

PLASTICS (POLYMERS) AND SUSTAINABILITY : DEFINING THE PROBLEM

**INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH, KOLKATA
SUSTAINABILITY AND CHEMISTRY: A SYSTEMS APPROACH
CH 5106- LECTURE 7
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PLASTICS AND SUSTAINABILITY

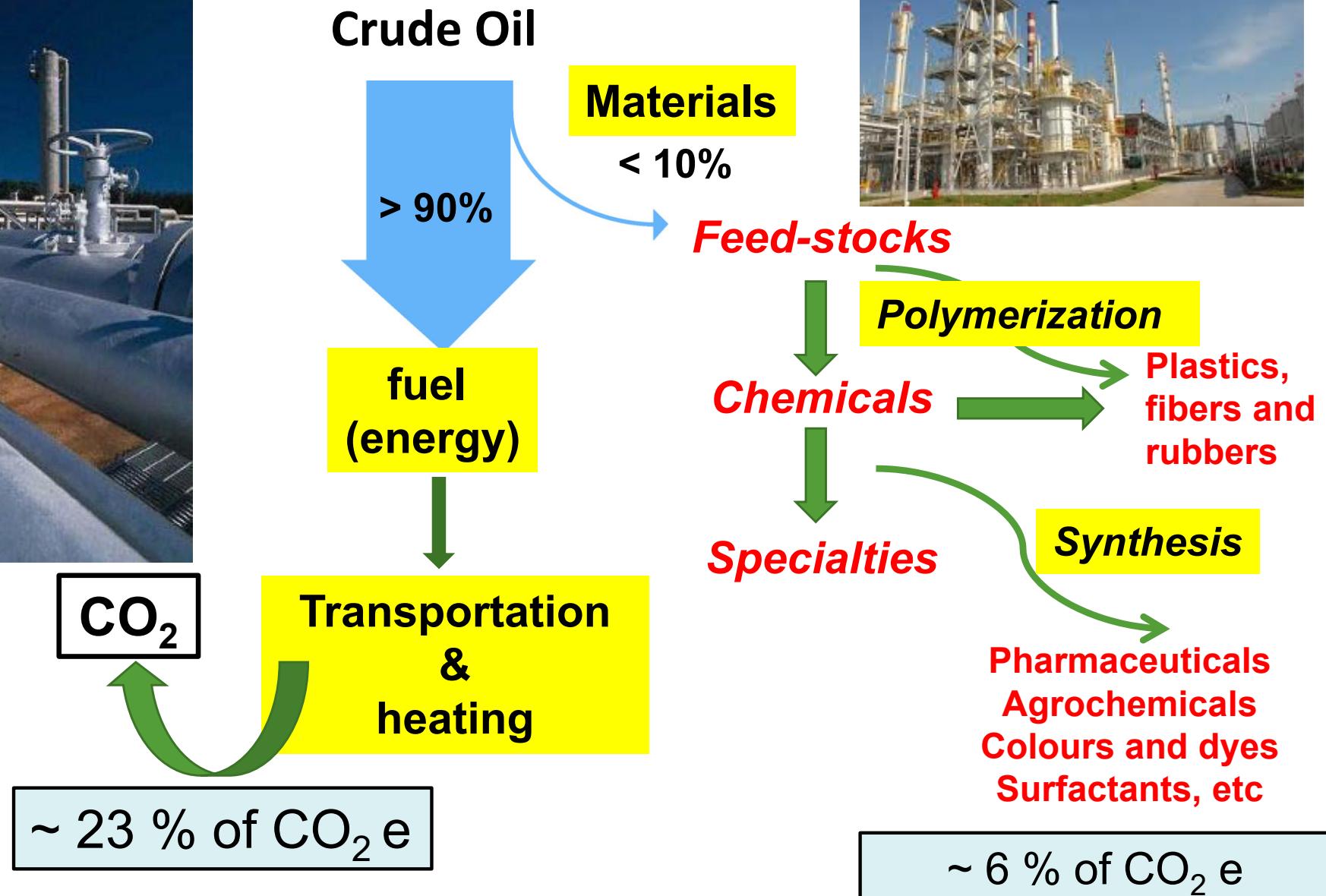
- 1. DEFINING THE PROBLEM**
- 2. SOLUTIONS TO THE PROBLEM**

PLASTICS AND SUSTAINABILITY : DEFINING THE PROBLEM

The Global Concerns

- GHG Emissions (Upstream manufacturing): *Climate Change and net zero-carbon goals*
- End-of-Life Disposal: *Conservation of natural resources and moving from linear to circular practices*
- Chemical Toxicity: Chemicals and additives in plastics: *Impact on human health*
- Micro- and Nano-plastics: *Contaminated food chain and impact on human health*

FOSSIL CARBON : BALANCE OF USE



GHG EMISSIONS FROM THE CHEMICAL INDUSTRY

~ 6 % of the global CO₂ (e) emissions

- ~ 2 % for direct energy needed for chemical transformations (Scope 1 +2 emissions)
- Rest, ~ 4 %, is embedded carbon in materials that we consume in applications, such as, construction, automotive, electronics, homeware, personal care, plastics, paints, pharmaceuticals, agrochemicals etc. (Fixed Carbon)
- However, at the end-of-life, these products end up as waste in our environment. Unless the products containing carbon biodegrade in the natural environment, they tend to persist. Often, they are incinerated when the carbon gets converted to CO₂ again.
- Emissions associated with extraction and production of feedstocks as well as end-of-life disposal constitute Scope 3 emissions

THE ISSUE : BURGEONING PLASTIC WASTE

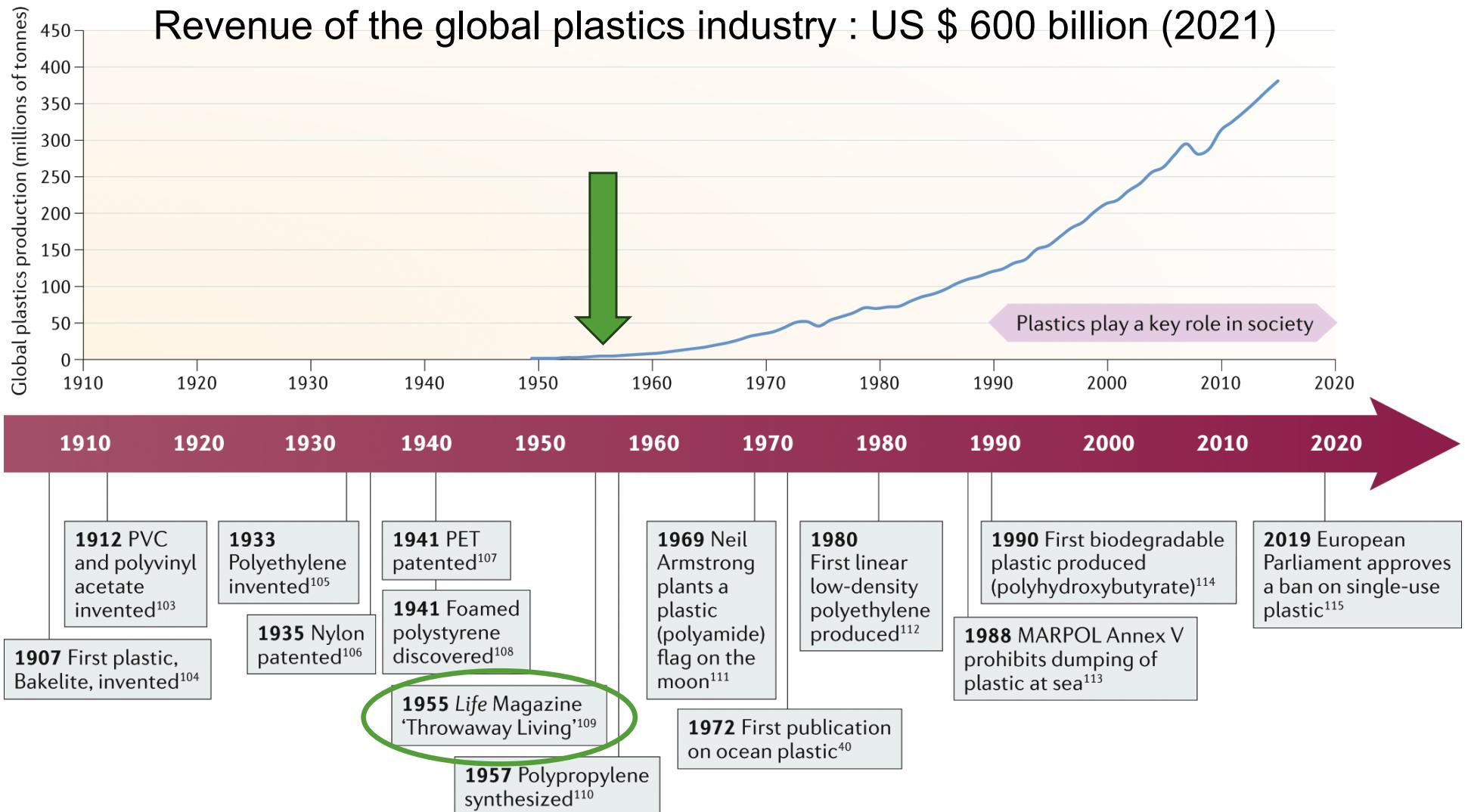
- Ever accumulating plastic wastes in the environment
- Leakages of end-of-use / life packaging products into the air and water bodies
- **Persistence and pervasive** (accumulative and non-biodegradable) in the environment and long term ecological effects



