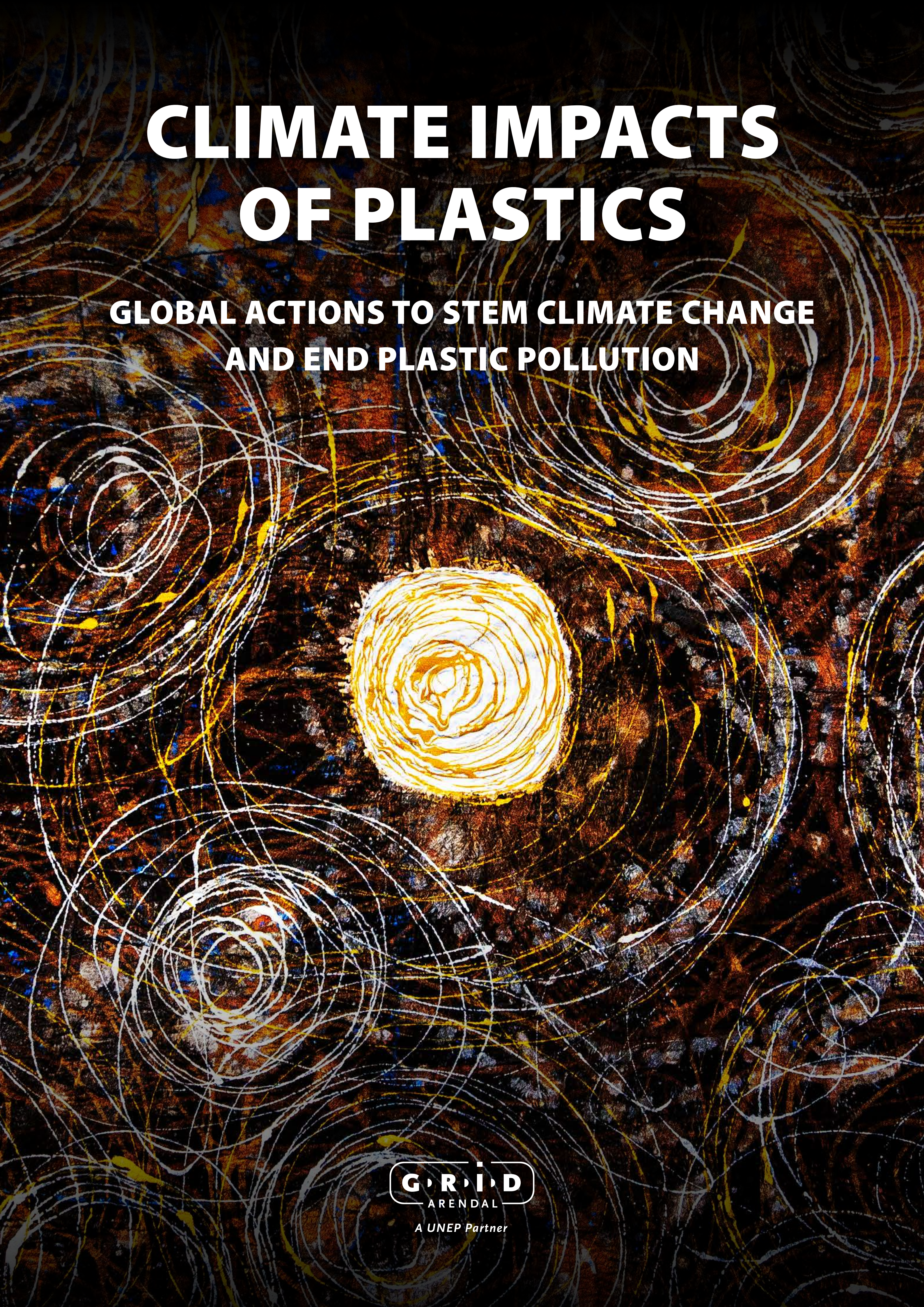
# CLIMATE IMPACTS OF PLASTICS

## GLOBAL ACTIONS TO STEM CLIMATE CHANGE AND END PLASTIC POLLUTION



GRID ARENDAL

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**ISBN:** 978-82-7701-219-3

**Recommended citation**
GRID-Arendal (2024). *Climate impacts of plastics: Global actions to stem climate change and end plastic pollution*. Norway.

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**Acknowledgements**
This publication was financially supported by the Government of Norway.

The following experts are gratefully acknowledged for being in the project's expert group and supporting the preparation of the report by providing comments and suggestions on the draft report: Alexandra R. Harrington (Lancaster University; IUCN WCEL); David Jose Vivas Eugui (UNCTAD); Fredric Bauer (Lund University); Joachim Peter Tilsted (Lund University); Luisa Cortat Simonetti Goncalves (the Academy of European Law); Carolyn Deere Birkbeck, Holly Kendall and Mahesh Sugathan (TESS) and the UNFCCC Secretariat.

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# Acronyms

| | |
|---|---|
| CCU | Carbon capture and utilisation |
| $CO_2e$ | Carbon dioxide equivalents |
| EPR | Extended Producer Responsibility |
| EPS | Expanded polystyrene |
| ETF | Enhanced Transparency Framework |
| EU | European Union |
| Eurostat | the Statistical Office of the European Union |
| FAOSTAT | the Statistical Division of Food and Agriculture Organization of the United Nations |
| GHG | Greenhouse gas |
| Gt | Giga tonnes |
| HAC | High Ambition Coalition |
| HDPE | High-density polyethylene |
| HFC | Hydrochlorofluorocarbon |
| HS | Harmonized System |
| IEA | International Energy Agency |
| IMO | International Maritime Organization |
| INC | Intergovernmental Negotiating Committee |
| IPCC | the Intergovernmental Panel on Climate Change |
| ISO | International Organization for Standardization |
| IUCN | International Union for Conservation of Nature |
| LCA | Life Cycle Assessment |
| LDPE | Low-density polyethylene |
| LT-LEDS | Long-term Low-emission Development Strategies |
| MARPOL | International Convention for the Prevention of Pollution from Ships |
| MEA | Multilateral Environmental Agreements |
| NACE | Statistical classification of economic activities |
| NCM | Nordic Council of Ministers |
| NDC | Nationally Determined Contributions |
| OECD | the Organisation for Economic Co-operation and Development |
| PE | Polyethylene |
| PET | Polyethylene terephthalate |
| PP | Polypropylene |
| PP&A | Polyester, Polyamide, and Acrylic |
| PS | Polystyrene |
| PU | Polyurethane |
| PUA | Problematic, unnecessary and avoidable products |
| PVC | Polyvinyl chloride |
| SDG | Sustainable Development Goals |
| SPI | Science-Policy Interface |
| SPP | Science-Policy Panel |
| UNCTAD | United Nations Conference on Trade and Development |
| UNDP | the United Nations Development Programme |
| UNEA | United Nations Environment Assembly |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNITAR | United Nations Institute for Training and Research |
| US | the United States of America |
| WBCSD | the World Business Council for Sustainable Development |
| WCEL | World Commission on Environmental Law |
| WEEE | waste of electrical and electronic equipment |
| WRI | the World Resources Institute |
| WTO | World Trade Organisation |
| XPS | Extruded polystyrene |

# Foreword

The triple planetary crisis, consisting of climate change, biodiversity loss, and pollution, threatens our most important asset – Nature. Climate change is well recognised as the world moves rapidly towards, and beyond, 1.5 degrees of warming. The impact of this warming is challenging both nature and people, with an increase of extreme weather, biodiversity loss, and economic loss. We must increase our actions to halt climate change, and look for synergies between our actions to tackle each planetary crisis.

Plastic is a useful material, an integral part of our daily lives that has helped shape our modern lifestyle. However, the mismanagement of plastic waste has resulted in widespread pollution, with plastic waste found from the high mountains to the deep sea. While plastic pollution has mostly been viewed as a waste-centric issue, there are hidden climate impacts throughout the plastics life cycle, including the sourcing of raw materials and plastic production. The science clearly indicates that greenhouse gas emissions from the plastics life cycle are substantial. The environmental impact of plastics is no longer only a waste management problem, and addressing plastics can also become a part of climate action.

Many of us aspire to make a difference by purchasing more sustainable products and increasing their reuse. However, individual actions alone are not sufficient to drive the transformative change needed to tackle the triple planetary crisis. This transformation requires courageous political decisions to implement and enforce measures that genuinely create change – such as limiting production and consumption, promoting reuse systems, and making the right decisions about managing waste.

The landmark resolution of the United Nations Environment Assembly (5/14) mandated the development of a binding global plastics instrument based on 'a comprehensive approach that addresses the full life cycle of plastics.' By adopting a whole of life cycle approach to plastics, we can not only address plastic pollution, but also the hidden greenhouse gas emissions, thus contributing to positive climate action.

**Karen Landmark**
Managing Director
GRID-Arendal

# Executive summary

**This report seeks to identify options for measures and strengthen governmental accountability in addressing the climate impacts of plastics. It aims to maximise the climate benefits of the plastics instrument, clearly delineating responsibilities in conjunction with the UNFCCC and the Paris Agreement.**

## The scientific foundation

Science provides strong evidence of the climate impacts generated across the full life cycle of plastics. Greenhouse gases are emitted throughout the entire life cycle of plastics, estimated as between 3.8 and 4.5 per cent of global greenhouse gas emissions. This is set to grow with a projected increase in primary plastic production.

The production landscape remains dominated by fossil-based plastics, accounting for approximately 90.6 per cent of global production. Secondary plastics constitute 9 per cent, bio-based plastics comprise 0.5 per cent, and carbon-captured based polymers <0.1 per cent. In addition, the production and manufacture of plastic polymers is energy intensive and relies predominantly on energy from fossil fuels, such as coal.

The plastic production stage accounts for 85 per cent of greenhouse gas emissions and the sourcing of raw materials for 9 per cent, whereas the waste management stage accounts for 6 per cent of total plastics-related emissions. The calculations of waste management exclude the emissions from unregulated disposal and open burning. Furthermore, the greenhouse gas emissions linked to the use and reuse of plastics are not quantified and remain an area of uncertainty.

Recent studies indicate that plastic pollution further exacerbates climate change through negative feedback loops observed in various environments, such as sediments, water columns, soil, the cryosphere, and the atmosphere. These complex interactions suggest that the true impact of plastics on greenhouse gas emissions is likely substantially higher than present estimates indicate, pointing to a considerable underestimation of their environmental impact.

## The role of the plastics instrument in stemming climate change

The development of the binding global plastics instrument (the instrument) provides a unique opportunity to strengthen global efforts in addressing climate change across the plastics life cycle.

The instrument should explicitly recognise greenhouse gas emissions as a plastic pollutant, in alignment with the United Nations Environment Assembly (UNEA) resolution 5/14 that mandates the development of an international legally binding instrument that is based on "a comprehensive approach that addresses the full life cycle of plastics" (United Nations Environment Programme [UNEP] 2022a). The zero draft of the plastics instrument supports this comprehensive approach by defining plastic pollution as "the negative effects and emissions resulting from the production and consumption of plastic materials and products across their entire life cycle" (UNEP 2023a). This inclusive definition is essential for addressing plastics pollution as part of a wider strategy to combat the triple planetary crisis, emphasizing the need to tackle it not just as a waste-centric problem, but also in relation to its impacts on climate change and biodiversity loss.

The instrument should align with the global goal set by the Paris Agreement to keep the global temperature increase below 2°C, preferably aiming for 1.5°C, compared with pre-industrial levels, and incentivise climate co-benefiting actions within the plastic pollution context. This could be further supported by acknowledging the instrument's role in the protection of the climate system alongside its role in safeguarding human health and the environment.

Against this backdrop, this report outlines specific measures to combat climate change along the plastics life cycle. To generate the greatest impacts regarding greenhouse gas reduction, the primary focus must be on reducing the production of plastics and focusing on low-carbon design. Limiting greenhouse gas emissions from waste management and remediation also play important roles. More specifically, under the plastics instrument, negotiators can strengthen global climate action by developing measures to:

- **Reduce overall production of primary polymers** by reducing their use, increasing use of secondary plastics, phasing out problematic, unnecessary, and avoidable plastic products and increasing the use of low-carbon non-plastics substitutes.
- Limit greenhouse gas emissions by developing **design criteria** that focus on 1) employing low-carbon polymers, 2) using polymers with low net-energy requirements considering the full life cycle, particularly production, and that are suitable for reuse/refill systems and mechanical recycling, and 3) minimising the release of microplastics.

- Limit greenhouse gas emissions of **waste management** by 1) limiting open burning and other forms of mismanagement of plastic waste, and 2) developing criteria to support the life cycle assessment of waste management facilities towards investment in lower-emitting technologies and avoiding lock-ins to high-emitting technologies.
- Highlight the critical need to address **plastic pollution in the environment** and its impacts on climate change through proactive measures on environmental and landfill remediation.
- Strengthen **trade control measures** to include considerations of greenhouse gas emissions.

## The role of the UNFCCC and the Paris Agreement in addressing plastic-related emissions

Under the UNFCCC and the Paris Agreement, there is opportunity to strengthen efforts to reduce greenhouse gas emissions from the processes and activities associated with the plastics life cycle, particularly the energy used for heat and transport, while acknowledging that it will be important to tackle "carbon lock-ins" of long-term infrastructure investments. To this end, decarbonisation of the plastics life cycle provides the greatest potential to reduce overall emissions across the plastics life cycle, complementing the activities of the plastics instrument.

However, the absence of direct reference to plastics as a material and the plastics industry is a critical gap in the UNFCCC and the Paris Agreement. The analysis of the national reports under the UNFCCC and the Paris Agreement revealed a lack of a comprehensive reporting mechanism to account for plastics contribution to climate change, and to assess the effectiveness of mitigation actions to reduce emissions associated with plastics.

Recent developments under the UNFCCC and the Paris Agreement provide momentum for more targeted action on plastics. The conclusion of the first global stocktake of climate action under the Paris Agreement at the UNFCCC COP-28 led to the adoption of a decision calling for "transitioning away from fossil fuels in energy systems, in a just, orderly, and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050" (UNFCCC 2023a). This marks a pivotal step towards decarbonising the plastics life cycle, although it presently addresses fossil fuels in energy systems rather than as raw materials in plastics production.

Recognising the energy-intensive nature of plastics production and the work towards decarbonising the plastics life cycle is also supported by the Sharm El-Sheikh Implementation Plan, adopted at the UNFCCC COP-27 in 2022. The plan notes "the importance of transition to sustainable lifestyles and sustainable patterns of consumption and production for efforts to address climate change" (UNFCCC 2022). Moreover, the decision on the first global stocktake adopted at COP-28 notes the importance of circular economy approaches in transitioning to sustainable lifestyles and sustainable patterns of consumption and production in efforts to address climate change (UNFCCC 2023a).

The role of Nationally Determined Contributions (NDCs) in decarbonising the entire life cycle of plastics should be emphasized. Similarly, Long-term Low-emission Development Strategies (LT-LEDS), encouraged under the Paris Agreement are also critical in this regard, especially for strategic long-term planning to transition to net-zero emissions by, or around, mid-century.

## Areas for collaborative arrangements to mitigate climate impacts of plastics

Under **the plastics instrument, the UNFCCC and the Paris Agreement**, collaboration between these Multilateral Environmental Agreements should aim to:

- Promote research, innovation and low-carbon technology development to expedite the reduction of greenhouse gas emissions and to remove uncertainties related to certain technologies, like chemical conversion and carbon capture and utilisation (CCU), before their inclusion in the agreements.
- Strengthen transparency and accountability by developing an indicator framework to track climate-related measures under the new plastics instrument and disaggregate plastics-related greenhouse gas emissions under the UNFCCC.
- Scale sustainable financing from public and private sources to address the climate component of plastics and emphasize the need for the financial sector to shift investments aways from fossil-based and emissions-intensive petrochemical production.

## Other findings

The findings of the report are supported by a review of country and group submissions to INC-3. A total of 125 countries provided inputs related to climate change, indicating the inclusion of greenhouse gas emissions as a plastic pollutant under the new global plastic instrument, and for the plastic instrument to strengthen action against climate change.

This report also points out that the absence of internationally agreed definitions and harmonised terminology in research and national reporting presents a significant challenge in understanding and communicating intervention points for addressing the climate impacts of plastics. Clear definitions for the life cycle stages and associated measures are needed to help generate a common understanding of the problem, its broader linkages to climate change and necessary interventions to address them.

# 1 Introduction

**Plastics make a substantial contribution to annual greenhouse gas emissions throughout their life cycle. It is estimated that plastics account for greenhouse gas emissions ranging from 1.8 gigatonnes (Gt) to 2 Gt of carbon dioxide equivalents ($CO_2e$), representing approximately 3.8 per cent to 4.5 per cent of global greenhouse gas emissions. The drivers of this trend extend throughout the plastics life cycle, including the sourcing of raw materials, plastic production, use and waste management stages. The plastic production stage, accounting for most greenhouse gas emissions, is an energy-intensive process which depends on fossil fuels.**

In 2015, at the twenty-first Conference of the Parties to the UNFCCC, 196 Parties committed to limiting global warming to well below 2°C, aiming for 1.5°C, compared with pre-industrial levels, by adopting the Paris Agreement. Further, in 2023, the Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) decided to transition away from fossil fuels in energy system towards renewable energy and increase energy efficiency (UNFCCC 2023a).

In contrast, the persistent issue of plastic pollution has only recently captured the attention of decision makers, resulting in a landmark decision in 2022 by the United Nations Environmental Assembly adopting resolution 5/14 to work towards an international legally binding instrument to end plastic pollution. This resolution mandated the United Nations Environment Programme (UNEP) to convene an intergovernmental negotiating committee (INC) to develop a legally binding instrument on plastic pollution based on a comprehensive approach to the full life cycle of plastics.

Given that addressing plastics is a necessary pathway in reducing greenhouse gas emissions and achieving the climate target, the aim of this report is to identify entry points for complementary international action to stem climate change and to end plastic pollution. Specifically, objectives of the report include the following:

1. To identify the existing plastics-climate efforts and provide additional options strengthening the accountability of governments to address plastic pollution and climate change at the global level
2. To maximise the climate benefits by providing measures through the global plastics instrument
3. To improve institutional capacity to jointly minimise the effects on climate change across the plastics life cycle at the national and global levels, including relevant multilateral environmental agreements (MEAs) and United Nations entities.

The report is organised into five chapters. Chapter 2 ("Greenhouse gas emissions across the plastics life cycle") is specifically dedicated to impacts of greenhouse gas emissions throughout the stages of the plastics life cycle, beginning from the sourcing of raw materials to waste management, and plastic pollution in the environment. Moreover, the transport and trade sector emerges as a cross-cutting issue relevant to every stage of the global plastics economy. Chapter 3 ("Current efforts to address the impact of plastics on climate change") examines the current efforts in addressing plastic impacts to climate change by analysing the plastics-related measures and actions reported in the UNFCCC and the Paris Agreement national submissions. Based on a review of relevant literature and complemented by the results of the analysis in section two, Chapter 4 ("Measures to optimise climate benefits across the plastics life cycle") suggests measures that co-benefit addressing plastic pollution and achieving the global climate target under both the plastics instrument and the UNFCCC, as well as areas of joint actions across the plastics instrument and the UNFCCC. Considering the interconnected nature of the plastics problem, Chapter 5 ("Institutional collaboration") provides an overview of synergies in existing MEAs and institutional mechanisms. The final considerations of the report are presented in the conclusions. The report includes a glossary, 4 appendices, 4 tables and 6 figures.

## Methodology

The methodology of the report encompasses the following interrelated components:

- **Literature review**: The review of the latest available scientific evidence of the drivers of climate change across the plastics life cycle, drawing from authoritative reports and academic articles. The literature review identified potential climate entry points in addressing plastics at the international level through control measures and voluntary approaches.
- **Empirical study**: This component provides the analysis of existing reports submitted by the Parties under the UNFCCC and the Paris Agreement as well as Member States' written submissions prior to the third session of the INC on Plastic Pollution. These reports include the nationally determined contributions (NDCs), biennial reports and biennial update reports available under the current requirements for reporting.[1] The documents were studied through the application of content analysis as a methodology, guided by research questions. NVivo, a qualitative data analysis computer software, was used to facilitate the analysis of the documents.
- **Analysis of official documents**: The analysis of the documents includes the synthesis report on the submissions received on elements not discussed at the second session, such as principles and scope of the instrument (UNEP/PP/INC.3/INF/1), the zero draft text of the international legally binding instrument on plastic pollution, including in the marine environment (UNEP/PP/INC.3/4) and plastics science (UNEP/PP/INC.1/7) prepared by the secretariat of the INC on Plastic Pollution.
- **Database assessment**: This part of the methodology involves a search in various online databases hosted by international organisations to understand if and how data on greenhouse gas emissions from the plastics life cycle is available beyond the UNFCCC.
- **Review of MEAs**: A mapping of MEAs obligations related to the impacts of plastics on climate change across life cycle. The mapping is general in nature and based on the conventions' texts.

In addition, to complement the literature review and gain insight into prospective and innovative solutions to addressing plastics from a climate perspective, an **online survey** was conducted. The survey was distributed to INC and the UNFCCC focal points and comprised the following questions:

- *Does your country have promising practices that address climate change by tackling plastic issues through its life cycle? If yes, provide examples of such practices.*
- *Does your country collect data on greenhouse gas emissions from the plastics life cycle stages, specifically in the production, consumption and waste management phases? This could include collection for national statistics or reporting outside the UNFCCC requirements, such as the Organisation for Economic Co-operation and Development (OECD) reporting. If yes, please provide further details of such reporting and links to any publicly available data on reports.*
- *Do you have suggestions for how the new global instrument to end plastic pollution should assist in addressing climate change?*

Collecting answers from a total of 162 respondents, the survey provided valuable insight to inform the report's content and validate national submissions under the UNFCCC.

Further, an **expert group** was established to provide input throughout the preparation of the report. The expert group provided a platform to consult with representatives from governments, NGOs, academia, MEA secretariats, foundations, think tanks and United Nations entities. The first meeting of the expert group was held on 28 May 2023 in Paris, France, where the report's outline and methodology were discussed. Two further online workshops were held as follows:

- 27 June 2023 – focus on identification of entry points for climate action in the plastics instrument
- 17 October 2023 – focus on provision of feedback for the first draft of the report

## Glossary

For the purposes of this report, the following terminology is used:[2]

- ***Avoidable plastic products***: Products with a function that is essential, but the demand for the product can be reduced with non-plastic substitutes, alternate designs and alternate practices (Nordic Council of Ministers [NCM] 2024).
- ***Bio-based plastics***: Composed or derived in whole or in part of biological products issued from the biomass (including plants, animal and marine or forestry materials) (adapted from Vert et al. 2012).
- ***Biodegradable plastics***: Plastics made from biomass- or fossil-based sources and are intended to biodegrade more rapidly than conventional plastics but require specific conditions.
- ***Carbon footprint***: The total amount of greenhouse gas emissions that is emitted by an individual, organisation, event, product or other entity, directly or indirectly, over a certain period, typically measured in units of CO2 equivalents and reflects the impact of that entity's activities on global warming.
- ***Chemical conversion***: A broad term for various processes that break down plastic waste into monomers, oligomers or hydrocarbons, mainly through solvolysis (i.e. depolymerising plastics into monomers), pyrolysis (i.e. converting plastics into pyrolysis oil) and gasification (i.e. converting plastics into syngas) (adapted from Jiang et al. 2022).
- ***Chemicals***: Chemical elements and compounds, and mixtures thereof, whether natural or synthetic (Chemicals Convention 1990).
- ***Circularity***: Using any resource more efficiently by keeping the material in use for as long as possible.
- ***Compostable plastics***: A subset of biodegradable plastics, mainly for industrial composting, with some

suitable for home composting (adapted from Scientists' Coalition 2023).

- ***Conversion***: The transformation of raw plastic resins into finished products through manufacturing techniques like moulding and extrusion.
- ***Cracking***: A specific technique of refining used for breaking down large hydrocarbon molecules into monomers/precursors, using methods like thermal, catalytic or hydrocracking.
- ***Decarbonisation***: The process by which countries, individuals or other entities aim to achieve zero fossil carbon existence. Typically refers to a reduction of the carbon emissions associated with electricity, industry and transport (Masson-Delmotte et al. 2018).
- ***Depolymerisation***: Breaking down plastics into monomers through solvolysis.
- ***Disposal***: Includes landfilling of plastic waste (controlled), as well as mismanagement of plastic waste (uncontrolled).
- ***Dumpsite***: An open location where collected waste is deposited in an uncontrolled manner allowing the top layer to be free to escape into the environment.
- ***Incineration***: Destruction and transformation of material to energy by combustion (UNEP 2023b).
- ***Gasification***: A chemical conversion process that transforms plastics into syngas (synthesis gas) through partial oxidation at high temperatures.
- ***Life cycle***: The consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal (International Organization for Standardization [ISO] 2006).
- ***Mechanical recycling***: A process that includes sorting, cleaning, shredding and melting plastic waste to reprocess it into new materials, while maintaining the plastic's original chemical structure.
- ***Microplastics***: Plastic particles less than 5 millimetres (<5mm) in diameter, including nano-sized particles (UNEP 2023b).
- ***Mismanaged waste***: Waste not handled by advanced collection or treatment systems, often burned in open areas, dumped in water or left in unsanitary landfills and dumpsites.
- ***Nanoplastics***: Plastic particles less than 1 micrometre (<1 µm) in diameter (Gigault 2018).
- ***Non-plastic substitutes***: Materials derived from natural, non-fossil sources including plants or minerals that are not considered plastic (adapted from United Nations Conference on Trade and Development (UNCTAD 2023a).
- ***Open burning***: Waste that is combusted without emissions cleaning (UNEP 2023b).
- ***Plastics industry***: Encompasses activities related to the production of raw materials and the processing of these materials into various plastic products.
- ***Plastic leakage***: Flow of plastics into the terrestrial and aquatic environment
- ***Plastics life cycle***: Extraction of natural resources and including material processing, manufacturing, marketing, distribution, use and waste management (UNEP 2016).
- ***Plastic pollution***: The negative effects and emissions resulting from the production and consumption of plastic materials and products across their entire life cycle, including plastic waste that is mismanaged (e.g. open-burned and dumped in uncontrolled dumpsites) and leakage and accumulation of plastic objects and particles that can adversely affect humans and the living and non-living environment (UNEP 2022b).
- ***Plastic pollution in the environment***: Existing and future contamination of the environment by plastics in all forms.
- ***Plastics***: Solid materials that contain as an essential ingredient one or more high-molecular-mass polymers, and which are formed (shaped) by heat and/or pressure during either the manufacture of the polymer or the fabrication into a finished product. Plastics have material properties ranging from hard and brittle to soft and elastic (International Convention for the Prevention of Pollution from Ships [MARPOL] 2011).
- ***Pollution***: Contamination of the environment by plastics in all forms, including plastics-related chemicals and greenhouse gas emissions across the life cycle.
- ***Polymerisation***: Process where monomers are chemically bonded under high temperatures, pressures and often with catalysts, to form polymers.
- ***Polymer***: Substance composed of macromolecules (International Union of Pure and Applied Chemistry 1996).
- ***Precursors***: Basic monomer chemicals derived from feedstocks like petroleum or natural gas, serving as the building blocks for polymers.
- ***Primary plastics***: Plastics manufactured from fossil-based (e.g. crude oil) or bio-based (e.g. corn) feedstock that has never been used or processed before.
- ***Primary polymers***: Polymers manufactured from fossil-based (e.g. crude oil) or bio-based (e.g. corn) feedstock that has never been used or processed before (OECD 2022a).
- ***Problematic plastic products***: Products with negative impacts across the life cycle of the polymers and products (environmental and human health) (NCM 2024).
- ***Product***: Manufactured combination of materials that contains plastic polymers, including component items containing plastic polymers and final manufactured products containing plastic polymers.
- ***Pyrolysis***: A chemical conversion method that transforms plastics into pyrolysis oil through thermal decomposition.
- ***Recycling***: Processing of waste materials for the original purpose or for other purposes, excluding energy recovery (ISO 2013).
- ***Refining***: Process of converting crude oil and processing renewable feedstocks into products like naphtha, while natural gas processing treats natural gas to extract liquids such as ethane and propane.
- ***Rehabilitation***: See restoration.
- ***Remediation***: The process of removing plastic pollution from the environment.
- ***Renewable feedstocks***: Carbon-based raw materials that are continuously renewed in nature, such as biomass or atmospheric CO2, and can be used as inputs for various processes or products.
- ***Resins***: a natural or synthetic solid or viscous organic polymer used as the basis of plastic, adhesives, varnishes or other products (UNEP 2023b).

- ***Restoration***: Ecological restoration of degraded ecosystems and wildlife populations affected by plastic pollution in the environment.
- ***Reuse***: Use of a product more than once in its original form (ISO 2013).
- ***Sanitary landfill***: Location where collected waste is safely disposed of and isolated from the environment.
- ***Secondary plastics***: Plastic polymers manufactured from recycled material (OECD 2022a).
- ***Single-use plastic products***: Often referred to as disposable plastics, they are commonly used plastic items intended to be used only once before they are thrown away or recycled e.g. grocery bags, food packaging, bottles, straws, containers, cups and cutlery (UNEP 2024).
- ***Solvolysis***: A chemical conversion method used to depolymerise plastics into monomers by reacting with a solvent.
- ***Sourcing of raw materials***: Obtaining feedstocks through the extraction of fossil-based sources, harvesting of bio-based sources and carbon capture.
- ***Synthetic feedstock***: Synthesis of hydrogen (produced from electrolysis of water) and CO2 (obtained via direct air capture, an electricity-intensive process) (Energy Transmissions Commission 2020).
- ***Unnecessary plastic products***: Products with a function that is not essential because they do not provide significant added value to society (NCM 2024).
- ***Waste management***: Includes segregation, collection, sorting, recycling, incineration, and disposal of plastics waste, as well as mismanagement of plastics waste.

# 2 Greenhouse gas emissions across the plastics life cycle

## Key findings

- In 2015, the sourcing, production, use and disposal of plastics collectively contributed to greenhouse gas emissions ranging from 1.8 Gt to 2 Gt of CO2e, accounting for approximately 3.8 per cent to 4.5 per cent of global greenhouse gas emissions (Hamilton and Feit 2019; Zheng and Suh 2019; Cabernard et al. 2022). Despite the ongoing efforts to reduce plastic consumption and improve recycling, global plastic production increased from 322 million tonnes in 2015 to 400 million tonnes (excluding polymers not converted to plastic parts) in 2022 (Plastics Europe 2023). Plastics have become one of the fastest growing materials in the global economy, surpassing the growth rates of commodities such as steel, aluminium, and cement (International Energy Agency [IEA] 2018; OECD 2022a).
- The production landscape remains dominated by fossil-based plastics, accounting for approximately 90.6 per cent of global production, while secondary plastics constitute 9 per cent, bio-based plastics comprise 0.5 per cent, and carbon-captured based plastics <0.1 per cent (Plastics Europe 2023). Furthermore, the production and conversion of primary plastic polymers is highly energy intensive and relies predominantly on energy from fossil fuels (Hamilton and Feit 2019).
- This rapid acceleration in plastic production and the reliance on fossil fuels poses a substantial challenge to global endeavours aimed at limiting global temperature rise to below 1.5°C (Masson-Delmotte et al. 2018).

## Overview

This section summarises the latest scientific evidence from the literature review, exploring the impacts on climate change through the various stages of the plastics life cycle (Figure 1). This section lays out the intersections of climate and plastics to argue for the measures to stem climate change and end plastic pollution.

Table 1 provides an overview of the key stages in the plastic life cycle as outlined in this report, demonstrating how greenhouse gas emissions are generated at each stage. Given that emissions from various stages of the plastic life cycle are yet to be quantified, it is probable that the climate impact of plastics is currently underestimated.

## 2.1 Sourcing of raw materials

The sourcing of raw materials for plastics accounts for approximately 9 per cent of the total greenhouse gas emissions in the plastics life cycle (Cabernard et al. 2022). Plastic feedstocks can be fossil-based, bio-based or captured $CO_2$-based. For each of these different feedstocks there are associated greenhouse gas emissions, described below.

