MINDEROO FOUNDATION

ACKNOWLEDGEMENTS

Minderoo Foundation

Established by Dr Andrew Forrest AO and Nicola Forrest AO in 2001, Minderoo Foundation is proudly Australian, and one of Asia Pacific's largest philanthropic organisations, with over AUD 2.6 billion committed to a range of global initiatives.

The Plastic Waste Makers Index is a project of Minderoo's Plastics initiative, which aims to create a world without plastic pollution – a truly circular plastics economy, where fossil fuels are no longer used to produce plastics. A critical step towards this goal is to bring greater transparency to the plastics supply chain – to better understand its material and financial flows, its environmental impacts, the commitments its companies have made to sustainability, and the effectiveness of government policies.

Analytical Partners

Wood Mackenzie is an energy research consultancy that empowers strategic decision-making in global natural resources with quality data, analysis and advice. For this report, it supported the analyses of single-use plastics material flows, capacity expansion for polymer production, and greenhouse gas emission estimates.

Carbon Trust is a global climate consultancy driven by the mission to accelerate the move to a decarbonised future. It has been a climate pioneer for over 20 years, partnering with businesses, governments, and financial institutions to drive positive climate action. For this report, it supported the analysis of greenhouse gas emission estimates.

Limited Assurance

Minderoo Foundation engaged KPMG to perform a limited assurance engagement with respect to its preparation of the: single-use plastic waste footprint; GHG footprint (from polymers bound for single-use plastic); and Circularity scores; as included in the "Results in detail" section of this report, in accordance with the Plastic Waste Makers Index: Basis of Preparation. KPMG's primary deliverable for the engagement was a limited assurance report. The engagement was performed in accordance with Australian Standard on Assurance Engagements ASAE 3000 Assurance Engagements Other than Audits or Reviews of Historical Financial Information issued by the Auditing and Assurance Standards Board (AUASB). As part of the engagement, KPMG performed procedures including testing that the calculation methodology is appropriately described in the Basis of Preparation, that the data sourced and key assumptions used in the methodology were clearly identified and supported by source documentation, and the calculations were performed with mathematical accuracy and in accordance with the methodology. Given the pioneering nature of the analysis, KPMG has not assured the methodology itself, only the accuracy of its application. KPMG does not undertake any responsibility arising in any way from reliance placed by a third party on their report.

A typical plastic shopping bag, made from fossil fuel that, when discarded, will be sent to a landfill, incinerated, or find its way to the ocean, posing a serious threat to human health, the environment, and climate. Photo credit: Shana Novak via Getty Images.

Authors

Dominic Charles and Laurent Kimman,
Minderoo Foundation

Contributors

Mark Barnaba, Deputy Chairman, Fortescue Metals Group and Director of Sea The Future, a project pioneered by Minderoo Foundation

Sam Fankhauser, Professor of Climate Economics and Policy, University of Oxford

Toby Gardner, Senior Research Fellow, Stockholm Environment Institute and Director, Trase

Steve Jenkins, VP Consulting, Wood Mackenzie

Lakshmi Poti, Senior Programme Manager, Materials, Laudes India LLP

Ambuj Sagar, Founding Head of Public Policy, Indian Institute of Technology, Delhi

John Willis, Director of Research, Planet Tracker

Tony Worby, Director, Planet Portfolio and Flourishing Oceans, Minderoo Foundation

Acknowledgements

We would like to thank Abdul Wahid Khan, Caroline Caldeira, Lakshya Katariya and Michael Scriba for their analytical contributions. We also thank our colleagues Michael Best, Matt Bolt, Simon Clarke, Tim Colica, Margot Dons, Sarah Dunlop, Kim Forrester, Lizzie Fuller, Stephen Gaisford, Marcus Gover, Paul Groth, Emily Hicks, Minke Hoekstra, Christine Lim-Abrahams, Louisa Miller, Philip McVey, Katherine Neaves, Louise Renwick and Emma Silver for their valuable contributions and support.

Disclaimer

Plastic Waste Makers Index 2023 is authored by The Minderoo Foundation Pty Ltd as trustee for The Minderoo Foundation Trust ABN 24 819 440 618 (**Minderoo Foundation**). Plastic Waste Makers Index 2023 is a pioneering analysis. Whilst Minderoo Foundation has exercised care and diligence in the preparation of this report and relied on information from public sources it believes to be reliable, neither Minderoo Foundation, nor any of its directors, officers, employees or agents make any representations or give any warranties, nor accept any liability, in connection with this report including as to the suitability for any purpose of any of its contents.

Minderoo Foundation would like to thank the organisations that contributed to the report for their constructive input. Contribution to this report, or any part of it, should not be deemed to indicate any kind of partnership or agency between the contributors and Minderoo Foundation, nor an endorsement of its conclusions or recommendations. Individuals and organisations listed in the Contributors section support the general direction of this report, but do not necessarily agree with every individual conclusion or recommendation.

To quote this report, please use the following reference: Charles D & Kimman L 2023, *Plastic Waste Makers Index 2023*, Minderoo Foundation.

This report and supplementary documentation may be updated from time to time – users should go online to access the current version.

Data statement

A full data set can be downloaded from the Plastic Waste Makers Index project page on the Minderoo Foundation website. Visit minderoo.org/plastic-waste-makers-index.

Emissions from a refinery complex. Most lifecycle emissions from single-use plastics are produced by the oil and gas and petrochemical industries in the "upstream" part.
Photo credit: Travelpix Ltd via Getty Images

CONTENTS

FOREWORDS

Dr Andrew Forrest AO

Chairman, Minderoo Foundation

More plastic, more waste and more pollution.

They're shocking findings, but they're the results of this second edition of the Plastic Waste Makers Index. For the petrochemical industry to argue otherwise is greenwashing of the highest order.

My eyes were opened to the devastating impacts of plastic pollution while researching for my PhD in marine ecology.

As a businessman, I know industry can and should take the bold collective action needed to fix problems.

But the fossil-fuel giants aren't tackling the problem of plastics – it's the opposite, they're making even more of a product that threatens our people and planet.

We need a fundamentally different approach, that turns the tap off on new plastic production. We need a "polymer premium" on every kilogram of plastic polymer made from fossil fuel. We need financial incentives that encourage re-use and recycling and the build of new, critical infrastructure.

Better waste management is part of the solution – it is paramount that we halt the increase in pollution and the threat to our health from microplastics. But that effort must be combined with reducing the production of new plastics from fossil fuels.

Growth in fossil-fuel plastics cannot be the "soft landing" for the oil and gas industry.

My message to you: the evidence is now overwhelming that your products are harming human health, and devastating our planet's wildlife and most remote ecosystems. It's the end of the line for fossil-fuel plastics and delaying change will only increase your cost of transition and regulatory risk.

We can eliminate plastic pollution within a decade but to do so we must abandon the idea that industry can transform of its own accord.

Finally, no large capital allocator should be sitting comfortably either. If you are an investor in virgin plastics, your hands are dirty. You are knowingly perpetuating a crisis.

It is time to change.

Casey C. Clark, CFA

President and Chief Investment Officer of Rockefeller Asset Management

The environmental and social implications of waste and pollution are significant and undeniable.

Collective efforts to combat these challenges are gaining momentum. In 2022, at the UN Environment Assembly in Nairobi, we witnessed an endorsement to forge a legally binding agreement to end plastic pollution. In Montreal, governments also collaborated to agree on a post-2020 global biodiversity framework, highlighting the sense of urgency needed to reach 2050 biodiversity goals.

Investors, regulatory bodies, and civil society have emphasized the need to reduce plastic consumption, increase waste management efforts, and transition to "circular" modes of living.

But even against that backdrop, as this report shows, the global intake of raw virgin materials and single use plastics continues to rise. Most plastic is left un-recycled and single-use plastic accounts for more than a third of our global annual plastic production. The trajectory is disturbing and has implications for ecosystems, biodiversity, human health, and climate ambitions.

In the second edition of the Plastic Waste Makers Index, the Minderoo Foundation, alongside research partners, highlight the critical linkages between plastics and net zero carbon emission goals. It also explains the environmental risks often overlooked by traditional financial analysis and reporting methods.

As awareness of the plastic/climate axis grows, and the potential for regulation increases, the implications for investors seeking to create long-term shareholder value become more apparent.

This comprehensive report provides a useful benchmark for everyone embarking on plastic and climate-related research and shareholder engagement efforts.

Plastic waste dumps serve as a visual reminder of the magnitude of the waste crisis, which is also a climate change issue. Photo credit: Zeljko Santrac via Getty Images.

GLOSSARY

Chemical recycling	Converts plastic waste by changing its chemical structure to produce substances (e.g., pyrolysis oil) that can be distilled and used as raw materials for the production of new plastics
Circular economy	An economic system that reuses plastic resources, generating no waste
Circularity target	For plastic producers, targets on the mass or share of plastic polymers produced from recycled plastic waste, or polymers made from alternative materials that are sourced sustainably and biodegradable
CO_2e	"Carbon dioxide equivalent" is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential, by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential
Cracking	Process of splitting large, heavy hydrocarbon molecules into smaller, lighter components, through temperature and pressure
Cradle-to-grave	Considers impacts at each stage of a plastic product's lifecycle, from the time natural resources are extracted from the ground and processed through each subsequent stage of manufacturing, transportation, product use, and ultimately, disposal. Cradle-to-grave GHG emissions are equivalent to combined Scope 1, 2 and 3 emissions (see definitions on next page)
Downcycling	Processing of plastic waste where the output material is repurposed into a different end-use application than the original waste input material, e.g., turning plastic bottles into benches or fences. This typically does not guarantee replacement of virgin plastics or sustainable end-of-life treatment
Feedstocks	Refers to the raw materials used to produce plastics
Flexible plastics	Any product or packaging made primarily from unmoulded plastic, such as plastic bags, films, wraps, pouches, or laminates
GDP	Gross Domestic Product, the total market value of all the finished goods and services made within a country over a certain time period
GHG	Greenhouse gas, a type of gas that contributes to the greenhouse effect by trapping heat in the earth's atmosphere, e.g., carbon dioxide (CO_2)
Greenwashing	An attempt to make people believe that a company is doing more to protect the environment than it really is
HDPE	High-density polyethylene, a type of plastic polymer
LDPE	Low-density polyethylene, a type of plastic polymer
Linear business model	A model of production based on a "take-make-consume-waste" approach to using resources. Raw material is transformed into a product that is discarded at the end of its life cycle
LLDPE	Linear low-density polyethylene, a type of plastic polymer

Mechanical recycling	Processing plastic waste into secondary raw material without significantly changing the chemical structure of the material. The waste is mechanically shredded, washed, and turned into flakes and pellets
MMT	Million metric tons
Monomer	A molecule that forms the basic unit for polymers; common monomers that are found in single-use plastics include ethylene, propylene, styrene and ethylene glycol
Net zero	The balance between the amount of greenhouse gas produced and the amount removed from the atmosphere
On par recycling	Mechanical or chemical recycling of plastic waste materials, which are repurposed into the same end-use application as the input material – e.g., recycling plastic waste bottles to produce feedstock for the production of new plastic bottles (i.e., bottle-to-bottle recycling). This ensures a genuine circular model of production which displaces new virgin plastics production. Also known as “closed-loop” recycling
PET	Polyethylene terephthalate, a type of plastic polymer
Polymerisation	Process of reacting monomer molecules together in a chemical reaction to form polymer chains, e.g., turning ethylene into polyethylene
PP	Polypropylene, a type of plastic polymer
PS	Polystyrene, a type of plastic polymer
Recycling	Processing of waste materials into products, materials, or substances, either for the original or another purpose, excluding energy recovery or fuel generation
Reuse	Plastic packaging that can be used many times over a prolonged period without reducing its functionality
Rigid plastics	Any item that has a relatively inflexible fixed shape or form and is capable of maintaining its shape or form, whether empty or full, under normal usage
rPET	Recycled polyethylene terephthalate
Scope 1 emissions	Direct emissions from company-owned and controlled resources that are released into the atmosphere as a direct result of a set of activities at a company level
Scope 2 emissions	Indirect emissions from the generation of purchased energy, from a utility provider, that is released into the atmosphere from the consumption of purchased electricity, steam, heat and cooling
Scope 3 emissions	Indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions
Unnecessary plastics	Plastic packaging items, components, or materials which can be eliminated, reduced in mass, or substituted with sustainable alternatives without compromising the utility of a product
Virgin plastics	New plastic polymers that have been produced using fossil fuels such as natural gas or crude oil

KEY FINDINGS OF THE 2023 EDITION

1

Despite rising consumer awareness, corporate attention, and regulation, there is more single-use plastic waste than ever before — an additional 6 million metric tons (MMT) generated in 2021 compared to 2019 — still almost entirely made from fossil fuel-based "virgin" feedstocks. The top 20 list of petrochemical companies producing virgin polymers bound for single-use plastic remains effectively unchanged.

While global capacity to produce these virgin polymers is expected to grow slower than the historical rate (2.7% CAGR in 2021-27 versus 3.9% in 2005-20), this still equates to an additional 60 MMT by 2027, of which we expect 17 MMT to be bound for single-use plastics.

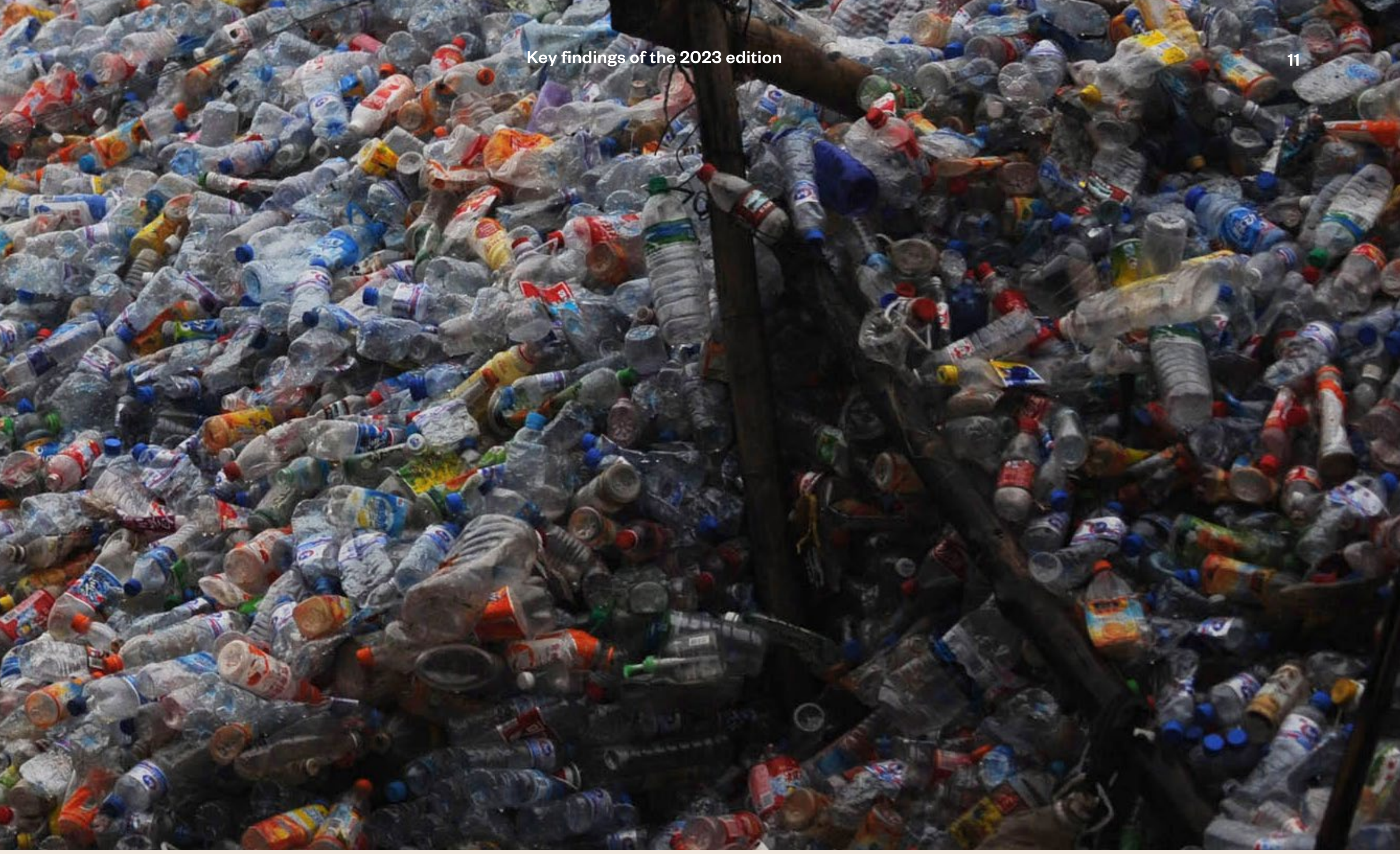
2

Single-use plastic is not only a pollution crisis but also a climate one. Cradle-to-grave (Scope 1, 2 and 3) greenhouse gas emissions (GHG) from single-use plastics in 2021 were equivalent to ~450 million metric tons of carbon dioxide (MMT CO_2e), more than the total GHG emissions of the United Kingdom.

Most emissions are produced by the oil and gas and petrochemical industries in the "upstream" part of the lifecycle. Mechanical recycling reduces cradle-to-grave emissions by at least 30 to 40% compared to producing polymers from fossil fuels by avoiding upstream emissions. While the emissions reduction opportunities from recycling are significant, they can only be part of the solution towards a net zero plastics economy.

••

Used plastic bottles pile up at a plastics recycling mill in Wuhan of Hubei Province, China. The majority of plastic bottles collected in China are "downcycled" into fibre for textiles. Photo credit: China Photos via Getty Images.



3 Recycling is failing to scale fast enough and remains, at most, a marginal activity for the plastics sector — from 2019-21, growth in single-use plastics made from virgin polymers was 15 times that from recycled feedstocks. Only strong regulatory intervention with economic incentives can solve what amounts to market failure.

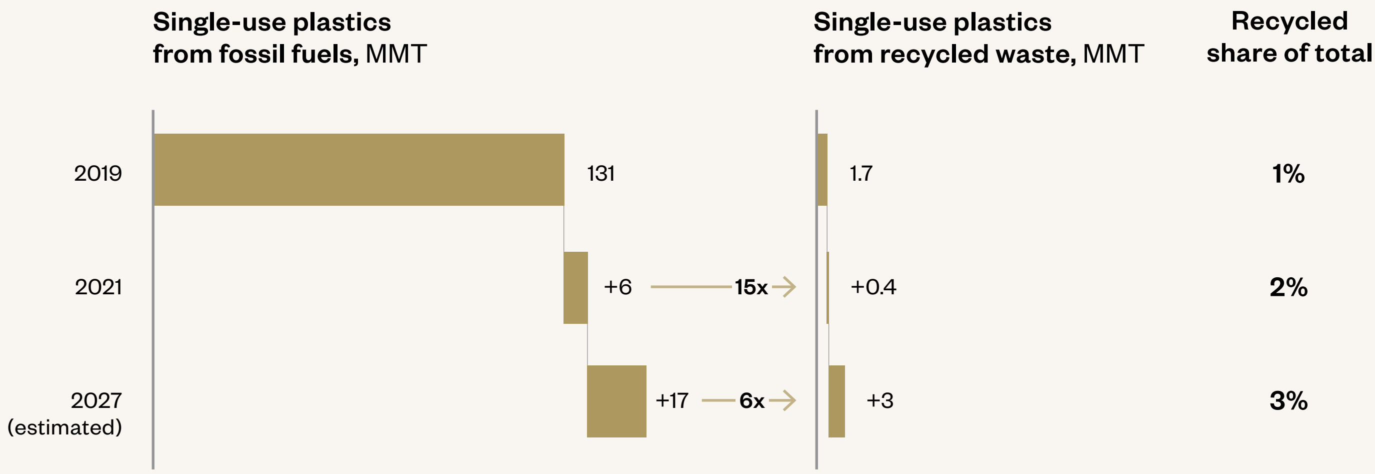
Petrochemical companies are (naturally) only expanding into recycling in markets where the economic conditions are (somewhat) more favourable. These are markets where policies are more progressive and demand for recycled plastics stronger. However, across all polymers and technologies, only 3 MMT of additional on par recycling capacity is expected to be brought online by 2027 (0.7 MMT by the petrochemical industry).

4 Within the petrochemical industry there are two outliers: Taiwan's Far Eastern New Century and Thailand's Indorama Ventures are making strong commitments to recycling and are also now producing on par recycled polymers at scale.

A further eight companies have recently set ambitious 2030 recycled targets of at least 20% of production. Compared to the first edition of the *Plastic Waste Makers Index (2021)*, there are signs that the industry in general is taking circularity more seriously, but this will only amount to greenwashing if representations are not made good with action and investment.