July 3, 2021

Sinha Ray, S. et.al, *Plastic pollution: A perspective on matters arising, challenges and opportunities*, ACS Omega, 2021, 6, 30, 19343 ; Vogt, B.D. et.al, *Why is recycling of postconsumer plastics so challenging*, ACS Appl. Polym. Mater, 2021, 3,9,4325

PLASTIC PRODUCTION HAS HAD A METEORIC GROWTH SINCE 1950s



THE BEGINNING OF THE THROW AWAY SOCIETY



Throwaway Living

DISPOSABLE ITEMS CUT DOWN HOUSEHOLD CHORES

The objects flying through the air in this picture would take 40 hours to clean—except that no housewife need bother. They are all meant to be thrown away after use. Many are new; others, such as paper plates and towels, have been around a long time but are now being made more attractive.

As the caption of the picture, to the left of a New York City Department of Sanitation trash can, are some throwaway roses and flowers, popcorn that pops in its own pan. Moving clockwise around the photograph come assorted from food containers,

a checkered paper napkin, a disposable diaper (seriously suggested as one reason for a rise in the U.S. birth rate) and, behind it, a baby's bib. At top are throwaway sugar shags, foil pans, paper tablecloths, guest towels and a reusuable plate. At right is an all-purpose basket and, scattered throughout the picture, paper cups for beers and lightbeers. In the basket are throwaway draperies, ash trays, garbage bags, hot pads, mats and a feeding dish for dogs. At the base of the basket are two items for hunters to throw away: disposable glove and duck decoys.

PHOTOMONTAGE



DISPOSABLE-PANS eliminate washing of pans after cooking. It consists of one base and forty foil pans to clean out. Price with eight pans is \$2.95.



DISPOSABLE PAN is used under each chair, aluminum shell and wire grill, charcoal to last one hour and charcoal topping for a quick light. It costs 75¢.



Now at a price you can afford for everyday home use!



Kids help themselves; less work for you with a Dixie Cup Dispenser! Now, your sink doesn't fill up with glasses. Instead of bothering you for every drink, the kids use Dixie Cups that can't spread colds. No broken glass, either. Refills everywhere. Get a Dixie Cup Dispenser!

Advertisements in the sixties extolling the virtues of disposable kitchen items



Distinctively different, these new Dixie Cups. Gaily colored, they add a perky touch to any party and they'll hold their drinks longer than any other cup. The gleaming Holders in gold-colored metallized finish serve as a cup base and reusable coaster.

Attractively packaged refills stimulate continuing use.



Floods are a very real danger to each of us in a time of disaster.

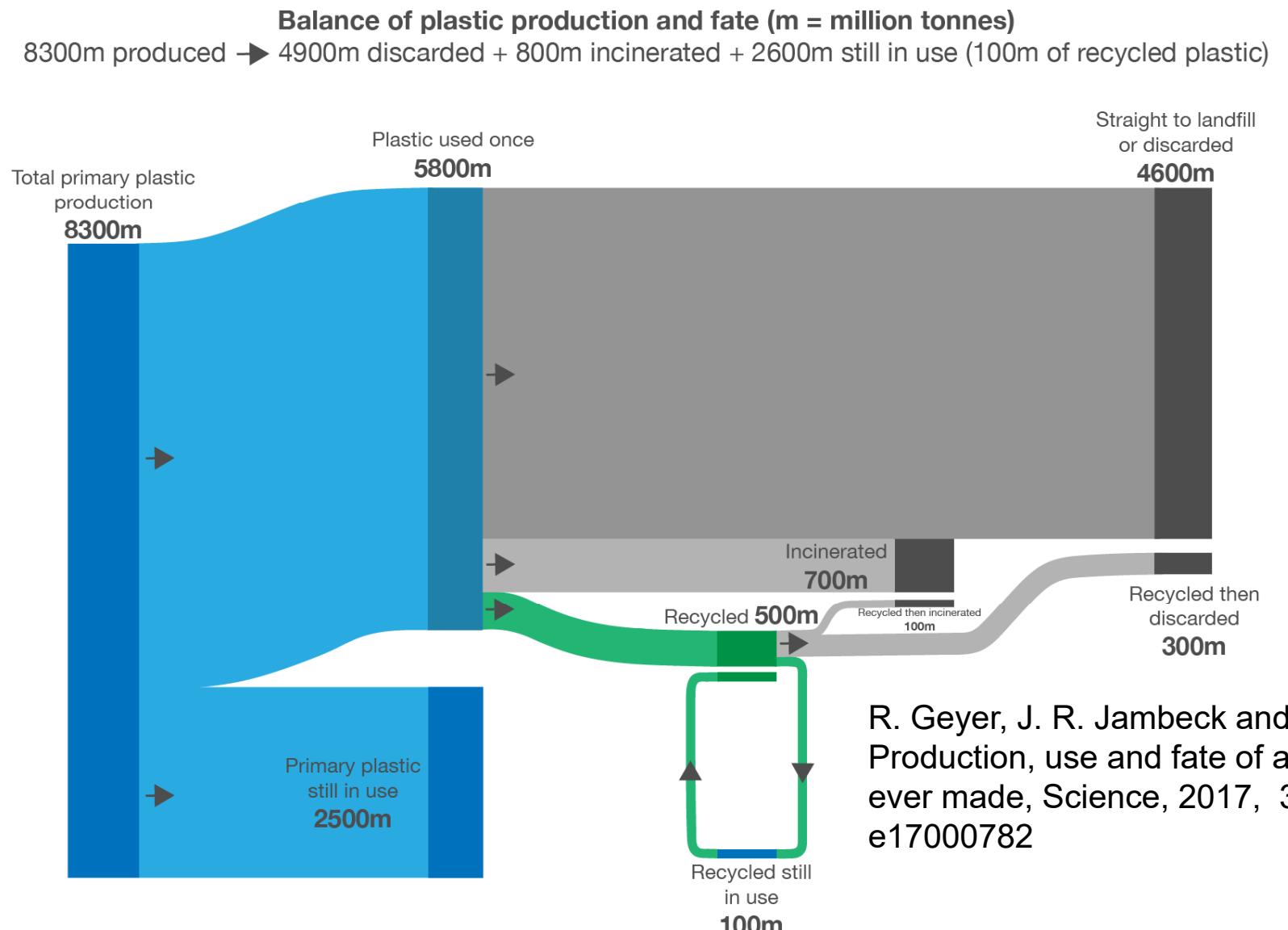
Disposing facilities are non-existent, or dangerous at best. With Dixie Cups, we can keep clean after getting out of flood waters. Used but once Dixie are proven clean, reusable.