### Fossil-based feedstocks

Most plastics currently produced are derived from fossil-based sources (90.6 per cent) (Plastics Europe 2023). Estimates vary regarding the exact share of fossil fuels designated for plastics production, yet research indicates

***Table 1***. *Description of main stages of the life cycle, plastic pollution in the environment and cross-cutting transport and trade.*

| Stage | Description | Contribution to greenhouse gas emissions |
|---|---|---|
| Sourcing of raw materials | This stage involves the extraction of fossil-based feedstocks such as crude oil, coal or natural gas. Despite the potential for alternative feedstocks like biomass and $CO_2$, their use remains minimal. | This stage accounts for 9 per cent of the plastics life cycle greenhouse gas emissions. |
| Production of plastics | In this phase, feedstocks are processed through refining and cracking in petrochemical plants, converting them into monomers. This is followed by polymerisation of monomers into polymers and then conversion into various plastic products. | This stage accounts for 85 per cent of the greenhouse gas emissions in the plastics life cycle. The energy requirements for refining, cracking, polymerisation and conversion are the key sources of emissions resulting from the reliance on fossil fuels. |
| Plastic use and reuse | This stage includes the distribution and use of plastic products and the potential for reuse, which can mitigate environmental and climate impacts if implemented effectively. | The greenhouse gas emissions from this stage have not been quantified in existing literature, but unsustainable consumption patterns are a significant driver behind the escalating use and associated greenhouse gas emissions. |
| Waste management | This stage includes segregation, collection, sorting, recycling, incineration and disposal of plastic waste, as well as mismanagement of plastic waste, including unregulated disposal and open burning. | This stage contributes to 6 per cent of greenhouse gas emissions, not including emissions from mismanagement of plastics. Mechanical recycling has the lowest emissions per unit, while open burning has the highest. However, only a few plastics are fit for mechanical recycling, necessitating redesign for broader suitability. |
| Plastic pollution in the environment | This stage covers the plastic leakage and accumulation of plastic waste in the natural environments. | The greenhouse gas emissions in this stage have not been quantified, but literature suggests that negative feedback loops from both macroplastics and microplastics in the environment exacerbate climate change. |
| Transport and trade | Transport and trade play a cross-cutting role in the plastics life cycle, driving climate change by necessitating energy use, mainly from fossil fuels, for the global movement of plastic products and waste. | The greenhouse gas emissions from transport and trade have not been quantified. |

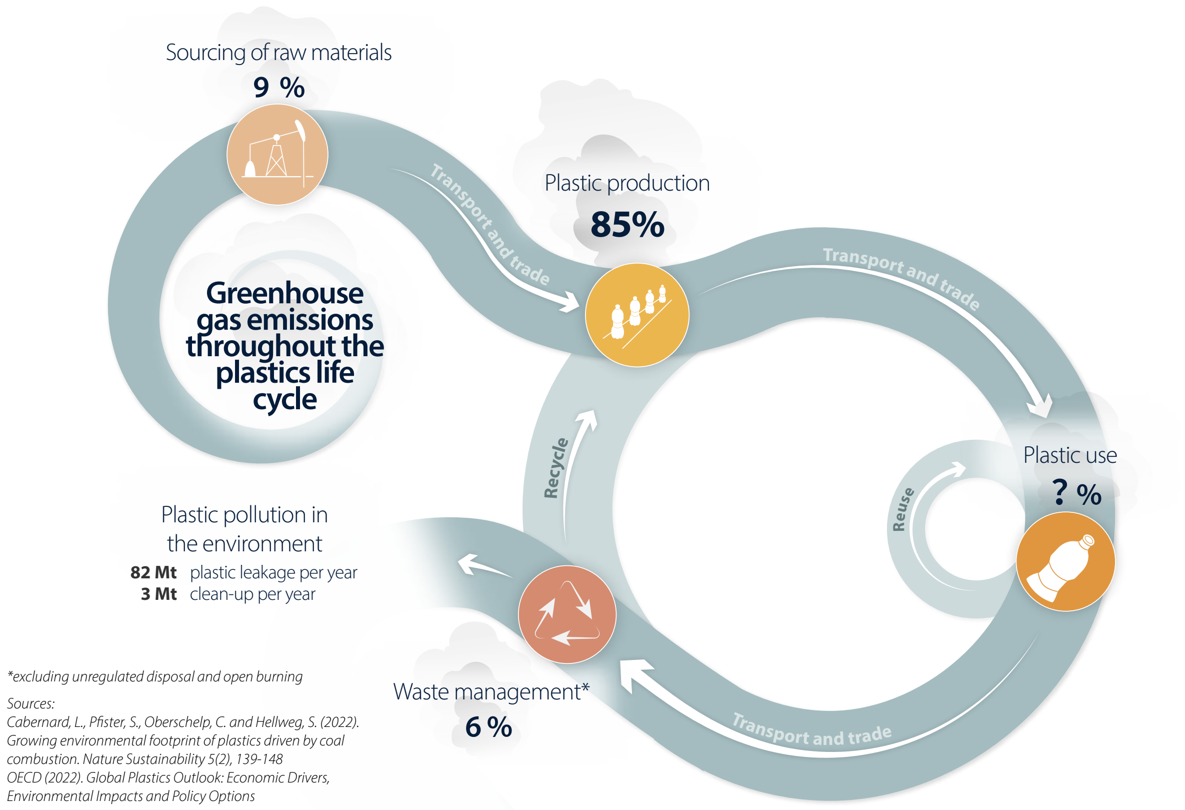



***Figure 1**. Plastic contribution to climate change through its life cycle.*

that between 4 and 8 per cent of global oil production is used to make plastics. This allocation encompasses both the material feedstock and energy required for the production processes. If the trend in plastic use persists as predicted, this percentage is estimated to rise to 20 per cent by the year 2050 (World Economic Forum 2016).

### *Sourcing*

The life cycle of plastics derived from fossil fuels begins with the sourcing of feedstocks such as crude oil, coal and natural gas. This process is associated with significant accounted greenhouse gas emissions, including $CO_2$, methane and nitrous oxide, with the oil and gas industry being a major contributor to these emissions among other natural resource extraction industries. Emissions occur at every stage of oil and gas production, encompassing activities from seismic testing and exploratory drilling to sourcing of raw materials and transportation (Rana 2008).

Gas flaring and venting, common practices in the oil and gas industry for managing waste gases, significantly contribute to greenhouse gas emissions, releasing $CO_2$, methane and other gases during oil production (Ismail and Umukoro 2012). In 2022 alone, gas flaring was responsible for emitting 315 million tonnes of $CO_2$ and 42 million tonnes of methane, a potent but short-lived greenhouse gas (World Bank 2023).

Coal mining represents another significant source of anthropogenic methane emissions, contributing to approximately 11 per cent of global methane emissions from human activities. Current estimates of methane emissions from fossil fuel extraction are likely underestimated; figures are suggested to be much greater (Kholod et al. 2020). Sourcing of raw materials and related transport activities also encompass unaccounted abundant fugitive emissions, which are unintended losses and leaks of methane to the atmosphere. It is reported that these emissions are a gross underestimate by 25–40 per cent (Hmiel et al. 2020; Erland et al. 2022). While specific data quantifying the contribution of methane emissions from fossil fuel extraction to the overall greenhouse gas footprint of plastics is lacking, it is anticipated to be a considerable factor.

## Alternative feedstocks

### *Bio-based feedstock*

In recent decades, bio-based plastics, which is a generic term for plastics made fully or partially from biological material, have been suggested as an alternative to conventional plastic. The industry is rapidly growing, and in 2020 the total global production capacity of bio-based plastics was 2.2 million tonnes, forecasted to keep growing to 6.3 million tonnes by 2027 European Bioplastics 2023). Bio-based plastics may or may not be biodegradable but are manufactured from biological materials or renewable feedstock, such as starch, cellulose, vegetable oil and vegetable fats (Zheng and Suh 2019; Atiwesh et al. 2021; European Commission, Directorate-General for Research and Innovation 2021). Although bio-based plastics are often perceived as environmentally friendly alternatives because of the "bio-" prefix, their true environmental impacts may be glossed over. In addition to their degradability, the production of bio-based plastics from crops like maize can entail extensive land use, potentially involving fertiliser-intensive farming practices, and might have a greater net environmental impact than conventional plastics. These impacts include conflicts with food production, clearing of natural habitats (e.g. deforestation), negative eutrophication consequences, land acquisition challenges, reduction of carbon sinks, and ozone depleting outcomes in the case of large-scale adoption (Abe et al. 2021; OECD 2023).

### *Captured $CO_2$-based feedstock*

$CO_2$ can be converted into value added products such as plastic polymers, by carbon capture and utilisation (CCU). This reduces the need for fossil resources and associated emissions of greenhouse gases. An advantage of capturing $CO_2$ as a feedstock, unlike many bioderived monomers, is its compatibility with existing infrastructure used in fossil-based polymer production. Specifically, the polymerisation process can take place seamlessly within current reactors and employ established methods for processing and purification. Additionally, it can also reduce the electricity required for otherwise new processes (Müller at al. 2020). The potential for $CO_2$ utilisation is estimated at 10 to 50 million tonnes annually by 2050 (Hepburn et al. 2019). In the present market, approximately 60 per cent of plastics are found in products other than packaging, in applications that involve the creation of durable materials in construction, household items and automotive components, with lifespans extending for decades or centuries. However, opponents argue that this technology is backed up by the interests of the fossil fuel industry and is associated with risks for lock-ins, when fossil fuel-intense systems perpetuate, delay or prevent the transition to low-carbon alternatives (Sato, Elliott and Schumer. 2021; Bauer et al. 2022a; Palm et al. 2024).

In a life cycle assessment focusing on the production of major organic chemicals (methanol, ethylene, propylene, benzene, toluene, mixed xylenes), the combination of CCU with water electrolysis, powered by offshore wind turbines, was found to significantly reduce greenhouse gas emissions by 88–97 per cent compared to traditional fossil-based production methods. However, this reduction in greenhouse gas emissions was accompanied by increased environmental impacts in terms of eutrophication and ozone depletion. The primary factors contributing to these environmental impacts were the energy supply required for water electrolysis and direct air capture (Rosental, Fröhlich and Liebich 2020).

Hence, the utilisation of $CO_2$ does not necessarily diminish the consequences of climate change. In fact, greenhouse gas emissions could potentially surpass conventional technologies, dependent upon the CCU technology, its supply chain, and the characteristics of the resulting product (Müller et al. 2020).

Advancing CCU technologies demands a thorough understanding of supply chains, application contexts and the scale of integration into existing sectors. For instance, implementing CCU would require costly modifications to core steam cracking processes, $CO_2$ capture from various industrial sources, and extensive infrastructure development to achieve the 90 per cent or higher capture rates needed for net-zero emissions. Consequently, the advancement of CCU technologies requires a comprehensive understanding of the associated supply chains, the circumstances in which the technology will be applied, and the scale of which CCU will be used (Müller et al. 2020). For instance, implementing CCU would require costly modifications to core steam cracking processes, $CO_2$ capture from various industrial sources, and extensive infrastructure development to achieve the 90 per cent or higher capture rates needed for net-zero emissions (Material Economics 2019).

## 2.2 Production of plastics

The production stage encompasses refining, cracking, polymerisation and conversion. Greenhouse gas emissions are generated both directly during processing and indirectly through processes contributing to the creation of finished polymers. This stage accounts for approximately 85 per cent of the life cycle greenhouse gas emissions from plastics (Cabernard et al. 2022). Figure 2 illustrates direct and indirect greenhouse gas emissions during the global plastics production.

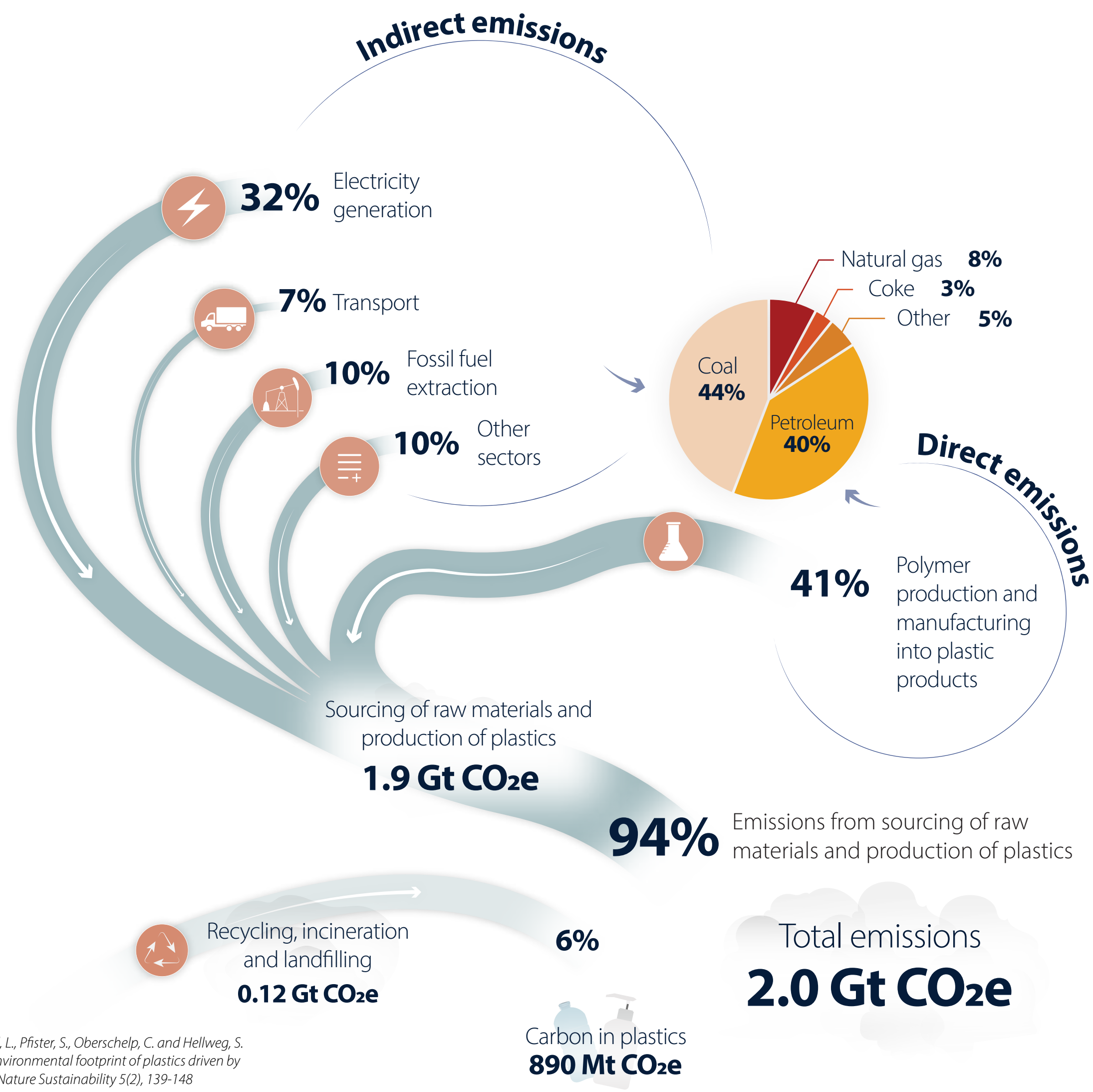
### *Refining and cracking*

Extracted fossil fuels are sent to refineries where they are converted into naphtha and ethane, which is mainly subjected to steam cracking processes to transform them into monomers or high-value chemicals such as ethylene, propylene and benzene. These substances serve as the primary chemicals in the petrochemicals industry (Material Economics 2019). Although plastics remain its largest subindustry, the global petrochemical industry also produces products like fertilisers and pesticides. Annually, the chemical and petrochemical industries contribute around 1.5 Gt of $CO_2$ globally, representing 18 per cent of industrial $CO_2$ emissions. Refining fossil fuels, a significant source of stationary greenhouse gas emissions, ranks as the third largest globally, constituting 40 per cent of emissions from the oil and gas supply chain and 6 per cent of all industrial greenhouse gas emissions (IEA 2018). In 2015 alone, the combustion of fossil fuels for the global production of plastics led to the release of a total of 1.7 Gt of $CO_2e$ (Cabernard et al. 2022).

The demand for high-value chemicals is projected to surge by 60 per cent by 2050, with the Asia–Pacific region taking the lead in production. Africa and the Middle East are also expected to experience a substantial production increase by 2050. North, Central and South America will experience more moderate growth but are poised to reach a combined high-value chemical production of 115 million tonnes in 2050. Plastic is the key force behind this surge and with higher demand for high-value chemicals, the demand for fossil-based feedstocks also increases (IEA 2018).

### *Polymerisation and conversion*

Many monomers are combined to create polymers in a chemical process called polymerisation. During the conversion stage, the polymers are mixed with a range of chemical compounds or additives designed to enhance the




*Gt = Gigatonnes*
*Source: Cabernard, L., Pfister, S., Oberschelp, C. and Hellweg, S. (2022). Growing environmental footprint of plastics driven by coal combustion. Nature Sustainability 5(2), 139-148*

***Figure 2***. *Greenhouse gas emissions during the global plastics production.*

performance and properties of plastic products. This stage includes technologies such as injection moulding, blow moulding and extrusion to create finished plastic products. The conversion stage accounts for 30 per cent of the plastics life cycle emissions, with a different production process for each polymer type (Zheng and Suh 2019). Estimates show that polypropylene (PP) have the highest production volume at 68 million tonnes, followed by low-density polyethylene (LDPE), polyester, polyamide, and acrylic (PP&A) fibres, high-density polyethylene (HDPE), polyvinyl chloride (PVC), polyethylene terephthalate (PET), polyurethane (PU) and polystyrene (PS) (Geyer, Jambeck and Law 2017). Among these polymers, PP&A fibres exhibit the highest greenhouse gas emissions. Additionally, the polyolefin family (consisting of PP, LDPE, linear LDPE and HDPE), which represents 50 per cent of global plastic consumption, made a substantial contribution to emissions (Zheng and Suh 2019).

The energy demand and emissions in polymer production is specific to the product. These vary further based on factors like production method efficiency, plant age and types of emission controls (Hamilton and Feit 2019). For more complex polymers like PS, PVC and PET, greenhouse gas emissions are usually higher than PE and PP because of additional additives or catalysts used in their production. Additives in the plastics industry fall into four primary categories: functional additives, colourants, fillers, and reinforcements (Hahladakis et al. 2018). Figure 3 illustrates greenhouse gas emissions deriving from selected polymer types across their life cycle.

### *Energy demand*

A significant portion of greenhouse gas emissions arise from the production stage of plastics. Processes such as refining and cracking demand substantial energy, primarily sourced from fossil fuels. The choice of fuels plays a crucial role in determining the overall greenhouse gas footprint of plastic production.

Integral to plastic production, the chemical and petrochemical industries is a significant energy consumer, utilising roughly 10 per cent of global energy use and nearly 30 per cent of global industrial energy use (UNEP 2019). Within this industry, it also holds the largest share in oil and gas consumption, representing 14 per cent and 8 per cent of

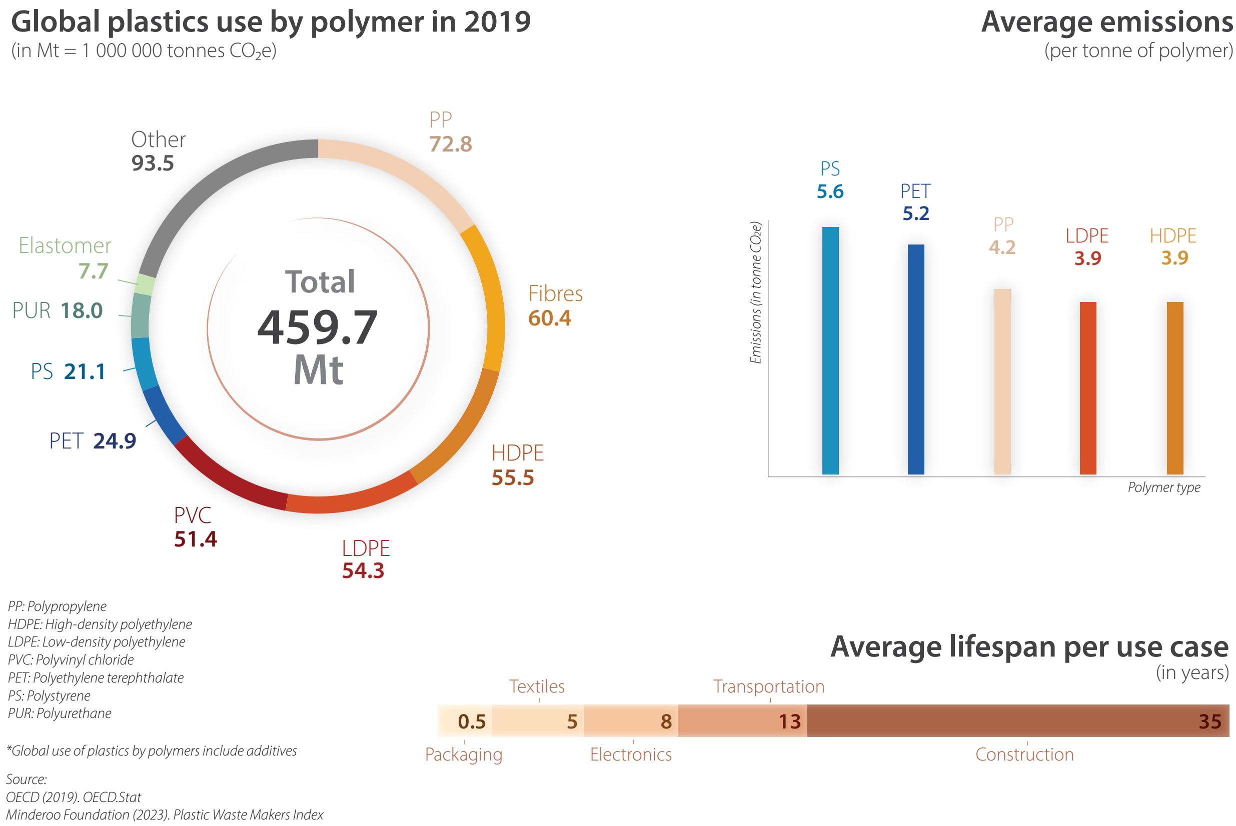



***Figure 3***. *Greenhouse gas emissions deriving from selected polymer types across their life cycle.*

global primary demand, respectively (IEA 2018). Among the different components, the production of raw materials for plastic stands out as the most energy-intensive subcategory (Hamilton and Feit 2019).

The major driver of greenhouse gas emissions is associated with the increased combustion of coal for electricity and heat supply during plastic production. In 2015 alone, 6 per cent of global coal electricity was used for plastic production and constituted nearly half of the total carbon footprint of global plastic production (Cabernard et al. 2022).

Despite the demand for energy, fossil fuel resources and uncounted externalities, the production of primary plastics remains cheap. Currently, the market price of plastics is linked to current fossil fuel prices and excludes the hidden costs of externalities (GRID-Arendal 2022). Therefore, it makes the competition between primary polymers and secondary plastics challenging.

## 2.3 Plastic use and reuse

In parallel with rapid economic growth, plastic consumption is steadily increasing across the world, and the manufacturing of plastic goods is projected to create further demand for fossil fuels that extends beyond other sectors, including energy and transport (IEA 2023).

In terms of demand, several industries stand out for plastic products. Packaging comprises the largest share, accounting for 36 per cent of global plastic demand, followed by building and construction (16 per cent), textiles (14 per cent) and consumer and institutional products comprising of everyday plastics (10 per cent) (Bauer et al. 2022a). Collectively, these industries encompass over three quarters of the global demand. Moreover, depending on its use, the average lifespan of plastic is approximately 10 years. Plastic packaging, designed for short-term use, typically only a few hours or days, has an average lifespan of less than a year. In contrast, plastics utilised in construction are engineered for durability, with an average lifespan of 35 years (Geyer, Jambeck and Law 2017).

The largest share of plastic demand originates from the plastic packaging industry. Plastic packaging typically involves single-use plastics that are difficult to recycle. This trend is largely driven by unsustainable consumption habits, which are perpetuated by the prevalence of avoidable and unnecessary plastic packaging. The United States of America (US) Environmental Protection Agency investigated the potential emission reduction associated with halving the annual production of plastic packaging generated in 2006. The study found that reducing production from 14 to 7 million tonnes could have led to a reduction of 14.85 million tonnes of $CO_2e$, marking a 67 per cent decrease (US, Environmental Protection Agency 2009).

Substituting single-use plastic products with another disposable product made from a different material (e.g. paper or biodegradable plastic) is likely to merely shift environmental challenges and potentially generate new issues, emphasizing the need to encourage current manufacturers of single-use products to transition to circular solutions such as the production of reuse products with improved design (UNEP 2021). Although most reduction strategies have focused on lightweight plastic recycling, estimates show that at least 20 per cent of plastic packaging could be replaced by reusable packaging that reduces energy use and greenhouse gas emissions (Ellen MacArthur Foundation 2019; Coelho et al. 2020). For example, the life cycle $CO_2e$ emissions of disposable paper, bio-based plastic cups, and other plastics have been reported to be 3–10 times higher than reusing ceramic, stainless steel and glass products in the food service industry (Gordon et al. n.d.). In fact, a reusable glass bottle that is used only two or three times would lead to a 40 per cent reduction in greenhouse gas emissions compared with a single-use glass bottle, and 70 per cent reduction in greenhouse gas emissions compared with a single-use PET-bottle. To put the reuse of plastic bottles into perspective: reusing a HDPE bottle instead of using a single-use HDPE bottle would result in a 65 per cent reduction in $CO_2$ emissions (Eunomia 2023). However, it will be important to address human health concerns relating to the reuse of plastic bottles, as increased reuse including opening and closing of the bottles have been reported to release high quantities of microplastics. One study found that opening and closing PET bottles with PP caps and polyethylene (PE) seals 11 times, as opposed to once, resulted in the detection of 242 ± 64 microplastic particles per litre, compared with 131 ± 25 microplastic particles per litre (Giese et al. 2021). Reusables also require dishwashing, which wears down the plastic and increases leaching of microplastics (Tisler and Christensen. 2022). Overall, the greenhouse gas emissions from refill and reuse systems will depend on the number of times the product is being reused, as well as its required transport distance, weight and manufacturing, its design and its disposal (Coelho et al. 2020). The energy efficiency aspect should also be considered in terms of the overall carbon footprint of reusable products.

Without fundamental redesign and innovation, around 30 per cent of plastic packaging will never be reused or recycled (Ellen MacArthur Foundation 2017). Emission reduction stemming from product redesign is currently based on limited examples and it is challenging to calculate the reduction in emissions this would achieve at scale. The European Environmental Bureau estimated that extending the scope of the existing European Eco-design Directive to address all consumer, industrial, and professional products could save 117 million tonnes of $CO_2e$ per year (European Environmental Bureau 2022).

In the construction industry, a large quantity of the global material consumption contains plastic, which contributes to the release of greenhouse gas emissions (Hertwich 2021; UNEP and Yale Center for Ecosystems + Architecture 2023). Building and construction use of plastic ranges from plumbing pipes to window frames, insulation, lining, building textiles and packaging. Moreover, in the construction of buildings, PVC and HDPE constitute a large share of the polymers used (Di et al. 2021).

Global plastic consumption enabled by the increasing demand from industry continues to support the linear life cycle of plastics. Moreover, unsustainable consumption patterns–through a fast-moving consumer goods industry and a robust growth of the e-commerce market–increase the environmental impacts of plastic. For example, the fast-moving consumer goods from multinational corporations are packaged goods sold at high volumes and low prices, which is often wrapped in plastics, giving online shopping a higher environmental impact than traditional shopping (Bocken, Harsch and Weissbrod 2022). Although consumption patterns at the end user level through actions and purchasing habits are important to consider in order to reduce and reuse plastics, there is a lack of connections between governance forms, market structures, materials and technology that contribute to feeding the strong carbon lock ing of plastic (Bauer et al. 2022a). The surge in global plastic consumption extends beyond consumer behaviour and is often driven by corporate interests that favour the continuation of certain plastic products. Further, the surge in global plastic consumption is not solely a result of consumer behaviour; industries' advocating for specific plastic products also play a significant role (Bauer and Fontenit 2021).

With high diversity, low costs, and a plentiful supply of fossil fuel, plastic continues to replace a variety of products and services that are fundamental for our society. As a result, greenhouse gas emissions will continue to be locked in for years to come (Erickson et al. 2015). Plastics have taken over traditional materials such as cotton, and although plastic fibres reduce water and land-use impacts, polyester has 50 per cent higher greenhouse gas emissions than cotton (European Environment Agency 2021a), increasing the overall carbon footprint of the textile industry (Sandin, Roos and Johansson 2019). Put into perspective, being primarily reliant on synthetic fibres like polyester, nylon and acrylic, the global apparel and footwear industries together were responsible for approximately 8 per cent of the world's greenhouse gas emissions in 2016 (Quantis 2018).

As we urgently transition towards greener practices to mitigate greenhouse gas emissions, the transport industry – covering aircraft, automotive, railway and maritime sectors – has adopted lighter structures, such as plastic materials, to reduce weight and fuel consumption. Similarly, in the building and construction sector, recognised as the second-largest plastics application sector, there is a shift from steel to plastic pipes for essential infrastructure like water supply, sewage removal, housing cables and technical installations (European Environment Agency 2021b). However, balancing the benefits of these lightweight materials in reducing emissions against their environmental and health impacts presents a significant challenge.

## 2.4 Waste management

Recent estimates reveal that the waste management stage of the plastics life cycle, encompassing recycling, disposal and incineration, accounts for approximately 6 per cent of overall plastics life cycle emissions (Cabernard et al. 2022). This does not account for greenhouse gas emissions from open burning, open dumpsites, and leakage that are yet to be assessed. Among all waste management options, landfills, open burning, and incineration stand out as the main contributors to greenhouse gas emissions.

Globally, greenhouse gas emissions from plastic recycling are estimated at approximately 50 million tonnes of $CO_2e$ (Cabernard et al. 2022). Bottle-to-bottle recycling can emit 30 per cent less greenhouse gases compared with landfilling and save more than 40 per cent compared with burning. Producing a plastic bottle from recycled PET requires 1.7 times less energy than producing the same bottle from primary polymers. The use of recycled HDPE and polypropylene saves three times the energy compared with primary polymers (Association of Plastic Recyclers 2020). Modelling suggests that by 2050 various circular solutions such as reduction, substitutes, mechanical and chemical conversion could reduce greenhouse gas emissions by 60 per cent in Europe (Systemiq 2022). Mechanical recycling is one of the most effective options.

However, currently only one fifth of plastic waste is economically recyclable (Pew Charitable Trusts and Systemiq 2020). Mechanical recycling is confined to thermoplastics, primarily to a few polymers such as HDPE, PP and PET. This leaves out a significant portion of plastic waste, including thermoplastics (e.g. PVC, PS), thermosets, composite materials, textiles, and rubber tyres (GRID-Arendal 2022). These materials, despite their notable climate footprints, remain largely unrecycled. Ultimately, these challenges are intertwined with the overall costs of recycling and material flexibility.

In high-income countries, the global costs of recycling, mainly associated with infrastructure, processing, and energy use, are prohibitively high and struggle to compete with primary polymers. Consequently, producing single-use plastics from primary material often proves to be cheaper than reusing or recycling them. In geographies where the informal recycling sector plays a significant role, low costs are linked to low social standards and weaker environmental compliance. However, while high-income countries have struggled to make plastic recycling cost-effective (Pew Charitable Trusts and Systemiq 2020), the informal recycling sector manages to collect more than 45 million tonnes of waste per year (Cook et al. 2024).

Estimates of greenhouse gas emissions from chemical conversion vary significantly, showing that they can range from two to nine times higher than those from mechanical recycling, depending on the source consulted (Pew Charitable Trusts and Systemiq 2020; Möck, Bulach and Betz 2022). However, chemical conversion comprises different technologies such as chemical depolymerisation, pyrolysis and gasification, each with varying rates of greenhouse gas emissions. Chemical depolymerisation technology breaks down polymers into monomers and emits fewer greenhouse gases than gasification or pyrolysis, which are thermal processes with and without oxygen, respectively. Pyrolysis emits the most due to the higher temperature requirements and long reaction times, followed by gasification, while chemical depolymerisation emits the least among those technologies. Compared with other waste management options, a recent study revealed that pyrolysis of mixed waste emits 50 per cent less $CO_2e$ than through energy recovery (Jeswani et al. 2021). Notably, pyrolysis carries health implications resulting from the toxins it releases (Pew Charitable Trusts and Systemiq 2020). However, chemical conversion can be considered for specific situations, such as recycling thermosets that cannot be remelted and reshaped like thermoplastics.

Bio-based plastics in waste management face different challenges. Bio-based plastics tend to be non degradable or have slow degradation rates, typically breaking down only under certain conditions such as high temperatures or in municipal composters or digesters. A lack of standards in biodegradability testing has led to false claims and perceptions regarding the plastic substitute, which further feed negative environmental outcomes (European Commission, Directorate-General for Research and Innovation 2021).

Waste incineration produces the highest greenhouse gas emissions of all waste management options, contributing to 140 million tonnes of $CO_2e$ (OECD 2023). It is typically used for mixed solid waste that is difficult to recycle, reuse, or repair, including plastics. The inclusion of plastics in the mixed solid waste stream complicates the potential to disaggregate and report on the greenhouse gas emissions, specifically from the combustion of plastic waste. The current literature suggests that greenhouse gas emissions from solid waste incineration remain relatively low on a global scale, possibly due to the widespread adoption of advanced technologies in many regions (Wilson 2023). However, the environmental impacts of waste incineration hinge on the design of incinerators and their operations, including the utilisation of energy recovery and emission control technologies. The design of incinerators and their operations are therefore a critical factor in the rate of emissions.

Although incinerating plastic can result in high energy gain because of its high caloric value, it is worth noting that, in general, incinerators demonstrate relatively low performance in overall electricity and heat generation (Hogg 2023). In addition, the incineration carries substantial environmental externalities, particularly in terms of greenhouse gas emissions, and is poised to become a significant contributor in the future (Hamilton and Feit 2019).

Countries are increasingly moving away from landfilling waste and towards substantial investments in waste incineration with energy generation. In making this transition, they commit to technological lock-ins, relying on a long-term consistent flow of feedstocks–including plastic waste–to recuperate the substantial investment costs running into billions of dollars (UNEP 2023b), which present risks in achieving a circular economy. It is possible that the use of renewable energy to power incinerators could result in some net-benefit in terms of energy, but a full life cycle would need to take all externalities into account, including the emissions from production of new primary polymers needed to replace those that are incinerated.

Thousands of tonnes of plastic waste go uncollected annually as an estimated 2.7 billion people currently lack access to waste collection systems (Wilson 2023). Inadequate waste service, as well as uncontrolled waste disposal, leads to open burning, which not only emits greenhouse gas emissions but also black carbon with a global warming potential of up to 5,000 times greater than $CO_2$ (Reyna-Bensusan et al. 2019; Cruz et al. 2022). Currently, 16 per cent of the world's total municipal waste is openly burned, significantly contributing to both greenhouse gas emissions and air pollution (Wiedinmyer, Yokelson and Gullett 2014). Emissions of reactive trace gases, which play a vital role in climate change and particulate matter from open waste burning, are currently not accounted for in existing inventories. Emissions from landfills account for approximately 11 million tonnes of $CO_2e$ (OECD 2023). The practice of waste disposal through dumpsites remains prevalent in many regions, despite releasing hazardous gases, including methane and ammonia, as organic materials decompose within these sites.

## 2.5 Plastic pollution in the environment

A significant amount of plastic waste has accumulated in the environment. Plastic waste that remains in the environment starts to degrade, becoming fragile and prone to breaking due to continuous environmental exposure such as winds, sunlight, currents and waves. Plastic waste in the form of microplastics has permeated all corners of our planet, appearing even in remote mountain and polar areas, where they have notable climate effects. Specifically, the light-absorbing properties of microplastics may contribute to accelerated warming by decreasing the reflectivity (albedo) of snow and ice (Zhang, Kang and Gao 2022). Recent estimations indicate that plastic leakage to the environment is set to double from 22 to 44 million tonnes between 2019 and 2060 (OECD 2022b).

The degradation of plastics, particularly through photodegradation, has been identified as a source of greenhouse gas emissions. Methane and ethylene emissions from various plastic types have been reported, particularly from LDPE, which has exhibited the highest emission rates (Royer et al. 2018). LDPE floats at the water surface and along with 65 per cent of all produced polymers, is less dense than seawater. This in turn leads to vast amounts of free-floating plastics in the aquatic environment. Moreover, as plastics break down into micro- and nanoplastics, greenhouse gas production increases. Such microparticles in the water column have been shown to cause adverse effects on phytoplankton photosynthesis and growth (Shen et al. 2020b) and reduce capacity for zooplankton to function as carbon sinks (Cole et al. 2016). Additionally, emissions from primary plastics rise over time, while aged plastics express relatively stable emissions, possibly because of previous use (Royer et al. 2018; Shen et al. 2020a). However, the degradation time of a plastic item will be highly dependent on the polymer used, its thickness and mass, eventually leading to the formation of microplastics. Moreover, plastic additives may leach from plastics into the environment during weathering. These additives can then be taken up by organisms such as phytoplankton, which act as major carbon sinks (Shen et al. 2020b; Ford et al. 2022).