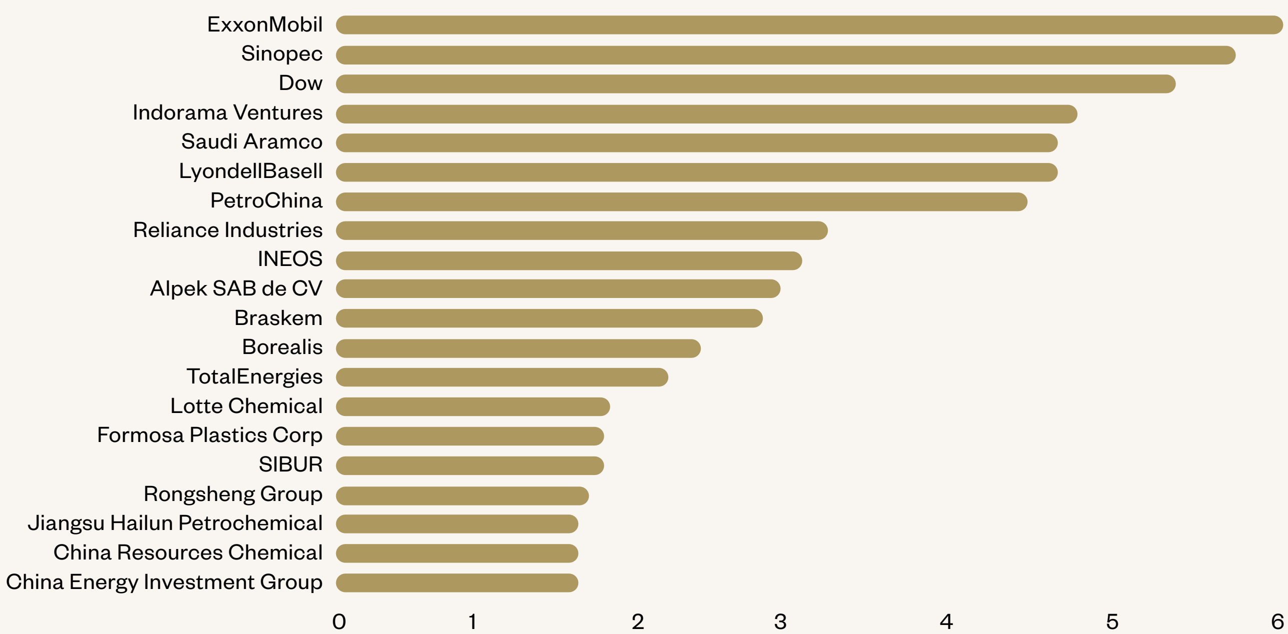
KEY FINDINGS OF THE 2023 EDITION

From 2019-21, an additional 6 MMT of single-use plastics were produced. Virgin fossil-fuel polymers contributed 15 times more to this growth than recycled feedstocks. Recycling is failing to scale fast enough and is expected to remain, at most, a marginal activity for the plastics sector.



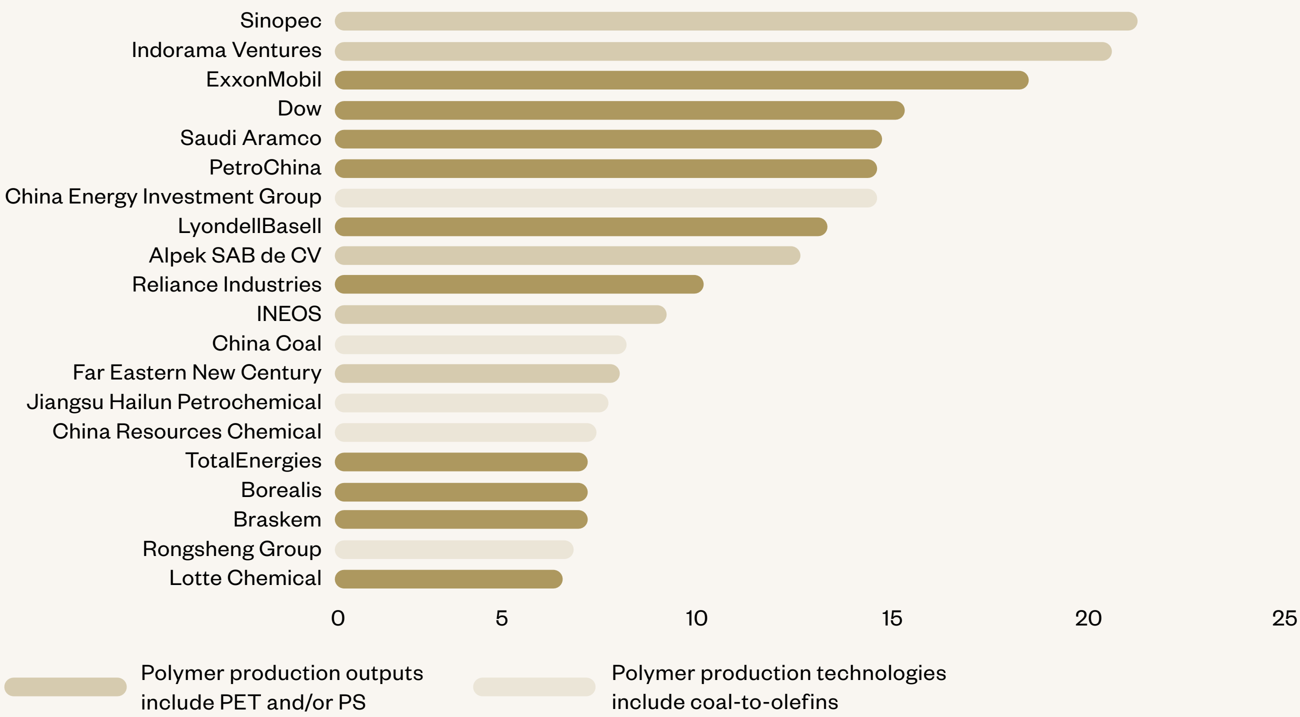
The top 20 list of petrochemical companies producing virgin polymers bound for single-use plastic remains effectively unchanged since 2019.

Contribution to single-use plastic waste generation in 2021 (MMT)

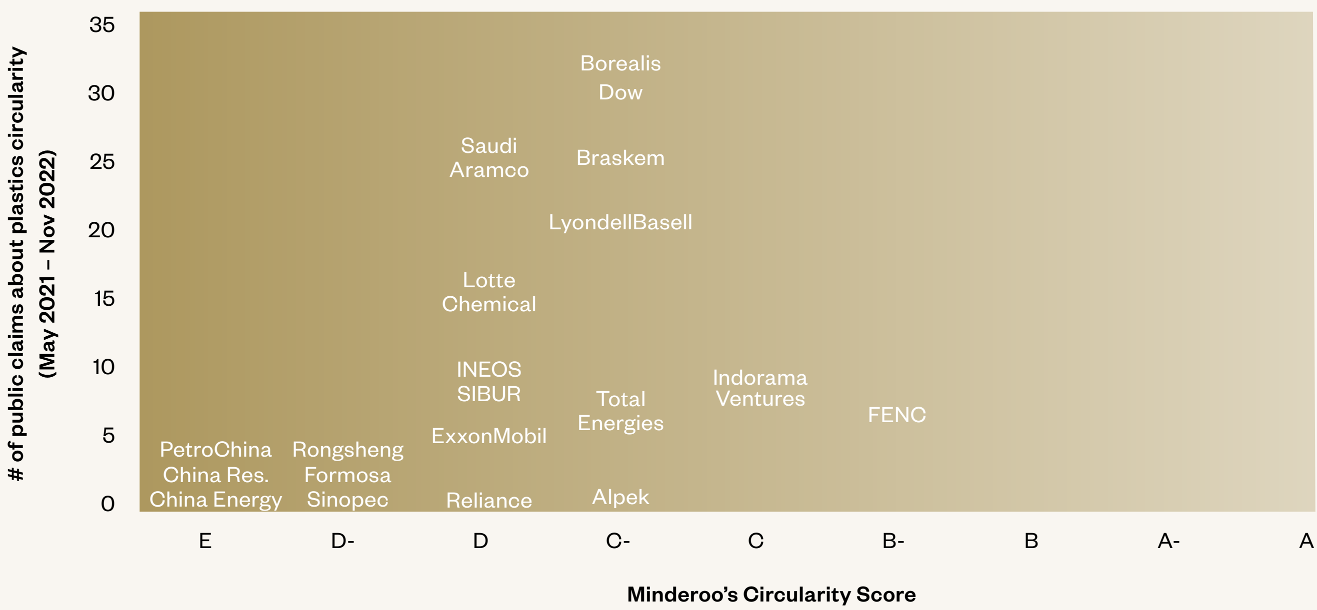


GHG emissions are proportionally higher for companies using coal-to-olefins technologies and those producing more complex polymers (PS, PET).

Total cradle-to-grave GHG emissions from contribution to single-use plastic waste in 2021, MMT CO2e



Only two companies score a "C" or better on our grade score. In some cases, the frequency of public claims about circularity is at odds with the overall result – investors should be on the alert for greenwashing.



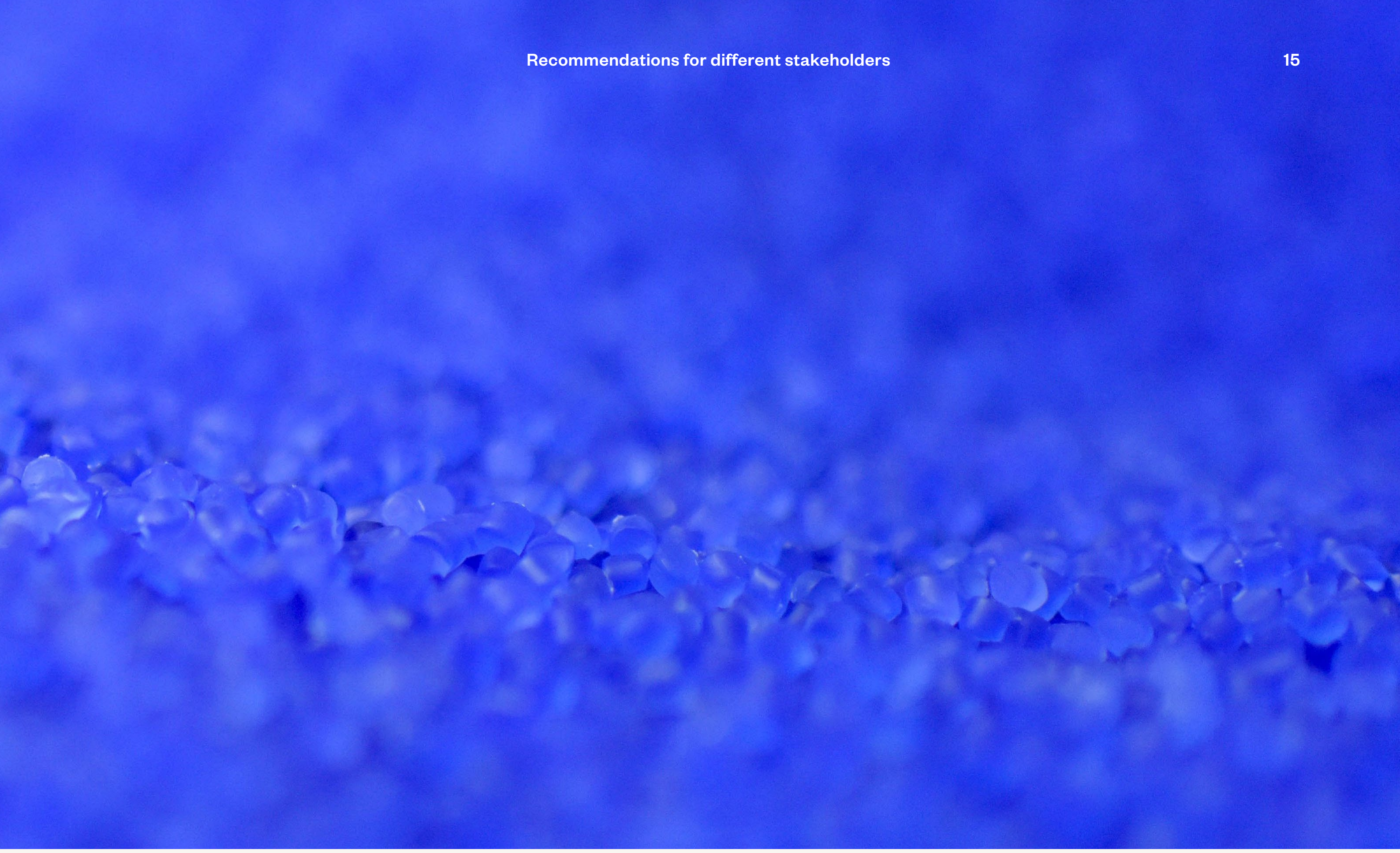
RECOMMENDATIONS FOR DIFFERENT STAKEHOLDERS

Three big interventions could deliver a step change in single-use plastic waste and associated greenhouse gas emissions

	POLYMER PRODUCERS	INVESTORS
1. Limit fossil fuel plastic production and consumption	Include Scope 1, 2 and 3 emissions from plastic polymers in net zero climate targets and strategies.	Actively engage with investees (or use voting rights) to stop the building of new fossil fuel-based polymer facilities, or divest.
2. Increase plastic products and materials that are designed for circularity and are circulated in practice	Set a minimum 20% target by 2030 for recycled vs fossil fuel feedstock in polymer production.	Demand clear, ambitious and time-bound targets for recycled vs fossil fuel feedstock in polymer production from every producer.
3. Eliminate plastic leakage to the environment across the lifecycle through environmentally sound waste management	Invest in or partner with plastic waste collection, sorting and recycling systems and capacities, with a focus on high-leakage countries.	Lend public support for policies that will create economic conditions for more investment in plastics collection, sorting and recycling (e.g., through the Business Coalition for a Global Plastics Treaty).

All of which needs to be supported by:

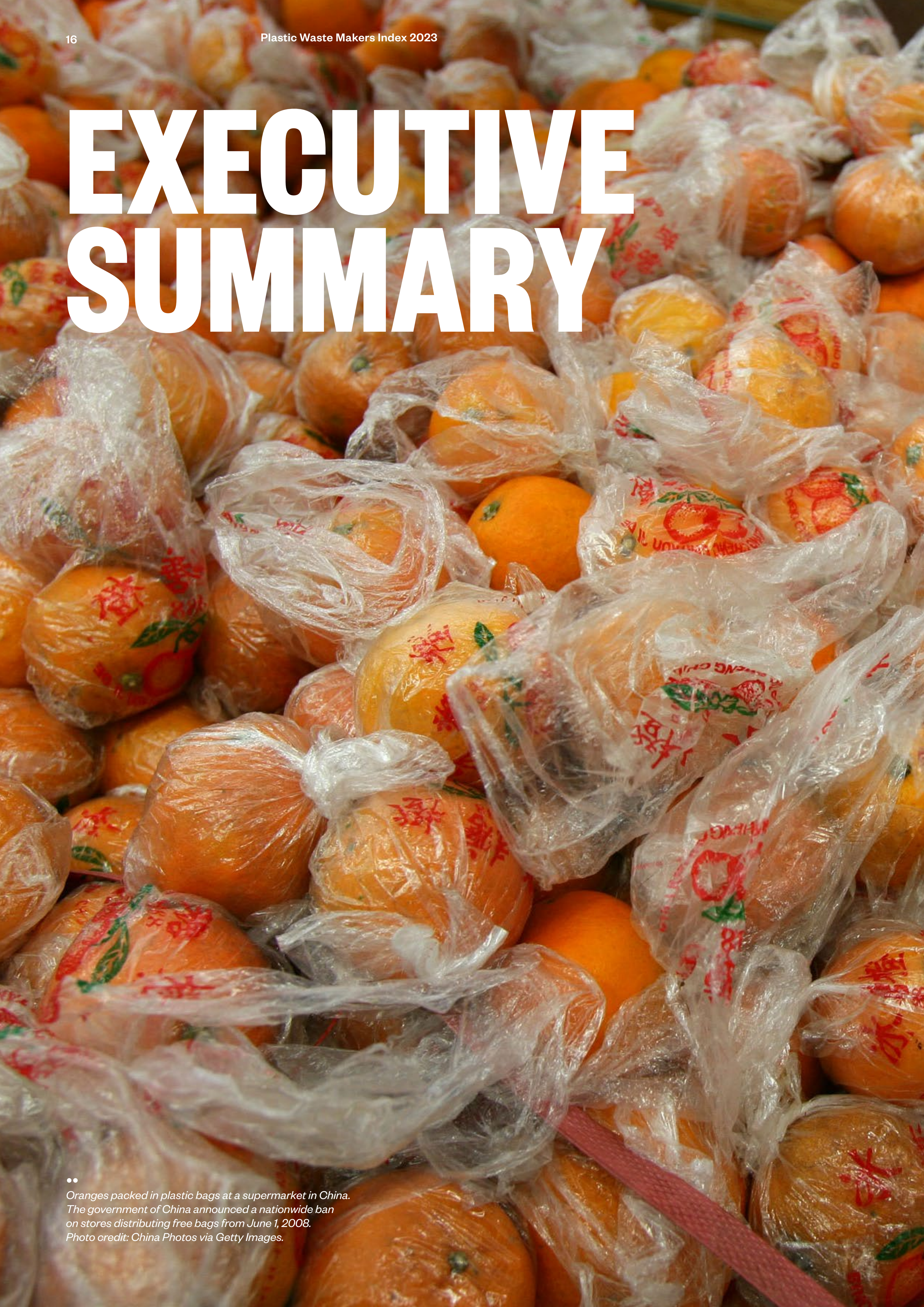
- **Disclosure and transparent reporting** (e.g., through CDP's forthcoming plastics disclosure platform)
- **Strong governance at every level** (e.g., board-/management-level accountability for recycled content targets with remuneration linked to target achievement)



POLICY MAKERS	OTHER COMPANIES IN THE VALUE CHAIN
Put a levy on fossil-fuel polymer production and/or consumption to generate funds for scaling plastics collection, sorting and recycling infrastructure.	Set clear corporate targets to reduce virgin plastic consumption – e.g., through EMF/UN's Global Commitment – and lend public support to policy measures with this objective.
Set target on overall plastic material circularity – i.e., combined mass of re-used, recycled, and sustainable plastics put on the market – including 20% minimum recycled content standards for all single-use plastics by 2030.	Create certainty for greater investment in recycling by entering into long-term forward contracts for recycled plastics at fixed and fair prices.
Under the Global Plastics Treaty, create a fund to support waste management systems in countries most impacted by plastic pollution (following the example of COP27's Loss and Damage Fund).	Harmonise design standards for safe plastics use, disposal and recyclability (including chemical additives).

Plastic pellets are the building blocks of all plastics. Photo credit: Sebastien Salom-Gomis via Getty Images.

EXECUTIVE SUMMARY



Oranges packed in plastic bags at a supermarket in China. The government of China announced a nationwide ban on stores distributing free bags from June 1, 2008. Photo credit: China Photos via Getty Images.

Single-use plastics – plastic packaging, and disposable plastic items such as bags, straws and cutlery that are used once then thrown away – represent the largest plastics application category and account for a third of all plastics consumed globally. Evidence shows that single-use plastics are also the most damaging to people and the planet.

They are the primary component of mismanaged plastic waste, which is either burned at the roadside, harming human health, or dumped on land and into rivers, from where they disperse to the ocean and harm marine life directly, or indirectly as they degrade into micro- and nano-sized particles over months, years and decades. Emissions from the production, use and disposal of single-use plastics are significant in their contributions both to climate change and air pollution. Almost all single-use plastics contain chemical additives that enhance performance and aesthetics, several of which are known to be harmful to health – at a huge social cost – and many more whose potential toxicity is unknown.*

** For additional background information and academic references see Merkl A & Charles D 2022, The Price of Plastic Pollution: Social Costs and Corporate Liabilities, Minderoo Foundation.*

Revealing the source of the single-use plastics crisis

In the initial edition of the *Plastic Waste Makers Index* (May 2021), we identified for the first time the companies at the start of the plastics supply chain that are responsible for producing the polymers bound for single-use plastics, almost all of which are fossil fuel-based. More than half of the world's single-use plastic waste could be traced directly to just 20 petrochemical companies. We revealed these companies as the source of the plastic waste crisis.

The virgin polymers these companies produce enjoy massive economies of scale, while their price reflects none of the externalities they create – neither the costs of safely managing plastic waste, nor the wider social costs of harms to human health and to the environment. As a result, it is still almost always cheaper to produce new single-use plastics from fossil fuels than to reuse or recycle them. This nullifies demand for plastic waste, suppresses its value as a commodity, and undermines the commercial viability of waste collection. In wealthy countries, waste collection is funded through taxation, and plastic waste is mostly incinerated, landfilled, or exported. Everywhere else – including for 85% of the world's population – waste collection is chronically underfunded, widely mismanaged and plastic pollution ubiquitous.