Life Magazine, August 1, 1955

Global plastic production and its fate (1950-2015)

Global production of polymer resins, synthetic fibres and additives, and its journey through to its ultimate fate (still in use, recycled, incinerated or discarded).

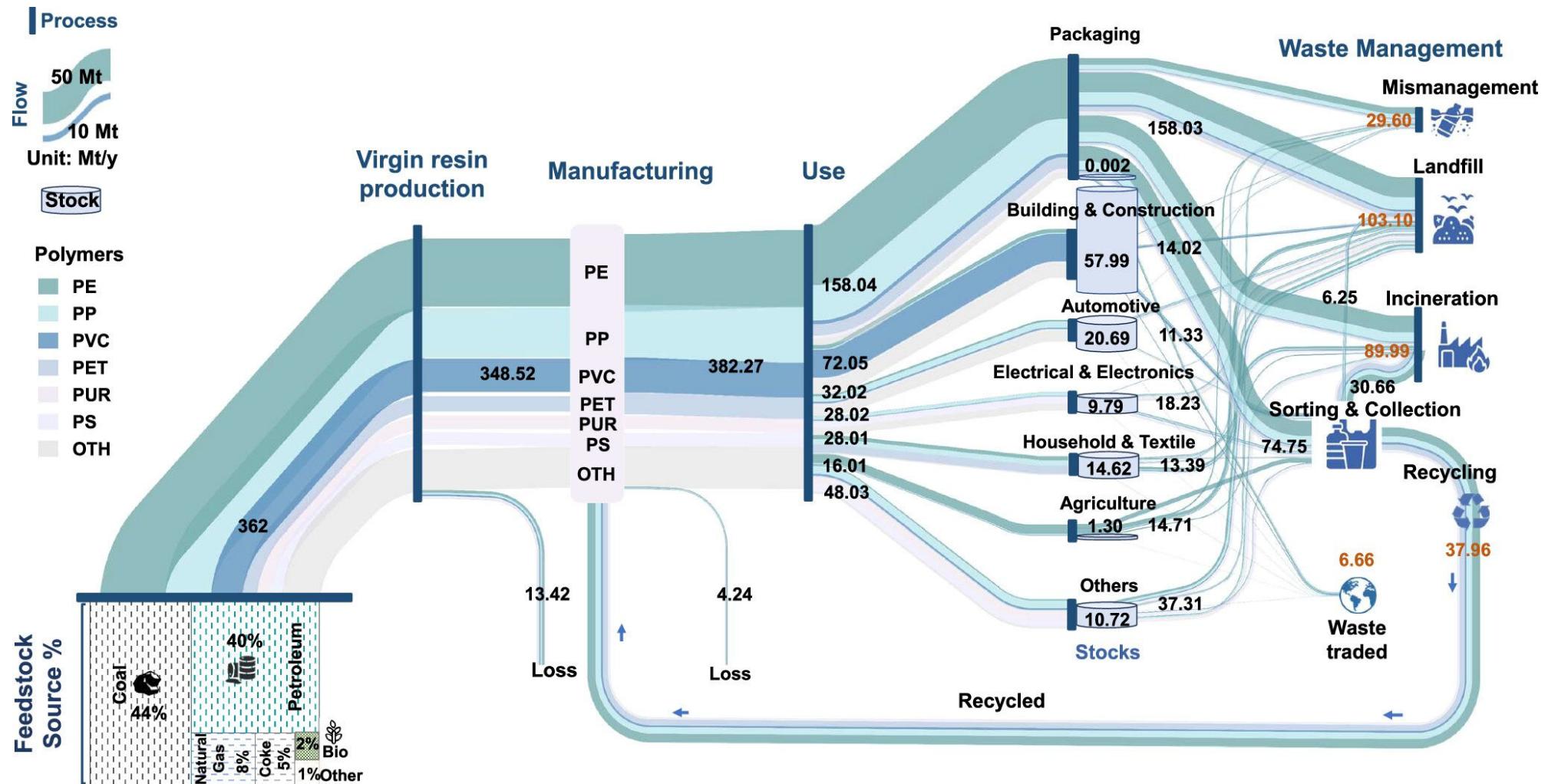
Figures below represent the cumulative mass of plastics over the period 1950-2015, measured in million tonnes.



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

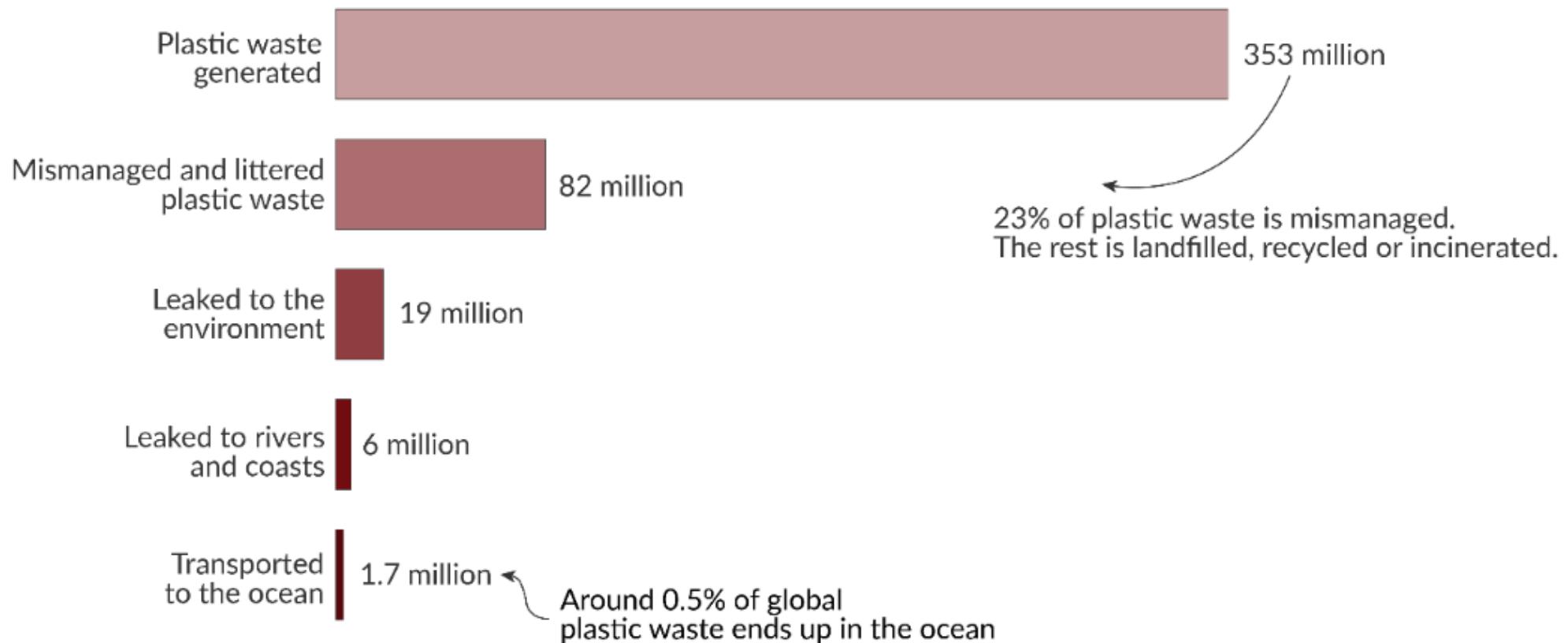
This is a visualization from OurWorldInData.org, where you find data and research on how the world is changing. Licensed under CC-BY-SA by Hannah Ritchie and Max Roser (2018).