Less dense primary plastic polymers can sink when bio-fouled or ingested, or sink as marine snow, while others have higher densities that lead to sinking (Ford et al. 2022). When deposited in sediments, sinking plastic may enter long-term sequestration. Therefore, sediments can become significant plastic sinks, particularly sediments with minimal resuspension. In the Red Sea and Arabian Gulf mangroves, microplastic levels in sediment samples, dating back to the 1930s, have exponentially risen since the 1950s, corresponding to global plastic production trends (Smith 2012). Approximately 50 ± 30 million tonnes and 110 ± 80 million tonnes of plastic may have been buried in the upper 20cm sediment layers (Smith 2012). Hence, any disturbance due to plastic in carbon capture ecosystems, including mangroves, could create a negative feedback loop that amplifies climate change (Adyel and Macreadie 2022). Moreover, sediment resuspension will continue to release greenhouse gas emissions from buried plastic for years to come. Recent studies have also documented the release of methane from microplastics found in bottom sediments, revealing that smaller particle sizes are associated with increased emissions (Kida, Ziembowicz and Koszelnik 2022).

More recent studies have looked at the effect of microplastic in terrestrial systems, such as its presence in soils. If soil is perturbed with microplastics, the stored organic carbon present in the soil and other greenhouse gases such as methane and nitrous oxide can be emitted into the atmosphere due to increased soil respiration (Chia et al.2023). Interestingly, as plastic contains carbon, it has the potential to form a large component of the total carbon in soil (Liu et al. 2023). This can give rise to various challenges, such as reduced plant growth, lowered soil nitrogen levels, and an elevated presence of microbial biomass (Liu et al. 2023). There are similar challenges in marine sediments (Ford et al. 2022), where plastics results in sediments having a diminished capacity to sequester carbon. This has been reported for mangroves in blue carbon ecosystems (Adyel and Macreadie 2022)

Plastic pollution that exaggerates climate change through positive feedback loops also has the potential to occur in the atmosphere. Zhang, Kang and Gao 2022 found that airborne microplastics may cause positive feedback loops affecting solar radiation (Zhang, Kang and Gao 2022). Similarly, Aeschlimann et al. (2022) noted that the presence of micro- and nanoplastics in the atmosphere can affect cloud formation, which could change cloud albedo and precipitation in sufficient amounts, collectively impacting Earth's climate. Micro- and nanoplastics may act as small cloud or ice particles after undergoing environmental ageing processes. However, the impact of micro- and nanoplastics

***Table 2***. *Summary of feedback loops of microplastics in the environment (Zhang et al. 2022; Cole et al. 2016; Chia et al. 2023; Kida et al. 2022; Shen et al. 2020b; Revell et al. 2021).*

| Sediment | Water column | Soil | Atmosphere | Cryosphere |
|---|---|---|---|---|
| Release of methane from microplastics in bottoms sediments | Reduced capacity for zooplankton to function as carbon sinks<br>Adverse effects on phytoplankton photosynthesis and growth | Soil-based microplastics increase soil respiration, leading to an increase of greenhouse gas emissions | Airborne microplastics may cause positive feedback loops on solar radiation | The light-absorbing properties of microplastics may contribute to accelerated warming by decreasing the surface albedo of snow and ice |

on the climate depends on their abundance relative to other particles. Currently, micro- and nanoplastics concentrations in the atmosphere are low, with a limited impact on regions currently dealing with high concentrations of air particles. However, should the release of micro- and nanoplastics increase, this could lead to significant alterations in the future (Aeschlimann et al. 2022).

Table 2 summarises above mentioned negative feedback loops of microplastics in the environment that have potential to exacerbate climate change. While most studies have currently focused on the feedback loops of plastics in the environment, there is still a large gap on the direct linkages between climate change and plastic pollution, both in the marine and terrestrial environment (Rillig, Leifheit and Lehmann 2021; Ford et al. 2022).

## 2.6 Transport and trade

All stages of the plastics life cycle rely on transport, both internationally and domestically, via air, road or sea. The transport sector is responsible for 20 per cent of global greenhouse gas emissions, making it the second-largest polluting sector globally (Statista 2023). Given that current transport systems heavily depend on oil for over 90 per cent of their energy, the greenhouse gas emissions stemming from the transportation of raw materials, plastics, and plastic waste are likely substantial (IEA 2023).

Out of 1.9 Gt of $CO_2$e emissions during the sourcing of raw materials and plastic production stages, both domestic and international transport contributes approximately 7 per cent of these emissions on a global scale (Cabernard et al. 2022). An increasingly high amount of plastic production takes place abroad, originating from consumer countries, thereby intensifying the overall carbon footprint (Beyond Plastics 2021; Cabernard et al. 2022). For example, to meet the demand for plastic, high-income countries partially rely on plastic production in low-income regions, particularly those with coal-based economies. In doing so, outsourcing plastic production accelerates the carbon footprint from the transport sector. The significant growth in plastics production in coal-based emerging economies has been a major driver of the rising carbon footprint of plastics since 2000 (Cabernard et al. 2022).

In 2021, the international transport system moved over 369 million tonnes of plastic, contributing to approximately 5.3 per cent of the world's trade (United Nations 2023a). The fast-moving consumer goods industry, known for delivering high volumes at low prices, plays a crucial role in this trade. Approximately 7 per cent of total greenhouse gas emissions throughout the life cycle of single-use plastics result from the trade in their constituent plastic materials, including polymers, bulk packaging, and final products (Minderoo Foundation 2023). In certain circumstances, the transport of plastic products can generate fewer greenhouse gas emissions compared with the transport of similar products made from other materials due to the relative lightness of the equivalent plastic items (McKinsey & Company 2022), although this does not recognise the significant emissions from the plastics production stage (Hamilton and Feit 2019).

Finally, waste management is a transport-based service linked to collection, recycling, incineration or disposal. The growth in global plastic production is followed by a parallel increase in the global trade of plastic waste. Rising volumes of plastic have strained domestic waste management systems, leading many affluent nations with high plastic consumption to export their plastic waste abroad. For instance, the 38 OECD member nations have accounted for 87 per cent of all plastic waste exports since comprehensive reporting began in 1988 (Rilig et al. 2021). This trend has been accompanied by an increase in greenhouse gas emissions. For example, greenhouse gas emissions generated from the global waste trade between China and its trading countries increased by 76 times between 1992 and 2012 when the trade almost reached its peak (Liu et al. 2021). Prior to China's ban on waste imports in 2018, about 70 per cent of plastic waste was shipped to the country (Brooks, Wang and Jambeck 2018). The peak of plastic waste trade occurred in 2014, reaching nearly 16 million tonnes globally, equivalent to almost 5 per cent of the global plastic production the same year (IEA 2018; Wang 2020). However, there has been a significant decline in global plastic waste trade since 2014, assumably decreasing the greenhouse gas emissions from associated transport.

# 3 Current efforts to address the impact of plastics on climate change

## Key findings

- The reports under the UNFCCC and the Paris Agreement lack the necessary level of detail and do not specifically report on national efforts to reduce greenhouse gas emissions in the plastics industry.
- There are variations in the coverage of plastics across their life cycle. The plastic which is at the waste management stage is reported relatively broadly, while little information is available about other stages of the plastics life cycle, including production.
- The analysis identified 11 sectors relevant for plastics from the climate change perspective among reported measures and actions. These include: agriculture, building and construction, cement industry, chemical and petrochemicals industries, electrical and electronic equipment, energy, fisheries and aquaculture, food and packaging, textiles, tourism, transport.
- Searches of databases with greenhouse gas emissions data from the plastics life cycle indicated that there is no global database with national greenhouse gas emissions data, from the plastics lifecycle, covering all countries.
- The analysis of INC-3 submissions indicated support for the inclusion of greenhouse gas emissions as a plastic pollutant under the plastics instrument, and for the plastics instrument to strengthen action to address climate change.
- A third of the submissions to INC-3 (18 individual country submissions and 3 group submissions) provided inputs related to climate change, which represent a total of 125 countries.

## Overview

Section 3.1 presents the results from the analysis of national submissions to the UNFCCC and the Paris Agreement to understand how they address the impact of plastics on climate change. It aims to describe the existing level of action and identify gaps. Section 3.2 provides an overview of the results of a databases assessment to identify whether and how data on greenhouse gases from the plastics life cycle is available under other forums besides the UNFCCC. Section 3.3 presents the results of country submissions to INC-3 to understand the expectations for addressing climate change aspects of plastics in the global plastic agreement.

## 3.1 Reporting on plastics under the UNFCCC and the Paris Agreement

A content analysis was carried out to gain a deeper insight into how plastics have been reported in the context of climate change and provide an understanding of current strategies, measures, and actions addressing the plastics issue. The empirical study was based on the analysis of the latest available Nationally Determined Contributions (NDCs),[3] biennial reports[4] and biennial update reports[5] submitted in the English language by the Parties under the UNFCCC and the Paris Agreement. The data was collected on 3 August 2023, generating a total of 219 documents. The sources used in the content analysis are available in Appendix 1: Available sources from the analysis of national submissions to the UNFCCC and the Paris Agreement.

### Strategies for reducing greenhouse gas emissions

The analysis investigated four primary strategies used to reduce greenhouse gas emissions: decarbonisation, reduction of emissions, energy efficiency and circularity, which are relevant for plastics. It was identified that the national submissions lack the necessary level of detail and do not specifically report on efforts to reduce greenhouse gas emissions in the plastics industry. Therefore, as the plastics industry forms integral parts of the chemical and petrochemical industries, the analysis looked at the current approach to strategies for reducing greenhouse gas emissions relevant for plastics applied in a broader context, looking into greenhouse gas emissions strategies of the chemical and petrochemical industries. Figure 4 summarises the main findings.

The analysis found that under decarbonisation, the countries mainly pursue two approaches:

1. Improving industrial processes and use of new technologies including hydrogen; methanol with high $CO_2$ content natural gas; carbon capture, utilisation and storage; bio-based sources of energy, fuels, and chemicals.
2. Developing low-carbon road maps and policies.

Several actions and measures to reduce emissions are also relevant for plastic production. The most common are associated with introducing new technologies, improving production processes and energy use. There is also a strong trend towards addressing the emissions from plastics at the waste stage of their life cycle by implementing a circular economy, reducing and recycling plastic waste and reducing plastic incineration.

Energy efficiency plays a significant role in minimising the carbon footprint of plastic production. This is currently being addressed by implementing energy efficiency standards and plans, energy intensity targets, as well as by introducing new technologies and upgrading of facilities.

A circularity of plastics is mainly being promoted through policies and legislation. Specific areas of focus include reducing consumption of plastic items and improving waste management. Several of the EU member States highlighted the Circular Economy Action Package, which sets several priority issues, including plastics, and serves as a framework for institutional interventions at the national level.

### Plastics across the life cycle

The analysis of the reports under the UNFCCC and the Paris Agreement provided an overview of measures and actions taken across the plastics life cycle: sourcing raw materials, production, plastic use and waste management and efforts to address plastic pollution in the environment. The main findings are summarised in Figure 5.

#### *Sourcing*

The analysis identified only one case where the use of raw materials for plastics has been mentioned. Germany reported on the further development of systems that separate $CO_2$ out of the atmosphere and utilise it as a raw material for synthetic fuels or plastics. At the same time, observations indicate that plastic waste is often seen as secondary raw material or secondary source. Meanwhile, circular economy is recognised as an approach to the recycling of plastic waste as a raw material. Efforts aimed at retaining plastics in the economy are approached as co-benefits including "reduced greenhouse gas emissions from the creation of new virgin plastics" (Canada, Environment and Climate Change 2022). Another identified example of financial incentive – a plastic packaging tax, intends to "encourage greater use of recycled plastic in plastic packaging, instead of new (primary) plastic" (United Kingdom, Department for Business, Energy and Industrial Strategy 2022).

#### *Production*

The analysis of plastics at the production stage revealed several regulations that ban and restrict the manufacturing of single-use plastic and polythene bags, single-use plastic products and foodservice items, expanded polystyrene (EPS), as well as the export of polystyrene (PS) products. The design of plastic products was also highlighted in the production stage. Design was referred to as a significant element of the value chain and life cycle for improving materials recycling, as well as preventing waste and promoting resource circulation.

# Strategies to reduce greenhouse gas emissions relevant for plastics

**Decarbonisation**

- Improvements of industrial processes
- Use of new technologies, including hydrogen
- Methanol with high $CO_2$ content natural gas
- Carbon capture, utilisation and storage
- Bio-based sources of energy, fuels, and chemicals
- Development of low-carbon road maps and regulations

**Emissions reduction**

- Introduction of new technologies
- Improvement of production processes and energy use
- Circular economy
- Reducing and recycling plastic waste
- Reducing of plastics incineration

**Energy efficiency**

- Implementation of energy efficiency standards and plans
- Energy intensity targets
- Introduction of new technologies and upgrading facilities

**Circularity**

- Policies and legislation promoting circularity
- Specific areas of focus are reduction in consumption of plastic items and improvement of waste management
- EU Circular Economy Action Package

***Figure 4**. Summary of the strategies to reduce greenhouse gas emissions relevant for plastics reported under the UNFCCC and the Paris Agreement.*

Other actions and measures relevant for the plastic production stage include:

- Introducing an environmental product fee, which stimulates the manufacture and marketing of environmentally favourable products and restricts environmentally undesirable products;
- Developing low-carbon technology road maps in manufacturing industries;
- Regulating obligations regarding plastic bottle production;
- Supporting the principles of responsible and sustainable production at the policy level.

The findings also point out that energy use has not received enough attention in relation to plastic production and only resulted in one example reported by Viet Nam – the development of guidelines for the implementation of energy use standards and measurement, reporting and verification system for emissions reduction for the plastics subindustry.

### *Plastic use*

At the consumption stage, there is a strong tendency to tackle the climate impacts of plastics by focusing on plastic bags and single-use products (e.g. tableware, foodware), with a small exception for non-recyclable plastic bottles. The analysis identified the following main groups of measures:

- Policies and regulations aimed at reducing consumption by restricting, phasing out, banning the use, prohibiting and eliminating certain plastic items;
- Trade regulations: bans and prohibitions on the import of plastics, which concern bags, expanded polystyrene (EPS) and products made of it, and specified food service items;
- Financial incentives: taxes, payments and fees, transforming plastic consumption by reducing the use of products or encouraging a greater use of secondary plastic;
- Sustainable procurement policies covering plastics.

The findings also showed some examples of efforts aimed at stimulating a behavioural shift in plastic consumption, particularly single-use, through public education, culture change, and awareness-raising among different target groups.

### *Waste management*

The analysis found that plastics at the waste stage have been more extensively reported in comparison with other stages of the life cycle. The national submissions provide information on the plastics category in the composition of municipal solid waste. These numbers range from 4–10 per cent for both plastic and rubber, to 35.9 per cent for plastic. However, the analysis discovered only one example reported by Thailand of how much plastic has been recycled. Despite this fact, the measures to support plastic recycling have been widely reported. The analysis revealed targets set by the countries, for example, a target of 50 per cent recycling by weight for plastic waste as well as minimum targets for recovery and recycling for packaging waste, which range between 20 and 22.5 per cent of plastic by weight, considering only secondary plastic material. In addition, the regulations and policies reinforce or expand the separate collection of plastic with the aim to increase the collection of plastic waste for recycling, minimise the amount of waste disposed at landfills, ensure a high quality of waste management, and reduce $CO_2$ emissions from waste incineration.

In several instances, countries reported measures of established or soon-to-be introduced extended producer responsibility (EPR) and deposit return schemes for plastics.

The analysis paid attention to plastic incineration, landfilling and open burning. The results unveiled a few instances where countries report greenhouse gas emissions from plastic incineration under the energy sector. Japan reported a case where actions were taken to reduce $CO_2$ emissions associated with the incineration of petroleum-based waste, such as plastic.

Diverse strategies have been employed to mitigate the accumulation of plastic waste in landfills:

- Introducing a recycling facility;
- Banning plastic landfilling as well as single-use plastics;
- Improving waste management by separation at source;
- Investing into the expansion of "a process that allows plastics to be recycled by using an enzyme that dramatically accelerates bacterial breakdown of plastics" (Australia, Department of Climate Change, Energy, the Environment and Water 2022). The process could potentially increase plastics recovery and reduce the volumes of plastics being disposed of at landfills.

Open burning of plastic was not featured in the documents analysed, except for two cases, which recognised open burning of waste containing plastics as sources of $CO_2$ emissions in the waste sector.

The analysis also investigated waste in electrical and electronic equipment (WEEE), since it represents a type of waste that contains approximately 25 per cent of plastic by weight (Taurino, Pozzi and Zanasi 2010; Ardolino, Cardamone and Arena 2021). The results showed that there are policies in place that address WEEE through prevention, separate collection, recycling and broader regulation of waste management. The examination also revealed two cases of EPR covering electric and electronic equipment and two examples of projects aimed at raising awareness on disposal and management of WEEE.

### *Plastic pollution in the environment*

Efforts aimed at addressing plastic pollution in the environment have been poorly covered in the analysed documents. The efforts identified include monitoring microplastics in the marine environment, monitoring of plastic waste, beach clean-ups and collection of marine plastic litter, as well as rehabilitating sea turtles' entanglements in fishing gear.

## Types of polymers

The analysis identified measures and actions taken in relation to specific polymers.

There are regulations banning the manufacture, use and import of polystyrene (PS) and products containing PS.

Expanded polystyrene (EPS) has been addressed through the prohibition of manufacturing, distribution and import of the foam and products made of it. The analysis identified one case where a tax was imposed on products including extruded polystyryne (XPS) for insulation.

Polyethylene (PE) has been addressed by banning polythene bags and by prohibiting the acceptance of polyethylene waste for landfilling. Plans are in progress for a programme to convert plastic waste into oil as an intermediary product to produce polyethylene, as well as increasing the energy efficiency of ethylene-polyethylene factory buildings.

Measures concerning Polyethylene terephthalate (PET) focus on the collection, reuse and recycling of PET bottles, with one example of prohibiting the acceptance of PET waste for landfilling.

Polyvinyl chloride (PVC) has been addressed through imposing taxes on consumer goods that cause discharges of polluting substances. Additional measures were taken to ensure the collection of recyclable and non-recyclable PVC, where recyclable PVC should be recycled, and non-recyclable PVC should be assigned to a landfill. The objective of this measure is to avoid adding PVC to incineration with the consequential pollution of flue gas and slag.

The analysis also identified one case of providing financial support to a research programme focused on developing new technologies, including PU/polyisocyanurate thermal insulation materials filled with nano-/microcellulose.

## Bio-based, biodegradable, compostable, biomass plastics and bioplastics

The analysis also investigated how other types of plastics such as bio-based, biodegradable, compostable, biomass plastics and bioplastics were reported in the documents. The main observation was that there were no definitions for these types of plastics, and they could be grouped into different

# Life cycle stages of plastics under the UNFCCC and the Paris Agreement

## Sourcing

- $CO_2$ utilisation as a raw material through innovative technologies
- Plastic as secondary raw material or secondary source
- Circular economy is a recognised approach to the recycling of plastic waste as a raw material

## Production

- Bans and restrictions on manufacturing of single-use plastic and polythene bags, single-use products, expanded polystyrene (EPS) and export of polystyrene products
- Design is recognised as a significant element in achieving circularity of plastics
- Energy use for plastic production constitutes a gap

## Plastic use

- Strong tendency to tackle climate impacts of plastics by focusing on plastic bags and single-use products
- Policies and regulation aimed at eliminating certain plastic items
- Import bans
- Financial incentives (taxes, payments
- and fees), transforming plastic consumption
- Sustainable procurement policies covering plastics
- Raising awareness about consumption of plastics

## Waste management

- More extensively reported on than other life cycle stages
- Plastics category in the composition of municipal solid waste
- Various actions to reduce plastic waste landfilling
- Focus on increasing recycling and collection
- Open burning is weakly featured
- One case identified where actions were taken to reduce $CO_2$ emissions associated with the incineration of petroleum-based waste, such as plastic
- Efforts to address WEEE: prevention, separate collection, recycling and broader regulation of waste management

## Efforts to address plastic pollution in the environment

- Poorly covered
- Monitoring of microplastics in the marine environment
- Monitoring of plastic waste
- Beach clean-ups
- Collection of marine plastic litter
- Rehabilitating sea turtle entanglement in fishing gear

***Figure 5**. Life cycle stages of plastic under the UNFCCC and the Paris Agreement.*

combinations under one set of measures in the reports. For example, specific policies focus on bio-based, biodegradable plastics to address the issue of plastics. Another group of measures and actions concerns biodegradable and compostable plastics by enhancing technology and innovation to develop biological resources or agricultural products as well as by prohibiting biodegradable single-use plastic bags and regulating the use of compostable single-use plastic bags. The analysis also identified a case specifically focused on planning a programme for manufacturing biodegradable plastic bags to avoid the accumulation of plastic waste in the marine and terrestrial environment and to increase the production of green petrochemicals.

The analysis identified that bioplastics are seen as a solution to minimising the carbon footprint of plastics. The strategies, polices, and mitigation actions incentivise bioplastics innovation through the development and commercialisation of carbon-free future technologies. This includes the replacement of existing petroleum-based plastics with bioplastics to reduce waste generation while increasing recycling, and the development of a bioeconomy.

A case of biomass plastics reported in Japan's submissions observed that the use of carbon-neutral biomass plastics will be promoted to replace petroleum-based plastics as a mitigation action. Japan's submission also points out that innovation and development will create new materials such as biomass plastics made from aquatic plants.

## Plastics through a sectoral approach

The analysis also investigated references to sectoral approaches to plastics and identified 11 sectors among measures and actions recognising plastics.

*Agriculture*. As a sector, agriculture represents a significant opportunity for the production of plastic materials made from renewable biomass sources. Despite this, the analysis revealed only one relevant case where bioeconomy was used as one of the principles in the National Waste Management Action Plan "to enhance technology and innovation to develop biological resources or agricultural products such as the development of biodegradable plastics (compostable plastics) or alternative plastic products from natural materials" (Thailand 2022).

*Building and construction*. In this sector, plastics are mainly referred to as a secondary material used for making pavers, tiles and construction products. The first case of identified measures and actions could be classified as development aid: providing support for recycling plastics into pavers in Armenia and roof tiles in Kenya. Another case is the funding measure, which aims at "achieving considerable increase in actual recycling and recyclate-input rates for plastics" (Germany, Federal Ministry for Economic Affairs and Climate Action 2023) and improve circular economy solutions for construction products. The third case is the incorporation of climate change adaptation criteria in any new construction through developing building codes regulating secondary stocks, such as tiles created from plastics.

*Cement industry*. The Waste-Derived Fuels By-law on Waste Incineration introduced co-incineration facilities and alternative fuels to Türkiye's legislation. This legislation is relevant for cement production plants in the country as they co-incinerate plastic waste by licence. Another identified action is part of the mitigation strategy and is set to improve the energy saving rate of the industry and use waste synthetic resin for reduced consumption of fossil fuels.

*Chemical and petrochemical industries*. The findings demonstrate that the interventions are forward-looking and indicate the ambition of countries to reduce emissions or increase sustainability of this industry in the upcoming future. The actions include producing advanced materials such as bioplastics, improving plastic production processes and increasing the output of pyrolysis oil from plastics recycling. It is also relevant to highlight one case where a planned nationwide ban on single-use plastic bags is approached as an action towards reducing greenhouse gas emissions from the production of plastics which use petrochemical derivatives as raw materials.

*Electrical and electronic equipment*. The actions and measures in this sector are focused on WEEE, which have been covered under waste in the section "Plastics across life cycle" above. Additionally, the analysis revealed measures tackling electrical and electronic products by providing a funding measure, which is expected to enhance the quality of plastic recycling, putting in place a reparability index to improve consumption as well as designing product stewardship.

*Energy*. The analysis revealed four cases where plastics are recognised as fuel for energy production:

- Reducing energy-related $CO_2$ emissions from fuel combustion by manufacturing fuel from waste plastics, replacing fossil fuels used in manufacturing and other industries;
- Repurposing plastic waste into refuse-derived fuels;
- A precondition to sort plastic waste to enable energy recovery and waste-to-energy;
- Fuel oil production from plastic waste (reported as one of the key mitigation projects under oil and gas sector).

*Fisheries and aquaculture*. Marine resources and particularly aquatic plants are recognised for the development and innovation of new materials such as biomass plastics.

*Food and packaging*. To examine this sector, the analysis looked at 1) bags, 2) bottles, 3) foodservice containers and foodware, 4) foodservice items and tableware, and 5) packaging. The analysis also examined the measures and actions concerning these groups of products. Based on the systematisation of measures and actions according to the groups of plastic products, the issue of plastic bags is primarily addressed through financial incentives, bans and prohibitions. Improved collection is an important action for tackling plastic bottle disposal. Plastic foodservice items, containers, foodware and tableware are mainly to be banned or prohibited. Packaging is well covered by measures and actions focusing on downstream measures. The lists of measures and actions is summarised in Table 3.

***Table 3**. Summary of measures and/or actions reported under the UNFCCC and the Paris Agreement. Food and Packaging.*[6]

**Bags**

- Planning of a programme on manufacturing biodegradable plastic bags
- A monitoring system for the consumption of lightweight plastic bags
- Regulating the use of compostable single-use plastic bags
- Law on the reduced consumption of plastic bags on a long-term basis
- Financial incentives:
  - levy on lightweight plastic bags
  - legal arrangement for the payment of plastic bags for transportation purposes at the sale points
  - requirement to pay an environmental fee per piece of lightweight plastic carrier bag
- Bans and prohibitions:
  - plastic bags
  - single-use plastic bags
  - non-biodegradable, oxo-biodegradable and biodegradable single-use plastic bags
  - importation of plastic shopping bags
  - importation and use of single-use non- biodegradable plastics including shopping bags
  - manufacturing, importation, sale, purchase, storage and use of polythene bags
  - importation, manufacture, distribution and use of single-use plastic bags
- Awareness campaign for the prevention and reduction of plastic bag pollution in the marine environment

**Bottles**

- Regulating obligations regarding plastic bottle production
- Setting a target: by 2030, all tourism accommodation and catering businesses should have phased out the use of non-recyclable plastic bottles and replace them with recyclable containers
- Enforcement of a separate waste collection for plastic bottles according to the EU Waste Directive
- Container deposit legislation for collection of PET bottles
- Setting up recycling system, incentivising plastic bottle collection
- Reuse and recycle measures initiated for PET bottles
- Policy guidelines for installing plastic bottle crushing machines at railway stations
- Education programmes covering the life cycle of a plastic bottle

**Foodservice containers and foodware**

- Bans and prohibitions:
  - single-use plastic foodware
  - importation and use of polystyrene containers
  - selected single-use plastic foodservice containers
  - foam food containers
- Promotion of sorted collection and recycling of plastic containers

**Foodservice items and tableware**

- Bans and prohibitions:
  - single-use plastic tableware for the consumption of food and beverages at the point of sale and retail
  - the importation of plastic food service items
  - the importation, manufacture, distribution and use of single-use plastic straws
  - plastic cutlery

## Packaging

- Financial incentives:
  - environmental fee levied on packaging and other plastic products
  - the plastic packaging tax
- Funding measures:
  - to improve exemplary circular economy solutions including in the area of plastic packaging
  - to achieve significant improvements in the recycling of plastic packaging via the use of artificial intelligence
- Designing product stewardship schemes for plastic packing
- The National Packaging Pact – signatory companies committed to reducing their use of plastic
- Downstream measures:
  - extending EPR to include plastic and combined packaging
  - extending sorting instructions for household packaging to all plastic packaging
  - promoting the sorted collection and recycling of plastic packaging
  - the Statutory Order on Waste requiring municipalities to improve the possibilities of people and enterprises to separate and deliver plastic packaging waste for recycling
  - incentivising alternative waste management systems for plastic packaging
  - regulation prohibiting the acceptance of waste PET packaging for landfilling
  - law on packaging waste providing targets for recovery and recycling
- Awareness-raising activities: return plastic items of packaging for recycling

*Textiles*. The analysis found only two relevant cases recognising greenhouse gas emissions from cloth and textiles of fossil fuel origin during incineration and open burning. In one case, the greenhouse gas emissions are counted into energy activities, while in the other case they stated that these textiles should not be included in the national $CO_2$ emissions estimate.

*Tourism*. Banning single-use plastics has been included in a national road map for responsible tourism in the circular economy. Besides that, the analysis identified a target set for tourism accommodation and catering businesses, which should phase out the use of non-recyclable plastic bottles and be replaced with recyclable containers by 2030.

*Transport*. The analysis identified various measures to address plastic pollution concerning tyres, which could be attributed to the sector. The measures include:

- An environmental fee levied on tyres;
- National end-of-life legislation for tyres rubber;
- Waste co-incineration of tyres as alternative fuels by licence;
- Regulation of the waste exports of tyres, providing standards for exporting;
- Creating an investment fund to support recycling or recycled content projects using clean energy technologies, with a focus on waste tyres, among others;
- Designing product stewardship schemes for tyres.

It is important to state that the coverage of 11 identified sectors recognising plastics is fragmented and disproportionate. However, this provides a step towards an understanding of relevant sectors where interventions could be implemented to address the plastic issue and generate climate co-benefits. Thus, *agriculture* and *fisheries and aquaculture* are recognised as sectors that could provide renewable bio- and marine resources to move away from fossil-based plastics.

The role of plastics is acknowledged as a secondary material in making construction products in the *building and construction* sector. *Food and packaging* presents a sector where countries have reported several bans and prohibitions of certain plastic items such as bags, foodservice containers and items. This includes outlining actions to improve the collection of PET bottles, and the waste management of plastic packaging. *Electrical and electronic equipment* also demonstrated actions addressing WEEE. *Tourism* indicated that the service-oriented sector could tackle plastic use at scale.

### Gaps in sectoral approach

The analysis of plastic through a sectoral lens also exposed gaps. The *chemical and petrochemical industries* demonstrated an ambition to make the industry more sustainable and include climate considerations concerning plastics. Plastic waste as fuel represents interest for the *energy sector and cement industry*, but the energy aspects of plastic production and waste management have been very poorly covered in the reports. Further, 66 per cent of countries globally have introduced some legislation controlling plastic bags (UNEP 2018). Yet, the analysis of the UNFCCC national submissions and NDCs only provides a small subset of these initiatives within *food and packaging* as represented in the reports. Despite *textiles* being one of the main users of plastic (Geyer, Jambeck and Law 2017; Bauer et al. 2022a), the reports have a very limited representation of this sector in the context of plastics. The analysis of plastics within *transport* provided a variety of measures, but they are fully focused on one product: tyres.

## 3.2 Reporting on plastics-related greenhouse gas emissions under other fora

To understand whether and how data on greenhouse gas emissions from the plastics life cycle is available under fora other than the UNFCCC and the Paris Agreement, a database search was conducted. These include OECD Stat,[7] Eurostat,[8] FAOSTAT,[9] SDG Indicator Database,[10] UNCTAD,[11] Hotspot Analysis Tool for Sustainable Consumption and Production,[12] and several life cycle assessment (LCA) databases. The below summarises the findings.

At the global level, the search found that the OECD Stat database has a data set providing estimates of global greenhouse gas emissions from the plastics life cycle, disaggregated by two life cycle stages (named "production and conversion" and "end of life" in the data set). This data set was developed for the OECD Global Plastics Outlook and is based on modelled data.

At the national level, the OECD Stat and Eurostat databases have data sets providing total greenhouse gas emissions at the national level for their respective countries. These are disaggregated by different economic activities following the standardized classification systems of the International Standard Industrial Classification of All Economic Activities Revision 4[13] (OECD) and NACE[14] (Eurostat). Similarly, the Hotspot Analysis Tool for Sustainable Consumption and Production contain greenhouse gas emissions data for 164 countries sorted by different economic activities. Because of the way greenhouse gas emissions are classified and the level of subcategories available in these three databases, greenhouse gas emissions from the plastics life cycle are grouped together with other sources of greenhouse gases and spread across several different categories. Thus, data on greenhouse gas emissions attributed specifically to the plastics life cycle is not available in these databases.

Several LCA databases contain data on the environmental impacts of plastics, including greenhouse gas emissions from the plastics life cycle. This data typically covers a specific polymer, process or plastic product. LCA databases relevant to plastics include the Global LCA Data Access network[15] database which is the largest directory of LCA data sets from independent LCA database providers. Key databases relevant to plastics providing data in the Global LCA Data Access database is the Plastics Europe eco-profiles set[16] which contains environmental impact data for various plastic materials. Another is the Ecoinvent[17] database which provides LCAs of products and processes across a range of different sectors worldwide, including various processes and types of plastics. The Carbon Minds LCA database for Chemicals and Plastics[18] also provides LCAs of plastics, although the data in this database is not openly available and requires a licence.

A search through the FAOSTAT, SDG Indicator and UNCTAD databases did not yield data on greenhouse gas emissions from the plastics life cycle.

## 3.3 INC expectations for addressing climate change aspects of plastics

To understand country expectations for the plastics instrument to address climate change, a content analysis of country submissions to INC-3 was carried out. Prior to INC-3, Observers and Members of the Committee were invited to make submissions on elements not discussed during INC-2. A template for the submissions in two parts was provided by the INC secretariat and guided the inputs:

- Part A: Elements not discussed at INC-2: Scope, principles and additional considerations of the plastics instrument.
- Part B: Any potential areas for intersessional work compiled by the co-facilitators of the two contact groups to inform the work of the INC-3.

The INC secretariat received submissions[19] from 59 individual countries and 5 groups of countries.[20] Parts A and B were submitted separately resulting in a total of 113 documents. The analysis was carried out by searching for climate-related proposals in the 101 documents available in English, corresponding to 53 individual country submissions and 4 group submissions, representing 164 countries in total.

The results of the analysis revealed that 18 individual countries and 3 groups of countries (African Region, EU and the High Ambition Coalition), representing a total of 125 countries, provided inputs related to climate change in their submissions. The climate-related inputs were included in proposed elements for the preamble, scope, principles and additional considerations of the plastics instrument (Part A). Climate-related inputs were also identified in proposed areas for intersessional work (Part B). The below summarises the findings.