In the first Index, we also assessed whether there was any evidence that these companies were making efforts to establish a more sustainable, circular model of production and transition away from a linear one based on fossil fuel extraction and waste disposal. We concluded that the industry paid only lip service to circularity, and we called on company directors, their shareholders, bankers and policymakers collectively to raise their circularity ambitions and address the systemic challenges.

The waste crisis is deepening and industry's transition away from fossil fuel dependency has barely progressed – which has significant consequences for climate and net zero ambitions

We have updated the benchmarks for this second edition with data up to the end of 2021 (the first edition covered 2019). The headline results are deeply troubling: in 2021, the world generated 139 million metric tons (MMT) of single-use plastic waste, 6 MMT more than in 2019 – roughly an additional kilogram more plastic packaging waste for every human on the planet.

The composition of the top 20 producers with the largest waste footprint is largely unchanged. The two new additions to the list of top 20 producers result from significant new virgin capacity expansion: Russia's SIBUR (1.5 MMT) and China's Rongsheng Group (1.4 MMT).

Almost all single-use plastics continue to be produced from fossil fuel feedstocks – 98% in 2021 versus 99% in 2019. There is an interwoven climate dimension to the plastics crisis. New analysis for this report (done in partnership with Carbon Trust and Wood Mackenzie) estimates that global cradle-to-grave emissions (combined scope 1, 2 and 3 emissions) from single-use plastics alone were around 450 MMT CO_2e in 2021, roughly equivalent to the annual GHG emissions of the United Kingdom.

We also estimate the associated cradle-to-grave GHG emissions for each company producing polymers bound for single-use plastic. Unsurprisingly, the largest producers of polymer are also the largest GHG emitters. However, emissions intensity (metric ton of CO_2e per metric ton of plastic) varies based on what polymers are produced (with polyethylene terephthalate and polystyrene being more intensive than polyethylene and polypropylene) and how they are produced (with coal-to-olefins technologies being far more intensive than those using gas or naphtha as feedstock).

Recycling has the potential – along with reduce and reuse – to play an important role in solving both the waste and climate crises, but its contribution is currently negligible

Higher recycling rates would create stronger demand for plastic waste, increase collection rates, reduce mismanaged waste, and prevent leakage of plastic into the environment. Creating polymers from (mechanically) recycled plastic waste could also displace at least half the GHG emissions compared to producing polymers from fossil fuels. For corporates, investors and policymakers alike, the benefits of recycling should be counted in reduced plastic pollution and in terms of carbon abatement and the route to net zero.

However, "on par" recycling – where materials remain in a circular model of production (e.g., using packaging waste to create new packaging) – continues to be a niche enterprise. Only 13% of food and beverage bottles, the most widely recycled type of single-use plastic, are produced from recycled polymers (predominantly rPET). Even if we include "downcycling" – which only extends a linear model of production by one turn (e.g., turning packaging waste into street furniture) – recycling is not scaling at the rate needed.

While awareness of single-use plastics waste and regulatory efforts to curb it have increased in the past two years, the extra attention has so far failed to result in significant change. The overall picture is one of continuing market failure: from 2019 to 2021, growth in the mass of single-use plastics from virgin polymer outpaced that from recycled feedstocks by a factor of 15 to one (6 MMT versus 0.4 MMT).

In this new edition of the Index, we have looked exhaustively at each petrochemical company's use of recycled plastic waste as feedstock for new polymers and estimated their contribution to single-use plastic waste net of material recovered for on par recycling. The impacts amount to rounding errors in all but a few cases.

••
A worker sorts out plastic bottles at a warehouse in Lahore, Pakistan. Recycling is failing to scale fast enough and remains, at most, a marginal activity for the plastics sector.
Photo credit: Arif Ali/AFP via Getty Images.

Cautious optimism that the petrochemical industry has the potential to change

While there is a collective lack of industry movement away from fossil fuels, a select few petrochemical players are emerging as outliers in recycling and circularity. Taiwan's Far Eastern New Century tops Minderoo's Plastics Circularity Assessment (scoring a "B-"), producing 11% recycled single-use plastic polymers in 2021, committing to doubling recycling capacity by 2027, and embedded circularity into its corporate strategy and governance. It is followed by Thailand's Indorama Ventures, which scored a "C", producing 6% recycled polymer in 2021 and committing to increasing capacity by one-third by 2027.

These two companies alone represent 20% of the global "PET bottle-to-bottle recycling capacity" – an indication that petrochemical companies can play a critical role in the transition towards a circular plastics economy. Logic might dictate that they should have the expertise, balance sheets and customer relationships to build, operate and commercialise large-scale recycling facilities.

Behind these two, there is a pack – which includes Spain's Repsol, US-based Dow, Mexico's Alpek and South Korea's Lotte Chemical, which has set more ambitious recycled polymer targets. If realised, their combined commitments would add significantly to existing on par recycling capacity: together representing 5 MMT of recycled polymer by 2030.

These commitments are long-term and mostly short on detail, and many of them include chemical recycling deployments that are still in the research and development stage with uncertain circularity credentials – i.e., the extent to which these technologies can actually produce new plastic from plastic waste, rather than fuel or energy, is unclear. All of which means these commitments need to be treated with scepticism – some of these companies are inclined to oversell their circularity credentials, and this will only amount to greenwashing if representations are not made good with action and investment.

Making the transition possible: the crucial role of public policy and regulation

The companies making more ambitious circularity commitments are all active in markets where there are more progressive and exacting regulations and policies that support the economics of recycling, albeit to different degrees – specifically, in Europe, USA, and parts of Asia (India, Japan, South Korea, and Taiwan). Outside these regions, expecting companies to commit any capital to recycling projects that deliver sub-standard returns compared to virgin polymer production is likely at odds with their fiduciary duty to shareholders.

To unlock greater capital flows into circular plastics production, pressure needs to be directed appropriately towards both polymer producers and policymakers. With respect to polymer producers – especially those with operations in Europe, the USA and Japan – investors will want to understand the business case and returns on investment from recycling commitments, or, in their absence, why companies are not leading or following peers in transitioning away from fossil fuels. Banks will want reassurance that demand will exist for investments in new virgin production infrastructure.

Engaging policymakers through coordinated advocacy that leverages industry, the finance sector and civil society perspectives is needed. Interventions that level the economic playing field against fossil-based plastics and create the enabling conditions for investment in recycling, as well as other circular solutions such as reuse models and alternative materials, are essential. Here, the approach from the renewable energy transition can be an informative example: government subsidies were instrumental in developing solar photovoltaic power generation, enabled production of panels at huge scale, leading to a rapid reduction in technology costs, and have resulted now in the cheapest source of electricity globally.

For the benefit of all stakeholders, but especially investors and other financial institutions, we present in this edition of the Index a comprehensive set of benchmarks, both leading and lagging indicators, intended to inform capital allocation decisions, investment stewardship and engagement efforts, and exclusion criteria. Our goal is to push companies producing polymers bound for single-use plastics to initiate and accelerate their transition to a circular plastics economy, end plastic pollution and achieve net zero.

Plastic waste near palm oil trees at an abandoned factory in Jenjarom, outside Kuala Lumpur. A stark reminder of the urgent need to address the shortfall in recycling capacity and solutions to transition to a circular plastic economy. Photo credit: Mohd Rasfan/AFP via Getty Images.

CHAPTER 1: SUPPLY AND DEMAND FOR SINGLE-USE PLASTICS

There are more single-use plastics than ever — an additional 6 MMT generated from 2019 to 2021 — almost all still entirely made from fossil fuels.

Supply and demand (2019-21): ever more virgin single-use plastics on the market

In preparing this edition of the Index, we updated our global material flow model to analyse how single-use plastics were produced, traded and consumed, from polymer production to waste generation. We found that the world's population consumed 139 MMT of single-use plastic in 2021, an increase from 133 MMT in 2019 – equivalent to just under an additional kilogram of single-use plastic waste generated for every person on the planet. Our research found 98% of these single-use plastics, and almost all the growth, came from polymers produced from fossil fuel feedstocks.

Growth in virgin single-use plastics production was driven by demand for flexible packaging (films, sachets, etc.) made from just two polymers: polypropylene (+3 MMT) and LLDPE (+3 MMT). Flexibles grew from a 55% share of all single-use plastics in 2019, to 57% in 2021. This trend is concerning given flexible plastics have lower collection rates, are more difficult to sort and recycle, and have higher rates of leakage into the environment. Rigid packaging growth was flat overall, with growth in PET resin for use in food and beverage bottles (+2 MMT) offsetting small declines in other rigid single-use formats.

Bags, and other plastic waste, float on the water surface of the Buriganga river in Dhaka. Due to their lower collection rates, flexible plastics are more likely to leak into the environment. Photo credit: Munir Uz Zaman/AFP via Getty Images.

Single-use plastics growth (2019-21): a deceleration versus the historical rate

Demand for virgin single-use plastics grew at an annualised rate of 2.6% over the two years to 2021, compared to a historical (15-year) compound annual growth rate (CAGR) of 4.1%. **Figure 1** shows how expansion of capacity to produce polymers bound for single-use plastics also declined in the same period, to 3.1% CAGR from an historical average of 5.2%.

Despite the slowdown in growth, 96 new production assets still came online in the period, with a capacity of 15 MMT. Russia's SIBUR accounted for 1.5 MMT (10% of the total capacity growth; six new assets), followed by China's Rongsheng Group adding 1.4 MMT (9%; four new assets), and US/Netherlands-headquartered LyondellBasell adding 1.2 MMT (8%; four new assets). Most new capacity was added in China, accounting for 50%.

Actual production output of polymers grew slightly faster than capacity, at 3.4% CAGR, suggesting marginally higher asset utilisation rates – although the global average masks both increases and declines in utilisation rates across regions (and for individual assets). Polymer production growth outpacing demand for single-use plastics means that other end-use applications (namely, building and construction, transportation, and electronics) accounted for a greater share of converted polymers.

There are multiple possible explanations for the slowdown in single-use plastics growth from 2019-2021. These include cyclicality in supply and demand, COVID-related disruptions to supply chains and end-market demand, and commodity price volatility leading asset operators to adjust utilisation as margins fluctuate. Increasing consumer and regulatory pressure to reduce virgin single-use plastics may have also contributed to the slowdown.

Looking forward: economic forces point to a structurally lower growth rate, with policy and consumer pressure likely to cause further deceleration

We replicated our global material flow analysis using data since 2005 and extrapolated the strong correlation between single-use plastic waste generation and population and GDP growth (**Figure 2**). These economic fundamentals indicate a lower future global growth rate for global single-use plastics consumption in the next 20 years of 2.7% CAGR, versus the historical rate of 4.1%. The huge growth in demand that came from China over the past 15 years is likely to slow markedly. This deceleration will not be fully made up by growth in other developing regions, while population and GDP growth in developed markets forecast to slow.

In this context, it is no surprise that there is a downward correction in the rate of virgin polymer capacity expansion. In the first edition of the Index, our estimate of planned expansion from 2019–25 was 4.8% CAGR – faster than the historical growth rate. Actual capacity growth from 2019–21 was only 3.1%, and planned expansion from 2022–27 is now 3.4%, which could be an early signal of market concerns about the growth in single-use plastics (**Figure 3**).

Demand may be further dampened by regulatory and consumer pressure to combat plastic waste and pollution, such as government policies that place more stringent regulations on plastic (e.g., the European Union's Single Use Plastics Directive or Packaging and Packaging Waste Regulation). Not least, there are high expectations that the United Nations process to negotiate a global instrument to end plastic pollution – which it recently commenced – will have a meaningful impact, curbing demand for single-use plastics and transitioning production away from fossil-based polymers.

Figure 1: While there is more single-use plastic than ever (+6 MMT 19-21), growth is slower than historical rates and in step with slower polymer capacity expansion

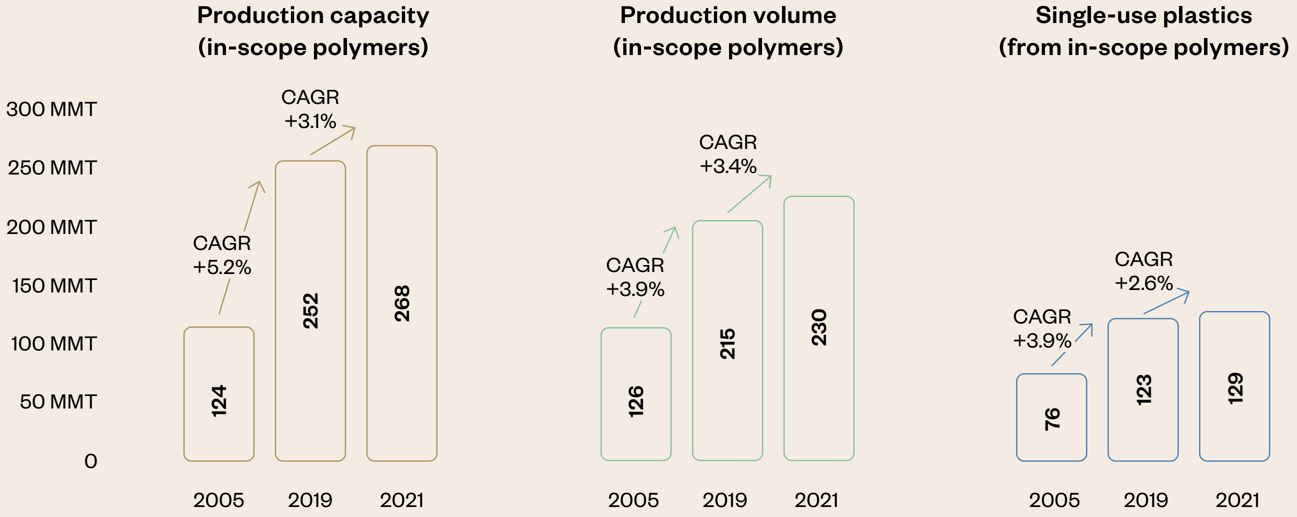
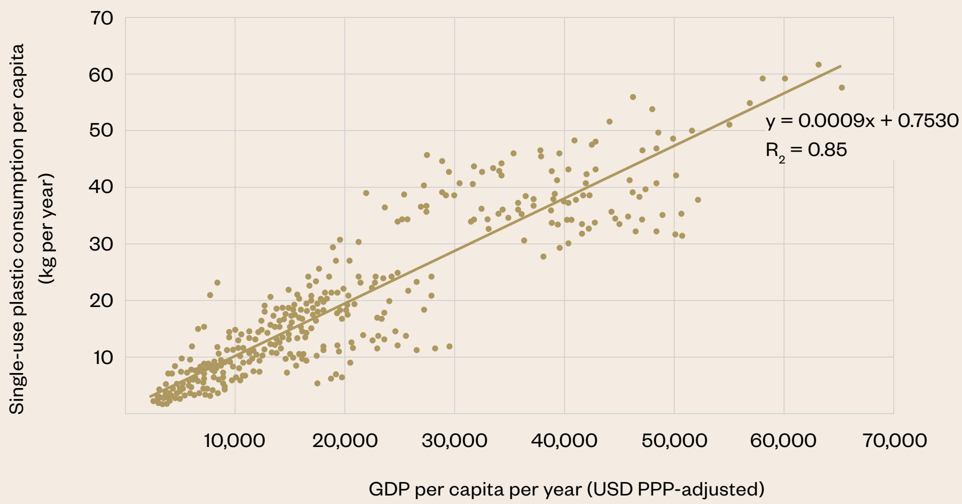


Figure 2: Structurally lower growth expected for single-use plastics based on GDP and population trends

Historical analysis from 2005-19 suggests a strong correlation between single-use plastic consumption per capita and population and GDP growth which implies structurally lower growth rate based on macroeconomic forecasts

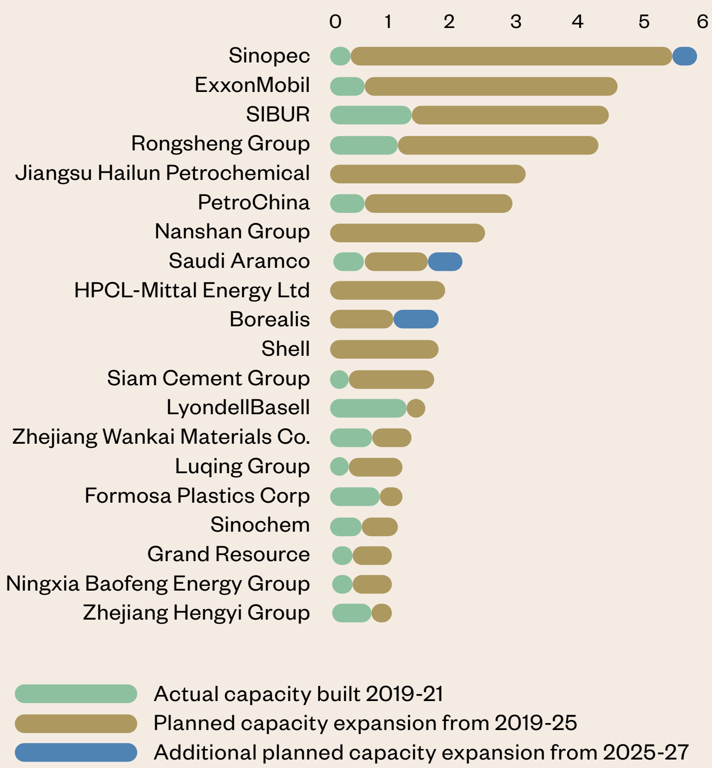
Results of global material flow model 2005-19 (39 country groupings) compared to GDP per capita



- Historical growth rate for single-use plastics consumption 2005-19 = 4.1% CAGR
- Predicted growth rate 2020-40 = 2.7% CAGR
- Based on forecast global slowdown in population growth [1.2% (2009-19) => 0.8% (2010-20); World Bank] and GDP growth (5.2% – > 2.9%; PwC)
- Policy and consumer-driven headwinds likely to put breaks on single-use plastics growth further

Figure 3: Reduction in virgin polymer capacity expansion from 2022-27 are expected

Top 20 petrochemical companies adding virgin capacity from 2019-27 (MMT)



Planned expansion 2019-25 was 4.8%

- In-line with the historical capacity growth rate

Actual capacity growth from 2019-21 was 3.1%

- Short-term downwards correction could be due to market cycles, or COVID-related issues, or to volatility in commodity prices

Planned expansion 2021-27 now 3.4%

- Lower long-term growth rate reflects changing macro trends (GDP and population) and demand for single-use plastic
- Demand may be dampened further by growing pressure from policy and consumers to combat plastic waste and pollution

The top 20 petrochemical companies producing single-use plastic polymers remain largely unchanged

This year's Index of the top petrochemical companies contributing to single-use plastic waste has been updated to include (1) single-use plastic made of polystyrene (in addition to PE, PP and PET); and (2) net impact of recovering plastic waste as a feedstock for producing on par recycled polymers.

To perform a like-for-like comparison of 2021 versus 2019, we re-based the 2019 results, accounting for these two changes in scope (**Figure 4**). The impact of including polystyrene-based single-use plastics was to push China's Sinopec from third to second place in the top 20 list. Further down, UK-headquartered INEOS, the world's largest producer of polystyrene, jumped three places to tenth, followed by France's TotalEnergies, up two places to twelfth. The impacts of waste recovery for recycling were marginal, with Taiwan's FENC the only company to move as a result, down from 16th to 19th.

Figure 5 presents the 2021 top 20 list. There is no change in the order of the top five: US-based companies ExxonMobil and Dow still place first and third, respectively; Sinopec second; with Thai-based Indorama Ventures fourth, and Saudi Aramco fifth. The only newcomers in the top 20 are China's Rongsheng Group, which doubled its production since 2019 and Russia's SIBUR which increased production by 75%. These companies displace Thailand's PTT and Taiwan's FENC, with the latter falling out of the top 20 as a result of its increased recovery of waste for recycling.

