Plastics: Exposing Their Climate Impacts

"Plastics: Exposing Their Climate Impacts, *What we know, what we need to know, & recommendations for research and policy"* is the first report to comprehensively assess the data on the climate impacts of plastics. The report analyzes existing peer-reviewed data, identifies critical data gaps, lays out a roadmap for continued research, and recommends policies and actions to support that research and include plastics' climate impacts in relevant analyses.

The report is authored by leading experts from The Plastics and Climate Project (Dr. Xia (Alice) Zhu, a Banting Postdoctoral Fellow in the Department of Ocean Sciences, Memorial University of Newfoundland, and Holly Kaufman, Senior Fellow at the World Resources Institute) and the Environmental Law Institute (Cecilia Diedrich, Staff Attorney, and Dr. John Doherty, Science and Policy Analyst), with key input from the Monterey Bay Aquarium and Dr. Karen Raubenheimer, Senior Lecturer, Australian National Centre for Ocean Resources and Security, University of Wollongong, Australia. The report is a non-technical summary of a published scientific paper, "The knowns and unknowns in our understanding of how plastics impact climate change: A systematic review", published in April 2025 in *Frontiers of Environmental Science.*

The Problem

Plastics are not just a "waste" problem, where visible trash accumulates in ocean gyres and garbage dumps, continually leaching harmful chemicals and shedding micro- and nano-plastic particles. Plastics are also a climate problem, emitting greenhouse gases and altering planetary systems such as the Earth's carbon cycle and radiation budget.

Plastics: Exposing Their Climate Impacts provides a comprehensive synthesis of the current scientific understanding of the impacts of plastics on the climate. The report reviews the existing literature on how plastics affect global warming and, consequently, climate change, identifies significant knowledge gaps, and proposes a research agenda and policy recommendations to address these critical gaps. The findings and proposals are intended to raise awareness and spur action by policymakers, scientists, industry, investors, educators, and non-governmental and community representatives. The report is timely, given the upcoming negotiations on an international legally binding treaty on plastic pollution in August 2025.

Key Scientific Findings

The report (and the scientific paper on which it is based) identified three primary pathways through which plastics impact the climate.

1. **Greenhouse Gas (GHG) Emissions Across the Plastics Lifecycle:** The plastics lifecycle is divided into four main stages: primary production (including fossil fuel extraction and creation of plastic monomers), manufacturing of plastic products, transportation/consumption, and waste management. The entire lifecycle of plastics generates substantial greenhouse gas emissions. Current data indicate that plastics are responsible for approximately 4% of global GHG emissions, making the plastics sector the world's fifth-largest emitter if it were a country. With plastic production expected to triple by 2060, these emissions are projected to rise considerably, using up even more of the remaining global carbon budget.
    - **Primary Production:** This stage is the most emissions-intensive, with estimates as high as 12.9 kg CO_2e per kg of plastic, over five times the GHG emissions intensity of coal burning.
    - **Waste Management:** The incineration of plastics appears to be the largest source of emissions among waste management strategies, though estimates vary widely. Chemical recycling, depending on the exact type, can also be quite emissions-intensive.
    - **Data Gaps:** Plastics' GHG emissions are likely undercounted due to current data gaps and methodological limitations. 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), and even there, the range of estimates can be very wide. Comprehensive data are lacking for the middle lifecycle stages (particularly transportation and consumption/use). National-level data are also lacking for all but 14 countries, making global estimates uncertain. In addition, there is 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.
2. **Impacts on the Carbon Cycle:** Plastics, including micro- and nano-plastics, disrupt key processes within ecosystems—terrestrial, marine, and coastal—essential to Earth's ability to sequester carbon.
    - **Ocean Impacts:** Plastics harm the ocean's "biological carbon pump" and marine phytoplankton, reducing marine systems' ability to remove and store carbon from the atmosphere.
    - **Soil Impacts:** Most studies indicate that plastics increase soil respiration, resulting in higher CO_2 release, though results are more mixed regarding plastics' impacts on soil microbes, soil biota, and soil carbon stores.
    - **Overall Trend:** Across 291, or about 68%, of the scientific tests, it was found that plastics would lead to additional warming by negatively affecting carbon sinks or increasing carbon release.
3. **Impacts on the Radiation Budget and climate instability:** This area is the least understood climate impact. Plastic particles may alter the Earth's radiative balance by influencing surface

reflectivity (albedo) or by interacting with clouds and atmospheric energy exchange. This has implications for Earth's surface temperature.