The list of INC-3 submissions featuring climate-related proposals is provided in Appendix 2: INC-3 Submissions featuring climate-related proposals.

### Identified proposed elements related to climate change for the preamble and scope

The preamble and scope of the plastics instrument received similar proposed elements related to climate change in the submissions. For the preamble, these include recognition of the interlinked triple planetary crisis (Norway A) and the co-benefits that the control measures of the plastics instrument will have for other issues including climate change (African Region A, Tunisia A, Uganda A). Similar elements were proposed for the scope of the instrument, including recognition of the contribution of plastic pollution to the triple planetary crisis (Australia A) and the risks to and impacts on climate change (Monaco A, EU A). Proposed elements for the scope also included taking into account positive impacts of the plastics instrument on climate change (EU A, Chile A). One country proposed the inclusion of greenhouse gas emissions across the plastics life cycle to be included in the definition of negative effects and emissions from plastic pollution in both the preamble and scope of the instrument (Cook Islands A). The same country also expressed strong support for decarbonisation of the plastics life cycle.

### Identified proposed principles related to climate change

Some countries proposed principles in relation to climate change. These principles include the equity principle taking into account the unequal contributions by countries to climate change and pollution and the unequal distribution of the impacts (Cook Islands A); the waste hierarchy principle as an opportunity to reduce the use of fossil fuels and prevent greenhouse gas emissions (Azerbaijan A); circular economy approaches to prevent or reduce greenhouse gas emissions (EU A); an interdisciplinary approach to consider the connection between plastic pollution, climate change and biodiversity (Bosnia and Herzegovina A); the right of the parties to choose policy mixes to combat plastic pollution taking into account their national climate circumstances (Russian Federation A); the equal treatment of plastics vis-à-vis all other materials (Russian Federation A); and the inadmissibility of measures that would hinder the achievement of other common goals including climate change (Russian Federation A).

### Identified proposed additional considerations related to climate change

Only one proposed element related to climate change under additional considerations for the plastics instrument was identified: the contribution of the plastics industry and plastic waste to climate change (Viet Nam A).

### Identified proposed potential areas for discussion in intersessional work related to climate change

Several climate-related proposals for potential areas of discussion in intersessional work were identified in the country submissions. Two submissions proposed the criteria to identify specific polymers and substances of concern which recognise the impact on climate (EU B, HAC). One submission highlighted that certain substances of concern may adversely impact the recyclability of plastics, affecting potential emissions to the environment and consequently greenhouse gas emissions from incineration/open burning, landfilling or dumping (EU B).

Other proposed areas for discussion were related to safe and sustainable alternative and substitutes to plastics: one included the consideration of a non-fossil target in the instrument to promote non-fossil alternatives and substitutes (EU B); others proposed that greenhouse gas emissions from alternatives and substitutes to plastics must be assessed (Brazil B) and compared with those from plastics in an unbiased way (Russian Federation B). The latter was proposed as a feature of a scientific and technical body, if created (Russian Federation B).

One submission proposed a discussion on the impact of plastic design and different waste management technologies on greenhouse gas emissions, and identification of minimum elements of greenhouse gas emissions from the plastics life cycle to be included in the LCAs of plastics (Cook Islands B).

Another submission highlighted the risk of including restrictions on the production and/or trade of plastic products in the plastics instrument leading to more damage to climate change through increased food waste and waste from alternative materials (Russian Federation B). Lastly, several countries highlighted the significant role of plastics for society and their role in reducing greenhouse gas emissions (Bahrain B, Kuwait B, Qatar B, Saudi Arabia B, United Arab Emirates B).

# 4 Measures for optimising climate benefits across the plastics life cycle

## Key findings

➔ **Under the plastics instrument**:

a) Reduce the overall production of primary polymers by reducing the use of primary polymers, increasing the use of secondary plastics, phasing out problematic, unnecessary and avoidable plastic products, and increasing the use of low-carbon non-plastics substitutes.

b) Limit greenhouse gas emissions by developing design criteria that focus on 1) employing low-carbon feedstocks, 2) using polymers with low net-energy requirements considering the full life cycle, particularly production, and that are also suitable for reuse/refill systems and mechanical recycling, and 3) minimising the release of microplastics.

c) Limit greenhouse gas emissions of waste management by 1) limiting open burning and other forms of mismanagement of plastic waste, and 2) developing criteria to support an Life Cycle Assessment of waste management facilities towards investment in lower-emitting technologies and avoiding lock-ins to high-emitting technologies.

d) Strengthen trade control measures to include considerations of greenhouse gas emissions.

➔ **Under the UNFCCC**, the greatest potential to reduce greenhouse gas emissions lies in the decarbonisation of the plastics life cycle, particularly energy used for heat and transport, while acknowledging that it will be important to tackle carbon lock-ins.

➔ **Under both instruments**:

a) Promote research, innovation and low-carbon technology development to expedite the reduction of greenhouse gas emissions and to remove uncertainties related to certain technologies, such as chemical conversion and carbon capture and utilisation, before their inclusion in the agreements.

b) Strengthen transparency and accountability by developing an indicator framework to track climate-related measures under the plastics instrument and disaggregate plastic-related greenhouse gas emissions under the UNFCCC.

c) Scale sustainable financing from public and private sources to address the climate component of plastics and emphasize the need for the financial sector to shift investments away from fossil-based and emissions-intensive petrochemical production.

## Overview

This chapter outlines measures for optimising climate benefits across the plastics life cycle. It clearly assigns roles between the plastics instrument, the UNFCCC and the Paris Agreement. A summary of these measures is provided in Table 4, building on the technical groundwork laid out in Chapter 2 of the report. For each of the life cycle stages, national market-based measures are suggested for promotion under the plastics instrument to strengthen implementation. Additionally, it includes specific indicators to clearly define the measures to be monitored, facilitating progress tracking under both the plastics framework, the UNFCCC and the Paris Agreement.

Figure 6 presents the relationship of recommended measures under the plastics instrument, the UNFCCC and the Paris Agreement. This aligns with the technical foundation of Chapter 2 which shows that the vast majority of greenhouse gas emissions originate from production of plastics. The primary focus of control measures should therefore be on reduction and redesign of plastic products to enhance climate outcomes across the plastics life cycle.

## 4.1 Core measures under the plastics instrument to reduce production

The primary objective of the measures outlined below is to achieve source reduction, providing positive outcomes for the sourcing stage of the plastics life cycle. This is recognised in the literature as having the highest potential to reduce greenhouse gas emissions (see Section 2.2).

The production of primary polymers can be supported by other measures that will inherently lead to a reduction in production. Primary polymer demand can decrease if measures are implemented effectively and supported by these reduction targets.

The measures discussed in this section which can assist in achieving this goal are:

- Reduce the use of primary polymers (fossil- and bio-based sources);
- Increase the use of secondary plastics;
- Minimise the production of problematic, unnecessary and avoidable products;
- Increase the use of low-carbon non-plastic substitutes.

### Reduce the use of primary polymers

***Description of measure(s)***

The plastics instrument could adopt restrictions on the annual production and consumption of controlled substances (i.e. primary plastic polymers from fossil- and bio-based sources). Restrictions could include a cap on production and consumption to be achieved by a target year (e.g. 2030) based on a certain baseline year (e.g. 1990), followed by a series of reduction steps ("phase-down") to lower production and consumption. Such targets could be set for groups of polymers. Alternatively, the target could include reversing the current annual growth rate of plastic demand from 4 per cent to 0 per cent by a target year (e.g. 2030). The use of targets and caps is expected to lead to innovation and resource efficiency, following the Montreal Protocol model (Raubenheimer and McIlgorm 2017).

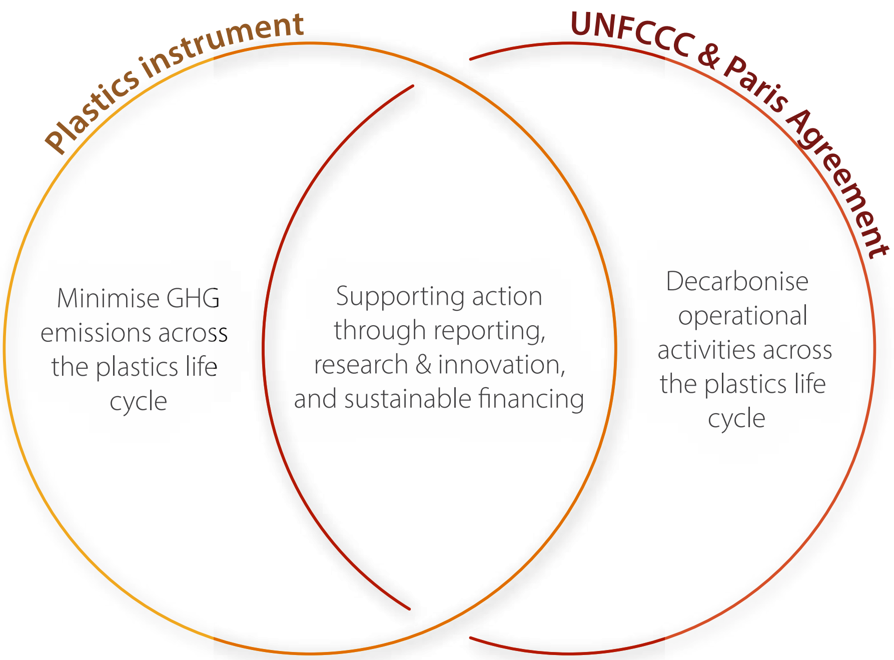



***Figure 6****. Relationship of recommended measures under the plastics instrument, the UNFCCC, and the Paris Agreement.*

*Table 4. Summary of measures suggested to optimise climate outcomes across the plastics life cycle.*

| **Plastics instrument** | | | | |
|---|---|---|---|---|
| • **Include greenhouse gas emissions as a plastic pollutant** | | | | |
| **Sourcing of raw materials** | **Production of plastics** | **Plastic use and reuse** | **Waste management** | **Plastic pollution in the environment** |
| • Sourcing/extraction reduced through effective implementation of measures under the plastics instrument | • Reduce use of primary polymers<br>• Increase use of secondary plastics<br>• Minimise production of problematic, unnecessary, and avoidable plastics<br>• Increase use of low-carbon non-plastic substitutes<br>• Include low-carbon feedstocks in design criteria<br>• Include low-carbon polymers in design criteria<br>• Include minimisation of microplastic releases in design criteria | • Develop and expand scalable models for reuse and refill systems | • Minimise open burning and other forms of plastic waste mismanagement<br>• Minimise the carbon footprint in plastic waste management | • Promote environmental and landfill remediation |
| **The UNFCCC and the Paris Agreement** | | | | |
| • **Decarbonise the plastics life cycle** | | | | |
| • Transition to renewable energy sources<br>• Incentivize energy efficiency to decrease energy demand<br>• Reduce greenhouse gas emissions from transport and trade | | | | |
| **Plastics instrument, the UNFCCC and the Paris Agreement** | | | | |
| • **Strengthen transparency, accountability and information sharing**<br>• **Accelerate research, innovation and low-carbon technology development**<br>• **Scale sustainable financing** | | | | |

Moreover, this could also stimulate the use of low-carbon non-plastic substitutes that have undergone a full life cycle assessment, including determination of socioeconomic net-benefits.

Combining a cap-and-trade system with a prior informed consent procedure would allow countries to restrict the import of primary material for use in domestic conversion facilities, thereby promoting end-markets for recycled content (domestically produced and traded). This aligns with the Basel Convention, which mandates Parties to reduce the generation of hazardous wastes and other wastes within its jurisdiction (Article 4.2).

***Feasibility***

A uniform standard would need to be established for measuring and monitoring plastic production and trade to ensure that all countries have adopted measures to contribute to the achievement of the agreed cap(s). This would require the development of a standardized methodology for tracking plastic production.

The cap would promote close tracking and traceability of primary materials associated with the plastics life cycle. Coupled with the removal of subsidies for plastic production (or a countermeasure tax on the use of fossil fuel-based primary material for conversion), a cap would be a significant lever in 1) increasing strategies to reduce the need for primary material (bans, reuse models, etc.) and 2) end-markets for secondary plastics. Both these levers would be enabled by improved design of materials and products to facilitate reduction, reuse and recycling.

A cap on fossil primary polymers could dramatically increase the production and use of non-plastic substitutes, many which have a higher climate impact than plastics, thus making efforts counterproductive. A cap must therefore be carefully aligned with an overall reduction in the consumption of plastics and significant improvements in the circularity of plastics. Moreover, a relatively small number of companies produce a significant portion of the world's plastic (Minderoo Foundation 2023); this could thus limit the impact of a cap-and-trade system if those companies do not participate.

### Increase the use of secondary plastics

***Description of measure(s)***

The demand for primary plastic polymers could be limited by setting targets for secondary polymers, possibly at the sector level and for product groups. This could include a global target, which is gradually raised, aiming to achieve over time a maximum level of safe secondary plastics that is technically feasible. Ideally, by 2040 most plastic products should be made from secondary polymers to the extent possible, while noting that presently plastics have limits on the number of times they can be mechanically recycled (Simon et al. 2021). Exemptions should only be granted for materials where there is no acceptable threshold of contamination, or for which no safe non-plastic substitutes exist (Simon et al. 2021). Provisions mandating a minimum content of secondary plastics can significantly increase demand for secondary feedstock and assist in maintaining a positive cash flow for the recycling industry during times of decreased commodity prices (Raubenheimer and McIlgorm 2017). Such provisions must be complemented by measures that increase the supply of high-quality materials for recyclers, reduce the use of specialised (problematic) plastics, and ensure design for safe recyclability (labelling, disassembly, polymer simplification, etc). Global design criteria developed under the plastics instrument could ensure products are not released to the market unless they meet recyclability criteria (also developed under the plastics instrument).

***Feasibility***

Recycling reduces the need for new feedstocks and associated greenhouse gas emissions, although it depends on a continuous supply of primary polymers to blend with secondary plastics for maintaining quality. Recycling also reduces waste sent to landfill or incinerated and reduces the likelihood of leakage into the environment. However, effective recycling is currently available only for PET, PP, and HDPE polymers. The economic viability of recycling is closely linked to the cost of primary materials, which are afforded financial support through subsidies. In addition, a strong policy landscape is needed to strengthen end-markets, while investing in collection and product design to support disassembly, polymer identification, and product simplification. These will help transition the majority of low-quality materials produced by recyclers.

The availability of high-quality secondary plastic could be a limiting factor in achieving secondary plastic targets. If there are insufficient secondary plastics available to meet the demand, companies may be forced to use primary polymers. To address this, investments in collection (including by workers in informal and cooperative settings) and recycling infrastructure and technologies would increase the supply of secondary plastic. The informal waste sector would benefit from a greater percentage of plastic products being made of PET, PP and HDPE. For both formal and informal systems, this would reduce the need for sorting and disposing of non-recyclable or non-profitable polymer types. Volumes of plastics sent to recyclers could increase, creating scale and efficiencies for such facilities.

Effective design strategies are essential to address the contamination challenges associated with the use of secondary plastics, as detailed in Section 4.2.

### Minimise the production of problematic, unnecessary, and avoidable products

***Description of measure(s)***

It is necessary to reduce production by phasing out unnecessary plastics, minimising avoidable plastics, and redesigning problematic plastics to curtail the overall impact on the environment, including climate impacts. Criteria to identify problematic plastics could include a criterion on the $CO_2$ emissions in addition to presence of chemicals of concern, hindrance of recyclability, and high likelihood of leakage (UNEP 2023c; United Kingdom 2023). Consideration should also be given to the elimination of problematic polymers (such as PVC, PS and expanded polystyrene [EPS]) which are hard to recycle and, consequently, lead to increased greenhouse gas emissions (Pew Charitable Trusts and Systemiq 2020).

***Feasibility***

Criteria can be developed at the global level under the new plastics instrument, which can lead to listings of products requiring mandatory global action as per measures outlined in the instrument. Examples can be found in existing MEAs (Secretariat of the Basel, Rotterdam and Stockholm Conventions 2023). These criteria can also assist countries with identifying additional products for regulation at the national level, going beyond the global listings. Relying on national action without the support of global control measures will lead to fragmentation and delays.

The decarbonisation of the plastics life cycle must be coupled with strong measures to reduce production. Targeting the phase-out and minimisation of products can incentivise research and innovation into alternate business models (e.g. reuse) and non-plastic substitutes, but these must be accompanied by full life cycle assessments using harmonised methodologies to ensure findings are comparable and regrettable substitutions avoided.

Control measures to phase out and minimise products will require comprehensive stakeholder consultation to identify socioeconomic factors to be considered by decision makers. This can be lengthy and resource intensive. Sharing findings from life cycle assessments can accelerate such processes e.g. through a global knowledge platform.

### Increase the use of sustainable, safe, and low-carbon non-plastic substitutes

***Description of measure(s)***
Careful selection of non-plastic substitutes, guided by global criteria, could reduce greenhouse gas emissions, if key impact considerations like packaging weight, sourcing and technological advances are well managed (Pew Charitable Trusts and Systemiq 2020). Central to these criteria should be low carbon, energy, and water footprint. Such non-plastic substitutes play a crucial role in transitioning to plastic reduction strategies. Countries will need to consider selection of non-plastic substitutes carefully and take national conditions into account to ensure that non-plastic substitutes can help reduce the climate impact associated with the production and use of traditional plastics. For this reason, locally sourced substitutes are preferrable in limiting greenhouse gas emissions i.e. they are affordable and accessible. Additionally, these criteria should include comprehensive life cycle assessments to help make informed decisions that mitigate environmental, climate and potential human health impacts, tailored to specific geographical contexts.

***Feasibility***
Carefully considered plastic substitutions with paper or compostable materials (e.g. bamboo fibres and araca leaves) could offer greenhouse gas emissions savings due to the transition from a fossil fuel-based product to a largely renewably sourced one (Pew Charitable Trusts and Systemiq 2020; UNEP 2021). Typically, the most suitable substitutes are found among locally available materials with a high potential for reusability (United Nations 2023a). Benefits include reduced fossil fuel reliance and potentially smaller carbon footprints during production, use and disposal. Biodegradable and compostable options can reduce landfill waste and associated methane emissions.

However, challenges such as investment needs in new technologies, supply chains, or research and development must be addressed. Moreover, life cycle assessments must be conducted to ensure the non-plastic substitutes promoted provide a net-benefit for greenhouse gas emissions across the full life cycle, including different energy mixes, using standardized methods such as ISO 14067:2018 (carbon footprint of products). Care must also be taken to avoid adverse effects like increased land use for crop-based alternatives, which could lead to deforestation and biodiversity loss.

### Market-based measures related to reduction in production

***Implement trade tariffs to promote sustainable and low-carbon non-plastic substitutes***

Plastic materials and products generally enjoy lower tariffs of around 10 per cent, while tariffs for non-plastic material and product substitutes range between 5 per cent and 25 per cent (United Nations 2023a). UNCTAD recommends the development of special classifications under the World Customs Organization's Harmonized System (HS Codes) for material non-plastic substitutes and alternatives to enable their promotion through adjustment of tariffs (United Nations 2023a). An increase in HS Codes generally translates to additional pressure on border authorities. The development of technological assistance can overcome some of the increased burden and potentially improve the accuracy of HS Codes' assignment to products exported. The World Customs Organization reviews and amends HS Codes every 4–6 years and negotiations tend to be lengthy (Barrowclough, Deere Birkbeck and Christen 2020).

**Box 1. Potential indicators for tracking control measures related to reduced production**

- Reduction in greenhouse gas emissions associated with sourcing of feedstocks and plastic production (refining, monomer production and polymerisation)
- Percentage reduction in the total volume of primary plastic polymers, as a percentage of the previous year's production
- Percentage increase in post-consumer feedstock use
- Number of plastic applications/groups replaced by sustainable non-plastic substitutes

## 4.2 Core measures under the plastics instrument for low-carbon design

The primary objective of the measures outlined below, targeting the production and conversion stage of the plastics life cycle, is to ensure a sustainable design of plastics. This is recognised in the literature as having a high potential to reduce greenhouse gas emissions (see Section 2.3) and consideration should be given to incorporating these into criteria for sustainable design under the new plastics instrument. The design criteria should focus on:
- Using low-carbon feedstocks;
- Using polymers with low energy requirements during production, that are also suitable for reuse/refill systems and mechanical recycling;
- Minimising microplastics releases.

### Include the use of low-carbon feedstocks in design criteria

*Description of measure(s)*

Using renewable feedstocks, such as biomass, offers a significant strategy for reducing greenhouse gas emissions. The use of $CO_2$ as a replenishable feedstock may also be considered where low-emitting capture and use methods are ensured. The design criteria, voluntary standards, and technical regulations developed under the plastics instrument could promote the use of sustainable bio-based feedstocks. This could be supported through the development of a harmonized methodology for comprehensive life cycle assessments (see Appendix 3 for applicable ISO standards) and certification programmes, possibly a single global certification mechanism to verify claims.

*Feasibility*

Despite the positive outlook of bio-based plastics in terms of greenhouse gas emissions, their environmental impact is controversial because of their potential to drive land-use changes such as deforestation that further drives greenhouse gas emissions (OECD 2022a) as well as their potential to further drive water scarcity. Where bio-based feedstocks are cultivated in drier regions, this could lead to increased use of agriplastics for irrigation and an increased use of the fertilizer and pesticide containers (Food and Agriculture Organization of the United Nations 2021). However, algae- and fungi-based feedstocks provide opportunities to develop bio-based feedstocks that do not compete with land-based food production. Benefits to developing countries in scaling environmentally safe and just seaweed farming, including for bio-based plastics, includes attracting investment, creating jobs, and diversifying their ocean economies, in addition to reducing the competition for land (United Nations 2023b). Seaweeds provide an array of opportunities to drive the blue circular economy, including their ability to sequester large amounts of $CO_2$. In the future, point source $CO_2$ capture and sequestration could further enhance this approach.

### Include the use of low-carbon polymers in design criteria

*Description of measure(s)*

The focus on utilising low-carbon polymers encompasses several key aspects:

- Evaluating and factoring in the variations in energy requirements for different polymers during production;
- Favouring polymers that are fit-for-purpose for reuse and refill systems but are also recyclable when products reach the end of their intended use;
- Opting for polymers that are suitable with less carbon-intensive recycling technologies, in particular mechanical recycling.

The criteria for chemicals and polymers of concern proposed under control measure 2 of the zero draft of the plastics instrument could potentially address climate change impacts (United Kingdom and Brazil 2023). This could include assessing the carbon footprint assessments as well as global warming potential of polymers (United Kingdom and Brazil, 2023).

*Feasibility*

First, it is essential to note that the carbon footprint varies significantly between primary polymers and secondary plastic, which should guide polymer selection (see Section 2.2). To fully grasp the carbon footprints of different polymers, a comprehensive life cycle analysis is necessary, from raw material sourcing through production, use, and waste management. PET is an example where innovation has broadened its market presence, extending its applications to sectors requiring packaging such as pharmaceuticals, health care, and home care (Sustainable Packaging News 2022). Toothpaste tubes are traditionally not recyclable, but a PET tube has been developed that can be recycled (Mohan 2022).

Second, the choice of polymers for reuse and refill systems should be guide by multiple factors, such as their physical properties, resistance to chemicals, ease of cleaning, and their ability to remain compatible across various products and temperature ranges.

Third, to minimise greenhouse gas emissions, polymer selection should favour those most suited to mechanical recycling, such as PET, HDPE and PP, as opposed to non-recyclable options, like PVC, PS, multilayer plastics, and thermosets (Pew Charitable Trusts and Systemiq 2020). Further, to enable effective mechanical recycling, design strategies should prevent plastic waste contamination, which encompasses the presence of other waste types, such as organic materials, as well as inks, additives, or mixed polymers (Pew Charitable Trusts and Systemiq 2020). Design should increase transparency regarding the use of chemicals and their risks, but also adhere to chemical simplification by limiting variety to a minimal number of less toxic substances (Carmona et al. 2023).

### Include minimisation of microplastic releases in design criteria

*Description of measure(s)*

Design should focus on reducing release of microplastics to mitigate their contribution to climate change exacerbation. Global design criteria developed under the instrument should include thresholds for releases of microplastics during their intended use and expected lifespan, possibly by sector and product groups. Additionally, preventing pellet loss from a manufacturing and handling point of view is important. Complementary measures include 1) capturing microplastics in wastewater treatment, 2) using filters in washing machines, and 3) prohibiting the use of sewage sludge containing microplastics as soil enhancer, unless certified as microplastic-free.

*Feasibility*
The global design criteria offer a proactive approach to minimising release of microplastics from the source, potentially easing the reliance on less effective and more expensive downstream interventions. Primary treatment of wastewater can remove the majority of microplastics, although significant amounts would still be released into the environment from such facilities. This would require greater investment in research on inexpensive technologies to reach zero releases, supported by the development of standardized methodologies for monitoring microplastics in wastewater (Sadia et al. 2022). However, a significant hurdle is that nearly half of global wastewater is currently untreated, highlighting the need for major investment in wastewater management (Jones et al. 2021).

## Market-based measures related to low-carbon design

### *Implement earmarked taxes on primary polymers for internalising greenhouse gas emissions*

*Description of measure(s)*
To internalize greenhouse gas emissions associated with primary polymers, the introduction of earmarked taxes is advised. Earmarking taxes specifically for environmental purposes enables the redirection of funds towards activities that enhance carbon sequestration, such as environmental rehabilitation projects. These taxes can be applied at different stages of the plastics life cycle. Taxing primary polymers and the production stage simplifies policy implementation by targeting a limited number of companies. Alternatively, taxing converters or companies selling plastic products allows for more precise targeting of specific, problematic plastics (NCM 2023).

*Feasibility*
Taxes can stimulate innovation, drive cost-effective pollution reduction, and generate revenue that can be used for various purposes (UNEP 2022b). Effective implementation depends on robust life cycle data to set appropriate tax rates. It is essential to assess economic and social impacts, especially how such taxes might affect consumer prices and potentially burden lower-income households. Careful local assessments are necessary to set tax rates that fairly distribute the economic impact and avoid inadvertently shifting costs onto consumers (NCM 2023).

### *Implement trade-related measures to promote sustainable and low-carbon materials and products*

*Description of measure(s)*
Trade is an important component of every stage of the plastics life cycle. While plastics are traded as a commodity, they are also used to package, protect, and add value to exports. All countries are both importers and exporters of plastic products and their predecessors, or products containing or packaged in plastics. Trade-related measures, such as tariffs and import/export bans, can be promoted at the global level under the plastics instrument and enacted at the national level by regulating imports. Trade-related measures can also be used to promote greater global diffusion and market access for environmentally sound non-plastic substitutes.

The plastics instrument could also restrict the trade of products between Parties to the instrument and with non-Parties, should the products not comply with control measures adopted under the instrument.[21] Control measures could include meeting sustainable design criteria, such as use of low-carbon materials, products, and non-plastic substitutes. The trade of fossil fuel feedstocks and precursors, as well as additives and chemicals of concern used in plastic products, could be tracked and restricted.

*Feasibility*
As discussed in Section 4.1.5, HS Codes would require revision to accommodate a significant expansion should all components of plastic products be tracked when traded. A global system of standards and labelling could be developed to facilitate identification and tracking of problematic materials and products, including those made from recycled materials. The disaggregation of feedstocks, precursors, and additives used specifically for production of plastics, as well as the "hidden trade" of plastics in products, may be challenging to identify and track in trade systems (Deere Birkbeck et al. 2023).

Following the conclusion of the first global stocktake of climate action under the Paris Agreement, the decision adopted at the twenty-eighth Conference of the Parties (COP 28) to the UNFCCC recognised that "Parties should cooperate on promoting a supportive and open international economic system aimed at achieving sustainable economic growth and development in all countries and thus enabling them to better to address the problems of climate change, noting that measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade" (UNFCCC 2023a). Trade-related measures must therefore align with the global rules of trade developed under the World Trade Organization.

**Box 2. Potential indicators for tracking control measures related to low-carbon design**

- Number of countries that have adopted policies to promote use of sustainable plastic alternatives
- Percentage of global plastic production using renewable feedstocks
- Percentage of polymers with lower climate impact used
- Number of countries with established EPR schemes aiming to reduce greenhouse gas emissions through improved product design

## 4.3 Core measures under the plastics instrument targeting plastic use and reuse

The measures outlined below aim to assist in achieving sustainable consumption of plastics. The literature is weak in modelling the contribution of this stage to the overall greenhouse gas emissions from the plastics life cycle (see Section 2.3.).

### Develop and expand scalable models for reuse and refill systems

***Description of measure(s)***
To reduce the demand for new materials, developing scalable alternative delivery models that support the expansion of reuse and refill systems is essential. This involves extending the lifespan of products through reuse, elimination of planned obsolescence, and promotion of repair. The goal is a significant scale-up in products sold in reusable/refill models, particularly in categories where change is most feasible or impactful (UNEP 2023b). Reuse models include home refills, on-the-go refills, home packaging pickup and in-store/drop-off returns. For businesses, there is opportunity to expand on the many existing business-to-business reuse models (Ellen MacArthur Foundation 2020). Reuse and refill targets, and related provisions, can be mandated in EPR legislation for appropriate product streams (Upstream 2022).

***Feasibility***
LCA studies usually confirm the environmental superiority of reuse systems over single-use systems. They also point out key parameters to be considered to ensure their preference, such as a minimum number of reuse cycles, efficient reverse logistics, or washing (UNEP 2021). The success of reuse models depends on return rates, washing systems (centralized or decentralized), and the use of collection platforms by multiple brands (Eunomia 2023). Reuse models require product design changes, including standardisation of containers to allow for durability and easy refilling and cleaning. Infrastructure changes are needed, including establishment of refilling stations and advanced cleaning mechanisms. Further, policies and legislation could incentivise reusable solutions, while imposing constraints on single-use plastics. Business models need to shift from product sales to refilling services, accompanied by consumer education on reuse benefits.

One challenge is the significant upfront costs that infrastructure and systemic changes to support and standardize refilling operations may involve. In addition, ensuring the consistent quality and safety of reused containers is paramount. Moreover, consumer behaviours and perceptions need to evolve. The water footprint for cleaning in arid regions, especially for food packaging, requires careful consideration. Transport systems must employ existing systems, such as for reverse logistics and backloading systems (see Section 4.5.3.). Comprehensive LCAs are needed to understand the break-even point where the number of reuses outweighs disposables for environmental benefits of greenhouse gas emissions, water use, land use, and waste generation. Reusable products will need to be designed to minimise releases of chemicals and microplastics over their expected reuse lifespan.

### Market-based measures related to use and reuse

#### *Provide incentives for transitioning to reuse and refill models*

***Description of measure(s)***
Economic incentives can encourage businesses to transition to reuse and refill models and can also increase rates of separation and return by consumers and commercial facilities. They can be based on a reward system or a charge (e.g. depot–refund schemes, pay-as-you-throw). These can be combined with government subsidies and tax exemptions for companies that invest in reuse and refill, reverse logistics, and backloading.

Policy incentives can include mandatory participation in EPR schemes for producers of products that are suitable for reuse and refill business models. Where such EPR schemes are intended to encourage transition to reuse and refill systems, producers will need to redesign products to enable such systems. EPR schemes can also make producers collectively responsible for establishing infrastructure appropriate for reuse and refill models. Due to the extended lifespan of plastic products in reuse and refill systems, global design criteria should be developed to ensure that such plastic products do not leach microplastics or chemicals of concern over their expected lifespan.

***Feasibility***
EPR schemes are increasingly being adopted at the national level, with over 80 per cent of European Union countries implementing such systems for packaging waste. In the US, 119 EPR laws span 33 States for various products (Tumu, Vorst and Curtzweiler 2023). EPR schemes can be complex to establish and require consultation with producers, the informal waste sector, and other relevant stakeholders. Where feasible, such schemes should cover rural areas as well as metropolitan areas. EPR schemes can initially be set up with non-binding targets supported by mandatory performance reporting, possibly later transitioning to mandatory targets and penalties. The administrative burden can be lessened for government agencies by making the private sector responsible for managing the scheme, including the central fund and subsidising of associated waste management services. Transitioning the informal sector into reuse and refill systems will be crucial in many countries.

#### *Sustainable procurement policies to minimise use of plastics*

***Description of measure(s)***
Sustainable public procurement can play an important role in closing material loops and driving the circular

economy. It can promote purchase of reusable products instead of single-use ones, hold the supply chain accountable for overconsumption of plastics, and raise awareness among policymakers.

*Feasibility*
The United Nations One Planet Network Sustainable Public Procurement programme has developed the Sustainable Public Procurement of Plastics Guidance,[22] providing public procurers with practical guidance, including on evaluating procurement spend areas to identify where plastics are found and how to adapt tendering procedures for procurement to reduce consumption of plastics by the public sector.

**Box 3. Potential indicators for tracking control measures related to use and reuse**

- Percentage of newly designed plastics that are recyclable
- Percentage increase in reuse and refill systems
- Return rate of reuse systems
- Number of reuse and refill systems using reverse logistics and backloading
- Number of reuse and refill systems using recycled water
- Number of countries with established EPR schemes aiming to reduce greenhouse gas emissions through reuse and refill systems
- Percentage of existing procurement of conventional plastic products replaced by recyclable plastics, reuse and refill systems and non-plastic substitutes over time
- Number of high-risk sectors that have adopted global and/or regional strategies to reduce use of plastics

## 4.4 Core measures under the plastics instrument targeting waste management and plastic pollution in the environment

The aim of the measures outlined in this section is to assist in achieving environmentally sound waste management through reduced greenhouse gas emissions. This stage of the plastics life cycle is recognised in the literature as having the second-highest potential to reduce greenhouse gas emissions (see Section 2.4.).

### Minimise open burning and other forms of plastic waste mismanagement

*Description of measure(s)*
The plastics instrument must emphasize the critical need to prevent mismanagement of plastics, particularly open burning, which is essential for reducing greenhouse gas and black carbon emissions. For this, reduced generation of plastic waste and access to effective waste management services are urgently needed. Improving the collection of plastic waste coupled with investment in reuse and recycling systems can lead to a reduction in leakage and open burning of plastic waste.

*Feasibility*
Minimising mismanagement of plastic waste will require a comprehensive approach to the generation and management of plastic waste more broadly. Measures for elimination of plastic pollution would inherently contribute to this goal if implemented effectively but can be supported by bans on open burning at the national level where safer waste management options are available.