Figure 4: Plastic Waste Makers Index 2019 re-based

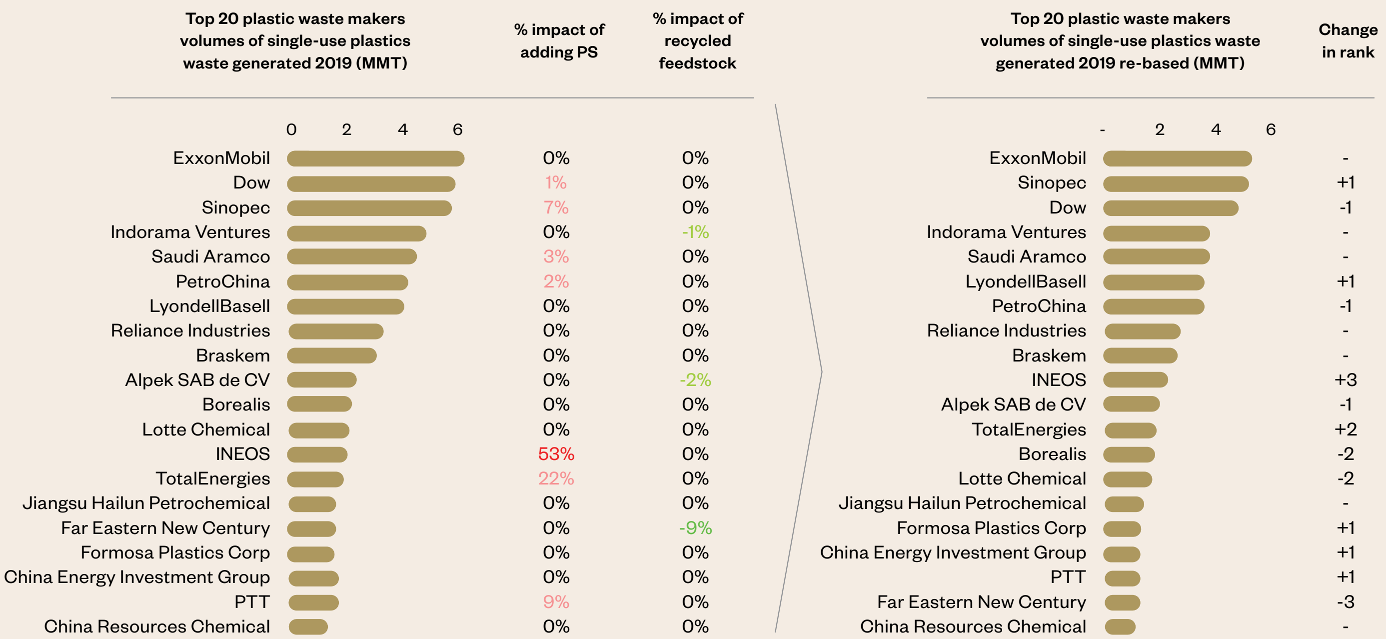
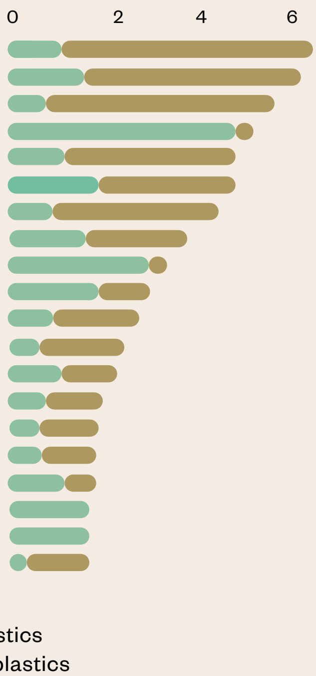


Figure 5: The top 20 list of petrochemical companies producing polymers bound for single-use plastic in 2021 remains effectively unchanged since 2019



Top 20 plastic waste makers	Change in rank versus 2019 re-based	Number of assets producing in-scope polymers		On par recycled feedstock (MMT)	Growth rate in single-use plastics waste 2019-21
ExxonMobil	-	58	+2	-	0%
Sinopec	-	92	+3	-	-2%
Dow	-	54	-1	-	-5%
Indorama Ventures	-	25	-	0.3	2%
Saudi Aramco	-	101	+3	-	2%
LyondellBasell	-	74	+4	-	7%
PetroChina	-	66	+4	-	2%
Reliance Industries	-	26	-	-	-3%
INEOS	+1	40	+4	-	4%
Alpek SAB de CV	+1	13	+1	0.1	23%
Braskem	-2	40	-	-	-13%
Borealis	+1	29	-	-	4%
TotalEnergies	-1	39	+5	-	-5%
Lotte Chemical	-	26	-	-	-9%
Formosa Plastics	+1	23	+1	-	15%
SIBUR	+19	18	+6	-	57%
Rongsheng Group	+14	8	+4	-	100%
Jiangsu Hailun Petrochemical	-3	1	-	-	-2%
China Resources Chemical	+1	4	-	-	16%
China Energy Investment Group	-3	11	-	-	1%

Implications

- **Peak virgin single-use plastics is still a distant milestone.** Make no mistake, the plastic waste crisis is intensifying and is going to get significantly worse before we see an absolute year-on-year decline in virgin single-use plastic consumption.
- **Flexibles-driven growth is a two-fold negative blow.** Countries in the Global South, with faster-growing populations and economies, are the major growth markets for single-use plastics. But these markets also have the strongest skew in demand towards flexible packaging formats, e.g., sachets. This is highly problematic given lower collection rates, higher leakage rates and recycling processes not yet proven to be commercially scalable for these multi-layer/multi-material products.
- **Supply/demand imbalances may create issues for some producers.** Planned increases in production capacity for polymers bound for single-use plastics are expected to exceed demand growth, given the prevailing trends: economic slowdown, a tightening regulatory environment, and consumer pressure. This would result in greater competition, lower average asset utilisation rates, and risks forcing the lowest marginal cost producers of polymer out of business. Investors and financers should take heed.
- **It will take significant leverage from governments to shift the largest global petrochemical companies to a different trajectory.** The top 20 petrochemical companies have collectively shown little progress and have a vested interest in maintaining the regulatory status quo. Even while public and political awareness of the plastics problem has increased markedly, it has so far failed to translate into meaningful impact on virgin polymer production. Public pressure and political will need to double-down and be converted into tangible outcomes.

CHAPTER 2: CRADLE-TO-GRAVE GREENHOUSE GAS EMISSIONS FROM SINGLE-USE PLASTICS

Single-use plastic is not only a pollution crisis but also a climate one. Cradle-to-grave (Scope 1, 2 and 3) GHG emissions from single-use plastics in 2021 were equivalent to ~450 MMT CO_2e, more than the total GHG emissions of the United Kingdom.

New analysis for this report (done in partnership with Carbon Trust and Wood Mackenzie) estimates the global cradle-to-grave emissions from single-use plastics. The analysis builds on our existing global material flow model from polymer production to waste generation, which was extended to include emissions from raw material extraction through to end-of-life treatment. The global results of ~450 MMT CO2e in 2021 compare well to other estimates of lifecycle plastic emissions (**Figure 6**).

A landfill site in Kyrgyzstan where rubbish, including plastic waste, can be seen burning. With greenhouse gas emissions across the plastic lifecycle being measured for the latest edition of the Plastic Waste Makers Index, the plastic waste dilemma is not only a pollution one but also a climate one. Photo credit: Collab Media via Getty Images.

Figure 6: Our estimate of global cradle-to-grave emissions from single-use plastics in 2021 of ~450 MMT CO_2e compares well to other estimates of lifecycle plastic emissions

Source	Total emissions ($GTCO_2$e)	Volume (MMT)	Lifecycle carbon intensity (tCO_2e/metric ton of plastic)	Estimate (pro-rata) based on PWMI in-scope volumes (MMT CO_2e)
Nature (2019)	1.7	380	4.5	528
OECD (2022)	1.8	460	3.9	462
Nature (2022)	2.0	540	3.7	437

Nature, 2019: Strategies to reduce the global carbon footprint of plastics | Nature Climate Change
Nature Sustainability, 2022: Growing environment footprint of plastics driven by coal combustion | Nature Sustainability
OECD, 2022: Executive summary | Global Plastics Outlook: Policy Scenarios to 2060 | OECD iLibrary (oecd-ilibrary.org)

Most emissions produced across the lifecycle of single-use plastics occur "upstream"

Figure 7 illustrates the global emissions associated with the major stages in the single-use plastics lifecycle. Our research shows that 60% (253 MMT CO_2e) of all emissions are generated "upstream" by the oil and gas and petrochemical industries from hydrocarbon extraction (of oil, gas and coal) and refining (e.g., oil to naphtha); production of monomer feedstocks (e.g., "cracking" naphtha or ethane gas to produce ethylene); and from polymerisation (to create the building blocks of all plastics). Of these stages, producing monomers is the most emissions intensive, accounting for a third of all emissions (145 MMT CO_2e), because of the high temperatures and pressures required.

Conversion of polymers into plastic products is the second most emissions-intensive stage (22%; 99 MMT CO_2e). This stage includes many different technologies, of which the most common in producing single-use plastics are film/sheet extrusion, and blow/injection moulding.

Emissions generated after plastics are disposed is the next most intensive stage (14%; 64 MMT CO_2e). Almost all these emissions are the result of burning plastics at end-of-life. Controlled incineration with energy recovery represents 6% of all cradle-to-grave emissions (28 MMT CO_2e) and is a major component of waste management in, for example, Japan and in parts of Europe (notably Scandinavia). Emissions from informal, open burning of plastic represents 5% (22 MMT CO_2e), and typically occurs in countries that lack adequate waste management infrastructure, and cause well-documented harms to human respiratory health. While the landfilling of plastics generates few GHG emissions 5% (3 MMT CO_2e), as a waste management solution it creates its own pollution issues, both when undertaken in controlled (e.g., chemical and microplastic leachates entering soil and water systems) and uncontrolled environments (e.g., leakage of waste into the surrounding environment).

Emissions from the trade in plastic materials across the lifecycle (as polymers, bulk packaging, and finished goods) represent 7% of total emissions. These emissions include transcontinental shipping (which is relatively less carbon intensive) and transboundary movement by road (which is relatively more carbon intensive but across shorter distances).

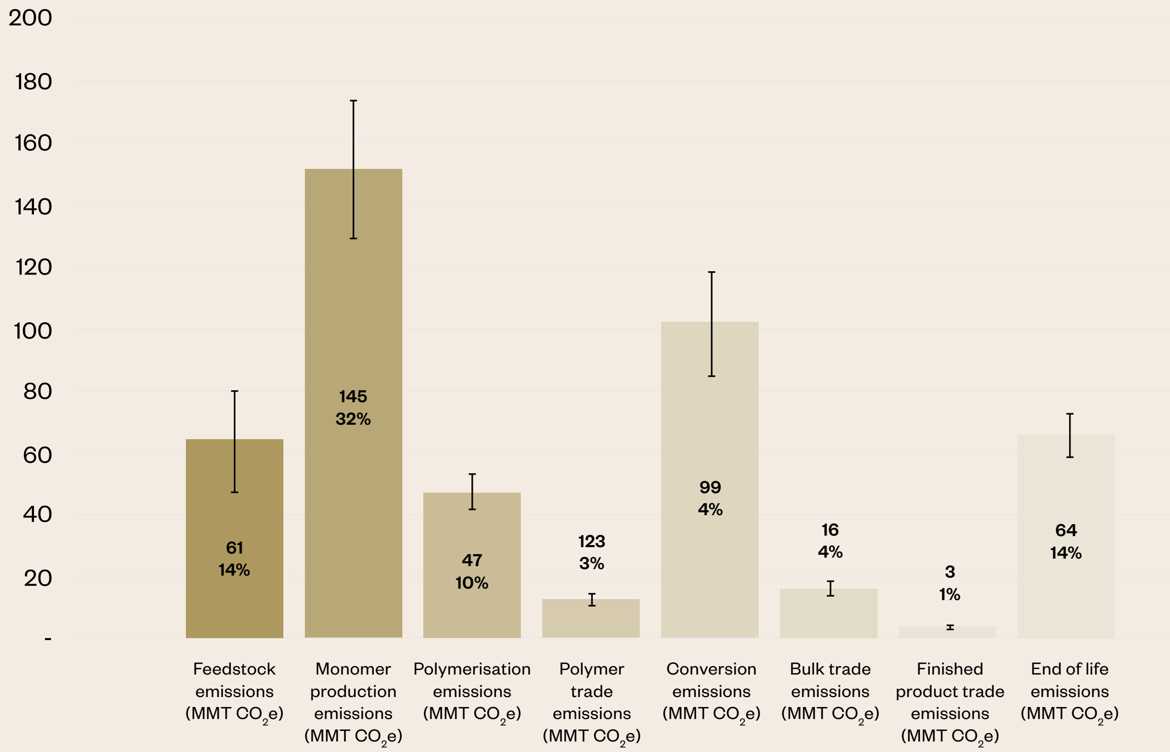
Emissions intensity depends principally on whether monomers were derived from coal, gas or naphtha, but also on the complexity of the polymer produced

In comparing emissions intensity from single-use plastics, the single largest source of variance comes where coal-to-olefins processes (producing plastic polymers from methanol converted directly from coal gasification) replace processes that "crack" gas and naphtha to produce monomers and then polymers. Coal-to-olefins is 2.5–3 times more energy intensive than other polymer production processes because of the low yields and high coal-based emission factors. We estimate that 5.7 MMT (4%) of the world's single-use plastic are produced in this way, generating ~55 MMT CO_2e (12%) of the total associated emissions. This technology is primarily deployed in China, where some producers enjoy privileged access to cheap coal, making the economics competitive with gas and naphtha routes.

Figure 8 shows the relative emissions intensity of the six polymers that account for more than 90% of all single-use plastics. The emissions intensity of polyolefin polymers (polypropylene, HDPE, LDPE, LLDPE) are all within a tight range (±10%) due to their similar, and simpler, chemistry. PET and polystyrene, by contrast, require more complex chemistry to produce so their emissions intensities are higher – by a third for PET, and by almost a half for polystyrene. Our results compare well with other estimates of lifecycle emissions by polymer type.

Figure 7: The majority of emissions produced across the lifecycle of single-use plastics occur "upstream"

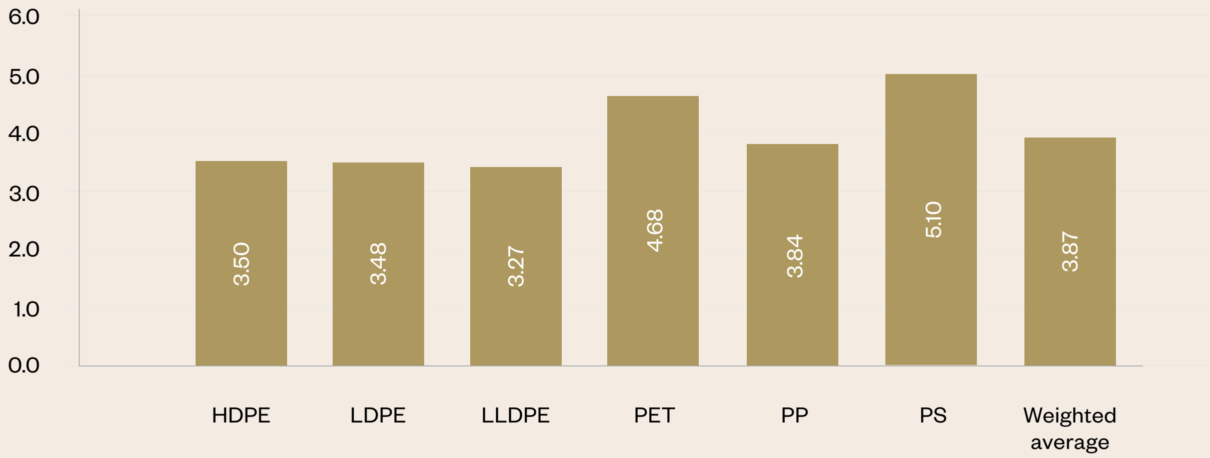
In-scope polymers for 2021



Error bars indicating uncertainty range

**Includes PET, PE, PP and PS*

Figure 8: Global variation in cradle-to-grave GHG emissions by polymer type (metric ton CO_2e/metric ton polymer)



Source	HDPE	LDPE	LLDPE	PET	PP	PS	Weighted average
Average emissions by polymer	3.5	3.5	3.3	4.7	3.8	5.1	3.9
OECD (2022) excl. end-of-life emissions	2.8	2.7	2.7	3.9	3.0	4.1	3.9
Nature (2019)	3.6	3.6	3.6	4.6	3.9	5.3	4

Mechanical recycling delivers meaningful reductions in carbon emissions and contributes to net zero carbon ambitions

Our analysis covers GHG emissions from all single-use plastics made from the virgin polymers listed above, as well as emissions from packaging produced from mechanically recycled PET.

We estimate that the reduced cradle-to-grave emissions from mechanically recycling PET in a "closed-loop" system (i.e., bottle-to-bottle) versus a linear one (virgin polymer and disposal) are significant: at least a 30% reduction (or 1.3 metric tons CO_2e per metric ton of polymer) in emissions compared to landfill, and more than 40% reduction (or 2.3 metric tons CO_2e per ton of polymer) compared to burning (**Figure 9**). These estimates are conservative, an average for recycling facilities operating today, and based on the material circulating only once. With newer and improving technologies, and as recycling operations scale, the reduction opportunity is set to improve further.

In this Index, we have not included emissions from recycled polyolefins or polystyrene, as their mass globally is almost negligible compared to overall production and, in the case of chemical recycling, the technologies deployed are diverse and proprietary, making it difficult to draw representative conclusions.

Twenty polymer producers account for 50% of the global GHG emissions from single-use plastics

Unsurprisingly, 18 of the 20 largest producers of polymers bound for single-use plastic waste also make the top 20 GHG emitters (**Figure 10**).

However, there are noticeable differences in the rankings, driven by factors described above. Chinese companies operating coal-to-olefins technologies rise up the ranking of GHG emitters, and are the highest emitters by intensity. Companies producing a high share of PET or PS also rise up the rankings.

Figure 9: Comparison of cradle-to-grave emissions in a circular versus linear plastics economy

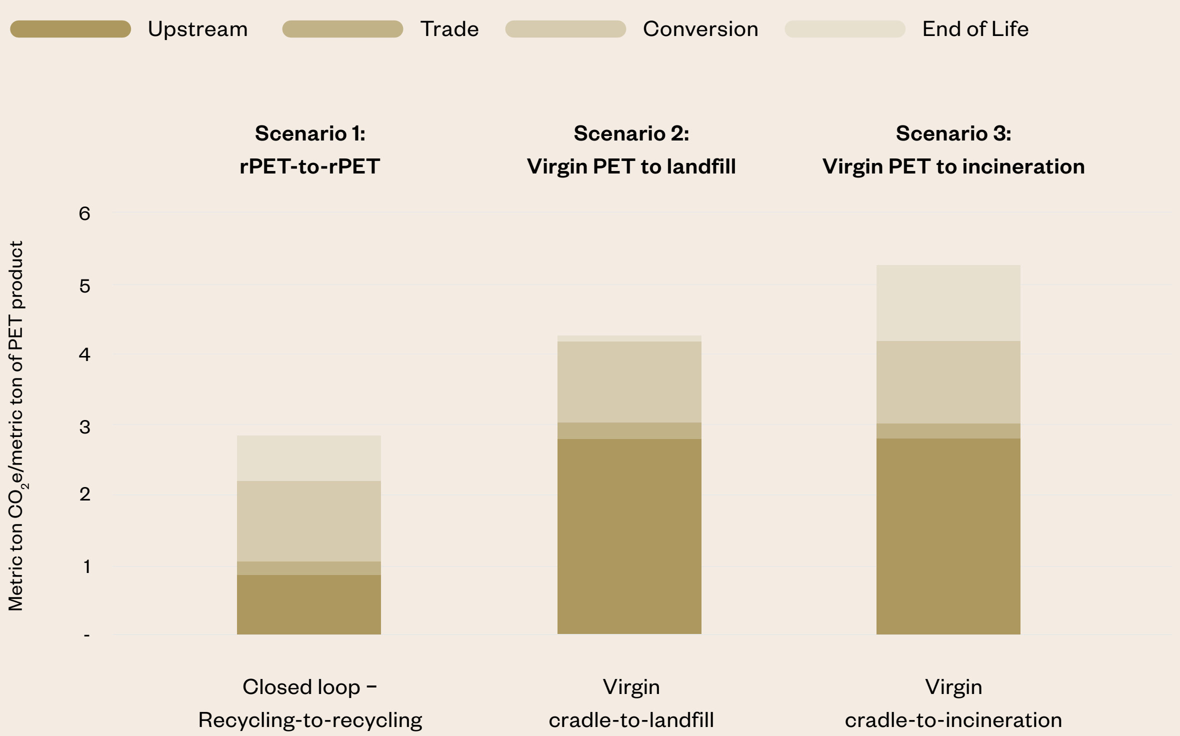
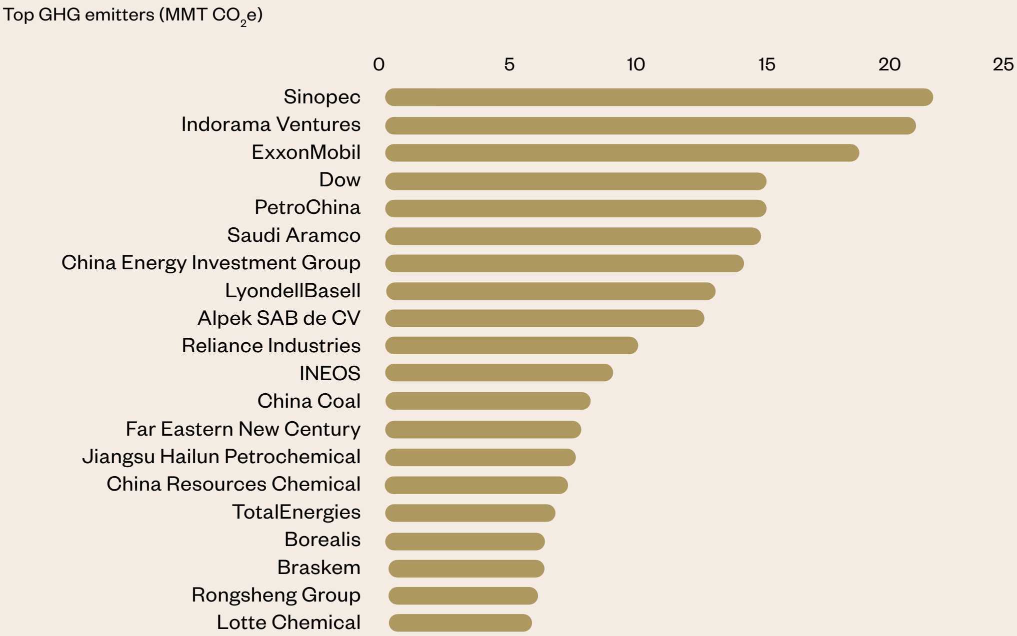


Figure 10: Top 20 GHG Emitters (total cradle-to-grave, MMT CO_2e)

The conclusions here are estimated lifecycle emissions for the companies' in-scope single-use plastics production, not the companies' aggregate emissions. With the exception of polymerisation technology, the estimates are not based on direct asset-level data.