- **Preliminary Findings:** Plastics on the planet's surface may increase reflectivity, potentially causing a cooling effect. Airborne plastics might affect energy flows and clouds. However, these effects are not well quantified, and the results are highly uncertain due to the limited number of studies.

These findings culminated from a systematic review of nearly 6,400 peer-reviewed papers, which were narrowed down to the most relevant and robust data and analyzed 143 studies in total.

- 36 studies on greenhouse gas emissions across the plastics lifecycle.
- 83 studies on the impact of plastics on carbon sinks.
- 24 studies on the impact of plastics on Earth's radiation budget.

Research Agenda and Knowledge Gaps

The body of evidence regarding the impact of plastics on climate is incomplete. Numerous knowledge gaps, unclear results, and methodological shortcomings limit the ability to gain a complete understanding of how plastics could be affecting climate change. The report identifies several critical research needs to be filled:

- **GHG Emissions:** More studies are needed across all lifecycle stages, particularly for understudied stages, at national and global scales. More studies are also needed on GHG emissions based on different feedstocks and across different polymer types.
- **Carbon Sinks:** Additional studies and models are required to understand plastics' effects on terrestrial, marine, and coastal carbon sinks, especially where current results are conflicting or unclear.
- **Radiative Effects:** Research into how plastics in the atmosphere and on the planet's surface impact the Earth's energy balance is urgently needed, including on what types of plastics and how much are getting into clouds at different altitudes and on how plastics affect the albedo and melting rate of ice and snow.
- **Methodological Improvements:** Future studies should use realistic mixtures of plastic types, shapes, and weathered states in their research and report results with greater specificity and standardization to enable data comparability.
- **Bioplastics:** As bioplastics production increases, their climate impacts must be studied with the same rigor as conventional plastics.

Policy Recommendations

The public and private sectors should take action 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.

Public Sector – International Organizations:

- The Intergovernmental Panel on Climate Change (IPCC) should explicitly include allowance for plastics' full climate impacts in its assessment reports, GHG emissions

scenarios, and models. The IPCC should produce a Special Report on Plastics, Petrochemicals, and Climate Change.
- Ongoing negotiations for the UN Plastics Treaty should ensure climate impacts are incorporated into plastics-related assessments and reporting frameworks.

Public Sector – National/Local Governments:
- Governments should support research and integrate plastics' climate impacts into national GHG emissions inventories and nationally determined contribution (NDC) submissions under the Paris Agreement to the UN Framework Convention on Climate Change.
- Governments should modify laws and regulations to have the private sector be more transparent about the ingredients used in plastics, which will aid in determining full-lifecycle emissions and impacts on planetary processes.

Private Sector:
- Companies should monitor and disclose the contribution of plastics to their GHG emissions, as well as micro/nanoplastic releases, and should incorporate these into their sustainability reports and reduction initiatives.
- Companies should provide information essential to calculating plastics' impacts on climate by improving transparency about the polymer makeup of plastics and the ingredients added to plastics.

Conclusion

The evidence is clear that plastics are not just an environmental waste, a human health and justice problem, but also an increasingly significant and underappreciated driver of climate change. Current data indicate that plastics account for at least 4% of global GHG emissions and affect planetary processes such as the carbon cycle and radiation budget. With plastic production expected to triple by 2060, these emissions and other impacts are projected to rise considerably. While the body of evidence related to the impacts of plastics on climate is growing, it remains woefully incomplete. Immediate action is needed to support targeted research, improve data collection and reporting, and ensure that plastics' climate impacts are fully integrated into climate policy, climate modeling, and carbon accounting. Only by enhancing understanding of and rigorously accounting for how these two global challenges are intertwined will it be possible to address them effectively.