### Minimise carbon footprint in plastic waste management

*Description of measure(s)*
Paragraph 94(g) of the technical guidelines on the environmentally sound management of plastic wastes developed under the Basel Convention promotes the adoption of legislation and/or permitting/approval processes that restrict greenhouse gas emissions across the life cycle of plastics, including in the waste management stage. The guidelines link such efforts to targets set within NDCs under the Paris Agreement.

Investment in waste management infrastructure should consider the level of greenhouse gas emissions associated with available technologies, with the aim of avoiding lock-ins to higher-emitting recycling, recovery, and disposal options. For example, solvolysis produces greenhouse gas emissions that are at least two times higher than those of mechanical recycling (Pew Charitable Trusts and Systemiq 2020). However, it is important to note that solvolysis still results in lower greenhouse gas emissions compared with other, more common chemical conversion methods, specifically pyrolysis and gasification, with pyrolysis emitting the most (Kwon et al. 2023) (see Section 2.4.).

To support the adoption of technologies with lower greenhouse gas emissions, the design of plastic products could promote use of types of polymers that are appropriate to low-emission waste management technology. For example, PET, PP, PS, EPS and nylon are polymers suitable for solvolysis (the lowest emitting 'chemical conversion' option). This may be an option once these polymers have exhausted their cycles under mechanical recycling. Despite many countries adhering to the waste hierarchy by transitioning from landfilling to incineration with energy recovery, this practice is not advisable as it frequently results in elevated system-level greenhouse gas emissions from plastics (Systemiq 2022). The plastics instrument must:

- Acknowledge the varying levels of greenhouse gas emissions associated with different waste management options;
- Develop criteria to support life cycle assessment of waste management facilities to foster investment in lower-emitting technologies and avoiding lock-ins in high-emitting technologies;
- Promote the offset of greenhouse gas emissions for existing waste management facilities through carbon capture technologies.

*Feasibility*
Paragraph 94a of the technical guidelines on the environmentally sound management of plastic wastes developed under the Basel Convention promotes the inclusion of life cycle assessments in the regulation and/or approval process for disposal facilities. Life cycle assessments should include greenhouse gas emissions and can assist in meeting the criteria for selection and approval of treatment facilities by governments and the private sector.

Recovery operations can reduce the carbon footprint of plastics by reusing waste or recovering energy. Although scaling up recycling is critically needed, capturing all plastic materials in the recycling process is neither technically nor financially feasible (Pew Charitable Trusts and Systemiq 2020). This is compounded by the fact that approximately 2.7 billion individuals lack access to waste collection systems (Wilson 2023), which limits scalability of recycling and makes developing comprehensive recycling infrastructure more challenging, often relying on the informal sector.

Mechanical recycling is a technology that is well understood and employed more commonly than chemical conversion. The latter is still developing and is energy intensive (Ragaert, Delva and Van Geem 2017; Bauer et al. 2022a). After collection and sorting, the plastics are washed and ground, maintaining the molecular structure. Challenges of mechanical recycling resulting in greenhouse gas emissions include the following:

- Only a fifth of current plastic is economically recyclable due to poor design (UNEP 2023b).
- Plastics often degrade after just two or three recycling cycles, requiring blending with primary materials or alternative disposal (Pew Charitable Trusts and Systemiq 2020).
- Only 10 per cent of polymer waste is mechanically recycled more than once (Vora et al. 2021).
- A limited range of polymers, mainly PET and HDPE, are recycled, with the rest often incinerated or landfilled.
- About 25 per cent of the recycling process results in non-recyclable residues (Pew Charitable Trusts and Systemiq 2020).
- Microplastic releases during recycling and contamination of recycling streams by chemicals of concern pose additional challenges (Suzuki et al. 2022).

Prerequisites for mechanical recycling include (Carmona et al. 2023):

- Increased transparency regarding the use of chemicals and their risks (see Section 1.2.3);
- Chemical simplification of the plastics on the market (see Section 1.2.3);
- Improved waste management infrastructure and methods with separated waste streams;
- Monitoring of chemicals of concern in waste streams.

### Promote environmental and landfill remediation to reduce greenhouse gas emissions

*Description of measure(s)*
Environmental and landfill remediation of existing plastic pollution will need to be featured in the plastics instrument to help prevent methane and other hydrocarbon emissions. Although well-managed landfills often have gas collection systems, a substantial portion of methane emissions, ranging from 10–65 per cent, may still escape (Spokas et al. 2006). Landfill mining, which involves segregation of organic matter, can help reduce methane production, while recovering useful materials and optimising waste disposal. Remediation can be complemented with rehabilitation or restoration of degraded ecosystems and/or wildlife populations. To this end, landfill sites have the potential to become natural carbon sinks.

*Feasibility*
By cleaning up and properly processing plastic waste, methane production in landfills and the environment from existing plastic pollution can be reduced. This process includes collecting waste plastic from landfills, dumpsites and the environment, and processing it into a suitable alternative fuel, which involves considerable investments and operational costs (UNEP 2023c). Addressing existing oceanic plastic pollution is daunting, as research indicates that a staggering 94 per cent of plastics entering the oceans eventually settle on the sea floor, while a mere 1 per cent remains at or near the surface (Sherrington et al. 2016). In addition, risks of clean-up operations include the potential release of other contaminants and the need for specialized equipment. A life cycle assessment of clean-up operations can help to determine the associated greenhouse gas emissions and other potential risks.

### Market-based measures related to waste management

#### *Promote EPR to make producers accountable for plastic waste and associated greenhouse gas emissions via eco-modulation*

*Description of measure(s)*
To address plastic waste and associated greenhouse gas emissions, the plastics instrument should promote the use of EPR schemes with eco-modulation. EPR schemes with modulated fees encourage products that are easier to recycle or that contain recycled content to incur lower charges than those that are harder to recycle (UNEP 2023b). By modulating these fees, products with circular designs either benefit or face penalties based on their design features (Laubinger et al. 2021). Modulated EPR fees can factor in advanced criteria, such as recyclability, recycled content, product lifespan and carbon footprint, driving the reduction of greenhouse gas emissions.

*Feasibility*
EPR can transfer the financial burden of waste management and clean-up from taxpayers and municipalities to producers. Eco-modulation of EPR fees provide a financial incentive to invest in product design, which can include greenhouse gas emission reductions. Although many jurisdictions are experimenting with modulated EPR fees for plastics, setting up such systems demands strong regulatory structures and collaborative industry participation. For instance, France has a 100 per cent fee increase for non-recyclable material, and

the province of Quebec in Canada has 2 per cent reduction of fee for packaging that is entirely manufactured with recycled content. Implementation of an EPR system may be met with resistance from industry stakeholders. Moreover, while EPR has seen success in many developed nations, its implementation in emerging economies has faced challenges such as stakeholder opposition and weak institutions (OECD 2016).

#### *Landfill fees and taxes, and bans on landfilling of recyclable materials*

*Description of measure(s)*
Landfilling is an end point in the linear economy and must be avoided to reduce the need for primary materials and their associated greenhouse gas emissions. The climate impact of incineration and landfilling can be reduced by diverting end-of-life products to recycling. Taxes on landfilling and incineration effectively foster recycling, addressing a large segment of plastic waste, including municipal solid waste and industrial streams (OECD 2022a). Imposing taxes on plastic waste, such as the EU's 800 euros per tonne tax on non-recycled plastic packaging, provides economic incentives that encourage recycling over landfilling or incineration.

*Feasibility*
Adopting landfill fees requires appropriate infrastructure to be installed; for example, installing weighbridges to determine appropriate fees. Where fees are higher for recyclable materials or a ban on landfilling of such materials is in place, sorting and checking of each load will ensure recyclables are not concealed in loads that attract a lower fee. This approach should consider the varied global waste collection and management systems, adapting strategies to regional specifics to ensure effectiveness and practicality across different contexts.

#### Box 4. Potential indicators for tracking control measures related to waste management

- Volume of wastes diverted to recovery operations as defined in the Basel Convention, including increased recycling rates as a preferred method over incineration and landfilling
- Number of upgraded or new waste collection and recycling facilities
- Reduction in greenhouse gas emissions through environmental and landfill remediation of plastic pollution
- Number of countries with established EPR schemes aiming to reduce greenhouse gas emissions through improved waste management

## 4.5 Measures under the UNFCC and the Paris Agreement to decarbonise the plastics life cycle

Decarbonising the plastics life cycle is particularly important as this industry is heavily reliant on fossil fuels, both as a raw material and in terms of energy used for production and transport. The conclusion of the first global stocktake of climate action under the Paris Agreement at the UNFCCC COP 28 led to the adoption of a decision calling for "transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net-zero by 2050" (UNFCCC 2023a). This is the first-ever COP decision to address fossil fuels, making it the backbone of efforts to decarbonise the plastics life cycle. This decision, however, is limited to addressing fossil fuels in energy systems only, not as feedstocks, in plastics production. Reduction of emissions from transport is encouraged, but this is limited to road transport (UNFCCC 2023a).

#### Promote renewable energy sources across the plastics life cycle

*Description of measure(s)*
This measure focuses on shifting the energy mix used within the plastics life cycle towards decarbonisation, particularly in polymer production and conversion, the primary sources of greenhouse gas emissions. Countries should leverage their local renewable resources and invest in suitable energy technologies, aiming for a complete shift to renewable energy by 2040, or at the latest by 2050. This goal aligns with the recent UNFCCC COP 28 decision to triple renewable energy capacity globally by 2030. Prior to that, UNFCCC COP 27 Decision 1 highlighted that "about USD 4 trillion per year needs to be invested in renewable energy up until 2030 to be able to reach net-zero emissions by 2050" (FCCC/CP/2022/10/Add.1).

*Feasibility*
Transitioning to renewable energy sources can drastically reduce the carbon footprint of the plastics industry. Over time, as the cost of renewable energy continues to decrease, industries might witness reduced operational costs, making products more affordable for consumers. Moreover, adopting renewable energy can reduce a country's dependency on imported fossil fuels, promoting economic stability.

With continuous advancements in renewable energy technologies, the feasibility of shifting to 100 per cent renewables is increasing. The initial switch to renewable energy sources can require a significant capital investment, especially in infrastructure and technology. However, to date, large strategic investments in renewable energy and new zero-emission production processes are scarce in the petrochemical industry (Bauer et al. 2022b; Bauer et al. 2023). Currently, renewable energy's role in the petrochemical industry is minimal, with only a 2 per cent capacity share (Bauer et al. 2023). Overcoming entrenched 'carbon lock-ins' across production, markets, waste management, industry organisation and governance domains will be critical (Bauer et al. 2022a). Another challenge is that countries engaged in polymer production and conversion often have limited access to renewable energy.

## Incentivise energy efficiency across the plastics life cycle

***Description of measure(s)***

Energy-efficient machinery, optimisation of processes, and improved recycling methods can complement the renewable energy shift and provide emission reductions by slowing the growth in energy demand. Encouraging the use of renewable energy sources in the production and processing of plastics can significantly reduce the carbon footprint of the plastics industry. In alignment with the recent UNFCCC COP 28 decision on doubling the global average annual rate of energy efficiency improvements by 2030, the UNFCCC should support the adoption of technologies and provide incentives for companies to increase energy efficiency across the plastics value chain. Best practices for energy efficiency can be shared on a global knowledge hub to promote energy savings across the value chain.

***Feasibility***

IEA rates energy efficiency as the most important measure to reduce energy demand. Although progress has been made in recent years, the rate of improvement in global energy intensity needs to improve greatly (IEA 2024c). Research has shown that primary energy savings of 34 per cent can be achieved in the production of plastics by using different energy sources. This can also depend on the location, with hotter climates requiring more energy for cooling compared with cooler climates that require more energy for heating. Where overall energy savings are not possible, using different renewable sources of energy in the mix can reduce the use of fossil-based energy and the resulting greenhouse gas emissions (Dunkelberg et al. 2018). Digital technologies are recognised as an important enabler to decarbonise the energy system (IEA 2024b).

## Reduce greenhouse gas emissions from the transport sector

***Description of measure(s)***

The transport sector incorporates domestic and international transport systems, covering domestic logistics as well as global trade.

For international transport, cooperation with key international organisations is needed. The International Maritime Organization has adopted a revised greenhouse gas strategy aiming to reach net-zero greenhouse gas emissions from international shipping by around 2050. Similarly, the International Civil Aviation Organization has set a goal for net-zero carbon emissions from international aviation by 2050 (IEA). To support these objectives, countries have implemented various fiscal and policy measures, including promoting the use of sustainable aviation fuel through targets setting and reduction of industry subsidies (IEA).

For domestic logistics, there is the potential to increase greenhouse gas emissions from the transport sector due to additional transport requirements arising from the introduction of new transport systems to support reuse, refill, and return models. To address this, the adoption of economic incentives and regulations to promote use of existing transport systems, such as reverse logistics and backloading, is proposed.  EPR schemes and retail supplier contracts can include a requirement for adoption of reverse logistics systems (Banguera et al. 2018). Programmes to accelerate the transition of transport systems to clean and renewable energy will be required to help decarbonise all transport associated with plastic feedstocks, products and waste.

Trade measures that are directly relevant to the plastics instrument include the following:

- Sustainable design criteria for plastic products can incorporate the various trade components across the life cycle as a factor for approving environmental claims.
- Life cycle assessments should factor all trade components into calculations.
- EPR schemes and plastics supply chains can be mandated to require minimum levels of greenhouse gas emissions from trade and promote uptake of alternative fuels (United Nations 2023b).

***Feasibility***

The International Maritime Organization has set milestones for international shipping to reach net-zero greenhouse gas emissions, aiming for reducing total annual greenhouse gas emissions by at least 20 per cent by 2030 and by at least 70 per cent by 2040, compared with 2008 levels. However, the increase in trade volumes could potentially offset these efficiency gains. In a similar vein, it has been noted that efficiency gains have tended to be outpaced by growth in aviation, although new aircraft are manufactured to be up to 20 per cent more fuel efficient. It is also possible to use plastic waste as a source of sustainable aviation fuel, defined by the International Civil Aviation Organization as "renewable or waste-derived aviation fuels that meets sustainability criteria" (International Civil Aviation Organization 2024). However, this would increase the need for primary polymers and reduce the circularity of plastics.

Reverse logistics and backloading are business models that can help to reduce emissions in domestic and international transport systems. Reverse logistics is mostly adopted in formalised distribution systems with related deposit schemes and other financial incentives to promote participation in the scheme. Such schemes can work across remote, rural, and urban settings. Backloading has been used as a cheap method of transporting sorted bales of plastic waste from remote areas to centralized facilities. This is often supported by online software to bring normally unrelated waste collectors and transporters together to negotiate the use of otherwise empty space on the return route of transporters.

An example of international backloading is the Moana Taka Partnership between the China Navigation Company Ltd./ Swire Shipping Agencies and the Secretariat of the Pacific Regional Environment Programme (2020).

Backloading offers additional income sources for transporters. Both mechanisms save on costs and pollution, as well as road wear-and-tear. Backloading schemes bring together suppliers and transporters who would normally have no business links. This requires a mechanism to be developed that allows them to connect, such as an online platform or a mobile app. Publicising and marketing to encourage participation may be needed.

### Market-based measures related to decarbonising the plastics industry

#### *Phase out inefficient subsidies for petrochemical and fossil fuel production*

*Description of measure(s)*
The decision from the UNFCCC COP 28 regarding the outcome of the first global stocktake calls for "phasing out inefficient fossil fuel subsidies that do not address energy poverty or just transitions, as soon as possible" (UNFCCC 2023a). The growth of the petrochemical industry has been heavily reliant on inexpensive, subsidised fossil fuel feedstocks (Bauer et al. 2023). Redirecting subsidies towards renewable energy sources is crucial for decarbonisation of the energy mix (Cabernard et al. 2022). Reforming these subsidies can boost the competitiveness of sustainable energy sources and materials, thus expediting the transition to alternative options.

*Feasibility*
Removal of fossil fuel subsidies would bring significant benefits, including reduced CO2 emissions, raised substantial revenues, and prevention of premature deaths from air pollution (Black et al. 2023). Although the G20 has reaffirmed its intention to curtail inefficient fossil fuel subsidies as stated in their 2009 commitment (Leaders of the G20 2023), current subsidy levels are historically high and projected to reach USD 8 trillion by 2030 (Black et al. 2023), highlighting the complexity of this task. In addition, subsidy reforms can spark political and social upheavals, sometimes even leading to strikes or violent protests that force governments to retract their changes (World Trade Organization 2022).

#### *Subsidise renewable energy use across the plastics value chain*

*Description of measure(s)*
Fossil fuel subsidies can distort energy markets and discourage the transition by industry to renewable energy sources. Renewable energy is typically generated domestically, reducing reliance on foreign fuels. In 2022, subsidies surged to twice the amount of 2021, exceeding USD 1 trillion for the first time (IEA 2024d). This significant escalation was largely driven by the global energy crisis that ensued following Russia's invasion of Ukraine (IEA 2024d).

*Feasibility*
Transitioning to renewable energy for plastics made from oil and gas has an estimated potential to lower emissions by 40–75 per cent but could also increase the cost of plastic by up to 50 per cent (Hieminga et al. 2023). The cost is mostly associated with technologies that are less mature. Subsidising the transition will therefore require action to accelerate research, innovation and low-carbon technology development in this regard.

**Box 5. Potential indicators for tracking control measures towards decarbonising the plastics life cycle**

- Share of energy use derived from renewables in the plastics industry
- Reduction in greenhouse gas emissions per tonne of plastic produced as a direct result of renewable energy use
- Number of countries adopting national programmes to incentivize reverse logistics and backloading transport systems
- Number of countries integrating reverse logistics, backloading and 'green transport' in EPR schemes
- Number of large national and global retail chains integrating reverse logistics, backloading, and 'green transport' in operations and supply chain contracts
- Number of Parties mandating inclusion in EPR schemes of greenhouse gas emission reductions from international trade as a component of producer fees
- Number of Parties with policies to promote consideration of greenhouse gas emissions in supply chains
- Reduction in subsidies for petrochemical and fossil fuel production
- Revenue collected from tax, specifically allocated to initiatives aiming to reduce greenhouse gas emissions
- Number of countries with established EPR schemes aiming to reduce greenhouse gas emissionsimproved waste management

## 4.6 Supporting measures under the plastics instrument and the UNFCC and the Paris Agreement

### Increase transparency, accountability and information-sharing

#### *Develop an indicator framework to track plastic material flows towards national reporting of plastic-related emissions under the UNFCCC and PA*

*Description of measure(s)*
Periodic tracking and assessment of greenhouse gas emissions and mitigation strategies will facilitate policy adjustments, ensuring that targets are met effectively. Regular and detailed reporting ensures transparency, fosters accountability, and can aid international collaborations aimed at reducing plastic-related greenhouse gas emissions. Reporting can also facilitate the integration of plastic emissions data into broader climate assessments, where they are currently largely absent (Stegmann et al. 2022).

At present, the level of national reporting on efforts to mitigate plastic pollution is inadequate to track the effectiveness of such actions in reducing plastic-related greenhouse gas emissions (see Section 3). While some developed countries have established methodologies for assessing national greenhouse gas emissions of plastics, their heterogeneity weakens comparability (US, Environmental Protection Agency, Office of Resource Conservation and Recovery 2020). Under the plastics instrument, it is advisable to develop an indicator framework to track plastic flows 1) from the environment into the economy, 2) within the economy (including production, circularity and waste management), and 3) from the economy into the environment. The indicators could be designed to promote collection of data that enables disaggregated national reporting under the UNFCCC/PA. Reporting could include actual greenhouse gas emissions from plastic-related activities, as well as avoided emissions resulting from implementation of control measures under the plastics instrument.

All measures adopted to eliminate plastic pollution should be assessed and tracked for their contribution to reducing plastic-related greenhouse gas emissions, including through determining baseline emissions prior to implementing action and ongoing tracking of trends. To support the indicator framework, the plastics instrument could encourage Parties to include plastic-related measures in NDCs and other national climate strategies and targets towards net-zero emissions (Minderoo Foundation 2023).

***Feasibility***

The System of Environmental Economic Accounting provides a statistical framework that can form a basis for a global plastics indicator framework. Currently, a statistical guideline for plastic flows at the national level is under development by UNEP and the United Nations Institute for Training and Research (UNITAR), with the aim of producing a statistical guideline on measuring flows of plastic along the life cycle. This guideline also tackles the challenges in tracking embedded plastics in products within the economy and trade.

It is very important to establish detailed and specific disaggregated reporting guidelines under the Intergovernmental Panel on Climate Change (IPCC) to report on plastic/polymer emissions in national greenhouse gas inventories. The plastic agreement should be aligned with these guidelines. This could facilitate disaggregation of data within GHG inventories by sources and removals. Data could be supplemented by inclusion of circular approaches adopted at the national level, as promoted in the toolbox developed by UNEP, the United Nations Development Programme, and the UNFCCC Secretariat for building circularity into NDCs (UNEP, United Nations Development Programme and the Secretariat of the United Nations Framework Convention on Climate Change 2023).

A considerable gap in current reporting methodologies is the national focus of emissions calculations. Reporting on cross-border life cycle emissions that consider emissions from production in one country, use in another country and disposal in a third country, for example, are a challenge. Moreover, the reporting capacity of low- and middle-income countries will need enhancement. An assessment of how quickly nations can adopt the system, starting with pilot regions or sectors, can facilitate international roll-out.

### *Improve private sector reporting on plastic-related greenhouse gas emissions*

***Description of measure(s)***

Parties can be mandated to require businesses to report on greenhouse gas emissions across their value chain and by products produced and consumed. The development of design criteria and product rules can also be supported to allow for comparison of emissions by product. For example, the Greenhouse Gas Protocol, developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), offers a standardized approach for companies to report their greenhouse gas emissions. Greenhouse gas accounting under the Protocol now recognises the need to report on 1) the full corporate value chain and 2) individual product emissions, with standards developed for both. Such accounting should incorporate emissions data on production, use and disposal of plastics.

***Feasibility***

There have been significant advances in tracking greenhouse gas emissions across multiple sectors. The example of the Greenhouse Gas Protocol encourages reporting on direct emissions from owned or controlled sources, indirect emissions from the generation of purchased energy, and all other indirect emissions that occur in a business's value chain (WRI and WBCSD 2024a). Methods may need to be developed to assist businesses in disaggregating the plastic-related emissions within their value chains and for the products produced or consumed during operations. Owing to significant variations in greenhouse gas emissions of different polymers and different final disposal methods used, it will be necessary to develop detailed methodologies to help harmonize such assessments. Importantly, the tools developed within the Greenhouse Gas Protocol are reported to have been developed to be consistent with IPCC methodologies (WRI and WBCSD 2024b).

## Accelerate research, innovation and low-carbon technology development

OECD classifies innovation in environmentally relevant plastic technologies that includes prevention through design and reuse, use of bio-based feedstocks, recycling and other waste disposal technologies, and leakage removal (OECD 2022a). Prioritising investment in research, innovation and technological development is essential to reduce greenhouse gas emissions and address uncertainties in emerging technologies. Short-term research objectives may involve identifying non-plastic alternatives and bio-based plastics with a low-carbon footprint. Meanwhile, long-term research objectives could focus on emerging technologies to ensure their safety before they are integrated into the agreements, including chemical conversion and CCU, as discussed in the following subsection (see also section 2.1 on Captured $CO_2$-based feedstock).

#### ***Identify low-carbon non-plastic substitutes***

***Description of measure(s)***
This measure involves research by academia and industry could focus on identifying non-plastic substitutes with an overall lower environmental and carbon footprint. Such research can be underpinned by the plastics instrument and pursued in collaboration with the UNFCCC. Government investment in academic programmes and incentives to promote research and development programmes by industry can assist in accelerating such research. Consideration of intellectual property and patents will be needed to expand adoption of low-carbon non-plastic substitutes. The European Union's Horizon Europe programme[23] is an example of a regional research and innovation fund that could facilitate the identification of such non-plastic substitutes.

***Feasibility***
Identification of low-carbon non-plastic substitutes will require rigorous validation of life cycle assessments and consultation with a wide range of stakeholders. Such assessments and consultations are costly. For assessments of products with longer life spans or products intended for reuse and refill, agreed methods of simulating emissions across such life spans will be needed. A single global certification may also need to be developed to verify research findings and manufacturer claims.

Due to the expenses associated with the process of identifying low-carbon non-plastic substitutes, as well as validation and certification thereof, the results of assessments and consultations should be made publicly available to benefit countries with limited resources to accomplish this.

#### ***Identify low-carbon feedstocks and polymers***

***Description of measure(s)***
The energy intake during polymer production and processing into finished products can be reused where products are recycled. Generally, the higher the energy intake during these stages, the greater value the product has as a post-consumer recyclable material. It is possible to compare the carbon footprint of primary polymers using their calorific value and the energy used during their production (Marczak 2022). By adopting approaches for energy efficiency and transitioning to renewable energy, the carbon footprint of a polymer can be reduced. However, as Section 2.2, Figure 3 shows, emissions by types of polymers vary and should be factored in with the market share and lifespan of the product. Where products have a short lifespan, polymers that have a lower carbon footprint should be prioritised and facilities producing these products should be prioritised for incentives to increase energy efficiency and transition to renewable energy.

***Feasibility***
Not all polymers are suitable for all plastic applications. Sustainably sourced feedstocks can be synthesised with green hydrogen[24] to create propylene ($C_3H_6$) and ethylene, which are used in most plastic products (US, Office of Energy Efficiency & Renewable Energy n.d.). (See also section 2.1 on Captured $CO_2$-based feedstock for discussion on current concerns).

#### ***Identify low-carbon solutions, including best environmental practices and best available technologies***

***Description of measure(s)***
Best practices and technologies can go beyond mandatory measures towards reducing the impacts of plastic production and consumption, including greenhouse gas emissions. Such practices may be implemented by businesses and consumers. Many examples exist today that require sharing to encourage their use at scale, with successful practices potentially identified and promoted by policymakers.

***Feasibility***
The European Environment Agency recently published a report highlighting good examples from countries, business, and citizens (Vanderreydt et al. 2023). The criteria applied in the selection of examples were that they:

- Were readily available on the market;
- Showed clear environmental benefits;
- Were accessible;
- Showed potential for replication to other product groups or polymers;
- Showed potential for replication in other regions.

#### ***Seek to identify sound chemical conversion technologies***

***Description of measure(s)***
Chemical conversion is a collective term for various thermal and chemical processes that break down plastic waste into monomers; oligomers; or liquid, solid, and gaseous hydrocarbon mixes (Bauer et al. 2022a). The main forms of chemical conversion include solvolysis (depolymerising plastics into monomers), pyrolysis (converting plastics into pyrolysis oil), and gasification (converting plastics into syngas) (Jiang et al. 2022). While some studies offer positive prospects for chemical conversion, it is important to fully understand its climate and other impacts before including them in the plastics instrument.

***Feasibility***
Currently, chemical conversion is feasible for only a few commodity polymers due to its resource- intensive nature (Vora et al. 2021). To date, it has been applied on a small

scale for select polymers such as PET, HDPE, PS, and nylon-6 (Vora et al. 2021). Looking ahead, it has been estimated that by 2040, chemical conversion could only replace 6 per cent of the current demand for primary plastic (Pew Charitable Trusts and Systemiq 2020). Therefore, while prioritising mechanical recycling is essential for meeting climate goals, chemical conversion is suited to some hard-to-recycle plastics (Creadore and Castaldi 2022). Moreover, to maximise its positive climate contribution, it is important to ensure that the energy used in the process originates from low-carbon sources.

### *Seek to identify sound carbon capture and utilisation technologies*

***Description of measure(s)***

Paragraph 28e of the UNFCCC COP 28 decision on the outcome of the first global stocktake highlights the need to accelerate zero- and low-emission technologies, including carbon capture, utilisation, and storage. CCU technologies aim to offer an alternative to conventional chemical production by capturing $CO_2$ from industrial point sources or ambient air, using it as a carbon source for producing chemicals and polymers. These technologies not only capture $CO_2$ emissions at their source for reuse, but also have significant potential to reduce greenhouse gas emissions both upstream and downstream. For instance, CCU technologies could be developed to capture $CO_2$ emissions from pyrolysis furnaces during fuel production from plastic waste (Energy Transitions Commission 2020). Plastic waste also has the capacity function as a carbon sorbent after it is treated with heat and potassium acetate (Algozeeb et al. 2022).

***Feasibility***

The overall climate benefit and global potential of CCU technologies in climate change mitigation remain debated, which has affected the integration of these technologies into policy frameworks (Kätelhön et al. 2019). Transitioning to CCU in the chemical industry requires a significant increase in electricity supply, preferably sourced from renewable or nuclear energy, to ensure a low-carbon footprint (Kätelhön et al. 2019). Additional challenges include resource intensity, such as the water footprint associated with hydrogen production (Grubert 2023). Moreover, the rising demand for green hydrogen in various sectors poses a constraint, as this limits its availability for production of green methanol, a crucial component in CCU technologies (Odenweller et al. 2022).

### Scale sustainable financing

***Description of measure(s)***

The Paris Agreement, particularly in article 2.1c and article 9, emphasizes the need to align financial flows with low greenhouse gas emissions and climate-resilient development, while ensuring climate finance availability.[25] Similarly, the zero draft of the plastics instrument advocates for leveraging both domestic and international funds, in addition to private sector financing and voluntary contributions. The financial mechanisms under both instruments could jointly help build capacities of countries to address plastic pollution and climate change, including though support for research, data collection, and implementation of best practices.

The financial sector plays an important role in shifting investments away from fossil-based and emissions-intensive petrochemical production. This shift is urgent, considering that 2050 is only one investment cycle away for the chemical industry. IEA stipulates in its net-zero scenario that by 2030, all new chemical industry investments must adhere to low-carbon standards.

***Feasibility***

A recent report by the IPCC acknowledges that the flows of climate finance have increased over the last decade, despite a slowing since 2018. The report notes that public and private finance flows for climate adaptation and mitigation are mostly directed at mitigation, but that overall, these remain substantially lower than finance flows for fossil fuels (The Core Writing Team, Lee and Romero eds. 2023).

### Box 6. Potential indicators for tracking supporting measures

- Number of countries requiring companies to implement and report on plastic-related emissions across the value chain and across products manufactured and consumed
- Level of funding directed to research and innovation concerning low-carbon non-plastic substitutes
- Level of funding directed to research and innovation concerning low-carbon feedstocks and polymers
- Level of funding directed to research and innovation seeking to identify sound chemical conversion technologies
- Level of funding directed to research and innovation seeking to identify sound CCU technologies

# 5 Institutional collaboration

## Key findings

- Collaboration and coordination among Multilateral Environmental Agreements (MEAs) are needed to address the climate component of plastics. Opportunities for collaboration could encompass 1) sharing data and information on plastic-related greenhouse gas emissions and their sources with the Paris Agreement and plastics instrument, 2) coordinating policies and measures among MEAs related to plastics with broader climate goals and targets, and 3) research, analysis, and assessment efforts to deepen understanding of the climate implications of plastics and identify mitigation opportunities.
- The Paris Agreement could play a pivotal role in decarbonising the plastics life cycle by offering guidance for the preparation of Nationally Determined Contributions (NDCs) and Long-term Low-emission Development Strategies (LT-LEDS). Such guidance would be instrumental in steering countries towards a transition to net-zero emissions by, or around, mid-century.
- The evolving Science-Policy Interface (SPI) for plastic pollution offers a significant opportunity to deepen understanding of how plastics intersect with climate change. There is also scope for improving existing SPI mechanisms, particularly the IPCC.

## Overview

This chapter outlines the findings from a review of the interconnection between climate change and plastic pollution in context of MEAs. It details relevant obligations across the five plastics life cycle stages, focusing on 1) **control measures**, as outlined in agreements such as the Minamata Convention, the Montreal Protocol, the London Convention, the London Protocol and MARPOL Annex V, 2) **national action plans**, particularly in relation to the Paris Agreement, and 3) **inventories**, pertinent to both the Paris Agreement and the Montreal Protocol.

The analysis highlights the necessity for MEAs to work together to effectively address and monitor the climate impacts of plastics. Additionally, collaboration beyond MEAs is essential. Notably, the SPI concerning plastic pollution holds significant potential to strengthen understanding of climate–plastics linkages. This can be particularly impactful if the development of these linkages is prioritised in the negotiations of the Science-Policy Panel on chemicals, waste, and pollution prevention, and more robustly integrated into IPCC reports, ideally through a collaborative approach. The results of the review of the MEA's obligations related to the climate impacts of plastics across their life cycle are summarised in Appendix 4: "Summary of key multilateral environment agreement obligations related to the impact of plastics on climate change".

## 5.1 Role of Multilateral Environmental Agreements

### The Paris Agreement

***Economy-wide absolute emission reduction targets (control measures)***

Article 4.4. of the Paris Agreement states that developed countries should lead by setting economy-wide absolute emission reduction targets, and developing countries are encouraged to progress towards similar goals, tailored to their national circumstances. Additionally, though not explicitly mentioning plastics, paragraph 36 of the COP 28 decision regarding the outcome of the first global stocktake offers vital political backing for collaboration in the realm of the circular economy. It notes "the importance of transitioning to sustainable lifestyles and sustainable patterns of consumption and production in efforts to address climate change, including through circular economy approaches, and encourages efforts in this regard" (UNFCCC 2023a).

***Nationally Determined Contributions (national action plans)***

The Paris Agreement, while not explicitly mentioning plastics, is a crucial agreement for addressing the climate impact of plastics. Article 4.2 of the Paris Agreement includes a commitment to formulate NDCs to accelerate efforts to achieve the 1.5°C climate target. However, as noted, plastics are often not specifically addressed in NDCs. The absence of clear obligations and metrics in NDCs related to plastic goals can make it challenging to fully integrate the plastic component into these climate contributions. However, article 4.14 and article 13 point to the need to address all relevant sectors contributing to anthropogenic emissions, which includes sectors related to plastics throughout their life cycle, such as energy, transport, industrial processes and product use, and waste.

***Long-term Low-emission Development Strategies (national action plans)***

LT-LEDS, encouraged under article 4.19 of the Paris Agreement, provide a framework for countries to develop and communicate long-term plans for greenhouse gas emissions across all sectors, helping to transition to net-zero emissions by or around mid-century. A key aspect of LT-LEDS should be the inclusion of measures aimed at decarbonising the entire life cycle of plastics. The first synthesis report on LT-LEDS, reflecting strategies from 75 countries representing 87 per cent of the global gross domestic product, highlights a gap in explicitly addressing the plastics within national mitigation efforts (UNFCCC 2023b). Incorporating the goal of decarbonising the plastics life cycle into LT-LEDS is increasingly important to align with the broader objectives set out at COP 28.