GLOBAL PLASTICS SUPPLY CHAIN, 2022



Around 0.5% of plastic waste ends up in the ocean

The pathway of global plastic waste to the ocean. Each stage of the chain is measured in million tonnes of plastic per year.

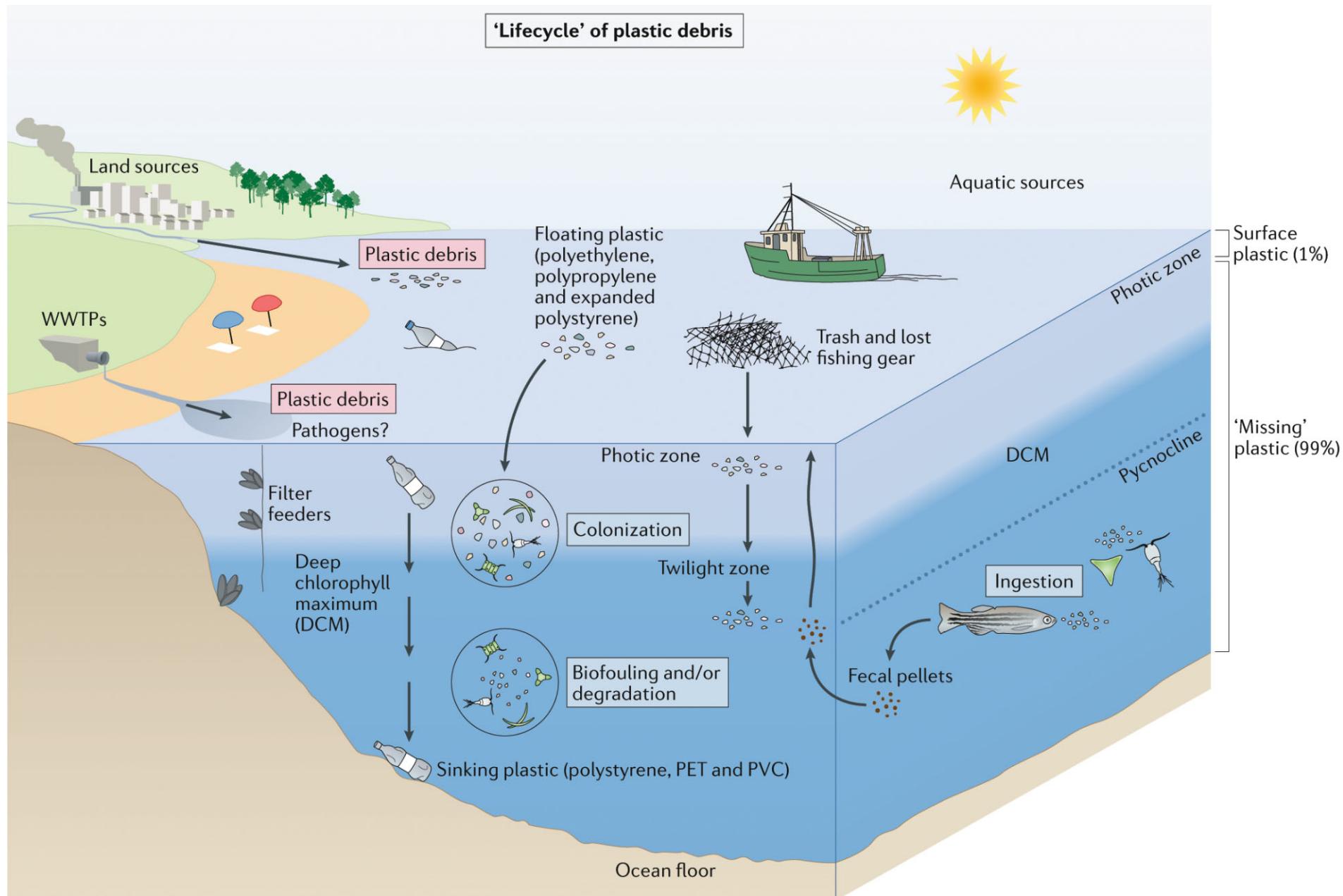


Data source: OECD Global Plastic Outlook (2022).

[OurWorldInData.org](https://ourworldindata.org) – Research and data to make progress against the world's largest problems.

Licensed under CC-BY by the author Hannah Ritchie.

