emissions intensity estimates are lacking for the consumption stage ▪ There are no data on GHG emissions from unmanaged waste at the global level, and more estimates are needed of GHG emissions from unmanaged large plastic items locally and globally, as well as the microplastics that fragment from these larger items ▪ National-level studies have only been done on 14 of 195 countries (excluding continental and global studies), which indicates that GHG data from the plastics lifecycle are missing for the vast majority of countries	▪ Quantify more GHG emissions and GHG emissions intensities at all stages of the plastics lifecycle, both nationally and globally ▪ Prioritize the quantification of GHG emissions and GHG emissions intensities, specifically at the transportation and use/consumption stages, as well as for unmanaged waste
▪ Polymer-specific GHG data across the plastics lifecycle are lacking, in particular, polymer-specific GHG emissions and polymer-specific GHG emissions intensities for stages beyond primary production and product manufacture	▪ Estimate more polymer-specific GHG emissions across the plastics lifecycle both nationally and globally, including for different feedstocks ▪ Estimate polymer-specific GHG emissions intensities across the plastics lifecycle, prioritizing stages beyond primary production and product manufacture, including the transportation, consumption, and after-use stages

Knowledge Gaps	Research Directions
IMPACT CATEGORY #2 Impact of plastics on Earth's natural carbon sinks	
▪ There has been a great deal of speculation and not enough experimenting and modeling related to the effects of plastics on the carbon cycle in marine ecosystems	▪ Reduce speculation around carbon cycle impacts in marine ecosystems by conducting more experimental tests and model simulations investigating the impact of plastics on marine carbon cycling
▪ Researchers are not controlling for the amount of carbon in plastic when measuring soil organic carbon content	▪ Correct for the carbon in plastics in experimental studies that examine the impact of plastics on soil carbon stores
▪ Global pooled estimates are lacking regarding plastics' effects on the planet's carbon sequestration, including on soil carbon	▪ Calculate a global mean percent change in soil carbon stores due to the infiltration of plastics into terrestrial ecosystems to estimate how much of Earth's remaining carbon budget would be used up via the impact of plastics on terrestrial carbon sinks ▪ Calculate a global mean change in carbon sequestration by the Earth due to the impacts of plastics across all ecosystems (terrestrial, freshwater, marine, coastal blue carbon)
▪ The coastal blue carbon ecosystem category has been studied far less than terrestrial and marine ecosystems	▪ Conduct more studies focusing on the climate effects of plastics on coastal blue carbon ecosystems, including the impact on soil properties, microbial communities, biota, and soil carbon stores of mangrove, seagrass, and salt marsh ecosystems
▪ The impact of plastics on the biological carbon pump, the health of marine bacteria, and carbon dioxide drawdown are the least tested endpoints	▪ Produce more experimental and field data on the impacts of plastics on understudied carbon cycle endpoints, including on the biological carbon pump, the health/integrity of marine bacteria, and carbon dioxide drawdown into surface waters
▪ Studies testing the impact of plastics on carbon fixation via plants, health of marine zooplankton, and other endpoints have produced conflicting results	▪ Produce more experimental and field data on the impact of plastics on carbon cycle endpoints that have had conflicting results, in particular, carbon fixation via plants and health/integrity of marine zooplankton ▪ Calculate effect sizes or magnitude of effect under specific experimental conditions across all carbon cycle endpoints