***Enhanced Transparency Framework (inventories)***

The Paris Agreement's Enhanced Transparency Framework (ETF) reporting and review system is based on, and supersedes, the UNFCCC reporting and review system starting with the submission of first biennial transparency reports by 31 December 2024. Article 13.7a of the Paris Agreement obligates countries to report greenhouse gas inventories for key sectors using the methodologies of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories as detailed in decision 18/CMA.1 and decision 5/CMA.3 on the modalities, procedures and guidelines for the ETF referred to in article 13 and the guidance for their operationalisation. Currently, emissions specifically related to plastics are not separately assessed and tracked. Future collaboration between the plastics instrument and the Paris Agreement, informed by the IPCC, could be necessary to better understand and address the climate impact of plastics.

### Basel Convention

***Waste minimisation and environmentally sound waste management (control measures)***

Article 4.2a-b of the Basel Convention emphasizes the importance of waste minimisation and environmentally sound waste management. This is highly relevant to plastics, as it encourages a shift towards more sustainable product design and management of plastic waste. Recycling and circular design principles can significantly benefit the climate by reducing the need for production of new plastics from fossil fuels, which is an energy-intensive process associated with greenhouse gas emissions.

***Proximity principle (control measures)***
The proximity principle, as outlined in article 4.2.b of the Basel Convention, encourages waste management facilities to be located as close as possible to where waste is generated, regardless of the place of disposal. This principle aligns with climate goals because it aims to reduce unnecessary transportation of plastic waste, including international trade. Transportation is a significant source of greenhouse gas emissions, so minimising it can contribute to lowering the carbon footprint associated with waste management.

### Minamata Convention

***Reduction of emissions from waste incineration (control measures)***
Article 8 aims to control and reduce emissions of mercury from point sources, including waste incineration facilities. The use of new incineration technologies can indeed generate co-benefits by reducing not only mercury emissions but also carbon emissions. Modern waste incineration technologies should be designed to be more energy-efficient and produce lower emissions, thus contributing to climate goals, while also addressing mercury pollution.

***Reduction of emissions from chlor-alkali production (control measures)***
Article 5.2 of the Minamata Convention restricts the use of mercury in specific manufacturing processes listed in Annex B, with sunset dates for phasing out mercury use. The Convention sets a target for phasing out the use of mercury in chlor-alkali production by 2025. Chlor-alkali plants produce chlorine gas, which is a key component in the production of vinyl chloride monomers used in PVC production. Transitioning to alternative, mercury-free technologies in chlor-alkali production can generate co-benefits by reducing mercury emissions and greenhouse gas emissions.

### Montreal Protocol

***Hydrochlorofluorocarbon production limitations (control measures)***
Article 2 of the Montreal Protocol sets targets for phasing down the production of hydrochlorofluorocarbons (HFCs) listed in Annex F that may include uses as blowing agents in the production of extruded PS and polyurethane foams and as refrigerants in air-conditioning and refrigeration systems. The reduced use of HFCs in plastic foam production helps to mitigate climate change. Moreover, when HFCs are replaced with alternative, more climate-friendly, refrigerants, this can lead to improved energy efficiency.

***Inventories of hydrochlorofluorocarbons (inventories)***
Article 7.2 and article 7.3 require Parties to provide statistical data on its annual production of each HFC listed in Annex F and, separately, for each substance: amounts used for feedstocks; amounts destroyed by technologies approved by Parties; and regarding imports from and to Parties and non-Parties, respectively.

### London Convention and the London Protocol

***Reduction of dumping of plastic wastes at sea (control measures)***
The London Convention and its 1996 Protocol (the London Protocol) are international agreements aimed at protecting the marine environment from pollution. They specifically address the dumping of wastes and other matter at sea. The overall reduction in plastics entering the ocean will help to mitigate climate change by reducing the amount of macroplastics at sea that degrade into microplastics, weakening the ability of oceans to function as carbon sinks.

### MARPOL Annex V

***Restrictions on the disposal of garbage at sea (control measures)***
MARPOL Annex V is an international regulation under the International Convention for the Prevention of Pollution from Ships (MARPOL). It specifically addresses the prevention of pollution by garbage, including plastics, from ships. Annex V places restrictions on the disposal of garbage at sea and sets out guidelines for the management and disposal of various types of ship-generated waste, including plastics. Reducing the amount of plastics entering the ocean can mitigate climate change by decreasing macroplastics that break down into microplastics, thereby preserving the ocean's capacity to act as a carbon sink.

## 5.2 Role of Science-Policy Interfaces

### The Science-Policy Panel on chemicals, waste, and pollution prevention

The forthcoming Science-Policy Panel (SPP) on chemicals, waste and pollution prevention can provide a platform of how plastics intersect with climate change. To realize this, it will be important to explicitly include in its mandate a reference of the need to explore linkages with other environmental issues, including climate change.

### Science-Policy Interface of the plastics instrument

The plastics instrument can provide an avenue to fulfil many SPI functions essential for tracking plastic pollution, including increasing understanding of how the agreement can generate co-benefits with efforts to address climate change (GRID-Arendal 2023). The creation of a subsidiary scientific body will be critical to address specific functions that do not fall within the mandate of the SPP, such as review of potential chemical and products of concern. However, a major obstacle for achieving this is that scientists' participation the INC process has been challenging, due to UNEP's restrictions on accrediting government-funded universities (Carney Almroth et al. 2023).

### Intergovernmental Panel on Climate Change

To comprehensively address the environmental impact of plastics, there is a clear need to incorporate the plastics industry into existing global environmental assessment mechanisms. Notably, none of the climate and socioeconomic models utilised in IPCC reports have provided a detailed representation of the plastics industry (Stegmann et al. 2022). Enhancing the inclusion of plastics in these assessments is imperative to formulating effective policies.

## 5.3 Cross-sector collaboration

Effective solutions require collaboration among diverse stakeholders, including the plastics industry, governments, civil society, and relevant partners. A global instrument should be established to foster multi-stakeholder partnerships, enabling collective action, knowledge-sharing, and the implementation of sustainable practices across various sectors.

# Conclusions

**The main objectives of this report are to identify entry points for complementary international action through the globally binding plastics agreement, and to strengthen the relevant existing international governance regimes. The publication is based on an extensive literature review of the plastics life cycle, coupled with an empirical analysis of the UNFCCC and the Paris Agreement reports and countries' submissions to INC-3. The report suggests measures that co-benefit addressing plastic pollution and achieving the global climate goals. In addition, the report provides an overview of synergies with the existing MEAs and institutional mechanisms.**

## I. Terminology and research

There is sufficient research to provide robust evidence of greenhouse gas emissions from sourcing of raw materials, plastic production, and some waste management stages. However, the literature does not often provide information about greenhouse gas emissions during the plastic use and reuse stage, particularly emissions arising from the use of plastic in various sectors. In addition, there is still a large gap in the direct linkages between climate change and plastic pollution, both in the marine and terrestrial environment. The analysis revealed ambiguity in the terms used to assess this subject. These terms allow for different interpretations, and consequently, may lead to difficulties establishing a common baseline. Definitions that are not internationally defined complicate the overall assessment. Universally agreed definitions would help to guide research, national reporting, and policy interventions in the future.

## II. Reporting on plastics under the UNFCCC and the Paris Agreement

The analysis of reports submitted under the UNFCCC and the Paris Agreement provided valuable information about countries' national actions for tackling plastics in the context of climate change and outlined the gaps. Firstly, it identified that the current method of reporting on strategies for reducing greenhouse gas emissions, such as decarbonisation, emission reduction, energy efficiency and circularity applied in the plastics industry has its limitations. The current reporting mainly approaches the plastics industry as an integral element of the petrochemical and chemical industries, therefore, the coverage of the strategies for reducing greenhouse gas emissions is usually available on a broader scale. This often prevents a more detailed analysis of the plastics industry as an area of intervention for reducing greenhouse gas emissions.

Secondly, it determined that the coverage of plastics life cycle stages varies in the reports, putting more emphasis on plastic at the waste management stage, while having little information about other stages of plastics life cycle. This suggests that countries recognise the climate-related implications of plastics at each stage of the life cycle but the fragmented coverage, especially of plastics production stage, which is responsible for 85 per cent for greenhouse gas emissions of plastic life cycle, complicates the traceability of plastics contribution to climate change in the reports. In addition, the analysis revealed that the coverage of energy from plastic production constitutes a gap in the UNFCCC national submissions and NDCs, which prevents a complete understanding of the climate impacts of plastics.

Thirdly, the reports provided an overview of measures and actions taken in relation to some types of polymers. The analysis of bio-based, biodegradable, compostable, biomass plastics and bioplastics confirmed a lack of precise definitions for these types of plastics.

Further, the analysis looked at the plastics issue applying a sectoral approach and identified 11 sectors relevant for plastics from the perspective of climate change (agriculture, building & construction, cement industry, chemical & petrochemicals industries, electrical & electronic equipment, energy, fisheries & aquaculture, food & packaging, textiles, tourism, transport). The sectoral approach identified a gap in assessing the relative climate impact of plastics by sectors. Despite general recognition that certain sectors dominate the use of plastics, their coverage was limited to national submissions from only a few countries, as exemplified by the case of the textile industry.

The overall picture of actions and measures taken to address plastics appears to be fragmented and contains gaps. The current reporting practice does not provide a systematised approach for tracking plastic-related greenhouse gas emissions and traceability of the impacts of plastics on climate change. One major weakness of the current reporting system under the UNFCCC and the Paris Agreement is the insufficient level of detail in covering decarbonisation efforts and creating an overview of energy composition across the plastics life cycle, since the plastics industry is closely integrated with other industries. In other words, there is a lack of comprehensive reporting mechanisms to account for plastics contribution to climate change and to assess the effectiveness of mitigation actions to reduce emissions associated with plastics.

## III. International Negotiating Committee expectations for addressing climate change aspects of plastics

The analysis of the country submissions to INC-3 provided valuable insights into country expectations for the plastics instrument to address climate change. The main finding of the analysis is that a third of the submissions to INC-3 contained climate-related proposals (18 individual country submissions and three group submissions, out of a total of 59 individual country submissions and five group submissions). Considering that three of these submissions were from groups of countries, and accounted for overlaps between individual country and group submissions, the total number of countries represented by these submissions is 125.

The analysis found that the climate-related elements proposed the most in the submissions were recognition of the impact of plastic pollution on climate change and the co-benefits the plastics instrument would have for addressing climate change. This indicates support for the inclusion of greenhouse gas emissions as a plastic pollutant under the plastics instrument, and for the plastics instrument to strengthen action against climate change.

## IV. Measures to optimise climate benefits across the plastics life cycle

UNEA resolution 5/14 calls for the development of the plastics instrument based on "a comprehensive approach that addresses the full life cycle of plastics" (UNEP/EA/5/Res.14). This inherently supports the consideration of greenhouse gas emissions, a pollutant emitted across each stage of the plastics life cycle. To align with this mandate, the following aspects should be integrated into the text of the instrument:

- **Establishing a foundation in the preamble**: The preamble should recognise the climate implications of plastics, emphasizing the importance of aligning the instrument with the 1.5°C goal set by the Paris Agreement. This acknowledgement lays a crucial foundation for setting climate-focused goals and initiatives within the instrument's text.
- **Explicit recognition of greenhouse gas emissions**: In line with UNEP's working definition of plastic pollution, as stated in the zero draft, greenhouse gas emissions should be explicitly recognised as a form of plastic pollution. This definition includes "the negative effects and emissions resulting from the production and consumption of plastic materials and products across their entire life cycle" (UNEP 2022c; UNEP 2023a).
- **Recognising the broader role of the instrument**: The instrument should acknowledge its significant contribution to the protection of the climate system, alongside its role in safeguarding human health and the environment. Additionally, it should highlight the necessity of reducing the carbon footprint associated with plastics throughout their life cycle as a key climate mitigation measure.

# Appendixes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|---|---|
| Appendix 1 | Available sources from the analysis of national submissions to the UNFCCC and the Paris Agreement. |
| Appendix 2 | INC-3 Submissions featuring climate-related proposals |
| Appendix 3 | Plastic-related International Organisation for Standardization standards relevant to climate outcomes |
| Appendix 4 | Summary of key multilateral environmental agreement obligations related to the impact of plastics on climate |

# Appendix 1: Available sources from the analysis of national submissions to the UNFCCC and the Paris Agreement

This Appendix provides references to the sources featured in the content analysis of Chapter 3.

### Reporting on plastics under the UNFCCC and the Paris Agreement

| **Strategies for reducing greenhouse gas emissions** | |
|---|---|
| ***Decarbonisation*** | |
| Use of new technologies | Submission under the Paris Agreement: The Republic of Korea's Enhanced Update of its First Nationally Determined Contribution, p. 2 |
| Hydrogen | Accelerating Action Towards a Green, Inclusive and Resilient Economy: Third Update of Second Nationally Determined Contribution for the UAE, p. 11<br>Eighth National Communication and fifth Biennial Report of the Federal Republic of Germany under the United Nations Framework Convention on Climate Change p. 235 |
| Methanol with high CO2 content natural gas | The People's Republic of China Second Biennial Update Report on Climate Change, p. 59 |
| Carbon capture, utilisation and storage | Singapore's Fifth National Communication and Fifth Biennial Update Report, p. 19 |
| Bio-based sources of energy, fuels and chemicals | Singapore's Fifth National Communication and Fifth Biennial Update Report, p. 19<br>United Kingdom's 8th National Communication, p. 378 |
| Low-carbon roadmaps and policies | Finland's Fifth Biennial Report under the UNFCCC, p. 34<br>South Sudan's Second Nationally Determined Contribution, p. 81<br>Eighth National Communication and Fifth Biennial Report of Türkiye under the UNFCCC, p. 161 |
| ***Reduction of emissions*** | |
| Introduction of new technologies | Eighth National Communication and Fifth Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change, p. 125 |
| Improvement of production processes | Submission under the Paris Agreement: The Republic of Korea's Enhanced Update of its First Nationally Determined Contribution, p. 2<br>Fourth Biennial Update Report of the Republic of Korea under the United Nations Framework Convention on Climate Change, p. 51<br>Viet Nam Third Biennial Updated Report to the United Nations Framework Convention on Climate Change, p. 65 |

| **Strategies for reducing greenhouse gas emissions** (continued) | |
|---|---|
| ***Reduction of emissions*** *(continued)* | |
| Improvement of energy use | First Biennial Update Report of the Republic of Uzbekistan under the UN Framework Convention on Climate Change, p. 92<br>Viet Nam Third Biennial Updated Report to the United Nations Framework Convention on Climate Change, p. 79 |
| Implementation of circular economy | Eighth National Communication of the Czech Republic under the United Nations Framework Convention on Climate Change, p. 157<br>Enhanced Nationally Determined Contribution: Submission by the Republic of North Macedonia, p. 22<br>Lithuania's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 182 |
| Reduction of plastic waste | Cambodia's Updated Nationally Determined Contribution, p. 91 |
| Recycling of plastic waste | Denmark's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 247<br>Eighth National Communication and Fifth Biennial Report of Türkiye under the UNFCCC, p. 179 |
| Reduction of plastic incineration | Japan's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 166 |
| ***Energy efficiency*** | |
| Energy efficiency standards | The First Biennial Update Report (BUR) Kingdom of Saudi Arabia, p. 51 |
| Energy efficiency plans | Sultanate of Oman: Second Nationally Determined Contribution, p. 10 |
| Energy intensity targets | The First Biennial Update Report (BUR) Kingdom of Saudi Arabia, p. 86 |
| Introduction of new technologies | Eighth National Communication of the Czech Republic under the United Nations Framework Convention on Climate Change, p. 17<br>First Biennial Update Report of the Republic of Uzbekistan under the UN Framework Convention on Climate Change, p. 92<br>Japan's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 135 |
| Upgrading of facilities | Accelerating Action Towards a Green, Inclusive and Resilient Economy: Third Update of Second Nationally Determined Contribution for the UAE, p. 30 |
| ***Circularity*** | |
| Policies and legislation | Eighth National Communication of the Czech Republic under the United Nations Framework Convention on Climate Change, p. 60<br>Japan's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 166<br>Eighth Netherlands National Communication under the United Nations Framework Convention On Climate Change, p.116 |

| **Strategies for reducing greenhouse gas emissions** (continued) | |
|---|---|
| ***Circularity** (continued)* | |
| | Portugal's 8th National Communication to the United Nations Framework Convention on Climate Change, p. 157<br>Fourth Biennial Update Report of the Republic of Korea under the United Nations Framework Convention on Climate Change, p. 60 |
| Reduced consumption of plastic items | France's 5th Biennial Report: United Nations Framework Convention on Climate Change, p. 34<br>Portugal's 8th National Communication to the United Nations Framework Convention on Climate Change, p. 157 |
| Improvement of waste management | Canada's 8th National Communication and 5th Biennial Report, p. 97<br>Cyprus Eighth National Communication & Fifth Biennial Report, p. 105<br>Eighth National Communication and Fifth Biennial Report from the European Union under the UNFCCC, p. xii<br>France's 5th Biennial Report: United Nations Framework Convention on Climate Change, p. 34<br>Fourth Biennial Report of Luxembourg under the United Nations Framework Convention on Climate Change, p. 94<br>Thailand's Fourth Biennial Update Report, p. 82 |
| European Union Circular Economy Action Plan | Fourth Biennial Report of the Republic of Croatia under the United Nations Framework Convention on Climate Change, p. 63<br>Eighth National Communication of the Czech Republic under the United Nations Framework Convention on Climate Change, p. 157<br>Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p.130<br>Lithuania's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 150 |
| **Plastics across the life cycle** | |
| ***Sourcing*** | |
| $CO_2$ utilisation as raw material | Eighth National Communication and fifth Biennial Report of the Federal Republic of Germany under the United Nations Framework Convention on Climate Change, p. 237 |
| Plastics as secondary raw material | Portugal's 8th National Communication to the United Nations Framework Convention on Climate Change, p. 157 |
| Plastics as secondary source | South Sudan's Second Nationally Determined Contribution, p. 20; p. 59 |
| Plastic waste as raw material | Eighth Netherlands National Communication under the United Nations Framework on Climate Change, p. 116<br>Fourth Biennial Update Report of the Republic of Korea under the United Nations Framework Convention on Climate Change, p. 17 |
| New virgin plastics | Canada's 8th National Communication and 5th Biennial Report, p. 97 |
| New (primary) plastic | United Kingdom's 8th National Communication, p. 208 |

| **Plastics across the life cycle** (continued) | |
|---|---|
| ***Production*** | |
| Bans and restrictions on manufacturing of: | |
| - single-use plastic | Fiji's Updated Nationally Determined Contribution, p. 3<br>Update of Nationally Determined Contribution (NDC) of Jamaica to the United Nations Framework Convention on Climate Change (UNFCCC), p. 3 |
| - polyethylene bags | Pakistan's First Biennial Update Report (BUR-1) to the United Nations Framework Convention on Climate Change, p. 13 |
| - single-use plastic products | Australia's 8th National Communication on Climate Change, p. 97 |
| - foodservice items | Saint Lucia's First Biennial Update Report, p. 24 |
| - expanded polystyrene (EPS) foam | Fiji's Updated Nationally Determined Contribution, p. 3<br>Saint Lucia's First Biennial Update Report, p. 24<br>Update of Nationally Determined Contribution (NDC) of Jamaica to the United Nations Framework Convention on Climate Change (UNFCCC), p. 3 |
| - export ban on polystyrene (PS) products | Fiji's Updated Nationally Determined Contribution, p. 3 |
| - design | Eighth National Communication and fifth Biennial Report of the Federal Republic of Germany under the United Nations Framework Convention on Climate Change, p. 236<br>Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p.163<br>Japan's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 195 |
| Environmental product fee | Hungary's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 20 |
| Low-carbon technology road maps in manufacturing industries | Eighth National Communication and Fifth Biennial Report of Türkiye under the UNFCCC, p. 161 |
| Regulating obligations regarding plastic bottle production | Slovenia's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 161 |
| Principles of responsible and sustainable production | Mauritius' First Biennial Update Report (BUR 1) to the United Nations Framework Convention on Climate Change, p. 84<br>Thailand's Fourth Biennial Update Report, p. 82 |
| Guidelines for the implementation of energy use standards and measurement, reporting and verification system for emission reduction for the plastic subindustry | Viet Nam's Third Biennial Updated Report to the United Nations Framework Convention on Climate Change, p. 79 |
| ***Plastic use*** | |
| Non-recyclable plastic bottles | Seychelles' Updated Nationally Determined Contribution, p. 25 |

| **Plastics across the life cycle** (continued) | |
|---|---|
| ***Plastic use*** *(continued)* | |
| Policies and regulations (restrictions, phasing out, bans, prohibitions) | Accelerating Action Towards a Green, Inclusive and Resilient Economy: Third Update of Second Nationally Determined Contribution for the UAE, p. 29, p. 29<br>Australia's 8th National Communication on Climate Change, p. 85; p. 97<br>Eighth National Communication and Fifth Biennial Report from the European Union under the UNFCCC, p. 237<br>Fiji's Updated Nationally Determined Contribution, p. 3<br>France's 5th Biennial Report: United Nations Framework Convention on Climate Change, p. 34; p. 61<br>India's Third Biennial Update Report to the United Nations Framework Convention on Climate Change, p. 449<br>Fourth Biennial Report of Luxembourg under the United Nations Framework Convention on Climate Change, p. 139<br>Maldives First Biennial Update Report under the United Nations Framework Convention on Climate Change, p.53<br>Micronesia's Third National Communication and First Biennial Update Report to the United Nations Framework on Climate Change, p. 31<br>Pakistan's First Biennial Update Report (BUR-1) to the United Nations Framework Convention on Climate Change, p. 13<br>Portugal's 8th National Communication to the United Nations Framework Convention on Climate Change, p. 158<br>Saint Lucia's First Biennial Update Report, p. 24<br>The Eighth National Communication of the Slovak Republic on Climate Change under the United Nations Framework Convention on Climate Change and the Kyoto Protocol, p. 308<br>Slovenia's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 161<br>Thailand's Fourth Biennial Update Report, p. 82<br>The Bahamas Updated NDC, p.25<br>Update of Nationally Determined Contribution (NDC) of Jamaica to the United Nations Framework Convention on Climate Change (UNFCCC), p. 3<br>The Republic of Vanuatu First Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 38 |
| Trade regulations | Antigua and Barbuda's First Biennial Update Report, p. 31<br>Fiji's Updated Nationally Determined Contribution, p. 3<br>Micronesia's Third National Communication and First Biennial Update Report to the United Nations Framework on Climate Change, p. 31<br>Pakistan's First Biennial Update Report (BUR-1) to the United Nations Framework Convention on Climate Change, p. 13<br>Saint Lucia's First Biennial Update Report, p. 24<br>Update of Nationally Determined Contribution (NDC) of Jamaica to the United Nations Framework Convention on Climate Change (UNFCCC), p. 3<br>The Republic of Vanuatu First Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 38 |

| **Plastics across the life cycle** (continued) | |
|---|---|
| ***Plastic use*** *(continued)* | |
| Financial incentives | Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p. 165<br>Eighth National Communication and Fifth Biennial Report of Türkiye under the UNFCCC, p. 180<br>United Kingdom's 8th National Communication, p. 208 |
| Sustainable procurement policies covering plastics | Antigua and Barbuda's First Biennial Update Report, p. 42<br>Norway's Eighth National Communication under the Framework Convention on Climate Change, p. 291 |
| Behavioural shift in consumption of plastics | Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p. 425–426; p. 454<br>India's Third Biennial Update Report to the United Nations Framework Convention on Climate Change, p. 449 |
| ***Waste management*** | |
| Plastics category in the composition of municipal solid waste | Third Biennial Update Report on Greenhouse Gas Emissions of Bosnia and Herzegovina, p. 40<br>Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p. 69<br>India's Third Biennial Update Report to the United Nations Framework Convention on Climate Change, p. 264<br>Jordan's Second Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 32<br>First Biennial Update Report of the State of Kuwait submitted to the United Nations Framework Convention on Climate Change, p. 25<br>Malawi's First Biennial Update Report to the Conference of Parties of the United Nations Framework Convention on Climate Change, p. 90<br>Mauritius' First Biennial Update Report (BUR 1) to the United Nations Framework Convention on Climate Change, p. 194<br>Uganda's First Biennial Update Report to the United Nations Framework Convention on Climate Change, p. 15<br>Eighth National Communication and Fifth Biennial Report of the United States of America to the United Nations Framework Convention on Climate Change, p. 37 |
| Recycled plastic | Thailand's Fourth Biennial Update Report, p. 82 |
| Target of 50 per cent recycling by weight for plastic waste | Fourth Biennial Report of the Republic of Croatia under the United Nations Framework Convention on Climate Change, p. 56<br>Eighth National Communication of the Czech Republic under the United Nations Framework Convention on Climate Change, p. 160<br>Denmark's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 250<br>Eighth National Communication and Fifth Biennial Report from the European Union under the UNFCCC, p. 235 |

| **Plastics across the life cycle** (continued) | |
|---|---|
| ***Waste management*** *(continued)* | |
| | Jordan's Second Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 33<br>Lithuania's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 148<br>Third Biennial Update Report of Montenegro to the United Nations Framework Convention on Climate Change, p. 124 |
| Minimum targets for recovery and recycling for packaging waste | Fourth Biennial Report of Luxembourg under the United Nations Framework Convention on Climate Change, p. 142<br>Third Biennial Update Report of the Republic of Moldova, p. 169 |
| Regulations and policies reinforcing or expanding separate collection of plastic | First Biennial Update Report of the Kingdom of Cambodia to the United Nations Framework Convention on Climate Change, p. 84<br>Cyprus Eighth National Communication & Fifth Biennial Report, p. 105<br>Eighth National Communication of the Czech Republic under the United Nations Framework Convention on Climate Change, p. 157; p. 160<br>Denmark's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 246<br>Eighth National Communication and Fifth Biennial Report from the European Union under the UNFCCC, p. 46; p. 235<br>Hungary's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 19<br>Japan's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 166<br>Jordan's Second Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 33<br>Eighth National Communication and Fifth Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change, p. 139<br>Portugal's 8th National Communication to the United Nations Framework Convention on Climate Change, p. 152<br>United Kingdom's 8th National Communication, p. 208 |
| EPR and deposit return schemes for plastics | India's Third Biennial Update Report to the United Nations Framework Convention on Climate Change, p. 264<br>Eighth National Communication and Fifth Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change, p. 78; p. 140<br>Micronesia's Third National Communication and First Biennial Update Report to the United Nations Framework on Climate Change, p. 31<br>Eighth National Communication and Fifth Biennial Report of Türkiye under the UNFCCC, p. 181 |
| Plastic incineration | Denmark's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 246; p. 248<br>Japan's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 166; p. 196<br>The People's Republic of China Second Biennial Update Report on Climate Change, p. 82 |

| **Plastics across the life cycle** (continued) | |
|---|---|
| ***Waste management** (continued)* | |
| Strategies to mitigate the accumulation of plastic waste in landfills: | |
| - introduction of a recycling facility | First Biennial Update Report (BUR1) of The Commonwealth of The Bahamas to the United Nations Framework Convention on Climate Change (UNFCCC), p. 293 |
| - banning plastic landfilling | Eighth National Communication and Fifth Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change, p. 16 |
| - banning single-use plastics to reduce the amount of non-biodegradable and compostable material entering the landfill | Micronesia's Third National Communication and First Biennial Update Report to the United Nations Framework on Climate Change, p. 104<br>Saint Lucia's First Biennial Update Report, p. 24 |
| - improvement of waste management by separation at source | Bulgaria's Eighth National Communication on Climate Change: United Nations Framework Convention on Climate Change, p. 60<br>First Biennial Update Report of the Kingdom of Cambodia to the United Nations Framework Convention on Climate Change, p. 84<br>The Commonwealth of Dominica Updated Nationally Determined Contribution for the Period 2020 to 2030, p. 52 |
| - bacterial breakdown of plastics | Australia's 8th National Communication on Climate Change, p. 79 |
| Open burning of plastic | Lebanon Fourth Biennial Update Report on Climate Change 2021, p. 138<br>Saint Lucia's First Biennial Update Report, p. 96 |
| Policies addressing WEEE | Third Biennial Update Report on Greenhouse Gas Emissions of Bosnia and Herzegovina, p. 75<br>Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p. 165<br>Hungary's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 19<br>India's Third Biennial Update Report to the United Nations Framework Convention on Climate Change, p. 264<br>Lithuania's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 150<br>Fourth Biennial Report of Luxembourg under the United Nations Framework Convention on Climate Change, p. 138<br>Poland's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 163<br>Third Biennial Update Report of the Republic of Moldova, p. 167<br>Rwanda's First Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 168<br>Eighth National Communication and Fifth Biennial Report of Türkiye under the UNFCCC, p.180 |

| **Plastics across the life cycle** (continued) | |
|---|---|
| ***Waste management** (continued)* | |
| EPR covering electric and electronic equipment | Eighth National Communication and Fifth Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change, p. 78<br>Sweden's Fifth Biennial Report under the UNFCCC, p. 93 |
| Raising awareness on disposal and management of WEEE | Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p. 365<br>Portugal's 8th National Communication to the United Nations Framework Convention on Climate Change, p. 262 |
| ***Plastic pollution in the environment*** | |
| Monitoring of microplastics in the marine environment | Thailand's Fourth Biennial Update Report, p. 12<br>Eighth National Communication and Fifth Biennial Report of Türkiye under the UNFCCC, p. 225 |
| Monitoring of plastic waste | India's Third Biennial Update Report to the United Nations Framework Convention on Climate Change, p. 315 |
| Beach clean-ups | Australia's 8th National Communication on Climate Change, p. 204<br>Cabo Verde 2020 Update to the first Nationally Determined Contribution (NDC), p. 29<br>Canada's 8th National Communication and 5th Biennial Report, p. 97<br>Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p. 456<br>Thailand's Fourth Biennial Update Report, p. 12 |
| Collection of marine plastic litter | Thailand's Fourth Biennial Update Report, p. 12 |
| Rehabilitation of sea turtles' entanglements in fishing gear | Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p. 457 |
| **Types of polymers** | |
| Polystyrene (PS) | Fiji's Updated Nationally Determined Contribution, p. 3<br>Micronesia's Third National Communication and First Biennial Update Report to the United Nations Framework on Climate Change, p. 104<br>The Republic of Vanuatu First Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 38 |
| Expanded polystyrene (EPS) | Accelerating Action Towards a Green, Inclusive and Resilient Economy: Third Update of Second Nationally Determined Contribution for the UAE, p. 29<br>Antigua and Barbuda's First Biennial Update Report, p. 31<br>Micronesia's Third National Communication and First Biennial Update Report to the United Nations Framework on Climate Change, p. 31<br>Saint Lucia's First Biennial Update Report, p. 24<br>Update of Nationally Determined Contribution (NDC) of Jamaica to the United Nations Framework Convention on Climate Change (UNFCCC), p. 3 |

| **Types of polymers** (continued) | |
|---|---|
| Extruded polystyrene (XPS) | Denmark's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 221 |
| Polyethylene (PE) | Second Biennial Update Report of the Republic of Azerbaijan to UN Framework Convention on Climate Change, p. 66–67; p.98<br>Egypt's Second Updated Nationally Determined Contributions, p. 15<br>Eighth National Communication and Fifth Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change, p. 78<br>Pakistan Updated Nationally Determined Contributions 2021, p. 43<br>Pakistan's First Biennial Update Report (BUR-1) to the United Nations Framework Convention on Climate Change, p. 13 |
| Polyethylene terephthalate (PET) | Eighth National Communication and Fifth Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change, p. 78<br>Maldives First Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 49<br>Mauritius' First Biennial Update Report (BUR 1) to the United Nations Framework Convention on Climate Change, p. 103<br>Micronesia's Third National Communication and First Biennial Update Report to the United Nations Framework on Climate Change, p. 31<br>The Republic of Vanuatu First Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 38 |
| Polyvinyl chloride (PVC) | Denmark's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 183; p. 250 |
| Polyurethane (PU) | Latvia's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 235 |
| **Bio-based, biodegradable, compostable, biomass plastics and bioplastics** | |
| Bio-based, biodegradable plastics | Eighth National Communication and Fifth Biennial Report from the European Union under the UNFCCC, p. 237 |
| Biodegradable and compostable plastics | Thailand's Fourth Biennial Update Report, p. 81<br>The Bahamas Updated NDC, p. 25 |
| Biodegradable | Egypt's Second Updated Nationally Determined Contributions, p. 15 |
| Bioplastics | Fourth Biennial Report of the Republic of Croatia under the United Nations Framework Convention on Climate Change, p.63<br>Fourth Biennial Update Report of the Republic of Korea under the United Nations Framework Convention on Climate Change, p. 17<br>Submission under the Paris Agreement: The Republic of Korea's Enhanced Update of its First Nationally Determined Contribution, p. 3 |
| Biomass plastics | Japan's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 165, p. 195 |

| Plastics through a sectoral approach | |
|---|---|
| Agriculture | Thailand's Fourth Biennial Update Report, p. 81 |
| Building and construction | Armenia's Third Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 79<br>Eighth National Communication and fifth Biennial Report of the Federal Republic of Germany under the United Nations Framework Convention on Climate Change, p. 236<br>South Sudan's Second Nationally Determined Contribution, p. 81<br>Sweden's Fifth Biennial Report under the UNFCCC, p. 171 |
| Cement industry | Submission under the Paris Agreement: The Republic of Korea's Enhanced Update of its First Nationally Determined Contribution, p. 2<br>Eighth National Communication and Fifth Biennial Report of Türkiye under the UNFCCC, p. 159 |
| Chemical and petrochemical industries | The Eighth National Communication of the Slovak Republic on Climate Change under the United Nations Framework Convention on Climate Change and the Kyoto Protocol, p. 162<br>Finland's Fifth Biennial Report under the UNFCCC, p. 84<br>Singapore's Fifth National Communication and Fifth Biennial Update Report, p. 19<br>Accelerating Action Towards a Green, Inclusive and Resilient Economy: Third Update of Second Nationally Determined Contribution for the UAE, p. 29 |
| Electrical and electronic equipment | France's 5th Biennial Report: United Nations Framework Convention on Climate Change, p. 63<br>Eighth National Communication and fifth Biennial Report of the Federal Republic of Germany under the United Nations Framework Convention on Climate Change, p. 236<br>New Zealand's Fifth Biennial Report, p. 206 |
| Energy | |
| - manufacturing fuel from waste plastics | Japan's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 189 |
| - plastic waste into refuse-derived fuels | South Sudan's Second Nationally Determined Contribution, p. 23; p. 106<br>The Republic of the Union of Myanmar: Nationally Determined Contributions, p. 41 |
| - waste-to-energy | The Fifth Biennial Report of Malta under the United Nations Framework Convention on Climate Change, p. 100<br>France's 5th Biennial Report: United Nations Framework Convention on Climate Change, p. 62 |
| - fuel oil production from plastic waste | Egypt's Second Updated Nationally Determined Contributions, p. 31 |
| Fisheries and Aquaculture | Japan's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 165 |