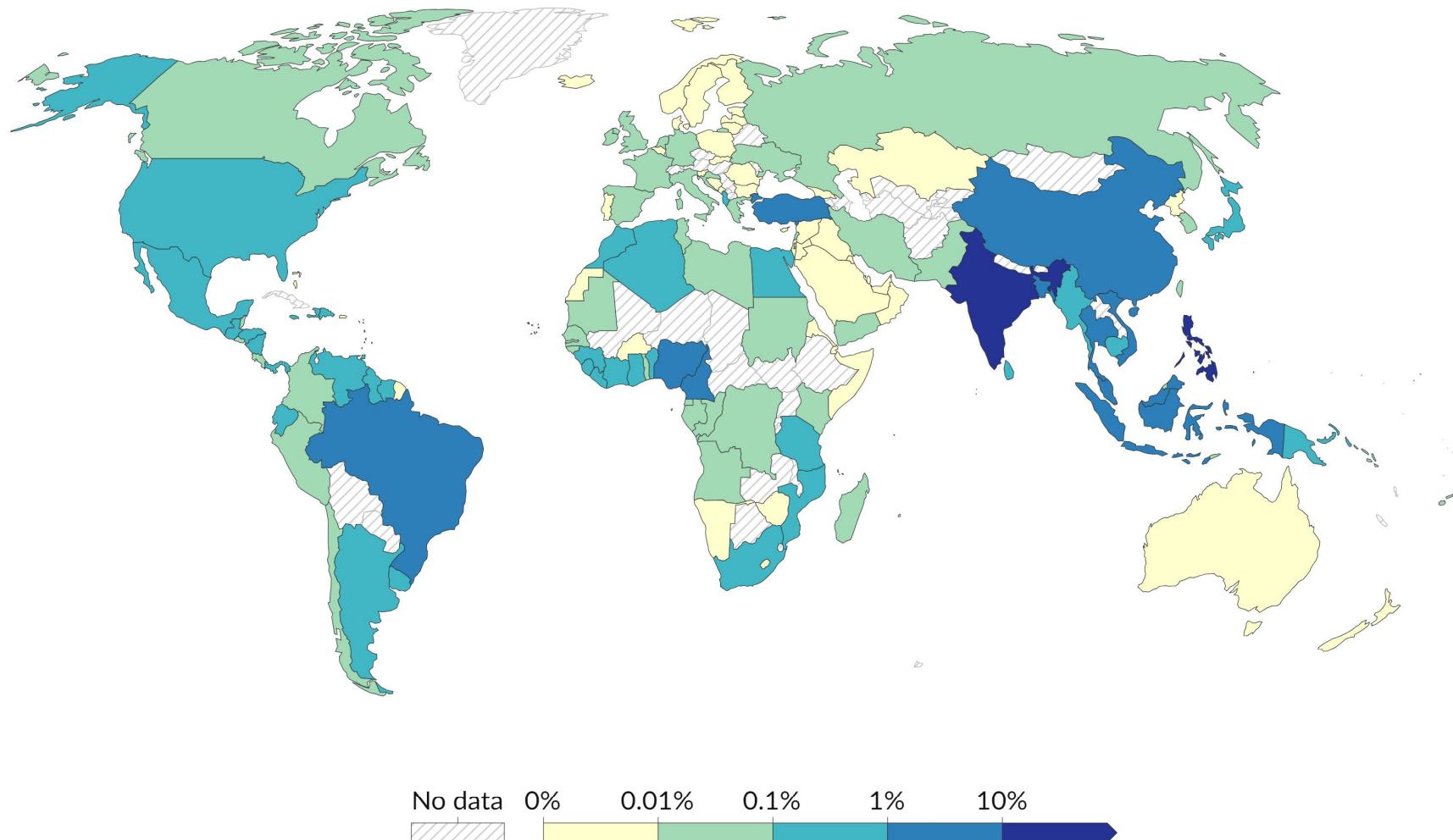
ECOLOGY OF THE PLASTISPHERE



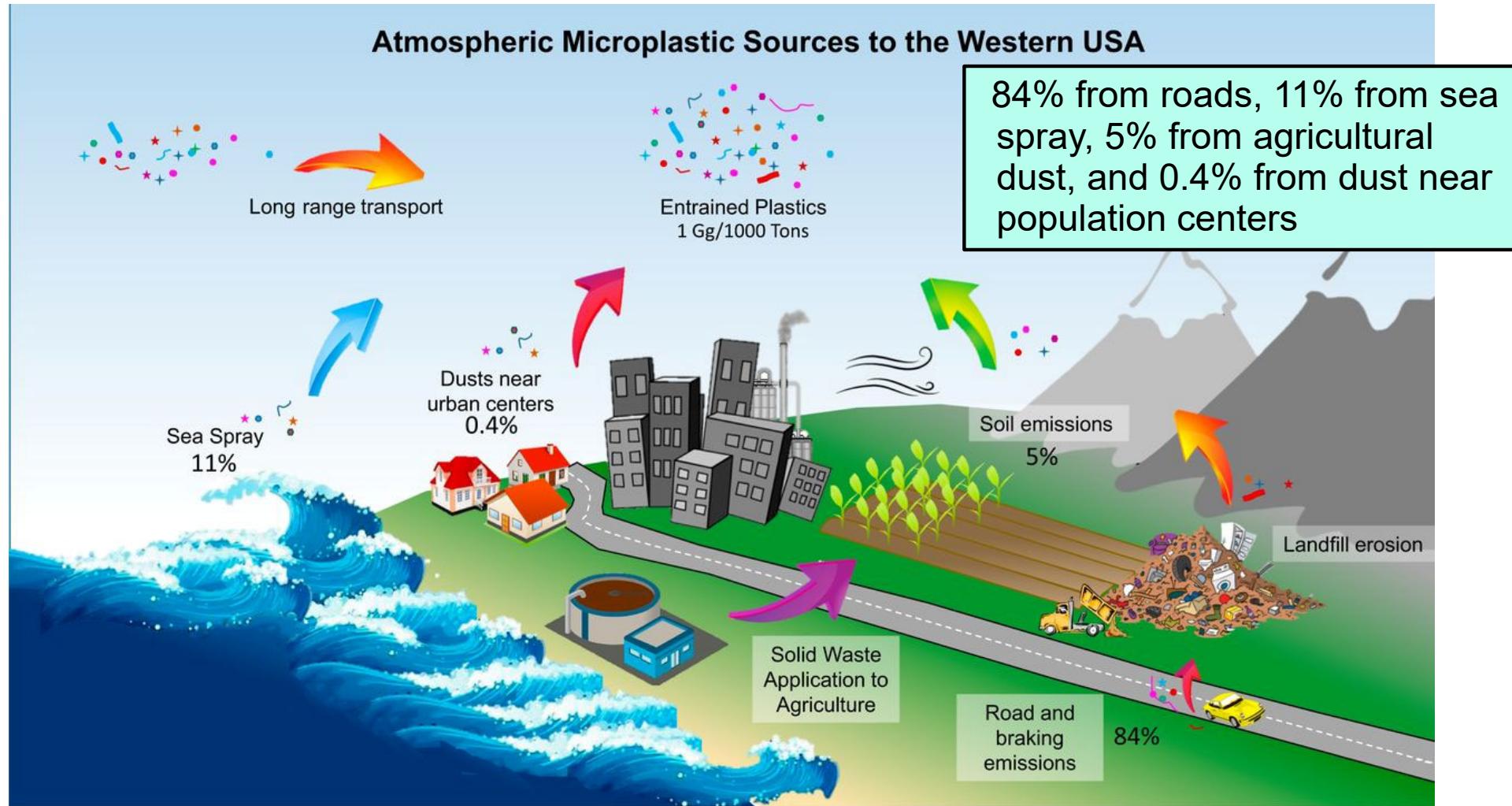
Nature Reviews Microbiology volume 18, pages 139–151 (2020)

Share of global plastic waste emitted to the ocean, 2019

Annual estimate of plastic emissions. A country's total does not include waste that is exported overseas, which may be at higher risk of entering the ocean.



MICRO-PLASTICS AS AN ATMOSPHERIC POLLUTANT



Micro-plastic particles and fibers generated from the breakdown of mismanaged waste are now so prevalent that they cycle through the earth in a manner akin to global biogeochemical cycles



The date when the amount of plastic waste outweighs the world's ability to manage it