Knowledge Gaps	Research Directions
IMPACT CATEGORY #3 Impact of plastics on Earth's radiation budget	
▪ Radiative impacts are the least understood category of impacts, with much speculation surrounding the impact of plastics on direct radiative forcing, indirect radiative forcing, albedo, and melting rates of snow and ice ▪ The least understood radiative impact is the role that plastics play in indirect radiative forcing via clouds	▪ Conduct greater spatial and temporal sampling of plastics in the atmosphere and in clouds at different altitudes and recognize that plastic aerosols have become an element of airborne pollution ▪ Measure what types of plastics and how much are getting into clouds of different kinds at different altitudes ▪ Once more field data become available, perform calculations of direct and indirect radiative forcing due to the presence of plastic debris in the atmosphere and clouds, respectively. ▪ Determine the radiative forcing of aerosols generated from the burning of plastic waste ▪ After more radiative forcing data become available, calculate a mean global average temperature change due to the radiative impacts of plastics ▪ Perform more experiments investigating how plastics affect the number and size of cloud condensation nuclei relative to a control ▪ Determine how plastics alter the albedo of surfaces including grassland, soil, and water ▪ Conduct more experiments that examine how plastics affect the albedo and melting rate of ice and snow ▪ Calculate changes to the albedo of surfaces, ice, and snow, as well as changes to the melting rate of ice/snow, arising from the incorporation of plastics into their bulk

Additional Information and Considerations Regarding Future Research

Reflecting the realities of plastic pollution in experiments

Experiments and studies involving the impacts of a single kind of plastic (e.g., one color or polymer type) do not replicate what is encountered in real-life environments. While these experiments can still be valuable as a starting point, **researchers should endeavor to reflect the realities of plastic pollution in their experiments across impact categories**.

For example, future experiments should consider using pellet, foam-shaped, and fibrous microplastics — morphologies or shapes of microplastics that are understudied at present. Pellet and foam-shaped plastic particles are present in nature, as pellets can enter the environment through pellet spills, and foam is shed from construction sites and the breakdown of polystyrene (e.g., Styrofoam) food containers. Fibers are the most abundant microplastic in the environment by count due to how easily they shed from the large number of products containing plastic fibers, including clothing, carpets, fishing gear, and many more.

There are also emerging primary microplastics types (that fall under the “fragment” morphology) "that are becoming increasingly widespread and have the ability to pose risks to living organisms. Notable examples include paint and tire wear particles. These microplastics categories are also poorly studied and should be deployed in future carbon cycling and radiative studies to elucidate their impact on climate.

Last but not least, experimental studies investigating the impact of plastics should consider deploying a combination of micro- and nano-plastics of various sizes, shapes, colors, and polymer types to mimic the concoction of MNPs seen in nature. Experimental studies should be conducted for longer durations of time (>1 year) and in the field so that experimental conditions are more realistic. Experiments should also try to deploy plastics that have been weathered, biofouled (e.g., marine plastic), and/or otherwise altered to more realistically represent the physical and chemical properties of plastic debris in the environment for some time. These efforts at realism apply not just to experimental studies but also to modeling studies, which should likewise aim to reflect the complex realities of plastic pollution.

Determining the impacts of bioplastics

The same knowledge gaps identified for conventional plastics derived from fossil fuels likely exist for bioplastics as well. Bioplastics are an emerging group of plastics of different materials and applications that are expected to be safer and more sustainable than their conventional counterparts while still having the same desirable qualities of longevity, durability, and lightness. However, bioplastics often fall short of these expectations. The impact of bioplastics on climate was not investigated in the *Frontiers* paper because they currently make up a very small fraction of global plastic production by volume (< 1%), and even less data are available about their climate impacts than conventional plastics**.** However, since their production and use are expected to increase over time, future research should investigate how bioplastics (including polylactic acid and polybutylene adipate-co-terephthalate) could be impacting climate through their lifecycle GHG emissions, carbon cycle impacts, and radiation budget impacts.

Improving specificity and standardization in reporting

Researchers conducting future studies on the impacts of plastics and climate should make their findings more useful by **disaggregating categories to the extent feasible**. For example, studies have traditionally tended to lump the transportation and consumption stages of the plastics lifecycle together when reporting GHG emissions and emissions intensities, despite these two stages being quite different from each other. Even within these stages, there could be greater disaggregation. For instance, the transportation of plastics contains numerous phases, including local truck traffic and international export and import shipping activities. Similarly, the *Frontiers* paper utilized a “recycling (unspecified)” category of waste management because several studies did not specify mechanical or chemical recycling.