* The intensity metric refers to per metric ton of polymer produced by these companies that is assumed to be converted to in-scope single-use plastics over its lifecycle.

Implications

- **The same solutions that can deliver a circular plastics economy can simultaneously deliver meaningful reductions in carbon emissions.** It is critical that corporates, investors and banks consider both the plastic waste and GHG abatement opportunities in the transition to a circular economy.
- **The next three to five years are a critical window for action.** Long technology maturity cycles and capex lock-in for large infrastructure investments mean that the decisions taken in the early 2020s will determine whether or not the plastics system will achieve a circular economy and net zero GHG emissions by 2050.
- **While the emissions reduction opportunities from recycling are significant, they are not sufficient to create a net zero plastics economy.** Not least, this is because the penetration of on par recycling remains so low. Recycling needs to be complemented by other – and in many cases more nascent – technologies and solutions. These will include transition from fossil-based to renewable energy sources; transition to renewable feedstocks (e.g., bio-mass); and carbon capture and storage.
- **Moving away from coal-to-olefins to less polluting feedstocks is an important short-term transitional carbon abatement opportunity.** Just as moving away from coal-fired power plants has and continues to be a critical step in the energy transition, capping and reducing coal-to-olefins is an important step in decarbonising plastics production. Policymakers need to engage China on this topic, and negotiations for a global plastics treaty are an opportunity to do so.
- **Reducing demand for plastics remains a critical lever for reducing overall system emissions.** Demand-management will require smart policy intervention, coordinated across countries and regions, and should encompass bans on unnecessary plastics; redesigning packaging to be more lightweight; as well as enabling innovative reuse models.

A refinery complex in Mexico. The "upstream" part of single-use plastic production from fossil fuels contribute the bulk of lifecycle emissions. Photo credit: Danil Shamkin/ NurPhoto via Getty Images.


TE-3

CHAPTER 3: RECYCLING DEVELOPMENTS

Recycling is failing to scale fast enough and remains a marginal activity for the plastics sector.

Labourers collect assorted plastic products from a garbage pile at a recycling centre on the outskirts of Beijing, China. Increased collection and sorting of plastic waste is reliant on increased demand for products made from recycled plastic. Photo credit: Guang Niu/Getty Images.

Recycling developments (2019-21): underwhelming growth, dwarfed by growth in fossil-fuel plastics

Total global recycling capacity for PE, PP, PS and PET grew from 23 MMT in 2019 to 25 MMT in 2021, equating to roughly 10% of virgin polymer capacity (230 MMT; in-scope polymers).

However, of this 25 MMT, only 2 MMT was genuinely circular, on par recycling for use in packaging and other single-use applications. While the 2019-21 growth rate for single-use plastics from recycled waste was higher than from virgin feedstocks (17% CAGR versus 2.6%), the absolute growth from virgin exceeded recycled by a factor of 15 to 1 (6 MMT versus 0.4 MMT). As a result, in 2021, recycled polymers accounted for just 2% of all single-use plastics consumed globally (**Figure 11**).

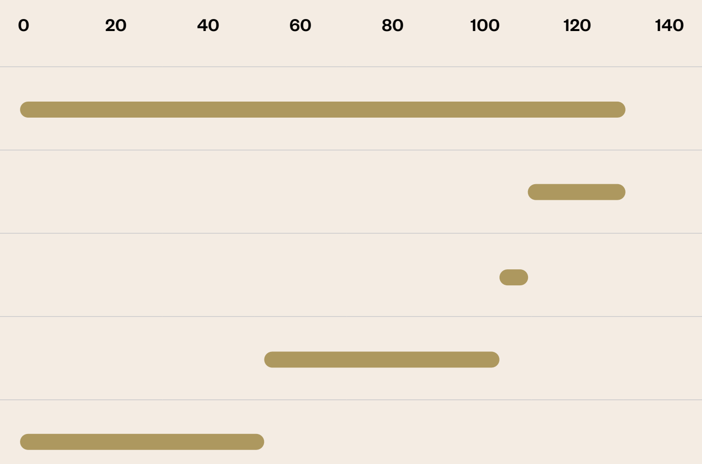
Almost all of the 2 MMT of on par recycling was mechanical recycling of PET bottles back into new bottles. While only six petrochemical companies were active in on par recycling of PET in 2021, they represented a meaningful share (28%; 0.6 MMT) of global capacity, with Indorama Ventures (10%; 0.23 MMT) and FENC (8%; 0.18 MMT) contributing the majority – a result of petrochemical companies tending to operate larger-scale facilities compared to the rest of the recycling industry. While encouraging, on par recycling remains a minority part of their businesses: Indorama Ventures produced 4 MMT of virgin PET (94% of its total) and FENC 2 MMT (89%) in the same year.

Both companies were also active in downcycling of PET, predominantly into fibres for use in textiles: FENC (0.6 MMT), Indorama Ventures (0.3 MMT). Four other petrochemical companies were also active in PET-to-fibre: Nan Ya Plastics Corporation (0.3 MMT), Reliance Industries (0.1 MMT), Toray Industries (0.1 MMT) and Hyosung Corporation (0.1 MMT). A further four petrochemical companies (Borealis, LyondellBasell, TotalEnergies, and Siam Cement Group) have ventured into downcycling of polyolefins for various end-use applications, all located in Europe and all at small scale (less than 0.1 MMT).

Demand for downcycled plastic products can support greater collection of plastic waste and help reduce environmental leakage. However, it will not always reduce overall demand for virgin feedstocks, as downcycled products in non-packaging sectors often replace other materials (e.g., natural fibres, road paving, street furniture).

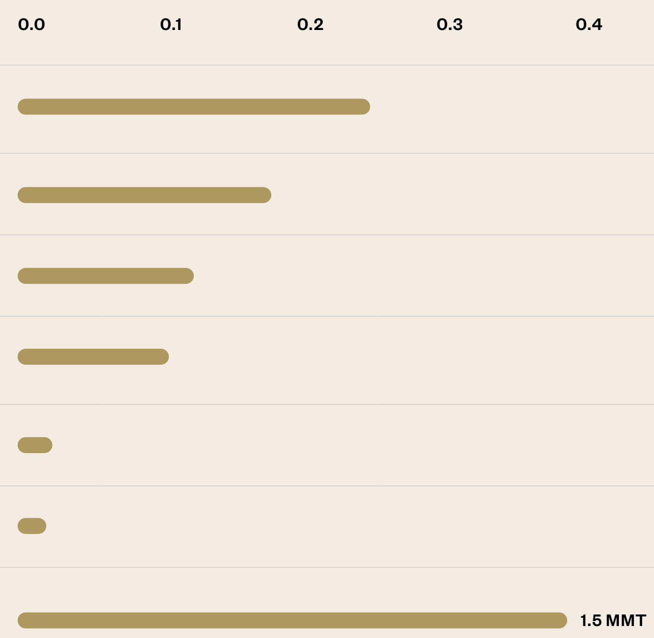
Figure 11: In 2021, only 2% of single-use plastics were produced from recycled plastic waste

On par mechanical recycling is growing capacity but is only 2 MMT of 25 MMT of the recycling market, almost all of which is PET recycling (MMT)



	Share of 2021	19-21 CAGR
Single-use plastic waste		2.6%
Downcycling	18%	0.7%
On par recycling	2%	17%
Landfill/incineration/ waste-to-energy	42%	2%
Mismanaged	38%	2%

There are some clear leaders among petrochemical companies that are active in on par PET recycling, operating large facilities primarily in Europe, USA and Japan



	No. of facilities	Location of facilities and capacity
Indorama Ventures	7	Brazil (9kt); France (13kt); Poland (18kt); USA (92kt, 40kt, 24kt, 18kt, 14kt)
Far Eastern New Century	3	Japan (140kt); USA (35kt)
Alpek SAB de CV	4	USA (45kt, 38kt, 20kt); Argentina (20kt)
Plastipak	3	France (66kt); USA (63kt); Luxembourg (16kt)
PET Processors	1	UK (18kt)
Tatneft	1	Latvia (15kt)
Non-petrochemical companies		North America (20%), Europe (41%), Japan (5%); RoW (34%)

Few signs that growth in on par recycling in next five years will reach the scale of growth in virgin plastics

Only 3 MMT of on par recycling is expected to be brought online by 2027 – equivalent to 5% of planned global virgin polymer capacity growth in the same period (60 MMT) – of which the petrochemical industry is expected to contribute 0.7 MMT.

PET mechanical recycling capacity expansion is expected to be 2 MMT (+100% growth). All of this is expected to be on par (i.e., bottle-to-bottle) mostly in Europe, USA and Japan, and some investment in India given the recent policies that allow recycled plastics in food-contact applications. Most expansion (85%, 1.7 MMT) is coming from outside the petrochemical industry, with only three companies expanding rPET capacity: FENC (+0.2 MMT, +134% growth), Indorama Ventures (+0.1 MMT, +31% growth), and SIBUR (+0.03 MMT, from zero) (**Figure 12**).

Seven petrochemical companies are expanding capacity in mechanical recycling of polyolefins: Dow (+0.08 MMT); LyondellBasell (+0.08 MMT); Braskem (+0.07 MMT); Borealis (+0.06 MMT); PTT (+0.05 MMT); ENI (+0.05 MMT); and Westlake Corporation (+0.04 MMT). While this might be an encouraging sign, all projects are small scale compared to virgin production. The lack of standardisation across the polyolefins single-plastic packaging products means most will end up being downcycled for use in other non-packaging sectors – where it is uncertain to displace virgin feedstock.

In chemical recycling, 5 MMT of capacity is projected to come online in the next five years, representing +2,000% growth, but from a small base. Petrochemical industry involvement is far greater in chemical than mechanical recycling – our analysis shows that more than 20 petrochemical companies are involved in the development of 45 new facilities, which expect to bring 2 MMT of chemical recycling capacity online in the next five years. This represents 40% of total capacity expansion (**Figure 13**).

However, of this 2 MMT total output, we estimate only 0.4 MMT will be recycled plastic polymer, with the majority of output intended for other applications, principally transportation fuel. Given the overall plastic-to-plastic yield is just 20%, referring to these projects collectively as “recycling” is a misnomer – as currently conceived, chemical recycling will fail to meaningfully displace fossil fuel plastic production and address its continued growth. The circularity credentials of projects need to be evaluated on a case-by-case basis, including the technology and strategic intent.

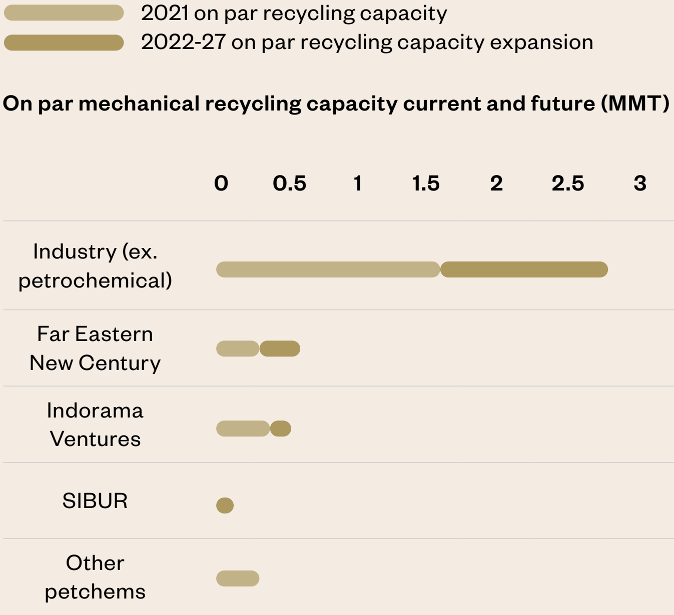
Of the 45 chemical recycling projects associated with petrochemicals companies that are expected to be operational by 2027, 35 use pyrolysis technologies, where intense heat transforms plastics into liquid oil and other by-products. Many different pyrolysis technologies are being developed and deployed. These are expected to deliver widely different results in terms of recycled polymer output, depending on strategic priorities. We describe them in three broad categories based on their expected “plastic-to-plastic” yields:

- **High plastic-to-plastic yield of 70-90%.** An example is Plastic Energy’s pyrolysis technology (being used by TotalEnergies, INEOS and Saudi Aramco/SABIC), targeting recycled polymer production as the primary output. Thirteen projects are expected to deliver 0.2 MMT of recycled polymer by 2027.
- **Low plastic-to-plastic yield of 10-25%.** An example is Shell using Pryme’s waste-to-chemicals technology, targeting non-plastic end-use applications, such as transportation fuel, as the main driver of value. Fourteen projects are expected to deliver 0.03 MMT of recycled polymer by 2027.
- **Zero plastic-to-plastic yield.** An example is Shell using Enerkem’s technology to produce methanol for alternative biofuels or renewable chemicals. These eight projects are not expected to deliver any recycled polymer and would be better described as “waste-to-fuel”.

The petrochemical industry is also planning to build 10 chemical recycling projects using de-polymerisation or solvent purification technologies that output monomer or polymer specifically for new plastics production (e.g., Saudi Aramco/SABIC and SK Innovation Co). These are expected to have plastic-to-plastic yields of 50-90% and collectively deliver 0.15 MMT.

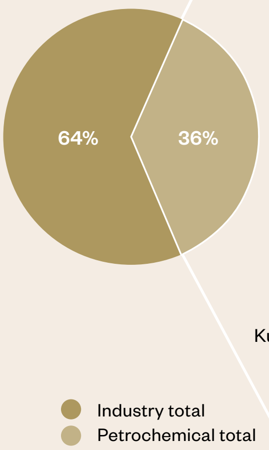
Of the 60% or 3 MMT of chemical recycling capacity not associated with petrochemical companies, half the projects are generating products with high plastic-to-plastic yields, while the other half are producing almost entirely transportation fuels. As noted above, these latter projects would be better categorised as “waste-to-fuel” rather than “recycling”.

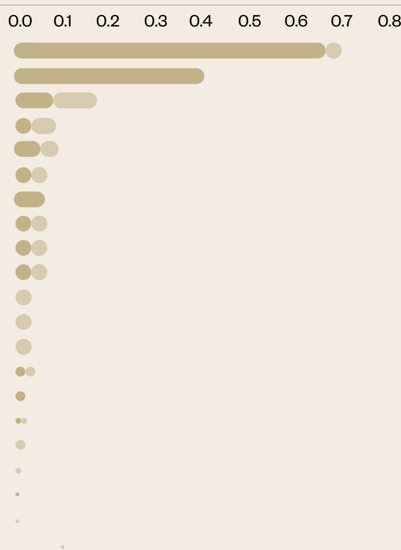
Figure 12: On par mechanical recycling of PET is expected to expand by 2 MMT – mostly from outside the petrochemical industry



	Absolute growth	5 year CAGR
Industry (ex. petrochemical)	102%	12%
Far Eastern New Century	134%	15%
Indorama Ventures	31%	5%
SIBUR	N/A	N/A
Other petchems	0%	0%

Figure 13: Petrochemical companies expected to develop 2 MMT of chemical recycling capacity by 2027 – but of this expected recycled plastic polymer yield only 0.4 MMT





Polymer producers advanced recycling facilities[1] (plastic waste input capacity in MMT/year)	No. of facilities	Output type	Polymer yield capacity (MMT, 2022-27)
Shell	4	Fuel	0.00
Repsol	2	Fuel	0.00
Braskem	2	Monomer	0.09
INEOS	6	Fuel; monomer	0.06
Dow	5	Fuel; monomer	0.02
SK Innovation Co	2	Monomoer; polymer	0.06
Showa Denko	1	Fuel	0.00
Saudi Aramco (SABIC)	2	Fuel; monomer	0.02
Toray Industries	1	Monomer	0.02
ExxonMobil	1	Fuel	0.00
Borealis	1	Fuel; monomer	0.02
Alpek SAB de CV	1	Ploymer	0.02
BP	1	Fuel	0.00
MOL Group	1	Polymer	0.01
Mitsui	1	Fuel	0.00
TotalEnergies	2	Fuel	0.01
Kuwait Petroleum Corporation	1	Polymer	0.01
Indorama Ventures	1	Polymer	0.01
Sumitomo Chemical	1	Fuel	0.00
Denka Company	1	Monomer	0.00
Americas Styrenics LLC	1	Monomer	0.00

[1] Either by operating or partnering through off-take agreements, post-consumer plastic waste input capacity

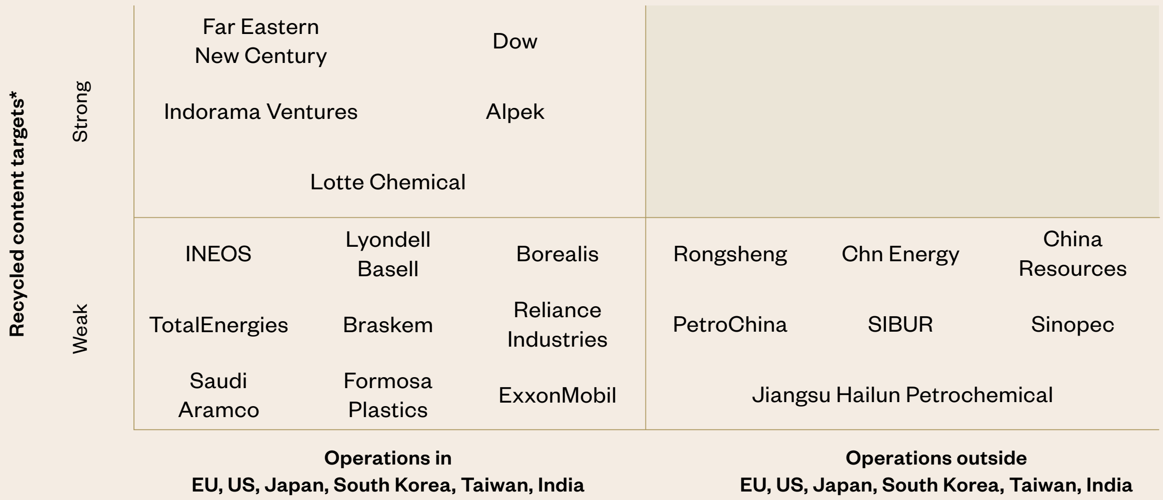
- Total chemical recycling capacity expansion from 2022-27 is 5 MMT
- Petrochemical companies account for 2 MMT

The inability of plastics recycling to scale is a market failure that requires urgent policy intervention to solve

Recycling continues to be a marginal activity due to many factors. These include the costs associated with the collection and sorting of waste; the logistics challenges of achieving economies of scale; issues of contamination that affect both quality and yield; and lack of design and material composition standards required to produce clean input streams and on par recycled polymer. On the flip side, virgin plastics producers are rarely required to price in the cost of the externalities that their products create – most obviously, the costs of sustainable waste management – and enjoy a price/cost advantage.