<https://plasticovershoot.earth/>

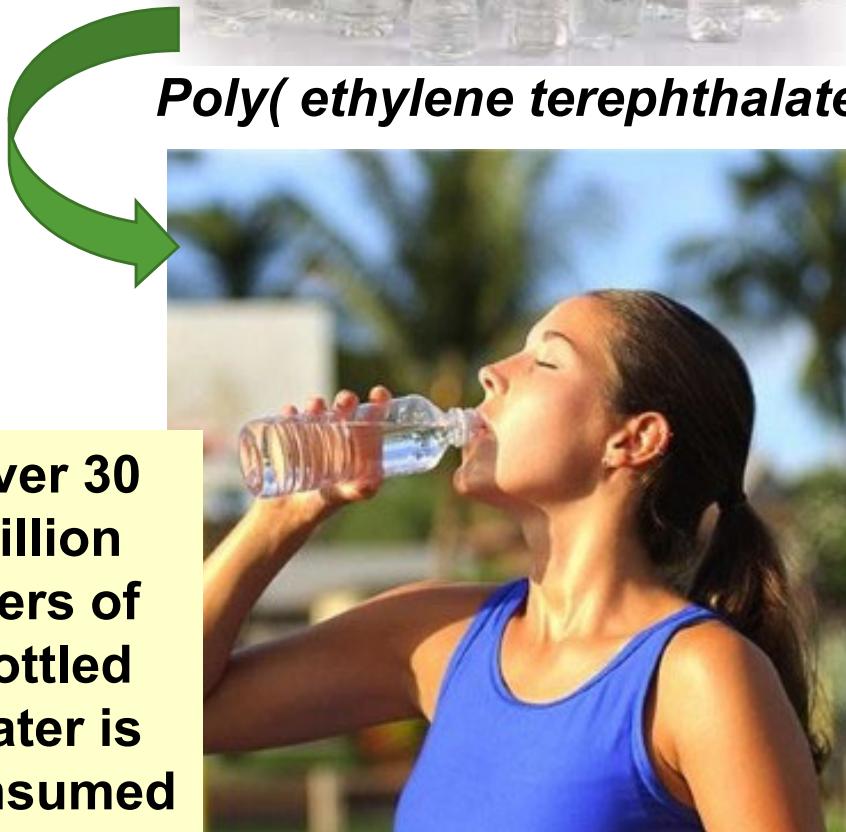
THE PROBLEM

- It takes 1 second to make a plastic bag that is used for 20 minutes on average before being thrown away. It then takes several hundred years for the bag to decompose if it is discarded in the environment
- We are using too much plastics for applications where it was not clearly intended; unsustainable consumption is the problem !
- The success of plastics (lightweight, diversity of properties, functionalities, aesthetics, manufacturing scale, inexpensive) has become its nemesis

500
Billion
bottles
consumed



Poly(ethylene terephthalate)



Every second we
throw away about
1500 bottles



What is
the
solution ?



Over 30
billion
liters of
bottled
water is
consumed
annually

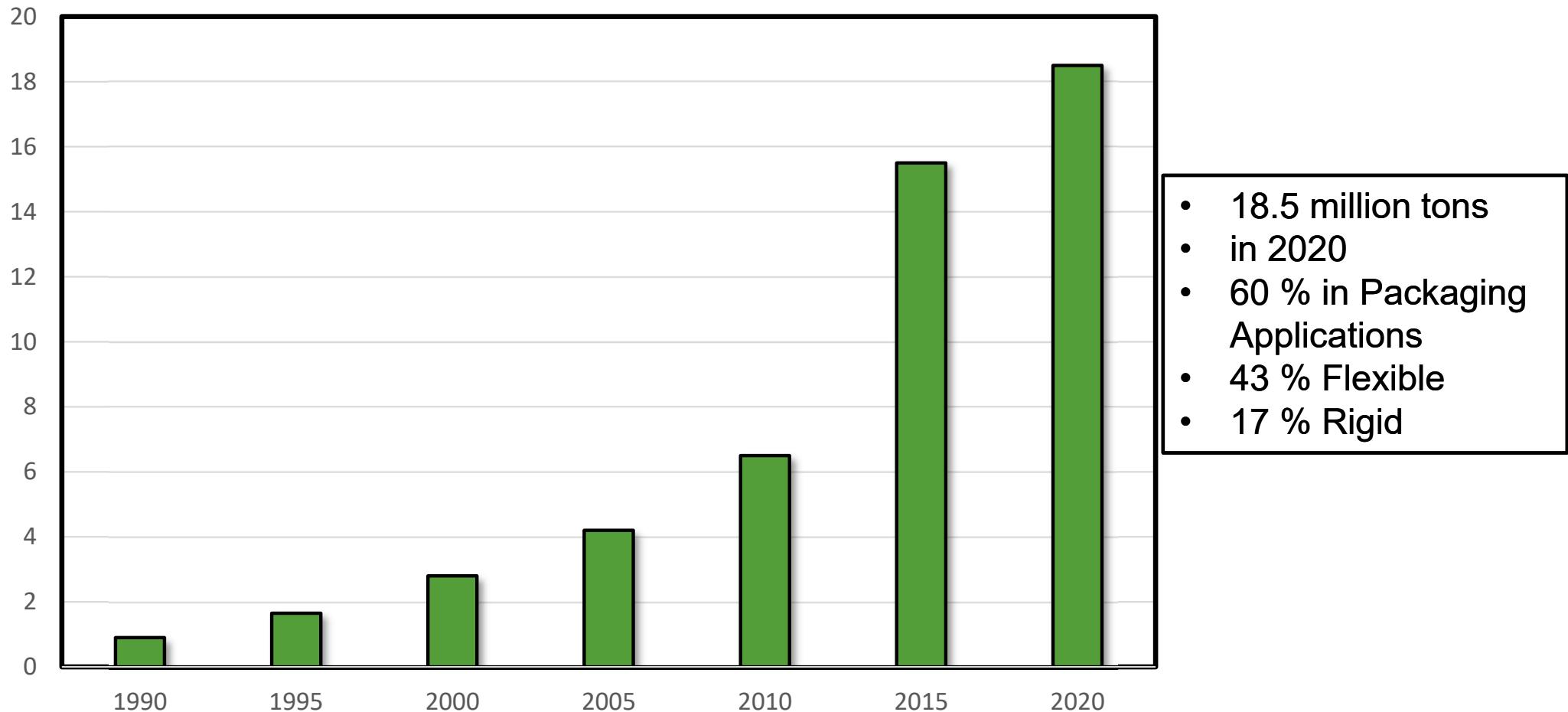
We produce 20,000 PET bottles every second

PLASTICS SUSTAINABILITY PROBLEM: INSATIABLE CONSUMPTION

- To date we have produced, consumed and discarded over **8 billion metric tons** of plastics; 60 % have been landfilled, 30 % are still in use and 10 % incinerated (Sci. Adv., 10.1126/sciadv.1700782, 2017)
- Humans consume 30 kg of packaging material per person per year, most of which ends up as waste.
- We discard about **one trillion** single use plastic bags each year; generate **two billion tons** per annum of municipal waste; **Five million tons** of plastics find their way into our oceans
- Estimated generation of plastic waste by 2050 : 700 million tons
- Plastics entering the aquatic system by 2030 : 50 million tons

Evaluating scenarios towards zero plastic pollution, W. W. W. Lau et al., Science, 2020, 369, 1455; Predicted growth in plastics waste far exceeds efforts to mitigate plastics pollution, S.B. Borelle, et al., Science, 2020, 369, 1515

GROWTH OF INDIA'S PLASTIC PRODUCTION



INDIA'S SHARE OF PLASTICS WASTE GENERATION

- With 20% of world's share, India is biggest generator of plastic waste
- India's official waste generation rate is approximately 120 grams per person per day (maybe an underestimate)

Country	Plastics waste, million tons per annum
India	9.3
Nigeria	3.5
Indonesia	3.4

<https://www.thehindu.com/sci-tech/energy-and-environment/india-is-the-worlds-largest-plastic-polluter-according-to-new-study/article68621895.ece>