Improvements in reporting are also necessary to promote **harmonization** across the field of plastic pollution studies. Researchers tend to use different terminology and different units to describe the same phenomena in their studies, or they leave out the information necessary for studies to be comparable to one another. Greater standardization in methodology and reporting would help. For example, future experimental studies investigating the impact of microplastics on a carbon cycle or radiative endpoint should either use a consistent unit of plastic concentration or report microplastic concentrations in both units of mass (e.g., kg per some mass or volume) and units of count (e.g., number of particles per some mass or volume) when describing how much plastic was added to treatments.

RECOMMENDED POLICIES & OTHER NEXT STEPS

Introduction

There are policies and other measures at all levels of government and in the private sector to reduce the demand for and the production, use, disposal, and impacts of plastics. These include "extended producer responsibility" policies at regional and subnational levels, reuse and refill systems at city and company levels, and reduction and elimination of packaging and single-use plastics at all levels.[6] These and other measures have the potential to reduce plastics' impacts on climate change and other environmental and human health challenges, depending on how they are designed and implemented. The focus of this chapter, however, is specifically on actions that the public and private sectors could take to address the widespread data gaps regarding the impacts of plastics on climate, and to promote the inclusion of those impacts in all relevant impact assessments, scenarios, models, analyses, accounting, and policies that involve plastics, climate, and connected issues such as health, justice, and biodiversity.

The recommendations in this chapter are not meant to be comprehensive. Rather, they are meant to provide concrete suggestions and spur ideas for additional ways to address the plastics and climate nexus.

Recommended Public Sector Actions

Public sector bodies and governments have important roles to play in advancing a plastics-climate research agenda and in incorporating plastics' impacts on climate in both climate and plastics assessment reports.

At the international and multilateral level, the **UN's Intergovernmental Panel on Climate Change (IPCC)**, as the world's leading scientific body on climate change, is particularly important in this regard. Every 6-8 years, the IPCC produces comprehensive assessment reports that review the full breadth of scientific literature on climate change and, from this exercise, identify where there is scientific consensus. It is unclear which aspects of the plastics lifecycle are included in IPCC emissions estimates. It does not appear that the IPCC considers the impacts of plastics on the planet's carbon cycle and radiation budget. Given the extent of scientific expertise that goes into IPCC reports, however, the IPCC is well-positioned to account for the full climate impacts of plastics. Emissions from the full plastics lifecycle should be explicitly represented in IPCC emissions scenarios and models, and the impacts of plastics on Earth's carbon cycle and radiation budget should be factored into the IPCC's assessments and projections of the drivers and impacts of climate change.

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6 For examples of international and multilateral recommendations, see GRID-Arendal's report, Climate Impacts of Plastics: Global Actions to Stem Climate Change and End Plastic Pollution and the Duke University Nicholas Institute's Plastics Policy Inventory Database (a searchable, global database of policies to reduce plastic pollution) and its accompanying study of policy effectiveness.

The IPCC also produces special reports that assess specific issues (e.g., oceans, the impacts of 1.5ºC of warming). The IPCC should consider producing a Special Report on Plastics, Petrochemicals, and Climate Change, ideally working with a scientific body that may emerge from the forthcoming UN Plastics Treaty and/or other UN-related entities such as the United Nations Environment Assembly's science-policy panel on chemicals, waste, and pollution prevention. (The panel was established "to ensure that all pillars of the triple planetary crisis of climate change, nature and biodiversity loss, and pollution and waste have a dedicated global science-policy interface.")