As a result, petrochemical companies are (naturally, given the need for returns on investment) only expanding into recycling in markets (Europe, USA and parts of Asia) where the economic conditions are somewhat more favourable, i.e., where policies are more progressive and demand for recycled plastics stronger. On the contrary, policy constraints in other regions (especially in China) on food-contact recycled use act as real barriers to the roll-out of on par recycling (**Figure 14**).

Figure 14: Circularity ambitions of the Top 20 single-use plastics producers depends on the level of regulatory support for recycling



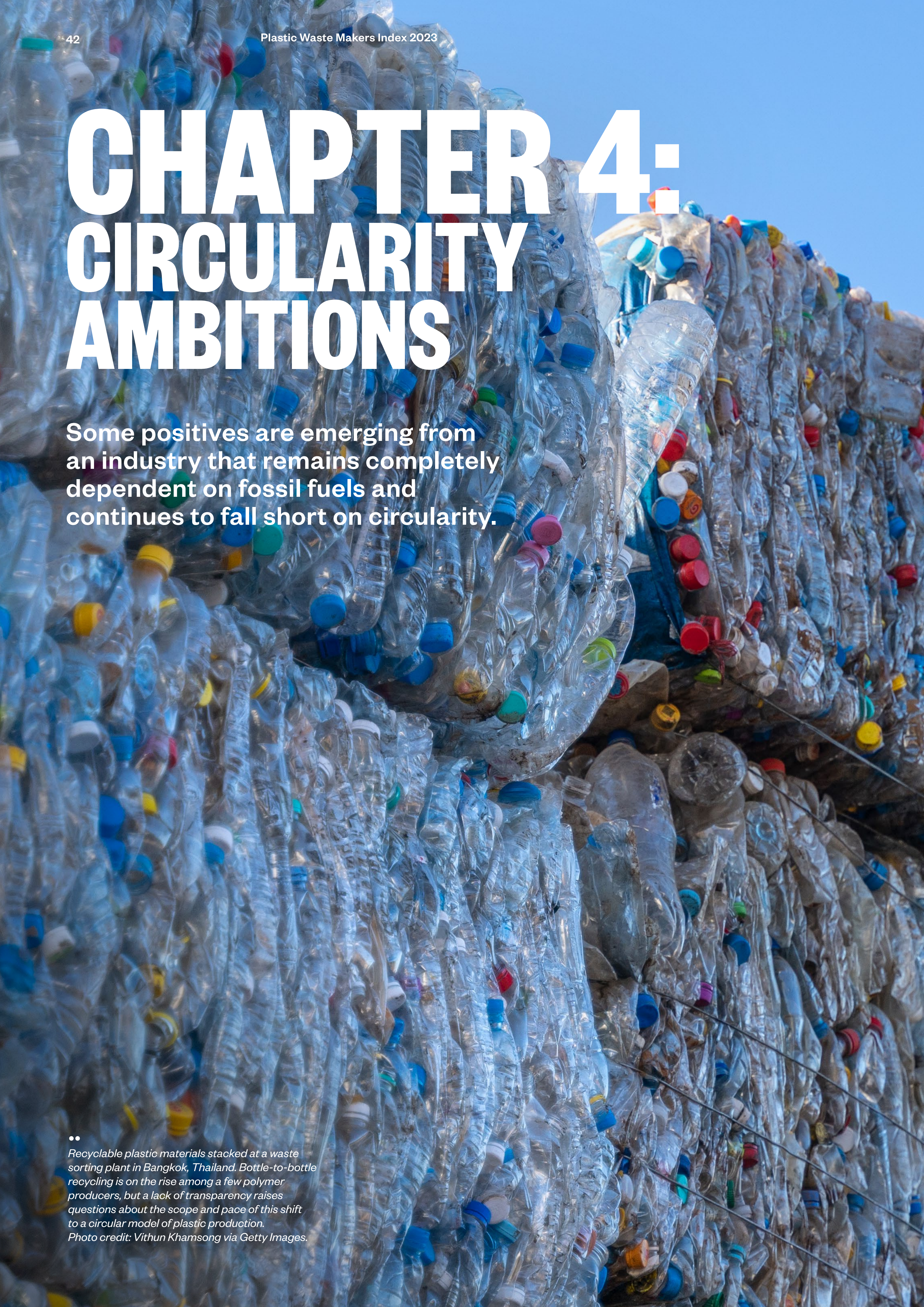
** Definition of strong recycled content target is more than 20% of virgin polymer production by 2030.*

Implications

- **Recycling will not scale without the necessary policy conditions that address the economic imbalance compared with virgin production.** Corporates and their shareholders will not commit capital if returns on investment are uncompetitive. Market intervention is therefore required in multiple areas to level the economic playing field and enable recycling to work at scale. This, in turn, should create the conditions for converters and brands to send clear demand signals for post-consumer recycled content through long-term forward contracts.
- **Petrochemical companies should play a critical role in a transition to a circular plastics economy.** Provided the economic playing field is levelled, this sector (including their shareholders and bankers) should be well positioned to seize greater opportunities to scale, given their strong balance sheets and technical expertise in operating larger facilities, which creates much-needed economies of scale. Further, the largest petrochemical companies have influence with their suppliers and customers across the plastics value chain which can lay the ground for system-wide collaboration.
- **On par recycling will not occur across single-use plastics unless there is standardisation in the product design, as is the case with PET bottles.** Complex packaging that includes multi-layers and chemical additives needs to be simplified to ensure products can be recycled back into their original applications, otherwise incineration or downcycling will be the more economical method for management of single-use plastic waste.
- **Chemical recycling appears to be the preferred route for petrochemical companies – but every project requires careful scrutiny to determine if it delivers genuinely circular plastic outputs.** These companies can influence and enhance the plastics circularity of chemical recycling projects by committing to long-term off-take contracts at competitive pricing for the output to be used as feedstock for new plastics.

CHAPTER 4: CIRCULARITY AMBITIONS

Some positives are emerging from an industry that remains completely dependent on fossil fuels and continues to fall short on circularity.



Recyclable plastic materials stacked at a waste sorting plant in Bangkok, Thailand. Bottle-to-bottle recycling is on the rise among a few polymer producers, but a lack of transparency raises questions about the scope and pace of this shift to a circular model of plastic production. Photo credit: Vithun Khamsong via Getty Images.

Two companies stand out from the rest in terms of single-use plastics circularity. FENC, from Taiwan, is in the number one spot, followed by Indorama Ventures, from Thailand. They are both positive outliers, but they still have a long way to go.

While there is a collective lack of industry movement away from fossil fuels, a select few petrochemical players are outliers in terms of recycling and circularity commitments (**Figure 15**). FENC tops our Circularity Assessment (scoring a “B-”) – it has the highest recycled content among its peers at 11% (up from 2% in 2019) and is committed to doubling its on par recycling capacity by 2027.

It is followed by Indorama Ventures, which scored a “C”, with a 6% recycled content in 2021 (up from 2% in 2019) and committed to increasing its on par recycling capacity by one-third by 2027.

FENC receives an “A-” for Enablers – that is, for the processes it has put in place that should support transition to a circular business model – and is the only company to score above a “B” grade. It earns the top “A” grade for strategy, risk management, and targets. It has the most ambitious recycled content target among its peers and aims to be the largest producer of recycled PET globally. Further, FENC is one of the only petrochemical companies with a dedicated sustainability committee overseeing its circular business initiatives. Indorama Ventures is close behind and scores similar on Enablers – it has the second most ambitious recycled content target and earns a “B-” on ambition.

FENC and Indorama Ventures are not just unique on Enablers, but also on Outcomes – the amount of on par recycled plastics they actually produce. Along with Alpek, they are the only companies not to receive the lowest, "E" grade. This makes FENC and Indorama Ventures the only companies to have (meaningfully) established a more sustainable, circular model of polymer production from recycled materials, albeit at a small scale.

CASE STUDY: FAR EASTERN NEW CENTURY

Overview: diversified petrochemicals business with global operations

Founded in 1949, FENC is a Taiwanese conglomerate with operations across Asia and the US. Its core activity is the manufacture and distribution of petrochemical products such as polyethylene terephthalate (PET) resins and purified terephthalic acid (PTA, a feedstock for PET), polyester fibres, and textiles. It is the leading polyester supplier globally, the third largest in virgin PET resin (with 2 MMT of capacity across Taiwan, China, Vietnam and USA), and the second largest provider of recycled PET (with 0.3 MMT of recycling capacity across Taiwan, China, Japan and USA).

Recycling efforts: focus initially on downcycling plastic into fibre

FENC's venture into recycling started more than 30 years ago in Taiwan by jointly establishing the first PET bottle recycling plant, in line with the government's new environmental protection policy to address the island's environmental issues. Focus was primarily on plastic-to-fibre for the textiles to diversify feedstock from petroleum and reduce energy consumption. Today, FENC has plastic-to-fibre recycling capacity of 0.2 MMT in Taiwan and Mainland China. It also has plans to expand in Malaysia, Vietnam, and Philippines based on existing virgin PET production lines by establishing vertically integrated businesses.

On par recycling: leading producer in Japan for rPET food-grade; expansion to the US

In 2012, the company moved into bottle-to-bottle recycling in Japan, partnering with Ishizuka Glass (a packaging manufacturer) to service growing demand from beverage companies. Through its municipality collection network, Japan had high waste collection rates but was producing low quality recycled resin – at that time, most recycling plants in Japan could only accept high-quality plastic bottles and produce recycled polyester for the textiles industry. FENC's strong balance sheet and technical expertise in recycling enabled it to build a facility that could accept different grades of plastic bottles and produce high-quality rPET pellets for new bottles. Today this joint venture is the largest recycled PET producer in Japan with a capacity of 0.1 MMT, with plans to double its capacity by 2023. Its customer base includes the top five beverage brands operating in Japan.

Following the acquisition of virgin PET producer, APG, in West Virginia in 2018, FENC acquired recycled PET producer Phoenix Technologies to become a one-stop shop for customers seeking pellets with recycled content for the local market. This followed the intervention from state governments to increase recycled content in plastic products through Extended Producer Responsibility (EPR) schemes. This added 0.05 MMT to its portfolio of food-grade rPET for drinks containers, food, cleaning products and other daily necessities.

Enablers: strong governance and understanding of material business risks and controls

Sustainability and circularity are at the top of the agenda for FENC management and its board of directors. In 2020, the company set up a Sustainability Committee to guide the implementation of sustainable development (including circular economy) initiatives and enhance reporting and disclosure – the only company to do so among the top 50 polymer producers.

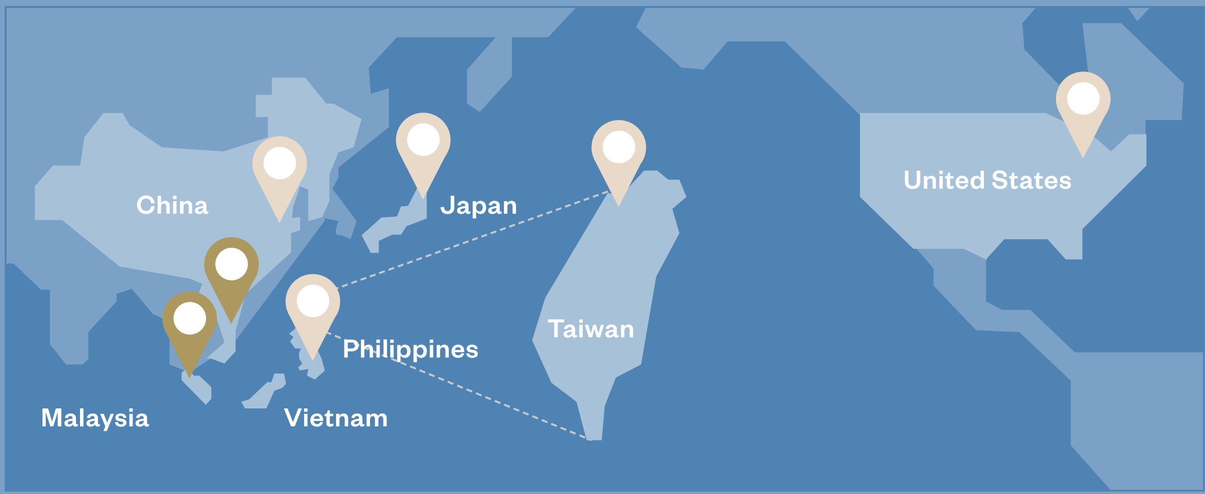
Further, its comprehensive risk management framework outlines environmental pollution (including plastic waste) and climate change as the most material risks to the business – and as a result has implemented control and evaluation mechanisms that avoid/reduce GHG emissions and increase recycling.

Lastly, in 2020, FENC was the first in Taiwan to issue sustainability bonds and the first to issue sustainability-linked loan and commercial paper in Asia. The secured funds are linked to its pursuit of sustainable development goals and earmarked for specific projects, such as PET recycling, development on renewable energy, and energy conservation.

A leading polyester recycling company

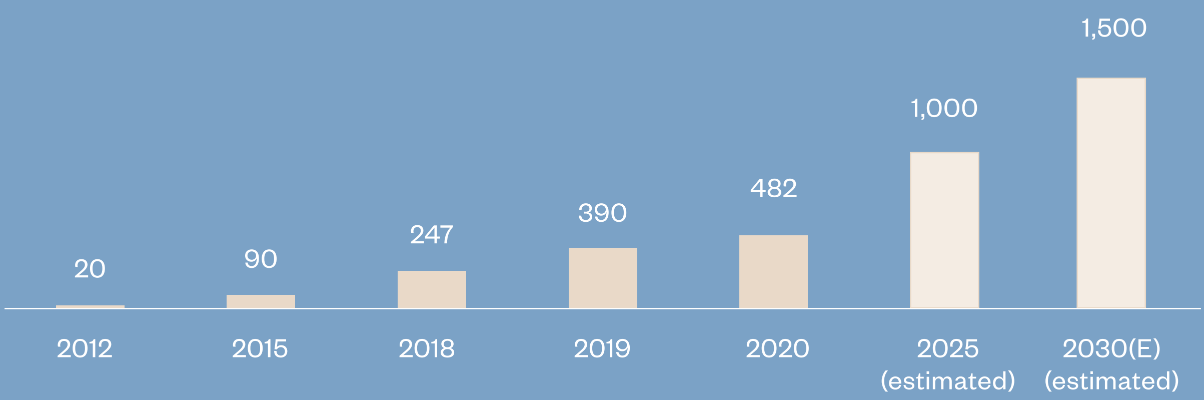
FENC has invested heavily in the recycled rPET industry since 1988 in Taiwan and then globally. New expansion plans have been launched in Japan, USA, China, Vietnam, Philippines and Malaysia.

Current production sites
Future expansion



rPET Annual Capacity

(K tons/year)



Sources: Minderoo analysis and company website.

Figure 15: Far Eastern New Century (FENC) has emerged as the clear #1, with Indorama Ventures a clear #2 on single-use plastics circularity

Rank	Producer	Overall Circularity score	Enablers score	Outcomes score	Enabler themes scores (scored A to E)									Outcome themes scores	
		A to E	A to E	A to E	Strategy	Risk	Targets	Target ambition	Infrast-ructure	Supplier engage-ment	Customer engage-ment	Compen-sation	Board oversight	% recycled inflows	% non-recycled outflows
1	FENC	B-	A-	C-	A	A	A	A	B	C	B	C	B-	C	D-
2	Indorama Ventures	C	B	D-	A	A	A	B-	B	C	B	C	B-	D-	E
3	Borealis	C-	B	E	A	A	A-	D-	B	C-	B	B	D	E	E
4	Alpek SAB de SV	C-	B-	D-	A	A-	B	C-	B	C	C	E	D	D-	D-
5	Repsol	C-	B	E	A	B-	A	C-	B	D	B	B	B-	E	D-
6	LyondellBasell	C-	B	E	A	A-	A-	D	B	C-	B	B	D	E	E
7	Braskem	C-	B	E	A	A-	A-	D-	B	C	B	C	B-	E	E
8	Dow	C-	B-	E	A	B-	A-	C	B	D	B	B	D	E	E
9	Total Energies	D	B-	E	A	B-	A	D	B	C-	B	D	D	E	E
10	Lotte Chemical	D	B-	E	A	B-	A-	C-	B	D-	B-	D	D	E	E
11	Siam Cement Group	D	C	E	B	A-	A-	E	B-	D	B-	D	B-	E	E
12	ENI	D	C	E	B	D-	B-	D-	B	D	B	C	D	E	E
13	Mitsui	D	C	E	A	A-	D	E	B-	C	B	E	E	E	D-
14	PTT	D	C	E	A	A-	B	E	B	D	B	E	D	E	E
15	Nova Chemicals Corporation	D	C	E	A	B-	D	E	B	C	B	B	D	E	E
16	SIBUR	D	C	E	A	A-	B	E	B	D	C	E	B-	E	E
17	Mitsubishi Chemical Corp	D	C	E	A	B-	C	E	B-	C	D	C	D-	E	D-
18	Saudi Aramco	D	C	E	C	A-	B	E	B	D	B	E	D	E	E
19	ExxonMobil	D	C	E	E	A-	A-	E	B	C-	D	B	D	E	E
20	Formosa Chemicals & Fibre Corporation	D	C	E	B	A	B	E	B	D	C-	E	D-	E	E

Compared to 2019, there is greater recognition from the petrochemical industry that it needs to address the single-use plastic waste crisis through transition to circular models of plastics production

A small number of companies – Spain's Repsol, US-based Dow, Mexico's Alpek and South Korea's Lotte Chemical – have set more ambitious recycled polymer targets. If realised, their combined commitments would be meaningful: representing 5 MMT of recycled polymer by 2030. However, the commitments are mostly longer-term and short on detail, without costed implementation plans or allocated capital expenditure. Most include chemical recycling deployments still in development with uncertain circularity credentials.

In addition to this group, there is some broader industry progress. Of the top 50 polymer producers, 30 companies scored considerably better on Enablers, driven by aligning their strategy to include a transition to circular economy, committing to recycling targets, and investing in circular plastics research and development (**Figure 16**).

All commitments should naturally be treated with a degree of scepticism until they are backed up by clear plans, actions and outcomes.

Speed of corporate transition from linear to circular business models will be driven by returns on investment – and the pressures facing single-use plastics suggest there is value at risk

As discussed above, the economic advantage of virgin versus recycled polymers can only be addressed by regulatory intervention. At the domestic policy level, new legislation is being written or enacted in a number of countries, and some include explicit fiscal interventions (e.g., the UK's plastic packaging tax).

At the global level, negotiations have commenced to develop a legally binding international instrument to end plastic pollution, which is likely to include measures that focus "upstream". The outcome of these negotiations will likely bring about significant change in the economic and operating landscape for polymer producers.

In light of the changing policy landscape, we provide guidance on the magnitude of risk faced by individual petrochemical companies. We have identified which companies are at risk based on two indicators: (i) their share of group revenue from single-use plastics; and (ii) the potential for negative impact from policy pressures on single-use plastics revenue based on their primary sales markets (both domestic and exports).

Twenty of the largest 50 polymer producers rely on single-use plastics for more than 20% of group revenue (**Figure 17**).

Given the higher dependence on single-use plastics in the business models of these 20 companies – and as many are operating in regions where the policy and regulatory pressures are growing strongest (especially in Europe) – it is no surprise that nearly half of these companies have made more ambitious circularity commitments. Those with 2025 targets are FENC, Indorama Ventures, and Alpek (committing to targets that equate to a recycled content of more than 10%) and Borealis, Braskem, INEOS and SIBUR (targeting 5%). Those with 2030 targets are Dow and Lotte Chemical (20%), and LyondellBasell (10%).

Implications

- **Small signs of progress – but now it is time for action.** While we acknowledge progress from across the industry to align their strategies, targets and commitments to the circular plastics economy, this industry has a history of greenwashing, and we need more than just good intentions – there must be action and detailed plans on implementation.
- **A common reporting framework is urgently required to monitor and evaluate progress towards circular plastics production.** There is a lack of clarity and transparency on recycled content targets for the majority of petrochemical companies. Several companies have announced some form of recycling target, but most are opaque and difficult to unpick. Ideally, targets should be reported as a share of virgin polymer production, leaving no room for ambiguity. That way stakeholders can hold the board of directors and management teams to account.
- **Investors need to understand and question the level of financial risk in their portfolios for petrochemical companies dependent on virgin single-use plastics demand for growth.** As primary sales markets for some companies become stricter on single-use plastics (e.g., in the EU, where reuse and refill has become a new priority in addition to recycling and reduction in the new Packaging and Packaging Wate Regulation), demand for virgin polymer is likely to fall, unless offset by growth in other end-use applications.