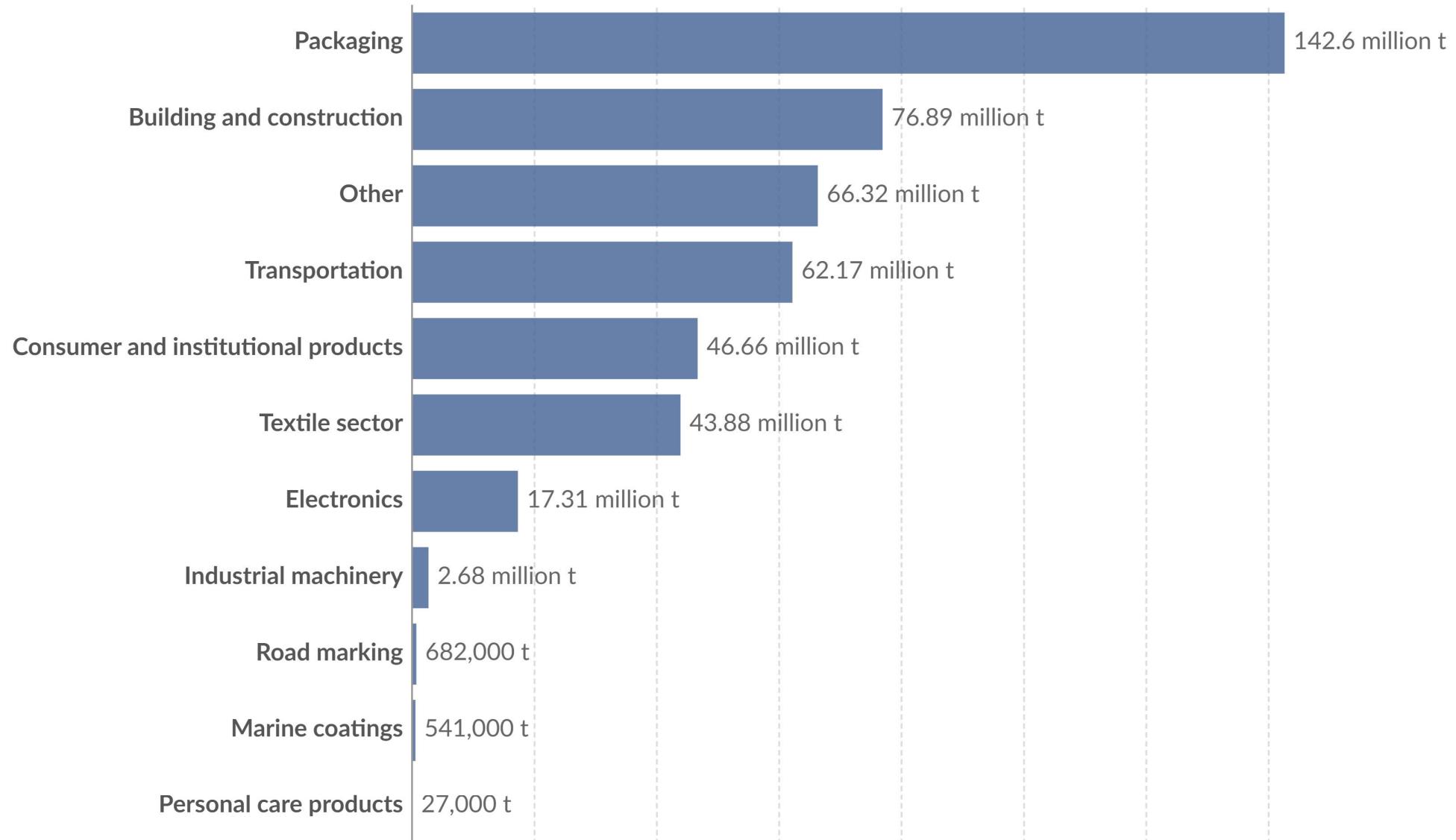
CIRCULARITY IN PLASTICS

Four Key Sectors

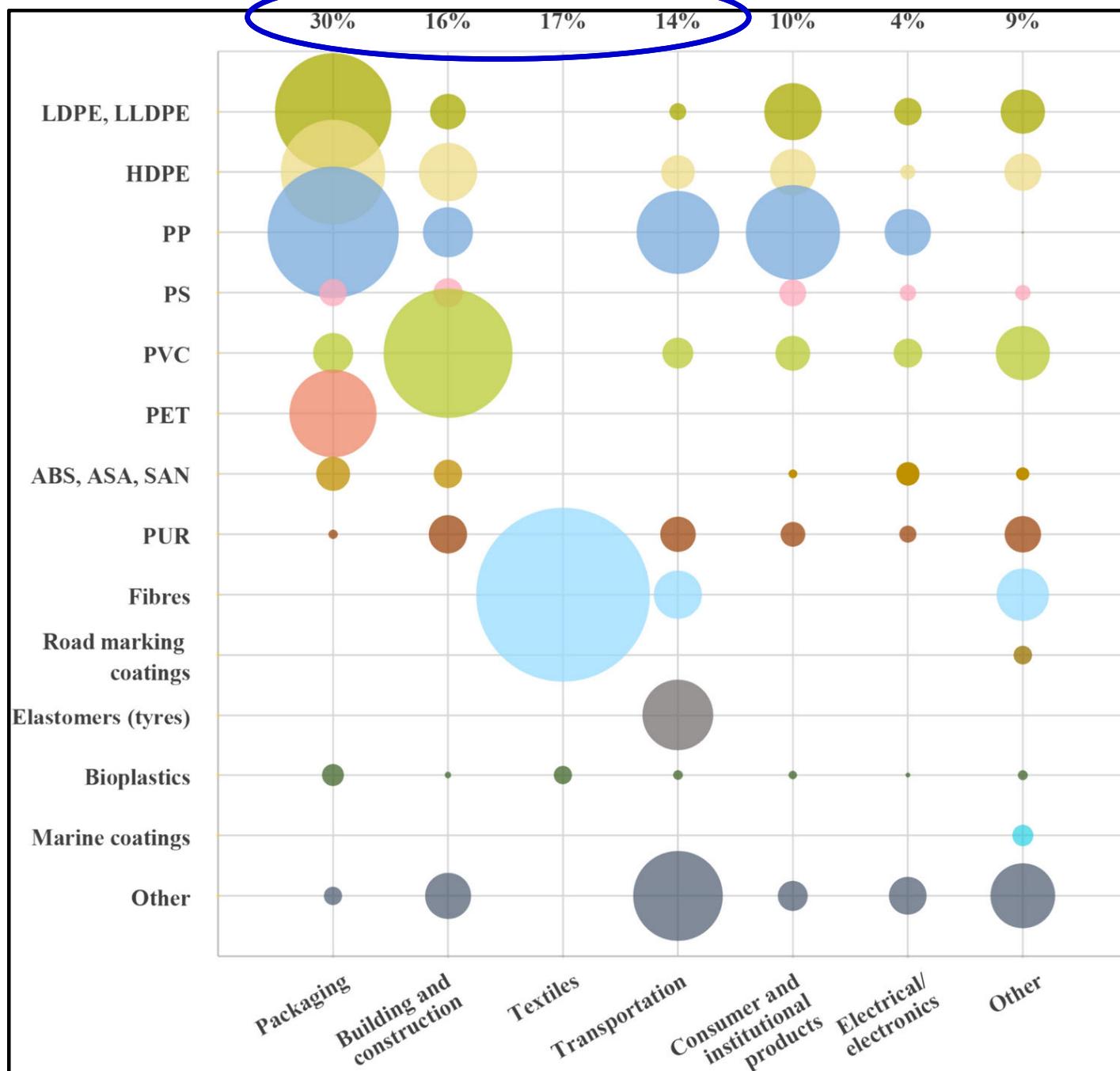
- **Packaging Materials**
- Construction Materials
- Automobiles
- Textiles, Apparels and Shoes

Annual global plastic waste generation by industrial sector, 2019

Global plastic waste generation is measured in tonnes per year.