| **Plastics through a sectoral approach** (continued) | |
|---|---|
| Textiles | Lebanon Fourth Biennial Update Report on Climate Change 2021, p. 138<br>The People's Republic of China Second Biennial Update Report on Climate Change, p. 82 |
| Tourism | Seychelles' Updated Nationally Determined Contribution, p. 25 |
| Transport | Hungary's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 20<br>Portugal's 8th National Communication to the United Nations Framework Convention on Climate Change, p. 157<br>Eighth National Communication and Fifth Biennial Report of Türkiye under the UNFCCC, p. 159<br>Australia's 8th National Communication on Climate Change, p. 35; p. 78<br>New Zealand's Fifth Biennial Report, p. 206 |
| **Food and packaging** | |
| ***Bags*** | |
| Planning of a programme on manufacturing of biodegradable plastic bags | Egypt's Second Updated Nationally Determined Contributions, p. 15 |
| Monitoring system for the consumption of lightweight plastic bags | Slovenia's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 161 |
| Regulation of the use of compostable single-use plastic bags | The Bahamas Updated NDC, p. 25 |
| Law on the reduced consumption of plastic bags on a long-term basis | Fourth Biennial Report of Luxembourg under the United Nations Framework Convention on Climate Change, p. 139 |
| Financial incentives: | |
| - levy on lightweight plastic bags; | Portugal's 8th National Communication to the United Nations Framework Convention on Climate Change, p. 152 |
| - legal arrangement for the payment of plastic bags for transportation purposes at the sale points | Eighth National Communication and Fifth Biennial Report of Türkiye under the UNFCCC, p. 180 |
| - requirement to pay an environmental fee per piece of lightweight plastic carrier bag | Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p. 165 |
| Bans and prohibitions: | |
| - plastic bags | Antigua and Barbuda's First Biennial Update Report, p. 31 |
| - single-use plastic bags | France's 5th Biennial Report: United Nations Framework Convention on Climate Change, p. 61<br>Accelerating Action Towards a Green, Inclusive and Resilient Economy: Third Update of Second Nationally Determined Contribution for the UAE, p. 29 |

| **Food and packaging** (continued) | |
|---|---|
| ***Bags** (continued)* | |
| - non-biodegradable, oxo-biodegradable and biodegradable single-use plastic bags | The Bahamas Updated NDC, p. 25 |
| - the importation of plastic shopping bags | Micronesia's Third National Communication and First Biennial Update Report to the United Nations Framework on Climate Change, p. 31 |
| - importation and use of single-use non-biodegradable plastics including shopping bags | The Republic of Vanuatu First Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 38 |
| - manufacturing, import, sale, purchase, storage and usage of polyethylene bags | Pakistan's First Biennial Update Report (BUR-1) to the United Nations Framework Convention on Climate Change, p. 13 |
| - the importation, manufacture, distribution and use of single-use plastic bags | Fiji's Updated Nationally Determined Contribution, p. 3<br>Update of Nationally Determined Contribution (NDC) of Jamaica to the United Nations Framework Convention on Climate Change (UNFCCC), p. 3 |
| Awareness campaign for prevention and reduction of plastic bag pollution in the marine environment | Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p. 365 |
| ***Bottles*** | |
| Regulating obligations regarding plastic bottle production | Slovenia's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 161 |
| Setting a target: "By 2030, all tourism accommodation and catering businesses should have phased out the use of non-recyclable plastic bottles and replaced them with recyclable containers." | Seychelles' Updated Nationally Determined Contribution, p. 25 |
| Enforcement of separate waste collection for plastic bottles according to the European Union Waste Framework Directive | Cyprus Eighth National Communication & Fifth Biennial Report, p. 105<br>Eighth National Communication and Fifth Biennial Report from the European Union under the UNFCCC, p. 46 |
| Container deposit legislation for collection of PET bottles | Micronesia's Third National Communication and First Biennial Update Report to the United Nations Framework on Climate Change, p. 31 |
| Setting up recycling system, incentivizing plastic bottle collection | Saint Lucia's First Biennial Update Report, p. 23 |
| Reuse and recycle measures initiated for PET bottles | The Republic of Vanuatu First Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 38 |
| Policy guidelines for installation of plastic bottle crushing machines at railway stations | India's Third Biennial Update Report to the United Nations Framework Convention on Climate Change, p. 264 |
| Education programmes covering the life cycle of a plastic bottle | The Eighth National Communication of the Slovak Republic on Climate Change under the United Nations Framework Convention on Climate Change and the Kyoto Protocol, p. 272 |

| **Food and packaging** (continued) | |
|---|---|
| ***Foodservice containers and foodware*** | |
| Bans and prohibitions: | |
| - single-use plastic foodware | The Bahamas Updated NDC, p. 25 |
| - importation and use of polystyrene containers | The Republic of Vanuatu First Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 38 |
| - selected single-use plastic foodservice containers | Saint Lucia's First Biennial Update Report, p. 24 |
| - foam food containers | Accelerating Action Towards a Green, Inclusive and Resilient Economy: Third Update of Second Nationally Determined Contribution for the UAE, p. 29 |
| Promotion of sorted collection and recycling of plastic containers | Japan's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 188 |
| ***Foodservice items and tableware*** | |
| Bans and prohibitions: | |
| - single-use plastic tableware for the consumption of food and beverages at the point of sale and retail | Portugal's 8th National Communication to the United Nations Framework Convention on Climate Change, p. 158<br>The Eighth National Communication of the Slovak Republic on Climate Change under the United Nations Framework Convention on Climate Change and the Kyoto Protocol, p. 308 |
| - importation of plastic food service items | Micronesia's Third National Communication and First Biennial Update Report to the United Nations Framework on Climate Change, p. 31; p. 104 |
| - importation, manufacture, distribution and use of single-use plastic straws | Update of Nationally Determined Contribution (NDC) of Jamaica to the United Nations Framework Convention on Climate Change (UNFCCC), p. 3 |
| - plastic cutlery | The Republic of Vanuatu First Biennial Update Report under the United Nations Framework Convention on Climate Change, p. 38 |
| ***Packaging*** | |
| Financial incentives: | |
| - an environmental fee, levied on packaging and other plastic products; | Hungary's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 20 |
| - the plastic packaging tax | United Kingdom's 8th National Communication, p. 208 |
| Funding measures: | |
| - to improve exemplary circular economy solutions including in the area of plastic packaging<br>- to achieve significant improvements in recycling of plastic packaging via use of artificial intelligence | Eighth National Communication and fifth Biennial Report of the Federal Republic of Germany under the United Nations Framework Convention on Climate Change, p. 236 |

| **Food and packaging** (continued) | |
|---|---|
| ***Packging*** *(continued)* | |
| Designing product stewardship schemes for plastic packing | New Zealand's Fifth Biennial Report, p. 206 |
| The National Packaging Pact, signatory companies committed to reducing their use of plastic | France's 5th Biennial Report: United Nations Framework Convention on Climate Change, p. 63 |
| Downstream measures: | |
| - Extending EPR to include plastic and combined packaging | Eighth National Communication and Fifth Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change, p. 78 |
| - Extension of sorting instructions for household packaging to all plastic packaging | France's 5th Biennial Report: United Nations Framework Convention on Climate Change, p. 62 |
| - Promotion of sorted collection and recycling of plastic packaging | Japan's Eighth National Communication and Fifth Biennial Report under the United Nations Framework Convention on Climate Change, p. 188 |
| - The Statutory Order on Waste requiring municipalities to improve the possibilities of people and enterprises to separate and deliver plastic packaging waste for recycling | Denmark's Fourth Biennial Report under the United Nations Framework Convention on Climate Change, p. 250 |
| - Incentivizing alternative waste management systems for plastic packaging | Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p. 164 |
| - Regulation prohibiting to accept waste polyethylene terephthalate packaging for landfilling | Eighth National Communication and Fifth Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change, p. 78 |
| - Law on packaging waste providing targets for recovery and recycling | Fourth Biennial Report of Luxembourg under the United Nations Framework Convention on Climate Change, p. 142<br>Third Biennial Update Report of the Republic of Moldova, p. 169 |
| Awareness-raising activities: return plastic items of packaging for recycling | Greece's 8th National Communication and 5th Biennial Report under the United Nations Framework Convention on Climate Change, p. 420 |

# Appendix 2: INC-3 Submissions featuring climate-related proposals

**Submissions from countries:**

***Australia***
Part A https://resolutions.unep.org/resolutions/uploads/australia_15092023_a.pdf

***Azerbaijan***
Part A https://resolutions.unep.org/resolutions/uploads/azerbaijan_14092023_a_0.pdf

***Bahrain***
Part B https://resolutions.unep.org/resolutions/uploads/bahrain_14092023_b.pdf

***Bosnia and Herzegovina***
Part A https://resolutions.unep.org/resolutions/uploads/bosnia_and_herzegovina_09102023_a.pdf

***Brazil***
Part B https://resolutions.unep.org/resolutions/uploads/brazil_b_0.pdf

***Chile***
Part A https://resolutions.unep.org/resolutions/uploads/chile_15092023_a.pdf

***Cook Islands***
Part A https://resolutions.unep.org/resolutions/uploads/cook_islands_15092023_a.pdf
Part B https://resolutions.unep.org/resolutions/uploads/cook_islands_15092023_b.pdf

***Kuwait***
Part B https://resolutions.unep.org/resolutions/uploads/kuwait_15092023_b.pdf

***Monaco***
Part A https://resolutions.unep.org/resolutions/uploads/monaco_15092023_a.pdf

***Norway***
Part A https://resolutions.unep.org/resolutions/uploads/norway_15092023_a.pdf

***Qatar***
Part B https://resolutions.unep.org/resolutions/uploads/qatar_15092023_b.pdf

***Russian Federation***
Part A https://resolutions.unep.org/resolutions/uploads/russian_15092023_a_eng.pdf
Part B https://resolutions.unep.org/resolutions/uploads/russia_15092023_b_eng.pdf

***Saudi Arabia***
Part B https://resolutions.unep.org/resolutions/uploads/saudi_arabia_15092023_b.pdf

***Thailand***
Part B https://resolutions.unep.org/resolutions/uploads/thailand_18092023_b.pdf

***Tunisia***
Part A https://resolutions.unep.org/resolutions/uploads/tunisia_15092023_a.pdf

***Uganda***
Part A https://resolutions.unep.org/resolutions/uploads/uganda_28082023_a.pdf

*United Arab Emirates*
Part B https://resolutions.unep.org/resolutions/uploads/united_arab_emirates_15092023_b.pdf

*Vietnam*
Part A https://resolutions.unep.org/resolutions/uploads/vietnam_15092023_a.pdf

**Submissions from groups of countries**

*African Region*
Part A https://resolutions.unep.org/resolutions/uploads/africa_15092023_a_3.pdf

*European Union*
Part A https://resolutions.unep.org/resolutions/uploads/eums_14092023_a.pdf
Part B https://resolutions.unep.org/resolutions/uploads/eums_14092023_b.pdf

*High Ambition Coalition to End Plastic Pollution*
https://resolutions.unep.org/resolutions/uploads/hac_15092023_a.pdf

# Appendix 3: Plastic-related International Organization for Standardization standards relevant to climate outcomes

**International Organization for Standardization standards relevant to emissions from bio-based plastics**

The International Organization for Standardization (ISO) has developed a standard that may serve as a starting point, namely ISO 22526-1:2020 Plastics – Carbon and environmental footprint of biobased plastics – Part 1: General Principles (see https://www.iso.org/standard/73389.html). In addition to the general principles, this standard provides an introduction and guidance on the system boundaries for the carbon footprint, and other environmental factors, of bio-based plastics. It can also be applied to fossil-based plastic products, materials and polymers.

Supporting ISO standards introduced in this standard include:

- ISO 22526-1:2020, Plastics – Carbon and environmental footprint of biobased plastics – Part 1: General principles
- ISO 22526-2:2020, Plastics – Carbon and environmental footprint of biobased plastics – Part 2: Material carbon footprint, amount (mass) of CO2 removed from the air and incorporated into polymer molecule
- ISO 22526-3:2020, Plastics – Carbon and environmental footprint of biobased plastics – Part 3: Process carbon footprint, requirements and guidelines for quantification
- ISO 22526-4:2023, Plastics — Carbon and environmental footprint of biobased plastics — Part 4: Environmental (total) footprint (Life cycle assessment)

**Other ISO standards of relevance include:**

- ISO 472, Plastics – Vocabulary
- ISO 14020, Environmental labels and declarations – General principles
- ISO 14040, Environmental management – Life cycle assessment – Principles and framework
- ISO 14044, Environmental management – Life cycle assessment – Requirements and guidelines
- ISO 14067, Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification
- ISO 16620-1, Plastics – Biobased content – Part 1: General principles
- ISO 16620-2, Plastics – Biobased content – Part 2: Determination of biobased carbon content
- ISO 16620-3, Plastics – Biobased content – Part 3: Determination of biobased synthetic polymer content
- ISO 16620-4, Plastics – Biobased content – Part 4: Determination of biobased mass content
- ISO 16620-5, Plastics – Biobased content – Part 5: Declaration of biobased carbon content, biobased synthetic polymer content and biobased mass content

In addition, EN 16760:2015, Bio-based products – Life cycle assessment provides requirements and guidance on life cycle assessment of bio-based products. It does not include energy, based on EN ISO 14040 and EN ISO 14044.

# Appendix 4: Summary of key multilateral environmental agreement obligations related to the impact of plastics on climate

| Obligation | Sourcing of raw materials | Production and conversion of plastic products | Use and reuse | Waste management | Plastic pollution in the environment |
|---|---|---|---|---|---|
| **The Paris Agreement** | | | | | |
| *Article 4.4 (control measure):* "Developed country Parties should continue taking the lead by undertaking economy-wide absolute emission reduction targets. Developing country Parties should continue enhancing their mitigation efforts, and are encouraged to move over time towards economy-wide emission reduction or limitation targets in the light of different national circumstances." | *Energy* Sourcing of raw materials requires energy and causes methane emissions. | *Energy, industrial processes* The production of plastics is highly energy intensive. | *Transport* The transport of plastic pellets and products for use and plastic waste for waste management causes greenhouse gas emissions. | *Waste* All waste management methods produce greenhouse gas emissions, but mechanical recycling is noted as having the lowest emissions. | *Agriculture* Untreated sludge, plastic mulch and plastic-coated fertilizers, pesticides and seeds release microplastics that increase soil respiration. |
| *Article 13.7 (inventory):* Parties are required to regularly provide a national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases, prepared using good practice methodologies accepted by the IPCC and agreed upon by the COPs serving as the meeting of the Parties to the Agreement. The greenhouse gas inventory includes the following categories: energy, industrial processes, solvent and other product use, agriculture, land use and forestry, waste and other. | *Energy* Inventories to include energy use during souring and related methane emissions. | *Energy, industrial processes* Inventories to include energy use of production of plastics. | *Transport* Inventories to include greenhouse gas emissions from transport, including plastic pellets, plastic products and plastic waste. | *Waste* Inventories to include greenhouse gas emissions from plastic waste management. | *Agriculture* Inventories to include greenhouse gas emissions from soil respiration due to microplastic contamination. |
| *Article 4.2 (NAP)* Each Party is required to prepare, communicate and maintain successive NDCs that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions. | NDCs are relevant for decarbonising sourcing of raw materials. | NDCs are relevant for decarbonising production of plastics. | NDCs are relevant for decarbonising transport of plastics. | NDCs are relevant for decarbonising plastic waste management. | NDCs are relevant for removal of plastics. |

| Obligation | Sourcing of raw materials | Production and conversion of plastic products | Use and reuse | Waste management | Plastic pollution in the environment |
|---|---|---|---|---|---|
| **Minamata Convention** | | | | | |
| *Article 8 (control measure):* This article aims to control and, where feasible, reduce emissions of mercury from the point sources listed in Annex D, including waste incineration facilities. | n/a | n/a | n/a | The climate impact from waste incineration will reduce with use of state-of-the-art technologies. | n/a |
| *Article 5.2 (control measure)* Parties are not allowed to use mercury in the manufacturing processes listed in Part I of Annex B. To this end, the use of mercury needs to be phased out in chlor-alkali production by 2025. Chlorine alkaline plants produce chlorine gas needed in the production of vinyl chloride monomers used as precursors in PVC production. Chlor-alkali production can have a high climate impact if older, mercury-based technologies are used. | n/a | The climate impact of chlor-alkali production will reduce with the introduction of mercury-free technologies. | n/a | n/a | n/a |
| **Montreal Protocol** | | | | | |
| *Article (control measure):* The Montreal Protocol includes targets for phasing down the production of HFCs listed in Annex F that may include uses as blowing agents in the production of extruded polystyrene and polyurethane foams and as refrigerants in air-conditioning and refrigeration systems. | n/a | The reduction in the use of HFCs in production of plastic foam helps to mitigate climate change. | Energy When HFCs are replaced with alternative, more climate-friendly refrigerants, this can lead to improved energy efficiency. | n/a | n/a |
| *Article 7.2 and Article 7.3 (inventory):* Each Party is required to provide statistical data on its annual production of each of the HFCs listed in Annex F and, separately, for each substance: amounts used for feedstocks; amounts destroyed by technologies approved by Parties; and regarding imports from and exports to Parties and non-Parties, respectively. | n/a | n/a | n/a | n/a | n/a |

| Obligation | Sourcing of raw materials | Production and conversion of plastic products | Use and reuse | Waste management | Plastic pollution in the environment |
|---|---|---|---|---|---|
| **Basel Convention** | | | | | |
| *Article 4.2a (control measure):* Parties are required to take measures to ensure that Parties are required to take, taking into account social, technological and economic aspects, and that adequate disposal facilities are available to the extent possible within it for the environmentally sound management of such wastes. | n/a | Minimising plastic waste generation entails a move towards reduction and redesign, lowering greenhouse gas emissions. | n/a | The availability of high-tech waste management facilities (i.e. recycling) reduces greenhouse gas emissions. | n/a |
| *Article 4.2b (control measure):* Parties are required to ensure the availability of adequate disposal facilities, for the environmentally sound management of hazardous wastes and other wastes, that shall be located, to the extent possible, within it, whatever the place of their disposal. | n/a | n/a | n/a | Availability of adequate waste management facilities helps to avoid leakage and associated climate impacts. Their proximity also reduces greenhouse gas emissions from transport. | n/a |
| **London Convention** | | | | | |
| *Article 4 (control measure):* Dumping of wastes or other matter listed in Annex I is prohibited. This includes persistent plastics and other persistent synthetic materials (e.g. netting and ropes), which may float or may remain in suspension in the sea in such a manner as to interfere materially with fishing, navigation or other legitimate uses of the sea (Annex I, para 4). | n/a | n/a | n/a | n/a | The prohibition of discharge of plastics prevents its degradation in water. Otherwise, it would result in amplification of climate change. |
| **London Protocol** | | | | | |
| *Article 4.1.1 (control measure):* The London Protocol prohibits the dumping of any wastes or other matter into the ocean, except for those listed in Annex I. This Annex therefore provides a "white list" of wastes that may be considered for dumping and, because plastics are not listed, they are included in the prohibition of dumping at sea. | n/a | n/a | n/a | n/a | The prohibition of discharge of plastics prevents its degradation in water. Otherwise, it would result in amplification of climate change. |

| Obligation | Sourcing of raw materials | Production and conversion of plastic products | Use and reuse | Waste management | Plastic pollution in the environment |
|---|---|---|---|---|---|
| **MARPOL Annex V** | | | | | |
| ***Regulations 1.9, 3.2, 7 and 4.4 (control measures):*** "MARPOL Annex V defines garbage as "all kinds of food wastes, domestic wastes and operational wastes, all plastics, cargo residues, incinerator ashes…" (Reg. 1.9). Plastic is further defined and include "all garbage that consists of or includes plastic in any form, including synthetic ropes, synthetic fishing nets, plastic garbage bags and incinerator ashes from plastic products." As per Annex V, the discharge of all plastics anywhere into the sea is prohibited (Reg. 3.2), with exemptions provided (Reg. 7). Should garbage be mixed or contaminated by plastics, it is also prohibited from discharge (Reg. 4.4)". (Secretariat of the Basel, Rotterdam and Stockholm Conventions 2023) | n/a | n/a | n/a | n/a | The prohibition of discharge of plastics prevents its degradation in water. Otherwise, it would result in amplification of climate change. |

# Notes

1. The current requirements for reporting will be superseded by the Enhanced Transparency Framework. See https://unfccc.int/FAQ-moving-towards-the-ETF#__Transitioning-from-Reporting-of-Biennial-Reports-and-Biennial-Update-Reports-to-Biennial-Transparency-Reports.
2. The terms in the report are not universally defined and have been adapted to meet the report's specific needs. This approach focuses on concise definitions that align with existing ones.
3. See: https://unfccc.int/NDCREG.
4. Biennial reports are reports to be submitted by Annex I Parties.
5. Biennial update reports are reports to be submitted by non-Annex I Parties: https://unfccc.int/BURshttps://unfccc.int/BURs.
6. The sources to the table are available in Appendix 1
7. See: https://stats.oecd.org/.
8. See: https://ec.europa.eu/eurostat/data/database
9. See: www.fao.org/faostat/en/#home
10. See: https://unstats.un.org/sdgs/dataportal
11. See: https://unctadstat.unctad.org/datacentre/
12. See: http://scp-hat.lifecycleinitiative.org/
13. See: https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf
14. See: https://ec.europa.eu/competition/mergers/cases/index/nace_all.html
15. See: www.globallcadataaccess.org/
16. See: https://plasticseurope.org/sustainability/circularity/life-cycle-thinking/eco-profiles-set/
17. See: https://ecoinvent.org/the-ecoinvent-database/
18. See: www.carbon-minds.com/
19. See: www.unep.org/inc-plastic-pollution/session-3/submissions.
20. This includes submissions submitted after the deadline 15. September 2023. Some countries/groups submitted only one part.  Submissions were received in English, Spanish and French.
21. For further discussion, see: www.ciel.org/reports/non-party-trade-provisions-in-meas/.
22. See: www.oneplanetnetwork.org/knowledge-centre/resources/sustainable-public-procurement-plastics-guidance.
23. See https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en.
24. Hydrogen generated using renewable energy and sustainable sources.
25. The importance of making finance flows consistent with a path towards low greenhouse gas emissions and climate-resilient development for the achievement of Article 2 and Article 9 is reiterated in paragraphs 90–92 of the COP 28 decision on the outcome of the first global stocktake.

# References


Abe, M.M., Martins, J.R, Sanvezzo, P.B., Macedo, J.V., Branciforti, M.C., Halley, P. et al. (2021). Advantages and disadvantages of bioplastics production from starch and lignocellulosic components. Polymers 13(15), 2484. https://doi.org/10.3390/polym13152484.

Adyel, T.M. and Macreadie, P.I. (2022). Plastics in blue carbon ecosystems: A call for global cooperation on climate change goals. The Lancet Planetary Health 6(1), e2-e3. https://doi.org/10.1016/S2542-5196(21)00327-2.

Aeschlimann, M., Li, G., Kanji, Z.A. and Mitrano, D.M. (2022). Potential impacts of atmospheric microplastics and nanoplastics on cloud formation processes. Nature Geoscience 15(12), 967–975 (2022). https://doi.org/10.1038/s41561-022-01051-9.

Algozeeb, W.A., Savas, P.E., Yuan, Z., Wang, Z., Kittrell, C., Hall, J.N. et al. (2022). Plastic waste product captures carbon dioxide in nanometer pores. ACS Nano 16(5), 7284-7290. https://doi.org/10.1021/acsnano.2c00955.

Ardolino, F., Cardamone, G.F. and Arena, U. (2021). How to enhance the environmental sustainability of WEEE plastics management: An LCA study. Waste Management 135, 347-359. https://doi.org/10.1016/j.wasman.2021.09.021.

Atiwesh, G., Mikhael, A., Parrish, C.C., Banoub, J. and Le, T.-A.T. (2021). Environmental impact of bioplastic use: A review. Heliyon 7(9), e07918. https://doi.org/10.1016/j.heliyon.2021.e07918.

Australia, Department of Climate Change, Energy, the Environment and Water (2022). Australia's 8th National Communication on Climate Change. https://unfccc.int/sites/default/files/resource/NatComm8%20Biennial%20Statement_2022_v8%2021%20Dec.pdf.

Banguera, L. A., Sapulveda, J. M., Ternero, R., Vergas, M., Vasquez, O. C. (2018). Reverse logistics network design under extended producer responsibility: The case of out-of-use tires in the Gran Santiago city of Chile. Journal of Production Economics 205: 193-200. https://doi.org/10.1016/j.ijpe.2018.09.006

Barrowclough, D., Deere Birkbeck, C. and Christen, J. (2020). Global Trade in Plastics: Insights From the First Life-cycle Trade Database. United Nations. .

Bauer, F. and Fontenit, G. (2021). Plastic dinosaurs – Digging deep into the accelerating carbon lock-in of plastics. Energy Policy 156, 112418. https://doi.org/10.1016/j.enpol.2021.112418.

Bauer, F., Nielsen, T.D., Nilsson, L.J., Palm, E., Ericsson, K., Fråne, A. et al. (2022a). Plastics and climate change—Breaking carbon lock-ins through three mitigation pathways. One Earth 5(4), 361-376. https://doi.org/10.1016/j.oneear.2022.03.007.

Bauer, F., Kulionis, V., Oberschelp, C., Pfister, S., Tilsted, J.P., Finkill, G.D. et al. (2022b). Petrochemicals and Climate Change: Tracing Globally Growing Emissions and Key Blind Spots in a Fossil-Based Industry. Lund: Lund University. https://lucris.lub.lu.se/ws/portalfiles/portal/117494791/Petrochemicals_climate_change_review_web.pdf.

Bauer, F., Tilsted, J.P., Deere Birkbeck, C., Skovgaard, J., Rootzén, J., Karltorp, K. et al. (2023). Petrochemicals and Climate Change: Powerful Fossil Fuel Lock-ins and Interventions for Transformative Change. Lund: Environmental and Energy Systems Studies, Lund University. https://lucris.lub.lu.se/ws/portalfiles/portal/146757003/LU_IVL_2023_petrochem_web.pdf.

Beyond Plastics (2021). The New Coal: Plastics & Climate Change. Vermont: Beyond Plastics at Bennington College. https://static1.squarespace.com/static/5eda91260bbb7e7a4bf528d8/t/616ef29221985319611a64e0/1634661022294/REPORT_The_New-Coal_Plastics_and_Climate-Change_10-21-2021.pdf.

Black, S., Liu, A.A., Parry, I. and Vernon, N. (2023). IMF Fossil Fuel Subsidies Data: 2023 Update. https://www.imf.org/en/Publications/WP/Issues/2023/08/22/IMF-Fossil-Fuel-Subsidies-Data-2023-Update-537281.

Bocken, N.M.P., Harsch, A. and Weissbrod, I. (2022). Circular business models for the fastmoving consumer goods industry: Desirability, feasibility, and viability. Sustainable Production and Consumption 30, 799-814. https://doi.org/10.1016/j.spc.2022.01.012.

Brooks, A.L., Wang, S. and Jambeck, J.R. (2018). The Chinese import ban and its impact on global plastic trade. Science Advances 4(6), eaat0131. https://doi.org/10.1126/sciadv.aat013.

C170 – Chemicals Convention, 1990 (No. 170) (1990), entered into force 4 November 1993.

Cabernard, L., Pfister, S., Oberschelp, C. and Hellweg, S. (2022). Growing environmental footprint of plastics driven by coal combustion. Nature Sustainability 5(2), 139-148. https://doi.org/10.1038/s41893-021-00807-2.

Canada, Environment and Climate Change (2023). Canada's Eighth National Communication on Climate Change and Fifth Biennial Report. Gatineau. https://unfccc.int/documents/624782.

Carmona, E., Rojo-Nieto, E., Rummel, C.D., Krauss, M., Syberg, K., Ramos, T.M. et al. (2023). A dataset of organic pollutants identified and quantified in recycled polyethylene pellets. Data in Brief 51, 109740. https://doi.org/10.1016/j.dib.2023.109740.

Carney Almroth, B., Abeynayaka, A., Diamond, M.L., Farrelly, T., Fernandez, M., Gündoğdu, S. et al. (2023). Obstacles to scientific input in global policy. Science 380(6649), 1021-1022. https://doi.org/10.1126/science.adi1103.

Chia, R.W., Lee, J.-Y., Lee, M., Lee, G.-S. and Jeong, C.-D. (2023). Role of soil microplastic pollution in climate change. Science of the Total Environment 887, 164112. https://doi.org/10.1016/j.scitotenv.2023.164112.

Coelho, P.M., Corona, B., ten Klooster, R. and Worrell, E. (2020). Sustainability of reusable packaging–Current situation and trends. Resources, Conservation & Recycling: X 6, 100037. https://doi.org/10.1016/j.rcrx.2020.100037.