Figure 16: Compared to 2019, there are signs that virtually the entire industry is taking circularity more seriously

Top 50 producers	Strategy Score		Targets Score		Infrastructure Score	
	2021	2019	2021	2019	2021	2019
AVERAGE	B ↑	B-	B- ↑	C-	B ↑	B-

	Top 50 producers of SUP waste ranked by circularity scores	Strategy Score		Targets Score		Infrastructure Score	
		2021	2019	2021	2019	2021	2019
1	Far Eastern New Century	A	A	↑ A	B	B	B
2	Indorama Ventures	A	A	A	A	B	B
3	Borealis	A	A	A-	A-	B	B
4	Alpek SAB de CV	A	A	↑ B	D	B	B
5	Repsol	A	A	↑ A	B-	B	B
6	LyondellBasell	↑ A	B	↑ A-	B	↑ B	C
7	Braskem	A	A	↑ A-	B	↑ B	C
8	Dow	A	A	↑ A-	B	↑ B	C
9	TotalEnergies	↑ A	C	↑ A	A-	↑ B	B-
10	Lotte Chemical	↑ A	C	↑ A-	E	↑ B	C
11	Siam Cement Group	B	B	↑ A-	B	B-	B-
12	ENI	↑ B	C	↑ B-	E	↑ B	B-
13	Mitsui	A	A	↑ D	D-	B-	B-
14	PTT	A	A	↑ B	B-	↑ B	B-
15	Nova Chemicals Corporation	A	A	↑ D	C	B	B
16	SIBUR	↑ A	B	↑ B	C	↑ B	C-
17	Mitsubishi Chemical Corporation	↑ A	C	↑ C	E	B-	B
18	Saudi Aramco	↑ C	E	↑ B	E	↑ B	C
19	ExxonMobil	E	E	↑ A-	E	↑ B	C
20	Formosa Chemicals & Fibre Corporation	↑ B	E	↑ B	E	↑ B	E
21	INEOS	↑ A	D	↑ A-	B	↑ B	C
22	Westlake Corporation	↑ B	E	E	E	B	B
23	Abu Dhabi National Oil Company	A	A	↑ B	E	↑ C	D-
24	LG Chem	A	A	↑ B-	B	↑ B	C
25	Chevron Corporation	↑ B	D	↑ B	D	↑ B	C
26	Hanwha Chemical	↑ B	D	↑ C-	E	↑ B	D
27	Phillips 66	↑ B	D	↑ B	C-	↑ B	C-
28	Reliance Industries	↑ A	C	C-	C-	B	B
29	MOL Group	↑ A	C	↑ C-	E	↑ B	B-
30	Sumitomo Chemical	↑ A	D	↑ B	D-	D	D
31	SK Innovation Co	↑ B	C	↑ B-	E	↑ C-	D
32	Shell	↑ B	C	↑ B-	C	C	C
33	Sasol	↑ B	E	↑ E	E	↑ D	E
34	Formosa Plastics Corp	D	D	↑ B	E	C-	C
35	GAIL India	↑ D	E	↑ D-	E	↑ B-	D-
36	Indian Oil Corporation	↑ B	D	↑ C-	E	↑ C-	D
37	Sinopec	↑ B	C	↑ D	C	D	C-
38	Rongsheng Group	↑ D	E	E	E	↑ B	D-
39	China Resources Chemical	↑ D	D	E	E	↑ B	E
40	Zhejiang Hengyi Group	↑ D	D	E	E	↑ B	D-
41	Oil and Natural Gas Corporation	↑ D	D	E	E	E	D-
42	Zhejiang Wankai New Materials Co	E	E	E	E	↑ D	E
43	Jiangsu Hailun Petrochemical	E	E	E	E	↑ D	E
44	PetroChina	E	E	E	E	E	E
45	China Coal	E	E	E	E	E	E
46	China Energy Investment Group	E	E	E	E	E	E
47	National Petrochemical Company	E	E	E	E	E	E
48	Bakhtar Petrochemical	E	E	E	E	E	E
49	Yanchang Group	E	E	E	E	E	E
50	Ningxia Baofeng Energy Group	E	E	E	E	E	E

Figure 17: It is no surprise that there is strong overlap between the companies making commitments on circularity and "value at risk" from their exposure to single-use plastics

>5% recycled polymer target by 2025

>10% recycled polymer target by 2025

>10% recycled polymer target by 2030

>20% recycled polymer target by 2030

Asia
Greater Europe
Africa
Oceania
Latin America & The Caribbean
Middle East
North America
China

Polymer producers ranked by their revenue dependency on producing polymers bound for single-use plastic application (MMT in 2021)	% of revenue from SUP	We have also mapped out the sales markets per producer (%)...	Weighted average impact policy and and assessed the impact of policy headwinds accordingly
	0 2 4 6	0% 50% 100%	
Zhejiang Wankai	100%		Low
Jiangsu Hailun Petrochemical	100%		Low
China Resources Chemical	100%		Low
JBF Industries	90%		High
Borealis	68%		High
Alpek SAB de CV	67%		Medium
Nova Chemicals Corporation	67%		Medium
Indorama Ventures	63%		High
SIBUR	60%		High
Braskem	59%		Low
Daelim Group	56%		Medium
LyondellBasell	43%		High
Lotte Chemical	32%		Medium
Dow	30%		Medium
Hanwha Chemical	29%		Medium
FENC	28%		Medium
Formosa Plastics Corp	26%		Medium
Ningxia Baofeng Energy Group	25%		Low
Siam Cement Group	21%		Medium
INEOS	20%		High

OUR APPROACH

For a detailed method of any of the below, see **BASIS OF PREPARATION.**

Who produces virgin polymers bound for single-use plastic and where does it ends up as waste?

We used our model built for the first edition of the Index of global single-use plastic material flows, from polymer production to waste generation (**Figure 18**).

We identified about 1,400 production facilities globally that produce the six main polymers that account for more than 90% of all single-use plastics: polypropylene (PP); high-density polyethylene (HDPE); low-density polyethylene (LDPE); linear low-density polyethylene (LLDPE); and polyethylene terephthalate (PET). For this new Index, we also included polystyrene (PS) for the first time. We then estimated the mass of plastic polymer produced in 2021 at each facility. These facilities are owned and operated by around 400 distinct companies. Wood Mackenzie, an energy research consultancy, provided both the facilities and the production estimates.

Turkish world record-holder free-diver Şahika Ercümen dives amid plastic waste to observe the pollution of the Bosphorus in Istanbul, Turkey. She was announced as a "Life Below Water Advocate" by United Nations Development Program (UNDP), for her work in raising awareness of plastic pollution. Photo credit: Sebnem Coskun/Anadolu Agency via Getty Images.

We then tracked how the polymers leaving each facility were traded globally using data from UN Comtrade. Within each country of destination, we also modelled what proportion of polymers were converted into single-use plastics versus non-single-use products, based on installed capacity of different conversion processors (e.g., sheet extrusion and roto-moulding), using data provided by Wood Mackenzie.

Finally, we estimated the mass of single-use plastic traded in bulk (i.e., raw packaging materials), and within finished/packaged goods themselves – and simulated those trade flows through to the consumption and disposal stage. We used UN Comtrade and World Bank data for these steps. This generated an estimate of every polymer producer's contribution to single-use plastic waste in every country.

We also backdated our single-use plastic material flow model using data from 2005. For each year in this time series, we took the single-use plastic waste generation level for each country and calculated per capita consumption rates using population data. We then compared single-use plastic consumption per capita to GDP per capita (purchasing power parity adjusted). We found a strong linear correlation, with an R2 value of 0.85. This means 85% of the growth in single-use plastics consumption can be explained by economic fundamentals: growth either in population or in GDP.

Figure 18: Our six-step approach to linking polymer producers to single-use plastic waste generation

Material flow	Polymer production	Polymer trade	Conversation	Single-use plastic trade in bulk	Trade of single-use plastics in finished goods	Single-use plastics in MSW
Key questions	Who produces polymers that form single-use plastic, where and how much?	What are the trading patterns between polymer producers and countries?	How are polymers converted into single-use plastic product categories?	How are the relevant categories of bulk packaging traded?	What mass of single-use plastic in finished goods is traded and what are the trade patterns?	What is the volume of single-use plastic in municipal solid waste (MSW) and what are the sources?
Key data sources	Wood Mackenzie	International Trade Centre	Wood Mackenzie	International Trade Centre	McKinsey & Company WITS	**Results of this analysis**
In-scope masses, MMT	~220	~90	~120	~40	~30	~120

Who is active in recycling plastic waste?

New for this edition of the Index, we present a full picture on mechanical and chemical recycling of all polymers and the participation from petrochemical companies. Wood Mackenzie provided an industry-wide database of all mechanical PET recycling assets and a database of mechanical polyolefin recycling assets operated by petrochemical companies, making assumptions on the plastic-to-plastic yield for both, i.e., polymer output for each metric tonne of plastic waste input. We also analysed which recycling facilities are on par versus downcycling, which has its challenges given the lack of transparency into feedstock inputs and the end-use applications of outputs.

For chemical recycling, Wood Mackenzie provided a database of all chemical recycling assets globally, including any associations with petrochemical companies, either as owned and operated or as partners through off-take agreements. Wood Mackenzie also analysed the plastic-to-plastic yields for the different chemical recycling technologies, that is, how much plastic waste is turned into outputs that can be used to produce new plastics, if any.

To calculate producers' single-use plastic footprint, we subtracted the mass of recovered plastic waste as a feedstock for recycling from the total virgin polymer bound for single-use plastic.

What is the near-term outlook for production of polymers bound for single-use plastic?

We estimated growth in virgin and, for the first time, recycled polymer production globally by 2027, based on data provided by Wood Mackenzie on expected growth in single-use plastic polymer capacity at an asset level. Only projects currently operational and/or deemed likely to occur were included.

Who are the leaders and laggards in the move to circularity?

We updated our 2019 methodology for the Circularity Assessment in consultation with a number of investors and banks to ensure useful benchmarking. We convened an Investor Working Group comprising financial institutions from Europe, North America and India – with combined assets under management of US$6 trillion – to refine the assessment criteria and improve the benchmarks and use cases.

The refined methodology continues to build from Ellen MacArthur Foundation's Circulytics survey, but also expands into new categories (e.g., governance, and risk management) and recalibrates the weighting to reflect the single-use plastics environment more accurately (e.g., no weight is given to downcycling operations or targets) (**Figure 19**).

Figure 19: Additions/refinements to 'enablers' based on investor feedback

2019

Enablers

10% Strategy	
10% Targets	**10%** Infrastructure
10% Supplier Engagement	**10%** Customer Engagement

5 questions

1. Strategy
2. Targets
3. Infrastructure
4. Supplier engagement
5. Customer engagement

2021

Enablers

10% Strategy	
10% Targets	**10%** Infrastructure
10% External Engagement	**10%** Governance

9 questions

1. Strategy
   A. Strategic priorities
   B. Risk management
2. Targets
   A. Target disclosure
   B. Target ambition
3. Infrastructure
4. External engagement
   A. Supplier
   B. Customer
5. Governance
   A. Compensation
   B. Board oversight

What are the greenhouse gas emissions associated with single-use plastics?

To reinforce the connection between plastic waste and greenhouse emission reduction plans, we estimated the cradle-to-grave GHG emissions based on material flows for polymers bound for single-use plastic waste, which included emissions factor calculations and estimates of hydrocarbon feedstocks and end-of-life treatment (**Figure 20**). Wood Mackenzie and Carbon Trust collaborated on this analysis.

Global emissions factors were applied for hydrocarbon extraction and refining based on the split of feedstock for production of monomers – i.e., from oil, gas or coal. Regional and sub-regional emissions factors were applied for the feedstock cracking process, based on technology and location of polymer assets. For significant intensive fuels, the region Asia Coal has been separated from a regional average to reflect assets that use coal-to-olefins instead of stream cracking. Wood Mackenzie provided energy requirements per kiloton of monomer and losses in the process by feedstock split and technology.

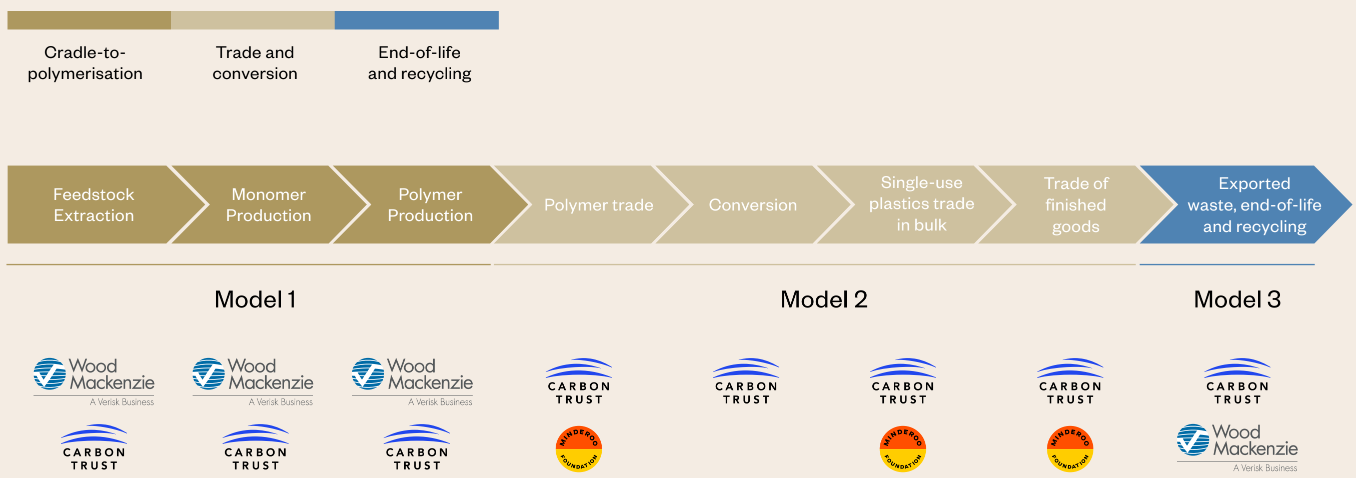
Country-level emissions factors were applied for polymerisation for polyethylene (PE), PP and PET as the technology and asset location are known. For PS, a general technology average was used across all assets so there is no variability by asset apart from the regional carbon intensity of energy. Wood Mackenzie provided energy requirements per kiloton of polymer from the different technology routes. The main limitation is that it is not possible to ascertain the exact carbon intensity of the assets used; the best proxy available is the grid mix and industrial heat mix for its country of location.

For conversion, we calculated the emission factors for each conversion process (from a combination of EcoInvent and Carbon Trust estimates). As there is no traceability or availability of data on the process efficiencies, each energy process efficiency was assumed to be a global constant. For the trade modules, we used the proportion traded and breakdown of where the goods go for each polymer and geography, taking an assumption on transport method for different distances.

To calculate emission factors for waste trade, we used country averages on the share of waste traded and disposed of in country of sale, sourced from UN Comtrade and Carbon Trust. For or end-of-life treatment, Wood Mackenzie provided a breakdown per country of what share of the waste is recycled (mechanically), landfilled, incinerated and open-burned. Carbon Trust then estimated the emissions factors for the different end-of-life treatment pathways.

Figure 20: The GHG footprint is a collaborative effort of Wood Mackenzie and Carbon Trust

Wood Mackenzie and Carbon Trust have worked collaboratively on various steps in the value chain footprint, with Wood Mackenzie data particularly important for modelling the carbon intensive cradle-to-polymer stages.



A person searches through waste at a rubbish tip near Moscow, Russia. Waste pickers throughout the world risk their lives to sort plastic waste for reuse and recycling. Photo credit: Oleg Nikishin via Getty Images.

RESULTS IN DETAIL

A worker inspects coloured chips from plastic soft drinks and mineral water bottle tops at the end of a mechanical recycling process. Mechanical recycling reduces cradle-to-grave emissions by at least 30 to 40% compared to producing polymers from fossil fuels by avoiding upstream emissions. Photo credit: David Silverman via Getty Images.

Single-use plastic waste footprint

	Polymer Producer	# of assets	versus 2019 re-based	Estimated production of in-scope polymers (MMT, 2021)	△ versus 2019 re-based	Estimated contribution to SUP waste (MMT, 2021)				Total contribution to SUP waste (MMT, 2021)	△ versus 2019 re-based	On par recycled feedstock (MMT, 2021)	Net contribution to SUP waste (MMT, 2021)
						Flexible formats	△ versus 2019 re-based	Rigid formats	△ versus 2019 re-based				
1	ExxonMobil	58	+2	11.5	0.2	4.9	0.1	1.1	-0.2	6.0	0.0	0.0	6.0
2	Sinopec	92	+3	12.4	0.3	4.3	0.0	1.5	-0.1	5.8	-0.1	0.0	5.8
3	Dow	54	-1	9.2	-0.2	4.5	-0.2	0.8	-0.1	5.3	-0.3	0.0	5.3
4	Indorama Ventures	25	-	5.2	0.1	0.1	0.0	4.7	0.2	4.8	0.2	0.3	4.6
5	Saudi Aramco	101	+3	10.0	0.4	3.3	0.1	1.1	0.0	4.5	0.1	0.0	4.5
6	LyondellBasell	74	+4	10.3	0.8	2.7	0.4	1.7	-0.1	4.4	0.3	0.0	4.4
7	PetroChina	66	+4	9.6	0.7	3.4	0.1	0.8	0.0	4.2	0.1	0.0	4.2
8	Reliance Industries	26	-	5.4	-0.1	1.7	-0.1	1.3	0.0	3.0	-0.1	0.0	3.0
9	INEOS	40	+4	6.5	0.4	1.0	0.2	1.7	-0.1	2.8	0.1	0.0	2.8
10	Alpek SAB de CV	13	+1	3.3	0.8	0.1	0.0	2.8	0.6	2.9	0.6	0.1	2.8
11	Braskem	40	-	6.1	-0.5	1.7	-0.2	0.9	-0.2	2.6	-0.4	0.0	2.6
12	Borealis	29	-	5.2	0.1	1.6	0.1	0.6	-0.1	2.2	0.1	0.0	2.2
13	TotalEnergies	39	+5	4.7	-0.2	0.9	0.0	1.1	-0.1	2.1	-0.1	0.0	2.1
14	Lotte Chemical	26	-	3.8	-0.1	1.0	0.0	0.8	-0.2	1.8	-0.2	0.0	1.8
15	Formosa Plastics Corp	23	+1	4.1	0.6	1.2	0.2	0.6	0.1	1.8	0.2	0.0	1.8
16	SIBUR	18	+6	3.7	2.4	1.1	0.8	0.7	0.3	1.8	1.0	0.0	1.8
17	Rongsheng Group	8	+4	2.5	1.3	0.5	0.4	1.1	0.5	1.7	0.8	0.0	1.7
18	Jiangsu Hailun Petrochemical	1	-	1.8	0.1	0.0	0.0	1.6	0.0	1.6	0.0	0.0	1.6
19	China Resources Chemical	4	-	1.7	0.3	0.0	0.0	1.6	0.2	1.6	0.2	0.0	1.6
20	China Energy Investment Group	11	-	3.5	0.1	1.2	0.0	0.3	0.0	1.5	0.0	0.0	1.5
21	Far Eastern New Century (FENC)	6	-	1.8	0.2	0.0	0.0	1.7	0.1	1.7	0.1	0.2	1.5
22	PTT	19	-	3.2	0.1	1.1	0.0	0.4	0.0	1.5	0.0	0.0	1.5
23	Zhejiang Wankai New Materials Co	2	+1	1.5	0.5	0.0	0.0	1.4	0.4	1.4	0.4	0.0	1.4
24	Siam Cement Group	19	-	2.7	0.2	1.0	0.0	0.3	0.0	1.2	0.0	0.0	1.2
25	NOVA Chemicals Corporation	7	-	1.9	0.0	1.0	0.0	0.2	0.0	1.1	-0.1	0.0	1.1
26	Zhejiang Hengyi Group	2	-	1.1	0.5	0.0	0.0	1.0	0.4	1.0	0.4	0.0	1.0
27	Hanwha Chemical	17	+1	1.9	0.3	0.8	0.1	0.2	0.0	1.0	0.1	0.0	1.0
28	LG Chem	12	+3	2.0	0.4	0.7	0.2	0.2	0.0	1.0	0.2	0.0	1.0
29	Phillips 66	23	-	2.3	-0.1	0.5	0.0	0.4	-0.1	0.9	-0.1	0.0	0.9
30	Sumitomo Chemical	23	+1	2.0	0.0	0.7	0.0	0.2	0.0	0.9	0.0	0.0	0.9
31	China Coal	14	+1	2.0	0.1	0.8	0.1	0.1	0.0	0.9	0.0	0.0	0.9
32	Chevron Corporation	24	+1	2.2	0.0	0.5	0.0	0.4	-0.1	0.9	-0.1	0.0	0.9
33	Abu Dhabi National Oil Company	10	-	2.0	0.1	0.6	0.1	0.2	0.0	0.8	0.1	0.0	0.8
34	Mitsubishi Chemical Corporation	19	-2	1.7	-0.1	0.4	0.0	0.4	0.0	0.8	-0.1	0.0	0.8