As for the forthcoming **UN Plastics Treaty**, negotiations on which are ongoing, climate should be accounted for in any assessments of plastics' environmental impacts (e.g., MNPs' effects on carbon sinks and the radiation budget) and considered when developing any potential reporting or action requirements (e.g., mechanisms for measuring emissions across the plastics lifecycle). If a scientific body comparable to the IPCC emerges from the UN Plastics Treaty, it should assemble and gather data on the climate impacts of plastics (and other intersectional issues among UN treaties, including on health, chemicals, biodiversity, justice, and more), or at least coordinate closely with bodies such as the IPCC to ensure that relevant data are collected in a standardized manner and synthesized. Other multilateral plastics initiatives, such as the Ocean Plastics Charter, should likewise support data collection and spread awareness of the climate impacts of plastics.

National and subnational governments also have levers they can use to support the plastics-climate research agenda and consideration of plastics' climate impacts. Governments should provide much-needed support (e.g., funding, data collection) for research and analyses of plastics' impacts on climate.[7] They should also factor plastics' impacts into their national greenhouse gas emissions inventories, their nationally determined contribution (NDC) submissions under the Paris Agreement to the UN Framework Convention on Climate Change, and their assessment reports exploring how climate change may affect their jurisdictions.

In addition, governments could consider modifying laws and regulations to encourage the private sector to be more transparent about the ingredients used in plastics (discussed below). In the United States, that could mean modifying the confidential business information provisions of the 1976 Toxic Substances Control Act (TSCA) and including the chemicals in plastics in the Toxics Release Inventory (TRI) established by the Emergency Planning and Community Right-to-Know Act (EPCRA). In the European Union, it could mean strengthening the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation.

7 As the Environmental Law Institute and Monterey Bay Aquarium note in their report on Existing U.S. Federal Authorities to Address Plastic Pollution, the United States could use legal authorities such as the Emergency Planning and Community Right-to-Know Act, Consumer Product Safety Improvement Act, and Marine Debris Research, Prevention, and Reduction Act to collect information and data and conduct research, including on pollutant emissions, plastic production, and waste releases.

Recommended Private Sector Actions

Businesses and other private entities have unique ways they can support enhanced understanding and incorporation of plastics' impacts on climate, as well as some ways that are similar to those in the public sector. Businesses, particularly those that operate across the plastics lifecycle, should both **monitor and disclose** the contribution of plastics to GHG emissions and, where relevant, the release of MNPs. The private sector should also factor GHG emissions from across the plastics lifecycle into emissions inventories and should generally consider the plastics-climate nexus in sustainability reports, targets, and plastics reduction initiatives.

One important way that businesses can contribute to providing information essential to calculating plastics' impacts on climate (and on ecosystem and human health) is by **improving transparency about the polymer makeup of plastics and about the ingredients added to plastics**. There are over 16,000 chemicals used in plastics, and rarely do regulators or the public know which ones are in which product. Depending on the mix of ingredients, different types and amounts of gases are emitted throughout the plastics lifecycle, including while they are in use and when they degrade in the environment. Similarly, knowledge about ingredients will be helpful in evaluating impacts to carbon sinks due to the physical and/or chemical properties of plastics. As just noted, governments should consider modifying laws and regulations to encourage or require such transparency.

CONCLUSION

The body of evidence related to the impacts of plastics on climate is growing, but it is still woefully incomplete, as the *Frontiers* gap analysis and this summary report show. Researchers must continue to build the body of evidence, including GHG emissions throughout the entire plastics lifecycle and the effects of plastics on the planet's carbon cycle and radiation budget. Without additional data, the impact of plastics on global average surface temperatures will remain underappreciated and undercounted.

Awareness must also be raised among scientists, policymakers, institutions, companies, investors, educators, and others about the climate impacts of plastics and the importance of accounting for them. Incorporating the full range of impacts in scenarios, models, analyses, and assessment reports — even while recognizing the limitations of current data — is important if the goal is to achieve both comprehensiveness and accuracy.

Only by enhancing understanding of and rigorously accounting for the ways these two global challenges are intertwined will it be possible to address them both effectively.

Plastics & Climate

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