Cole, M., Lindeque, P.K., Fileman, E., Clark, J., Lewis, C., Halsband, C. et al. (2016). Microplastics alter the properties and sinking rates of zooplankton faecal pellet. Environmental Science & Technology 50(6), 3239-3246.

https://doi.org/10.1021/acs.est.5b05905.
Cook, E., Cottom, J.W., Velis, C.A., Contribution of Informal Recycling Sector to Plastic Pollution Mitigation Model. University of Leeds, UK (2024-Unpublished)
Creadore, L.T. and Castaldi, M.J. (2022). Quantitative Comparison of LCAS on the Current State of Advanced Recycling Technologies. New York: Earth Engineering Center, City University of New York. https://ccnyeec.org/wp-content/uploads/2022/10/comparisonOfAdvRecyclingLCAs.pdf.
Cruz, M.B., Saikawa, E., Hengstermann, M., Ramirez, A., McCracken, J.P. and Thompson, L.M. (2023). Plastic waste generation and emissions from the domestic open burning of plastic waste in Guatemala. Environmental Science: Atmospheres 3, 156-167. https://doi.org/10.1039/d2ea00082b.
Deere Birkbeck, C., Barrowclough, D., Sugathan, M., Bellmann, C. and Souza Campos Rodrigues, L. (2023). Trends in Trade Flows Across the Life Cycle of Plastics: Preliminary Review. Geneva: Forum on Trade, Environment, & the SDGs. https://cdn2.assets-servd.host/lyrical-cormorant/production/assets/images/Publications/TESS-Briefing-Note-Trends-in-Trade-Flows-Across-the-Life-Cycle-of-Plastics-Preliminary-Review.pdf.
Di, J., Reck, B.K., Miatto, A. and Graedel, T.E. (2021). United States plastics: Large flows, short lifetimes, and negligible recycling. Resources, Conservation and Recycling 167, 105440. https://doi.org/10.1016/j.resconrec.2021.105440.
Dunkelberg, H., Wagner, J., Hannen, C., Schlüter, B.A., Phan, L., Hesselbach, J. et al. (2018). Optimization of the energy supply in the plastics industry to reduce the primary energy demand. Journal of Cleaner Production 192, 790-800. https://doi.org/10.1016/j.jclepro.2018.04.254.
Durán González, D. (2023). Reducing Plastic Production to Achieve Climate Goals: Key Considerations for the Plastics Treaty Negotiations. Center for International Environmental Law. https://www.ciel.org/wp-content/uploads/2023/09/Reducing-Plastic-Production-to-Achieve-Climate-Goals_Sept21_V5.pdf
Ellen MacArthur Foundation (2017). The New Plastics Economy: Rethinking the Future of Plastics & Catalysing Action. https://emf.thirdlight.com/file/24/RrpCWLER-yBWPZRrwSoRrB9KM2/The%20New%20Plastics%20Economy%3A%20Rethinking%20the%20future%20of%20plastics%20%26%20catalysing%20action.pdf.
Ellen MacArthur Foundation (2019). Reuse: Rethinking Packaging. https://emf.thirdlight.com/file/24/_A-BkCs_aXeX02_Am1z_J7vzLt/Reuse%20%E2%80%93%20rethinking%20packaging.pdf.
Ellen MacArthur Foundation (2020). Upstream Innovation: A Guide to Packaging Solutions. https://emf.thirdlight.com/file/24/h_Pf1MahttEqT6h_OwchCrKU2/Upstream%20Innovation.pdf.
Energy Transitions Commission (2020). Mission Possible: Reaching Net-zero Carbon Emissions from Harder-to-abate Sectors by Mid-century. https://www.energy-transitions.org/wp-content/uploads/2020/08/ETC-sectoral-focus-Plastics_final.pdf.
Erickson, P., Kartha, S., Lazarus, M. and Tempest, K. (2015). Assessing carbon lock-in. Environmental Research Letters 10(8), 084023. https://doi.org/10.1088/1748-9326/10/8/084023.
Erland, B.M., Thorpe, A.K. and Gamon, J.A. (2022). Recent advances towards transparent methane emissions monitoring: A review. Environmental Science &Technology 56(23), 16567-16581. https://doi.org/10.1021/acs.est.2c02136.
Eunomia (2023). Assessing Climate Impact: Reusable Systems vs. Single-use Takeaway Packaging. Bristol: Eunomia Research & Consulting Ltd. https://circulareconomy.europa.eu/platform/sites/default/files/2023-09/Assessing-the-Climate-Impact-Reusable-systems-vs.-Single-Use-Takeaway-Packaging-v-2.2.pdf.
European Bioplastics (2023). Bioplastics: Facts and Figures. Berlin. https://docs.european-bioplastics.org/publications/EUBP_Facts_and_figures.pdf.
European Commission, Directorate-General for Research and Innovation (2021). Biodegradability of Plastics in the Open Environment. Luxembourg: Publications Office of the European Union. https://doi.org/10.26356/biodegradabilityplastics.
European Environment Agency (2021a). Plastic in Textiles: Towards a Circular Economy for Synthetic Textiles in Europe. Publications Office of the European Union. https://doi.org/10.2800/555165.
European Environment Agency (2021b). Plastics, the Circular Economy and Europe' s Environment: A Priority for Action. Luxembourg: Publications Office of the European Union. https://www.eea.europa.eu/publications/plastics-the-circular-economy-and.
European Environmental Bureau (2022). New EU Eco-design Proposals: Case Studies to Illustrate Their Potential Impact. Brussels. https://eeb.org/wp-content/uploads/2022/12/Impact-of-EU-ecodesign-regs.pdf.
Food and Agriculture Organization of the United Nations (2021). Assessment of Agricultural Plastics and Their Sustainability: A Call for Action. Rome. https://www.fao.org/3/cb7856en/cb7856en.pdf.
Ford, H.V., Jones, N.H., Davies, A.J., Godley, B.J., Jambeck, J.R., Napper, I.E. et al. (2022). The fundamental links between climate change and marine plastic pollution. Science of the Total Environment 806(1), 150392. https://doi.org/10.1016/j.scitotenv.2021.150392.
Germany, Federal Ministry for Economic Affairs and Climate Action (2023). Eighth National Communication and Fifth Biennial Report of the Federal Republic of Germany Under the United Nations Framework Convention on Climate Change. https://unfccc.int/documents/626516.
Geyer, R., Jambeck, J.R. and Law, K.L. (2017). Production, use, and fate of all plastics ever made. Science Advances 3(7), e1700782. https://doi.org/10.1126/sciadv.1700782.
Giese, A., Kerpen, J., Weber, F. and Prediger, J. (2021). A preliminary study of microplastic abrasion from the screw cap system of reusable plastic bottles by Raman microspectroscopy. ACS ES&T Water 1(6), 1363-1368. https://doi.org/10.1021/acsestwater.0c00238.
Gigault, J., ter Halle, A., Baudrimont, M., Pascal, P.-Y., Gauffre, F., Phi, T.-L. et al. (2018). Current opinion: What is a

nanoplastic?. Environmental Pollution 235, 1030-1034. https://doi.org/10.1016/j.envpol.2018.01.024.
Gordon, M. (n.d.). Reuse Wins: The Environmental, Economic, and Business Case for Transitioning from Single-use to Reuse in Food Service. Upstream Policy Institute, Inc. https://drive.google.com/file/d/10_2xn4C03VW1_xh-lbz-AIlc0tXhRbBi/view.
GRID-Arendal (2022). Plastics myths – what can we do?, 24 February. https://plasticsmyths.com/. Accessed 1 February 2024.
GRID-Arendal (2023). Science-Policy Interface for Plastic Pollution. Arendal. https://gridarendal-website-live.s3.amazonaws.com/production/documents/:s_document/1057/original/SPI-report_fixed.pdf?1699351194.
Grubert, E. (2023). Water consumption from electrolytic hydrogen in a carbon-neutral US energy system. Cleaner Production Letters 4, 100037. https://doi.org/10.1016/j.clpl.2023.100037.
Hahladakis, J.N., Velis, C.A., Weber, R., Iacovidou, E. and Purnell, P. (2018). An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. Journal of Hazardous Materials 344, 179-199. https://doi.org/10.1016/j.jhazmat.2017.10.014.
Hamilton, L.A. and Feit, S. (2019). Plastic & Climate: The Hidden Costs of a Plastic Planet. Switzerland: Center for International Environment Law. https://www.ciel.org/wp-content/uploads/2019/05/Plastic-and-Climate-FINAL-2019.pdf.
Hepburn, C., Adlen, E., Beddington, J., Carter, E.A., Fuss, S., Mac Dowell, N. et al. (2019). The technological and economic prospects for CO2 utilization and removal. Nature 575(7781), 87-97. https://doi.org/10.1038/s41586-019-1681-6.
Hertwich, E.G. (2021). Increased carbon footprint of materials production driven by rise in investments. Nature Geoscience 14, 151-155. https://doi.org/10.1038/s41561-021-00690-8.
Hieminga, G., Stellema, T., Dantuma, E., Patterson, W. and Zhang, C. (2023). How the plastics industry can go green and at what cost, 8 November. https://think.ing.com/articles/how-the-plastics-industry-can-go-green-and-at-what-cost. Accessed 1 February 2024.
Hmiel, B., Petrenko, V V., Dyonisius, M.N., Buizert, C., Smith, A.M., Place, P.F. et al. (2020). Preindustrial 14CH4 indicates greater anthropogenic fossil CH4 emissions. Nature 578(7795), 409-412. https://doi.org/10.1038/s41586-020-1991-8.
Hogg, D. (2023). Debunking Efficient Recovery: The Performance of EU Incineration Facilities – Executive Summary. Zero Waste Europe. https://zerowasteeurope.eu/wp-content/uploads/2023/01/Exec-Summary-_-Debunking-Efficient-Recovery-EN.docx-1.pdf.
International Convention for the Prevention of Pollution from Ships. Resolution (2011)MEPC.201(62)
International Energy Agency (2018). The Future of Petrochemicals: Towards More Sustainable Plastics and Fertilisers. Paris. https://doi.org/10.1787/9789264307414-en.
International Energy Agency (2023). Oil 2023: Analysis and Forecast to 2028. Paris. https://iea.blob.core.windows.net/assets/6ff5beb7-a9f9-489f-9d71-fd221b88c66e/Oil2023.pdf.
International Energy Agency (2024a). Aviation, n.d. https://www.iea.org/energy-system/transport/aviation. Accessed 1 February 2024.
International Energy Agency (2024b). Decarbonisation enablers, n.d. https://www.iea.org/energy-system/decarbonisation-enablers. Accessed 1 February 2024.
International Energy Agency (2024c). Energy efficiency and demand, n.d. https://www.iea.org/energy-system/energy-efficiency-and-demand. Accessed 1 February 2024.
International Energy Agency (2024d). Energy subsidies, n.d. https://www.iea.org/topics/energy-subsidies. Accessed 1 February 2024.
International Energy Agency (n.d.). Transport. https://www.iea.org/energy-system/transport. Accessed 1 February 2024.
International Civil Aviation Organization (2024). Sustainable aviation fuel (SAF), 2 January. https://www.icao.int/environmental-protection/pages/SAF.aspx. Accessed 1 February 2024.
International Organization for Standardization (2006). ISO:14040:2006 (en): Environmental Management – Life Cycle Assessment – Principles and Framework. https://www.iso.org/obp/ui/en/#iso:std:iso:14040:ed-2:v1:en.
International Organization for Standardization (2014). ISO:472:2013: Plastics – Vocabulary. https://www.iso.org/obp/ui/en/#iso:std:iso:472:ed-4:v1:en.
Ismail, O.S. and Umukoro, G.E. (2012). Global impact of gas flaring. Energy and Power Engineering 4(4), 290-302. https://doi.org/10.4236/epe.2012.44039.
Jeswani, H., Kruger, C., Russ, M., Horlacher, M., Antony, F., Hann, S. et al. (2021). Life cycle environmental impacts of chemical recycling via pyrolysis of mixed plastic waste in comparison with mechanical recycling and energy recovery. Science of the Total Environment 769, 144483. https://doi.org/10.1016/j.scitotenv.2020.144483.
Jiang, J., Shi, K., Zhang, X., Yu, K., Zhang, H., He, J. et al. (2022). From plastic waste to wealth using chemical recycling: A review. Journal of Environmental and Chemical Engineering 10(1), 106867. https://doi.org/10.1016/j.jece.2021.106867.
Jones, E.R., van Vliet, M.T.H., Qadir, M. and Bierkens, M.F.P. (2021). Country-level and gridded estimates of wastewater production, collection, treatment and reuse. Earth System Science Data 13(2), 237-254. https://doi.org/10.5194/essd-13-237-2021.
Kätelhön, A., Meys, R., Deutz, S., Suh, S. and Bardow, A. (2019). Climate change mitigation potential of carbon capture and utilization in the chemical industry. PNAS 116(23), 11187-11194. https://doi.org/10.1073/pnas.1821029116.
Kholod, N., Evans, M., Pilcher, R.C., Roshchanka, V., Ruiz, F., Coté, M. et al. (2020). Global methane emissions from coal mining to continue growing even with declining coal production. Journal of Cleaner Production 256, 120489. https://doi.org/10.1016/j.jclepro.2020.120489.

Kida, M., Ziembowicz, S. and Koszelnik, P. (2022). CH4 and CO2 emissions from the decomposition of microplastics in the bottom sediment—preliminary studies. Environments 9(7), 91. https://doi.org/10.3390/environments9070091.

Kwon, S., Kang, J., Lee, B., Hong, S., Jeon, Y., Bak, M. et al. (2023). Nonviable carbon neutrality with plastic waste-to-energy. Energy & Environmental Science 16(7), 3074-3087. https://doi.org/10.1039/D3EE00969F.

Laubinger, F., Brown, A., Dubois, M. and Börkey, P. (2021). Modulated Fees for Extended Producer Responsibility Schemes (EPR). Paris: OECD Publishing. https://doi.org/10.1787/19970900.

Leaders of the G20 (2023). G20 New Delhi leaders' declaration. 2023 G20 New Delhi Summit. New Delhi, India, 9-10 September. https://www.mea.gov.in/Images/CPV/G20-New-Delhi-Leaders-Declaration.pdf.

Liu, Z., Liu, W., Walker, T.R., Adams, M. and Zhao, J. (2021). How does the global plastic waste trade contribute to environmental benefits: Implication for reductions of greenhouse gas emissions? Journal of Environmental Management 287, 112283. https://doi.org/10.1016/j.jenvman.2021.112283.

Liu, Z., Su, Z., Chen, J., Zou, J., Liu, Z., Li, Y. et al. (2023). Polyethylene microplastics can attenuate soil carbon sequestration by reducing plant photosynthetic carbon assimilation and transfer: Evidence from a 13C-labeling mesocosm study. Journal of Cleaner Production 385, 135558. https://doi.org/10.1016/j.jclepro.2022.135558.

Marczak, H. (2022). Energy inputs on the production of plastic products. Journal of Ecological Engineering 23(9), 146-156. https://doi.org/10.12911/22998993/151815.

Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (eds.) (2018). Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Cambridge and New York: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf.

Material Economics (2019). Industrial Transformation 2050: Pathways to Net-zero Emissions from EU Heavy Industry. Cambridge: University of Cambridge Institute for Sustainability Leadership. https://www.cisl.cam.ac.uk/system/files/documents/material-economics-industrial-transformation-2050.pdf.

McKinsey & Company (2022). Climate impact of plastics, 6 July. https://www.mckinsey.com/industries/chemicals/our-insights/climate-impact-of-plastics#/. Accessed 1 February 2024.

Minderoo Foundation (2023). Plastic Waste Makers Index. https://www.minderoo.org/plastic-waste-makers-index. Accessed 1 February 2024.

Möck, A., Bulach, W. and Betz, J. (2022). Climate Impact of Pyrolysis of Waste Plastic Packaging in Comparison with Reuse and Mechanical Recycling. Darmstadt: Öko-Institut. https://zerowasteeurope.eu/wp-content/uploads/2022/09/zwe_2022_report_climat_impact__pyrolysis_plastic_packaging.pdf.

Mohan, A.M. (2022). Recyclable toothpaste tube from NICE prevents 3,000 tons of landfill waste, 14 September. https://www.packworld.com/design/materials-containers/article/22405852/nice-and-dow-create-recyclable-toothpaste-tube. Accessed 2 February 2024.

Müller, L.J., Kätelhön, A., Bringezu, S., McCoy, S., Suh, S., Edwards, R. et al. (2020). The carbon footprint of the carbon feedstock CO2. Energy & Environmental Science 13(9), 2979-2992. https://doi.org/10.1039/D0EE01530J.

Nordic Council of Ministers (2023). Towards Ending Plastic Pollution by 2040: 15 Global Policy Interventions for Systems Change. Copenhagen. https://pub.norden.org/temanord2023-539/.

Nordic Council of Ministers (2024). Global Criteria to Address Problematic, Unnecessary and Avoidable Plastic Products. Copenhagen. https://pub.norden.org/temanord2024-508/.

Odenweller, A., Ueckerdt, F., Nemet, G.F., Jensterle, M. and Luderer, G. (2022). Probabilistic feasibility space of scaling up green hydrogen supply. Nature Energy 7(9), 854-865. https://doi.org/10.1038/s41560-022-01097-4.

Organisation for Economic Co-operation and Development (2016). Extended Producer Responsibility: Updated Guidance for Efficient Waste Management. Paris: OECD Publishing. https://doi.org/10.1787/9789264256385-en.

Organisation for Economic Co-operation and Development (2022a). Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options. Paris: OECD Publishing. https://doi.org/10.1787/de747aef-en.

Organisation for Economic Co-operation and Development (2022b). Global Plastics Outlook: Policy Scenarios to 2060. Paris: OECD Publishing. https://doi.org/10.1787/aa1edf33-en.

Organisation for Economic Co-operation and Development (2023). Climate Change and Plastics Pollution: Synergies Between Two Crucial Environmental Challenges. https://www.oecd.org/environment/plastics/Policy-Highlights-Climate-change-and-plastics-pollution-Synergies-between-two-crucial-environmental-challenges.pdf.

Palm, E., Tilsted, J.P., Vogl, V. and Nikoleris, A. (2024). Imagining circular carbon: A mitigation (deterrence) strategy for the petrochemical industry. Environmental Science & Policy 151, 103640. https://doi.org/10.1016/j.envsci.2023.103640.

Pew Charitable Trusts and Systemiq (2020). Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution. https://www.pewtrusts.org/-/media/assets/2020/07/breakingtheplasticwave_report.pdf.

Plastics Europe (2023). Plastics – The Fast Facts 2023. https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2023/.

Quantis (2018). Measuring Fashion: Environmental Impact of the Global Apparel and Footwear Industries Study. https://quantis.com/wp-content/uploads/2018/03/measuringfashion_globalimpactstudy_full-report_

quantis_cwf_2018a.pdf.
Ragaert, K., Delva, L. and Van Geem, K. (2017). Mechanical and chemical recycling of solid plastic waste. Waste Management 69, 24-58. https://doi.org/10.1016/j.wasman.2017.07.044.
Rana, S. (2008). Facts and data on environmental risks—oil and gas drilling operations. SPE Asia Pacific Oil and Gas Conference and Exhibition. Perth, Australia, 20-22 October 2008. https://doi.org/10.2118/114993-MS.
Raubenheimer, K. and McIlgorm, A. (2017). Is the Montreal Protocol a model that can help solve the global marine plastic debris problem?. Marine Policy 81, 322-329. .
Revell, L. E., Kuma, P., Le Ru, E. C., Somerville, W. R. C., & Gaw, S. (2021). Direct radiative effects of airborne microplastics. Nature, 598(7881), 462–467. https://doi.org/10.1038/s41586-021-03864-x
Reyna-Bensusan, N., Wilson, D.C., Davy, P.M., Fuller, G.W., Fowler, G.D. and Smith, S.R. (2019). Experimental measurements of black carbon emission factors to estimate the global impact of uncontrolled burning of waste. Atmospheric Environment 213, 629-639. https://doi.org/10.1016/j.atmosenv.2019.06.047.
Rillig, M.C., Leifheit, E. and Lehmann, J. (2021). Microplastic effects on carbon cycling processes in soils. PLOS Biology 19(3), e3001130. https://doi.org/10.1371/journal.pbio.3001130.
Rosental, M., Fröhlich, T. and Liebich, A. (2020). Life cycle assessment of carbon capture and utilization for the production of large volume organic chemicals. Frontiers in Climate 2, 586199. https://doi.org/10.3389/fclim.2020.586199.
Royer, S.-J., Ferrón, S., Wilson, S.T. and Karl, D.M. (2018). Production of methane and ethylene from plastic in the environment. PLOS ONE 13(8), e0200574. https://doi.org/10.1371/journal.pone.0200574.
Sadia, M., Mahmood, A., Ibrahim, M., Irshad, M.K., Quddusi, A.H.A., Bokhari, A. et al. (2022). Microplastics pollution from wastewater treatment plants: A critical review on challenges, detection, sustainable removal techniques and circular economy. Environmental Technology & Innovation 28, 102946. https://doi.org/10.1016/j.eti.2022.102946.
Sandin, G., Roos, S. and Johansson, M. (2019). Environmental Impact of Textile Fibers – What We Know and What We Don't Know: The Fiber Bible Part 2. Göteborg: RISE Research Institutes of Sweden AB. https://doi.org/10.13140/RG.2.2.23295.05280.
Sato, I., Elliott, B. and Schumer, C. (2021). What is carbon lock-in and how can we avoid it?, 25 May. https://www.wri.org/insights/carbon-lock-in-definition. Accessed 5 February 2024.
Secretariat of the Basel, Rotterdam and Stockholm Conventions (2023). Global Governance of Plastics and Associated Chemicals. Geneva. https://www.basel.int/Implementation/Plasticwaste/Globalgovernance/tabid/8335/Default.aspx.
Secretariat of the Pacific Regional Environment Programme (2020). Moana Taka Partnership: A Guide for Pacific Island Countries & Territories. Apia. https://www.sprep.org/sites/default/files/documents/publications/moana-taka-partnership.pdf.
Shen, M., Huang, W., Chen, M., Song, B., Zeng, G. and Zhang, Y. (2020a). (Micro)plastic crisis: Un-ignorable contribution to global greenhouse gas emissions and climate change. Journal of Cleaner Production 254, 120138. https://doi.org/10.1016/j.jclepro.2020.120138.
Shen, M., Ye, S., Zeng, G., Zhang, Y., Xing, L., Tang, W. et al. (2020b). Can microplastics pose a threat to ocean carbon sequestration? Marine Pollution Bulletin 150, 110712. https://doi.org/10.1016/j.marpolbul.2019.110712.
Shen, M., Liu, S., Hu, T., Zheng, K., Wang, Y. and Long, H. (2023). Recent advances in the research on effects of micro/nanoplastics on carbon conversion and carbon cycle: A review. Journal of Environmental Management 334, 117529. https://doi.org/10.1016/j.jenvman.2023.117529.
Sherrington, C., Darrah, C., Hann, S., Cole, G. and Corbin, M. (2016). Study to Support the Development of Measures to Combat a Range of Marine Litter Sources. Bristol: Eunomia Research & Consulting Ltd. https://mcc.jrc.ec.europa.eu/documents/201606243248.pdf.
Simon, N., Raubenheimer, K., Urho, N., Unger, S., Azoulay, D., Farrelly, T. et al. (2021). A binding global agreement to address the life cycle of plastics. Science 373(6550), 43-47. https://doi.org/10.1126/science.abi9010.
Smith, S.D.A. (2012). Marine debris: A proximate threat to marine sustainability in Bootless Bay, Papua New Guinea. Marine Pollution Bulletin 64(9), 1880-1883. https://doi.org/10.1016/j.marpolbul.2012.06.013.
Spokas, K., Bogner, J., Chanton, J.P., Morcet, M., Aran, C., Graff, C. et al. (2006). Methane mass balance at three landfill sites: What is the efficiency of capture by gas collection systems?. Waste Management 26(5), 516-25. https://doi.org/10.1016/j.wasman.2005.07.021.
Statista (2023). Transportation Emissions Worldwide – Statistics & Facts. https://www.statista.com/topics/7476/transportation-emissions-worldwide/#topicOverview. Accessed 5 February 2024.
Stegmann, P., Daioglou, V., Londo, M., van Vuuren, D.P. and Junginger, M. (2022). Plastic futures and their CO2 emissions. Nature 612(7939), 272-276. https://doi.org/10.1038/s41586-022-05422-5.
Sustainable Packaging News (2022). Future market insights research report on PET packaging market, 7 April. https://spnews.com/pet-packaging-market/. Accessed 2 February 2024.
Suzuki, G., Uchida, N., Tuyen, L.H., Tanaka, K., Matsukami, H., Kunisue, T. et al. (2022). Mechanical recycling of plastic waste as a point source of microplastic pollution. Environmental Pollution 303, 119114. https://doi.org/10.1016/j.envpol.2022.119114.
Systemiq (2022). Reshaping Plastics: Pathways to a Circular Climate Neutral Plastics System in Europe. https://plasticseurope.org/wp-content/uploads/2022/04/SYSTEMIQ-ReShapingPlastics-April2022.pdf.
Taurino, R., Pozzi, P. and Zanasi, T. (2010). Facile characterization of polymer fractions from waste electrical and electronic equipment (WEEE) for mechanical recycling. Waste Management 30(12), 2601-2607. https://

doi.org/10.1016/j.wasman.2010.07.014.
Thailand (2022). Thailand's Fourth Biennial Update Report. https://unfccc.int/documents/624750.
The Core Writing Team, Lee, H. and Romero, J. (eds.) (2023). Climate Change 2023: Synthesis Report – Summary for Policymakers. Geneva: Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf.
Tisler, S. and Christensen, J.H. (2022). Non-target screening for the identification of migrating compounds from reusable plastic bottles into drinking water. Journal of Hazardous Materials 429, 128331. https://doi.org/10.1016/j.jhazmat.2022.128331.
Tumu, K., Vorst, K. and Curtzwiler, G. (2023). Global plastic waste recycling and extended producer responsibility laws. Journal of Environmental Management 348, 119242. https://doi.org/10.1016/j.jenvman.2023.119242.
United Nations Environment Programme (2016). Follow-up to the Indonesian-Swiss Country-led Initiative to Improve the Effectiveness of the Basel Convention. 17 November. UNEP/CHW.13/4/Add.1. https://www.basel.int/Default.aspx?tabid=5847. Accessed 5 February 2024.
United Nations Environment Programme (2018). Legal Limits on Single-use Plastics and Microplastics: A Global Review of National Laws and Regulations. https://www.unep.org/resources/publication/legal-limits-single-use-plastics-and-microplastics-global-review-national.
United Nations Environment Programme (2019). Global Chemicals Outlook II: From Legacies to Innovative Solutions – Synthesis Report. https://wedocs.unep.org/20.500.11822/27651.
United Nations Environment Programme (2021). Addressing Single-use Plastic Products Pollution Using a Life Cycle Approach. Nairobi. https://www.unep.org/resources/publication/addressing-single-use-plastic-products-pollution-using-life-cycle-approach.
United Nations Environment Programme (2022a). UNEA Resolution 5/14 Entitled "End Plastic Pollution: Towards an International Legally Binding Instrument". 10 May. UNEP/PP/OEWG/1/INF/1. https://wedocs.unep.org/bitstream/handle/20.500.11822/39812/OEWG_PP_1_INF_1_UNEA%20resolution.pdf. Accessed 5 February 2024.
United Nations Environment Programme (2022b). Plastics Science. 13 September. UNEP/PP/INC.1/7. https://wedocs.unep.org/bitstream/handle/20.500.11822/40767/K2221533%20-%20%20UNEP-PP-INC.1-7%20-%20ADVANCE.pdf. Accessed 5 February 2024.
United Nations Environment Programme (2022c). Study on Industry Involvement in the Integrated Approach to Financing Sound Management of Chemicals and Waste. Geneva. https://wedocs.unep.org/bitstream/handle/20.500.11822/40069/industry_waste.pdf.
United Nations Environment Programme (2023a). Zero Draft Text of the International Legally Binding Instrument on Plastic Pollution, Including in the Marine Environment. UNEP/PP/INC.3/4. 4 September. https://wedocs.unep.org/bitstream/handle/20.500.11822/43239/ZERODRAFT.pdf. Accessed 5 February 2024.
United Nations Environment Programme (2023b). Turning Off the Tap: How the World Can End Plastic Pollution and Create a Circular Economy. Nairobi. https://wedocs.unep.org/bitstream/handle/20.500.11822/42277/Plastic_pollution.pdf.
United Nations Environment Programme (2023c). Potential Options for Elements Towards an International Legally Binding Instrument, Based on a Comprehensive Approach That Addresses the Full Life Cycle o Plastics as Called for by United Nations Environment Assembly Resolution 5/14. 13 April. UNEP/PP/INC.2/4. https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/42190/UNEP-PP-INC.2-4%20English.pdf?. Accessed 5 February 2024.
United Nations Environment Programme (2024). Plastic glossary, n.d. https://leap.unep.org/knowledge/toolkits/plastic/glossary. Accessed 5 February 2024.
United Nations Environment Programme and Yale Center for Ecosystems + Architecture (2023). Building Materials and the Climate: Constructing a New Future. Paris. https://wedocs.unep.org/20.500.11822/43293.
United Nations Environment Programme, United Nations Development Programme and Secretariat of the United Nations Framework Convention on Climate Change (2023). Building Circularity into Nationally Determined Contributions (NDCs): A Practical Toolbox User Guide. Nairobi. https://doi.org/10.59117/20.500.11822/43594.
United Nations Framework Convention on Climate Change (2022). Decision -/CP.27: Sharm el-Sheikh Implementation Plan. Sharm el-Sheikh Climate Change Conference. Sharm El-Sheikh, Egypt, 6-20 November. https://unfccc.int/documents/624444.
United Nations Framework Convention on Climate Change (2023a). Outcome of the First Global Stocktake: Draft Decision -/CMA.5. 13 December. FCCC/PA/CMA/2023/L.17. https://unfccc.int/documents/636608. Accessed 5 February 2024.
United Nations Framework Convention on Climate Change (2023b). Long-term low-emission development strategies: Synthesis report by the secretariat. 14 November. FCCC/PA/CMA/2023/10. https://unfccc.int/documents/632339. Accessed 5 February 2024.
United Kingdom, Department for Business, Energy & Industrial Strategy (2022). 8th National Communication. London. .
United Kingdom and Brazil (2023). Evaluation of potential criteria for identifying chemicals and polymers of concern and problematic plastic products A briefing report for the INC-3 about the results of the informal technical dialogue cochaired by the UK Government and Government of Brazil. https://resolutions.unep.org/resolutions/uploads/report_0.pdf. Accessed 8 February 2024.
United Nations (2023a). Plastic Pollution: The Pressing Case for Natural and Environmentally Friendly Substitutes to Plastics. New York: United Nations Publications. https://unctad.org/system/files/official-document/ditcted2023d2_en.pdf.
United Nations (2023b). Trade and Environment Review 2023: Building a Sustainable and Resilient Ocean Economy Beyond 2030. New York: United Nations Publications. https://unctad.org/publication/trade-and-environment-review-2023.

United Nations Climate Change News (2023). COP28 agreement signals "beginning of the end" of the fossil fuel era. 13 December. https://unfccc.int/news/cop28-agreement-signals-beginning-of-the-end-of-the-fossil-fuel-era.

United States of America, Environmental Protection Agency (2009). Opportunities to Reduce Greenhouse Gas Emissions Through Materials and Land Management Practices. https://www.epa.gov/sites/default/files/2016-08/documents/ghg-land-materials-management.pdf.

United States of America, Environmental Protection Agency, Office of Resource Conservation and Recovery (2020). Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM): Containers, Packaging, and Non-Durable Good Materials Chapters. https://www.epa.gov/sites/default/files/2020-12/documents/warm_containers_packaging_and_non-durable_goods_materials_v15_10-29-2020.pdf.

United States of America, Office of Energy Efficiency & Renewable Energy (n.d.). Low carbon feedstocks basics. https://www.energy.gov/eere/iedo/low-carbon-feedstocks-basics. Accessed 5 February 2024.

Upstream (2022). The New Reuse Economy: How Reuse Systems and Services Will Revolutionize How We Consume. https://drive.google.com/file/d/1QD8GufolsA7ZBFnRvt45g_BwCXD1Fea2/view.

Vanderreydt, I., Almasi, A., Strömberg, E., Tenhunen-Lunkka, A., Arnold, M., Mortensen, L.F. et al. (2023). Pathways to Circular Plastics in Europe: Good Examples From Countries, Businesses and Citizens. European Topic Centre on Circular Economy and Resource Use. https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-products/etc-ce-report-2023-1-pathways-to-circular-plastics-in-europe-good-examples-from-countries-business-and-citizens.

Vert, M., Doi, Y., Hellwich, K.-H., Hess, M., Hodge, P., Kubisa, P. et al. (2012). Terminology for biorelated polymers and applications (IUPAC Recommendations 2012). Pure and Applied Chemistry 84(2), 377-410. https://doi.org/10.1351/PAC-REC-10-12-04.

Vora, N., Christensen, P.R., Demarteau, J., Baral, N.R., Keasling, J.D., Helms, B.A., et al. (2021). Leveling the cost and carbon footprint of circular polymers that are chemically recycled to monomer. Science Advances 7(15), eabf0187. https://doi.org/10.1126/sciadv.abf0187.

Wiedinmyer, C., Yokelson, R.J. and Gullett, B.K. (2014). Global emissions of trace gases, particulate matter, and hazardous air pollutants from open burning of domestic waste. Environmental Science & Technology 48(16), 9523-9530. https://doi.org/10.1021/es502250z.

Wilson, D.C. (2023). Learning from the past to plan for the future: An historical review of the evolution of waste and resource management 1970–2020 and reflections on priorities 2020–2030 – The perspective of an involved witness. Waste Management & Research: The Journal for a Sustainable Circular Economy 41(12), 1754-1813. https://doi.org/10.1177/0734242X231178025.

World Bank (2023). Global Gas Flaring Tracker Report. Washington, D.C.: World Bank Publications. https://thedocs.worldbank.org/en/doc/5d5c5c8b0f451b472e858ceb97624a18-0400072023/original/2023-Global-Gas-Flaring-Tracker-Report.pdf.

World Economic Forum (2016). The New Plastics Economy: Rethinking the Future of Plastics. Geneva. https://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf.

World Resources Institute and World Business Council for Sustainable Development (2024a). Greenhouse Gas Protocol: FAQ. https://ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf

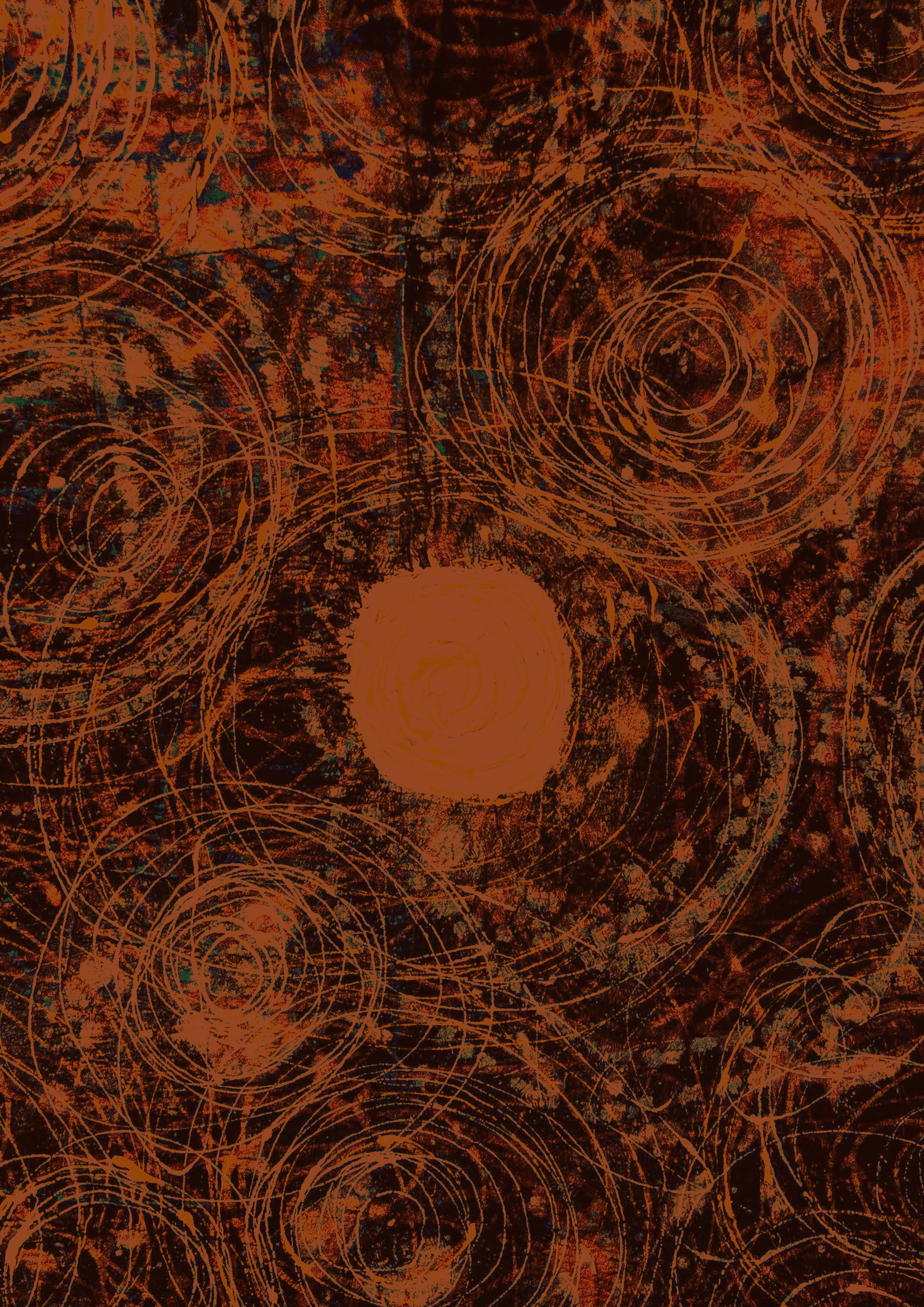
World Trade Organization (2022). The trade implications of a low-carbon economy. In World Trade Report 2022: Climate Change and International Trade. Chapter C. 50-77. Geneva. https://www.wto.org/english/res_e/booksp_e/wtr22_e/wtr22_ch3_e.pdf.

WRI and WBCSD (2024a). The Greenhouse Gas Protocol: FAQ. https://ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf

WRI and WBCSD (2024b). The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard – Revised Edition. https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

Zhang, Y.-L., Kang, S.-C. and Gao, T.-G. (2022). Microplastics have light-absorbing ability to enhance cryospheric melting. Advances in Climate Change Research 13(4), 455-458. https://doi.org/10.1016/j.accre.2022.06.005.

Zheng, J. and Suh, S. (2019). Strategies to reduce the global carbon footprint of plastics. Nature Climate Change 9(5), 394-378. https://doi.org/10.1038/s41558-019-0459-z



This report seeks to identify possible options for measures that could strengthen accountability in addressing the climate impacts of plastics. It aims to maximise the climate benefits of the plastics instrument, clearly delineating responsibilities in conjunction with the UNFCCC and the Paris Agreement. The report shows that the absence of internationally agreed definitions and harmonised terminology in research and national reporting presents a significant challenge in understanding and communicating interventions that could address climate impacts of plastics.

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