34	Mitsubishi Chemical Corporation	19	-2	1.7	-0.1	0.4	0.0	0.4	0.0	0.8	-0.1	0.0	0.8
35	Indian Oil Corporation	6	-	1.7	0.5	0.6	0.2	0.1	0.0	0.8	0.2	0.0	0.8
36	Eni	11	-	1.5	0.1	0.5	0.0	0.3	0.0	0.8	0.0	0.0	0.8
37	Yanchang Group	9	+1	1.8	0.2	0.6	0.1	0.2	0.0	0.7	0.1	0.0	0.7
38	Mitsui	17	-	1.2	0.0	0.2	0.0	0.5	0.0	0.7	0.0	0.0	0.7
39	GAIL India	13	-	1.6	0.0	0.5	0.0	0.1	0.0	0.7	0.0	0.0	0.7
40	JBF Industries	3	-	0.8	0.2	0.0	0.0	0.6	0.1	0.6	0.1	0.0	0.6
41	Westlake Corporation	10	-	1.0	0.0	0.5	0.0	0.1	0.0	0.6	-0.1	0.0	0.6
42	Sasol	6	+1	1.1	0.1	0.5	0.2	0.1	0.0	0.6	0.2	0.0	0.6
43	Repsol	11	-	1.2	0.1	0.4	0.0	0.2	0.0	0.6	0.0	0.0	0.6
44	Nan Ya Plastics Corporation	2	-	0.6	0.0	0.0	0.0	0.6	0.0	0.6	0.0	0.0	0.6
45	SK Innovation Co	10	+1	1.2	0.1	0.4	0.0	0.1	0.0	0.5	0.0	0.0	0.5
46	Formosa Chemicals & Fibre Corporation	7	-	1.0	0.0	0.2	0.0	0.3	0.0	0.5	0.0	0.0	0.5
47	MOL Group	7	-	1.2	0.1	0.3	0.0	0.2	0.0	0.5	0.0	0.0	0.5
48	Oil and Natural Gas Corporation	6	-	1.1	0.0	0.4	0.0	0.1	0.0	0.5	0.0	0.0	0.5
49	Ningxia Baofeng Energy Group	5	-	1.1	0.4	0.4	0.1	0.1	0.0	0.5	0.2	0.0	0.5
50	Daelim Group	8	+1	0.9	0.2	0.4	0.2	0.1	0.0	0.4	0.1	0.0	0.4
51	Bakhtar Petrochemical	6	-	1.0	0.0	0.3	0.0	0.1	0.0	0.4	0.0	0.0	0.4
52	Shell	14	-	1.0	0.0	0.3	0.0	0.1	0.0	0.4	0.0	0.0	0.4
53	PT Chandra Asri Petrochemical Tbk	7	-	0.8	0.2	0.3	0.1	0.1	0.0	0.4	0.1	0.0	0.4
54	Wanhua Chemical Group Co., Ltd	2	+2	0.8	0.8	0.4	0.4	0.0	0.0	0.4	0.4	0.0	0.4
55	Shin Kong	2	-	0.4	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.4
56	Americas Styrenics LLC	7	-	0.6	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.4
57	Eastern Petrochemical Company	4	-	0.8	0.0	0.3	0.0	0.0	0.0	0.4	0.0	0.0	0.4
58	Tasnee	4	-	0.9	0.0	0.3	0.0	0.1	0.0	0.4	0.0	0.0	0.4
59	China National Offshore Oil Corporation	6	-	0.9	0.0	0.3	0.0	0.1	0.0	0.4	0.0	0.0	0.4
60	Neo Group	1	-	0.4	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.3
61	Saudi International Petrochemical Company	4	-	0.7	0.0	0.3	0.0	0.1	0.0	0.3	0.0	0.0	0.3
62	Haldia Petrochemicals Ltd	5	-	0.9	0.0	0.3	0.0	0.1	0.0	0.3	0.0	0.0	0.3
63	Idemitsu Kosan	16	-	0.8	0.0	0.1	0.0	0.2	0.0	0.3	0.0	0.0	0.3
64	Dhunseri Petrochem	2	-	0.4	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.3
65	Jam Petrochemical Company	3	-	0.7	0.0	0.3	0.1	0.1	0.0	0.3	0.1	0.0	0.3
66	PKN Orlen	6	-	0.9	0.1	0.2	0.0	0.2	0.0	0.3	0.0	0.0	0.3
67	National Petrochemical Company (Saudi Arabia)	4	-	1.0	0.0	0.2	0.0	0.2	0.0	0.3	0.0	0.0	0.3
68	QatarEnergy	14	-	0.6	0.0	0.3	0.0	0.1	0.0	0.3	0.0	0.0	0.3
69	KPIC Corporation	6	-	0.9	0.0	0.2	0.0	0.1	0.0	0.3	0.0	0.0	0.3

70	Petronas	4	-	0.6	0.1	0.2	0.0	0.1	0.0	0.3	0.1	0.0	0.3
71	Gatron Industries	1	-	0.3	-0.1	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.3
72	State Oil Company of Azerbaijan Republic	7	-	0.6	0.1	0.2	0.0	0.1	0.0	0.3	0.0	0.0	0.3
73	Oriental Energy	2	-	0.7	0.0	0.2	0.0	0.1	0.0	0.3	0.0	0.0	0.3
74	Pucheng Clean Energy	3	-	0.6	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.3
75	Bazan Group	4	-	0.7	0.0	0.2	0.0	0.1	0.0	0.3	0.0	0.0	0.3
76	TK Chemical	1	-	0.3	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.3
77	Ecopetrol S.A.	3	-	0.6	0.1	0.2	0.0	0.1	0.0	0.3	0.0	0.0	0.3
78	Trinseo	5	-	0.6	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.3
79	Equate Petrochemical Company	4	-1	0.5	-0.1	0.1	0.0	0.2	0.0	0.3	0.0	0.0	0.3
80	Saudi Kayan	3	-	0.6	0.0	0.2	0.0	0.1	0.0	0.3	0.0	0.0	0.3
81	KAP Industrial Holdings	3	-	0.4	0.0	0.0	0.0	0.2	0.0	0.3	0.0	0.0	0.3
82	Prime Polymer	2	-	0.4	0.0	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.3
83	Jiutai Energy	3	-	0.6	0.2	0.2	0.1	0.0	0.0	0.3	0.1	0.0	0.3
84	Yansab	3	-	0.6	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.2
85	Asahi Kasei Corporation	8	-	0.5	0.0	0.1	0.0	0.2	0.0	0.2	0.0	0.0	0.2
86	Ningbo Fund Energy	2	-	0.6	0.0	0.2	0.0	0.1	0.0	0.2	0.0	0.0	0.2
87	Henan Energy Group Co Ltd	1	-	0.3	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.2
88	SASA Polyester Sanayi A.S.	1	+1	0.3	0.3	0.0	0.0	0.2	0.2	0.2	0.2	0.0	0.2
89	Kazanorgsintez PJSC	6	-	0.7	0.1	0.2	0.0	0.1	0.0	0.2	0.0	0.0	0.2
90	Amir Kabir Petrochemical Company	4	-	0.5	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.2
91	USI Group	4	-	0.4	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.2
92	Qatar Petrochemical Company	4	-	0.4	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0	0.2
93	CHIMEI Corporation	2	-	0.5	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.2
94	Luqing Group	4	+2	0.5	0.1	0.2	0.1	0.0	0.0	0.2	0.1	0.0	0.2
95	BASF	4	-	0.4	0.1	0.1	0.0	0.1	0.0	0.2	0.0	0.0	0.2
96	Billion Industrial Holdings	1	-	0.2	0.2	0.0	0.0	0.2	0.2	0.2	0.2	0.0	0.2
97	Pan-Asia PET Resin	1	-	0.2	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.2
98	Novapet	1	-	0.2	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.2
99	Advanced Petrochemical	2	-	0.5	0.0	0.2	0.0	0.1	0.0	0.2	0.0	0.0	0.2
100	Sanyuan	2	-	0.5	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.0	0.2

GHG footprint (from polymers bound for single-use plastic)

	Polymer Producer	Total GHG emissions for cradle-to-polymer (MMT CO_2e)	Total GHG emissions for polymer-to-grave (MMT CO_2e)	Total GHG emissions for cradle-to-grave single-use plastics (MMT CO_2e)	Total GHG emissions intensity per tonne of single-use plastic (tonne per tonne CO_2e)
1	Sinopec	12.2	9.9	22.1	3.7
2	Indorama Ventures	13.0	8.7	21.7	4.5
3	ExxonMobil	9.0	8.8	17.8	3.0
4	Dow	8.4	7.1	15.6	3.0
5	Saudi Aramco	7.6	7.3	14.9	3.3
6	PetroChina	8.0	6.8	14.9	3.6
7	China Energy Investment Group	12.2	2.6	14.8	9.6
8	LyondellBasell	6.4	7.1	13.4	3.0
9	Alpek SAB de CV	7.8	4.8	12.6	4.3
10	Reliance Industries	5.7	5.1	10.8	3.6
11	INEOS	5.0	4.2	9.3	3.7
12	China Coal	6.5	1.5	8.0	8.6
13	Far Eastern New Century (FENC)	4.9	3.1	8.0	4.7
14	Jiangsu Hailun Petrochemical	4.3	3.2	7.6	4.7
15	China Resources Chemical	4.3	3.1	7.4	4.8
16	TotalEnergies	3.8	3.4	7.2	3.5
17	Borealis	3.2	4.0	7.2	3.2
18	Braskem	3.4	3.7	7.1	2.7
19	Rongsheng Group	3.8	3.1	6.9	4.1
20	Lotte Chemical	3.4	3.3	6.7	3.6
21	Zhejiang Wankai New Materials Co	3.8	2.8	6.7	4.7
22	SIBUR	3.2	2.7	5.9	3.3
23	Formosa Plastics Corp	2.7	2.8	5.4	3.0
24	Yanchang Group	4.1	1.2	5.3	7.4
25	PTT	2.4	2.6	4.9	3.3
26	Zhejiang Hengyi Group	2.8	2.1	4.9	4.7
27	Ningxia Baofeng Energy Group	3.5	0.8	4.2	9.1
28	Siam Cement Group	1.9	2.1	4.0	3.2
29	LG Chem	1.6	1.6	3.2	3.3
30	Hanwha Chemical	1.6	1.6	3.2	3.2
31	Nova Chemicals Corporation	1.6	1.4	3.0	2.7
32	Sumitomo Chemical	1.4	1.6	3.0	3.3
33	JBF Industries	1.8	1.2	3.0	4.8
34	Phillips 66	1.5	1.4	2.9	3.1
35	Abu Dhabi National Oil Corporation	1.3	1.5	2.8	3.5
36	Chevron Corporation	1.4	1.4	2.8	3.2
37	Mitsubishi Chemical Corporation	1.3	1.4	2.7	3.4
38	Mitsui & Co.	1.4	1.3	2.7	3.9
39	Ningbo Fund Energy	2.2	0.4	2.6	11.1
40	Eni	1.4	1.2	2.6	3.4
41	Nan Ya Plastics Corporation	1.5	1.0	2.5	4.5
42	Pucheng Clean Energy	2.1	0.4	2.5	9.3
43	Jiutai Energy	1.9	0.4	2.3	9.2
44	Indian Oil Corporation	1.1	1.2	2.3	3.0
45	Formosa Chemicals & Fibre Corporation	1.2	1.0	2.1	4.3
46	GAIL India	1.1	1.0	2.1	3.1
47	Sasol	1.0	0.8	1.9	3.3

48	Shinkong	1.1	0.8	1.9	4.8
49	Americas Styrenics LLC	1.3	0.5	1.8	4.9
50	Repsol	0.8	1.0	1.7	3.0
51	SK Innovation Co	0.8	0.9	1.7	3.2
52	Datang Group	1.4	0.3	1.7	11.1
53	Neo Group	1.0	0.7	1.7	4.8
54	Westlake Corporation	1.0	0.7	1.7	2.8
55	Wanbei Coal & Electricity Group	1.3	0.3	1.6	8.6
56	Dhunseri Petrochem	1.0	0.6	1.6	4.8
57	MOL Group	0.6	0.9	1.5	3.2
58	Bakhtar Petrochemical	0.8	0.7	1.5	3.4
59	Gatron Industries	0.8	0.6	1.4	4.8
60	Oil and Natural Gas Corporation	0.6	0.8	1.4	2.9
61	Jiangsu Sailboat Petrochemical	1.1	0.3	1.4	7.5
62	Shell	0.7	0.7	1.4	3.3
63	Idemitsu Kosan	0.7	0.7	1.4	4.1
64	Daelim Group	0.6	0.7	1.4	3.1
65	Trinseo	0.8	0.5	1.3	5.1
66	PT Chandra Asri Petrochemical Tbk	0.6	0.7	1.3	3.2
67	Jiangsu GPRO Group	1.0	0.3	1.3	8.9
68	TK Chemical	0.8	0.5	1.3	4.8
69	Tasnee	0.6	0.6	1.2	3.4
70	Wanhua Chemical Group Co., Ltd	0.7	0.6	1.2	3.2
71	CHIMEI Corporation	0.8	0.5	1.2	5.4
72	Eastern Petrochemical Company	0.6	0.5	1.2	3.3
73	Saudi International Petrochemical Company	0.6	0.6	1.2	3.5
74	China National Offshore Oil Corporation	0.6	0.6	1.2	3.3
75	National Petrochemical Company (Saudi Arabia)	0.6	0.6	1.2	3.8
76	KAP Industrial Holdings	0.7	0.5	1.1	4.5
77	PKN Orlen	0.5	0.7	1.1	3.5
78	Equate Petrochemical Company	0.6	0.5	1.1	4.3
79	Asahi Kasei Corporation	0.6	0.5	1.1	4.5
80	Billion Industrial Holdings	0.7	0.4	1.1	5.0
81	Henan Energy Group Co Ltd	0.6	0.5	1.1	4.7
82	Jam Petrochemical Company	0.5	0.5	1.1	3.2
83	Haldia Petrochemicals Ltd	0.5	0.5	1.1	3.1
84	QatarEnergy	0.5	0.5	1.0	3.4
85	Petronas	0.5	0.5	1.0	3.5
86	KPIC Corporation	0.4	0.6	1.0	3.4
87	SASA Polyester Sanayi A.S.	0.6	0.4	1.0	4.4
88	Pan Asia PET Resin	0.6	0.4	1.0	4.7
89	Novapet	0.6	0.4	1.0	4.7
90	BASF	0.5	0.4	0.9	3.5
91	Saudi Kayan	0.5	0.4	0.9	4.2
92	Shahid Tondguyan Petrochemical Company	0.6	0.3	0.9	4.7
93	State Oil Company of Azerbaijan Republic	0.5	0.4	0.9	3.2
94	Oriental Energy	0.4	0.5	0.9	3.2
95	Dragon Special Resin	0.5	0.4	0.9	4.7
96	Jiangsu Laidun Baofu Plastifying Co., Ltd.	0.5	0.3	0.8	5.4
97	Yansab	0.4	0.4	0.8	3.3
98	Arabian Industrial Fibres Company	0.6	0.3	0.8	4.3
99	Bazan Group	0.4	0.4	0.8	3.0
100	Amir Kabir Petrochemical Company	0.4	0.4	0.8	3.5

Circularity Scores

Rank	Producer	Overall Circularity score	Enablers score	Outcomes score	Enabler themes scores (scored A to E)									Outcome themes scores	
		A to E	A to E	A to E	Strategy	Risk	Targets	Target ambition	Infrast-ructure	Supplier engage-ment	Customer engage-ment	Compen-sation	Board oversight	% recycled inflows	% non-recycled outflows
1	FENC	B-	A-	C-	A	A	A	A	B	C	B	C	B-	C	D-
2	Indorama Ventures	C	B	D-	A	A	A	B-	B	C	B	C	B-	D-	E
3	Borealis	C-	B	E	A	A	A-	D-	B	C-	B	B	D	E	E
4	Alpek SAB de SV	C-	B-	D-	A	A-	B	C-	B	C	C	E	D	D-	D-
5	Repsol	C-	B	E	A	B-	A	C-	B	D	B	B	B-	E	D-
6	Lyondell-Basell	C-	B	E	A	A-	A-	D	B	C-	B	B	D	E	E
7	Braskem	C-	B	E	A	A-	A-	D-	B	C	B	C	B-	E	E
8	Dow	C-	B-	E	A	B-	A-	C	B	D	B	B	D	E	E
9	Total Energies	D	B-	E	A	B-	A	D	B	C-	B	D	D	E	E
10	Lotte Chemical	D	B-	E	A	B-	A-	C-	B	D-	B-	D	D	E	E
11	Siam Cement Group	D	C	E	B	A-	A-	E	B-	D	B-	D	B-	E	E
12	ENI	D	C	E	B	D-	B-	D-	B	D	B	C	D	E	E
13	Mitsui	D	C	E	A	A-	D	E	B-	C	B	E	E	E	D-
14	PTT	D	C	E	A	A-	B	E	B	D	B	E	D	E	E
15	Nova Chemicals Corporation	D	C	E	A	B-	D	E	B	C	B	B	D	E	E
16	SIBUR	D	C	E	A	A-	B	E	B	D	C	E	B-	E	E
17	Mitsubishi Chemical Corp	D	C	E	A	B-	C	E	B-	C	D	C	D-	E	D-
18	Saudi Aramco	D	C	E	C	A-	B	E	B	D	B	E	D	E	E
19	Exxon-Mobil	D	C	E	E	A-	A-	E	B	C-	D	B	D	E	E
20	Formosa Chemicals & Fibre Corporation	D	C	E	B	A	B	E	B	D	C-	E	D-	E	E
21	INEOS	D	C	E	A	D-	A-	D-	B	D	C-	E	D	E	E
22	Westlake Corporation	D	C	E	B	D	E	E	B	C	C	B	D	E	E
23	Abu Dhabi National Oil Corporation	D	C	E	A	A	B	D	C	D-	D-	E	D	E	E
24	LG Chem	D	C	E	A	D-	B-	E	B	D	C	D	D	E	E

25	Chevron Corporation	D	C	E	B	D-	B	D	B	C	D	E	D	E	E
26	Hanwha Chemical	D	C	E	B	A	C-	E	B	D-	C	E	D	E	E
27	Phillips 66	D	C	E	B	D-	B	D	B	C-	D-	D	D	E	E
28	Reliance Industries	D-	C-	E	A	C	C-	E	B	D	C-	E	D	E	E
29	MOL Group	D-	C-	E	A	E	C-	E	B	C-	D	E	D	E	D-
30	Sumitomo Chemical	D-	C-	E	A	B-	B	E	D	D-	C-	E	D	E	E
31	SK Innovation Co	D-	C-	E	B	A	B-	E	C-	C-	E	E	D	E	E
32	Shell	D-	D	E	B	E	B-	E	C	D	D-	E	D	E	E
33	Sasol	D-	D	E	B	B-	E	E	D	D-	D-	C	D	E	E
34	Formosa Plastics Corp	D-	D	E	D	A	B	E	C-	D-	E	E	E	E	E
35	GAIL India	D-	D	E	D	E	D-	E	B-	D-	D	D	D	E	E
36	Indian Oil Corporation	D-	D	E	B	E	C-	E	C-	D-	D-	E	D	E	E
37	Sinopec	D-	D	E	B	E	D	E	D	D	D	E	D	E	E
38	Rongsheng Group	E	D-	E	D	E	E	E	B	E	E	E	D	E	E
39	China Resources Chemical	E	D-	E	D	E	E	E	B	D	E	E	E	E	E
40	Zhejiang Hengyi Group	E	D-	E	D	E	E	E	B	E	E	E	E	E	E
41	Oil and Natural Gas Corporation	E	E	E	D	E	E	E	E	E	E	E	D	E	E
42	Zhejiang Wankai New Materials Co	E	E	E	E	E	E	E	D	E	E	E	E	E	E
43	Jiangsu Hailun Petrochemical	E	E	E	E	E	E	E	D	E	E	E	E	E	E
44	Petro-China	E	E	E	E	E	E	E	E	E	E	E	D	E	E
45	China Coal	E	E	E	E	E	E	E	E	E	E	E	D	E	E
46	China Energy Investment Group	E	E	E	E	E	E	E	E	D-	E	E	E	E	E
47	National Petrochemical Company (Saudi Arabia)	E	E	E	E	E	E	E	E	E	E	E	E	E	E
48	Bakhtar Petrochemical	E	E	E	E	E	E	E	E	E	E	E	E	E	E
49	Yanchang Group	E	E	E	E	E	E	E	E	E	E	E	E	E	E
50	Ningxia Baofeng Energy Group	E	E	E	E	E	E	E	E	E	E	E	E	E	E

MINDEROO.ORG