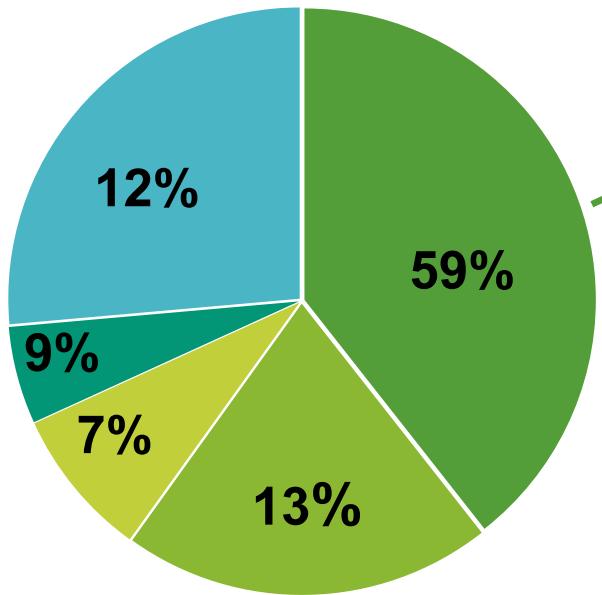
DISTRIBUTIONS OF PLASTICS BY END-USE SECTORS IN INDIA, 2018–19



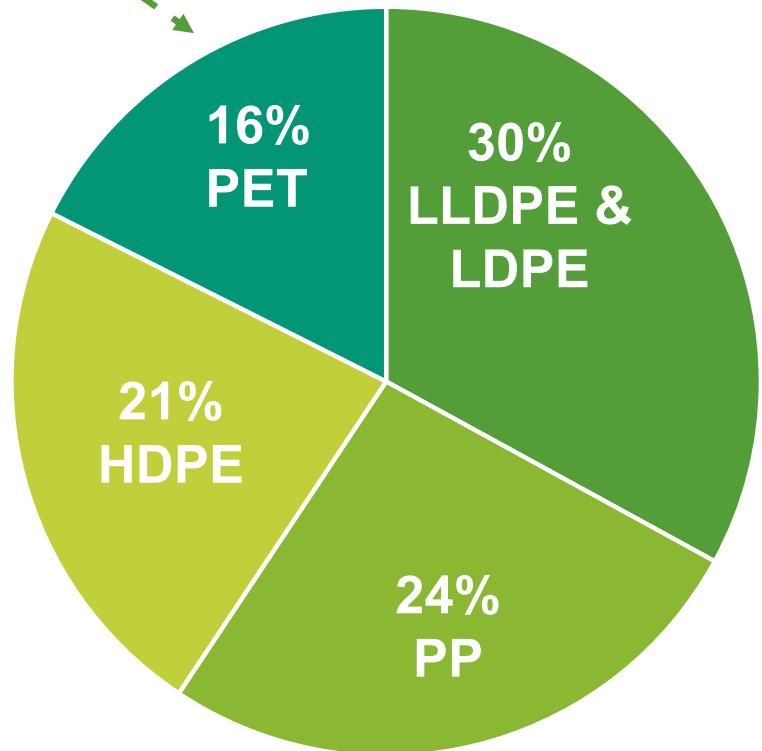
N. Emami, et.al., J.
Mater. Cycles Waste
Manag., 2024, 26,
3584

PLASTICS IN PACKAGING : GROWTH AND TYPES

Global production of plastics by 2060 : 1.5 billion tons from the present ~400 million tons



- Packaging
- Building and Construction
- Automotive
- Engineering
- Others



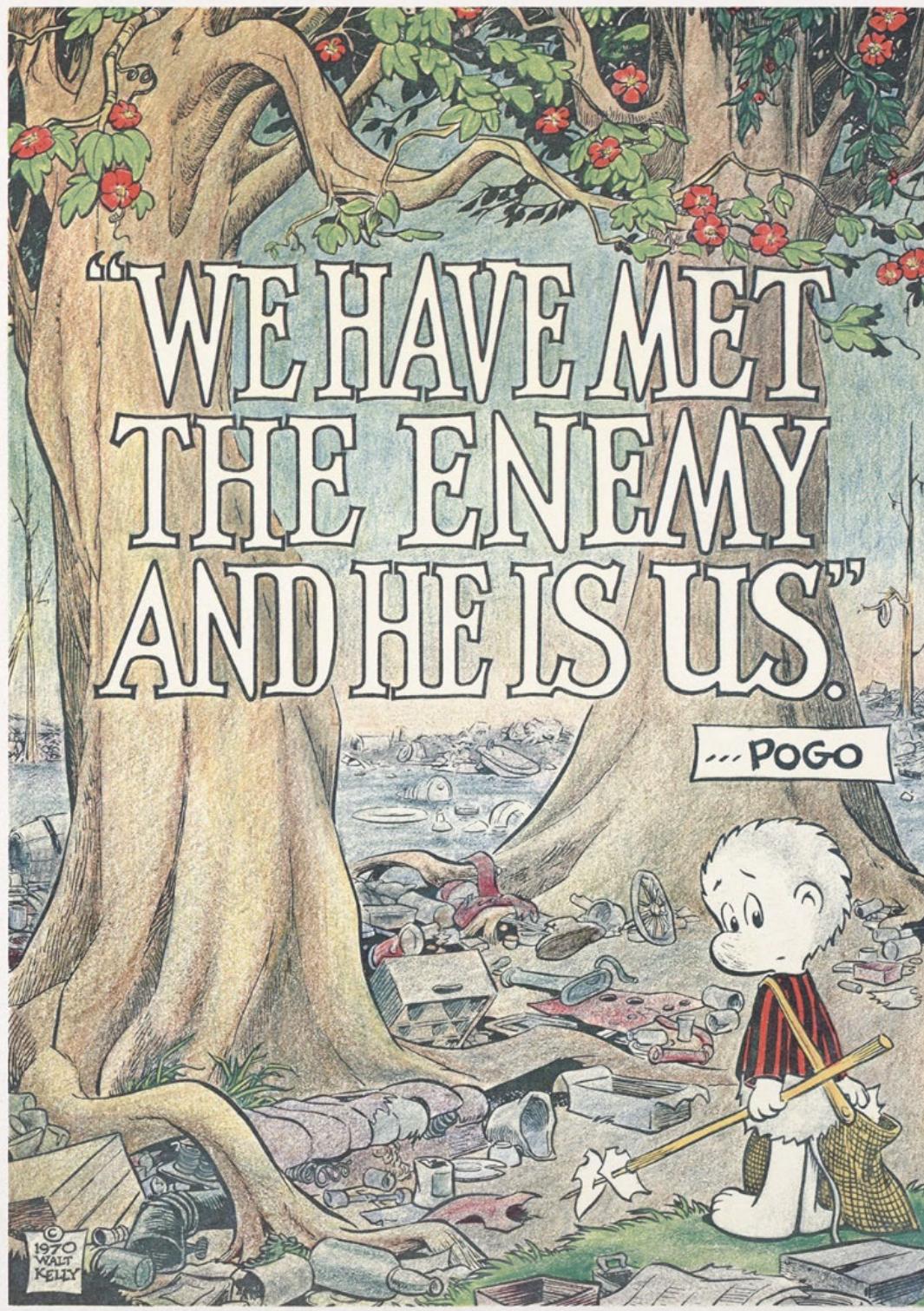
Challenge

How do we make ***polyolefins*** and ***PET*** packaging materials sustainable and circular?

"WE HAVE MET
THE ENEMY
AND HE IS US"

...POGO

©
1970
WALT
KELLY



WHAT ARE THE SOLUTIONS ?

How do we make the use of plastics circular?

- Mechanical Recycling
- Chemical Recycling
- Biodegradable / Compostable Plastics
- Waste plastics to energy
- Incineration

targets
zero-waste
cascade-circles
renewable-materials
eco-design
LCA
multiple-circles
inner-circles
products

action-plan
research
eco-innovation
renewable-energy
EMAS
production-processes
ISO



THANK YOU

