Plastic - Global menace or miracle material?

Pearl Ryall – WEA tutor

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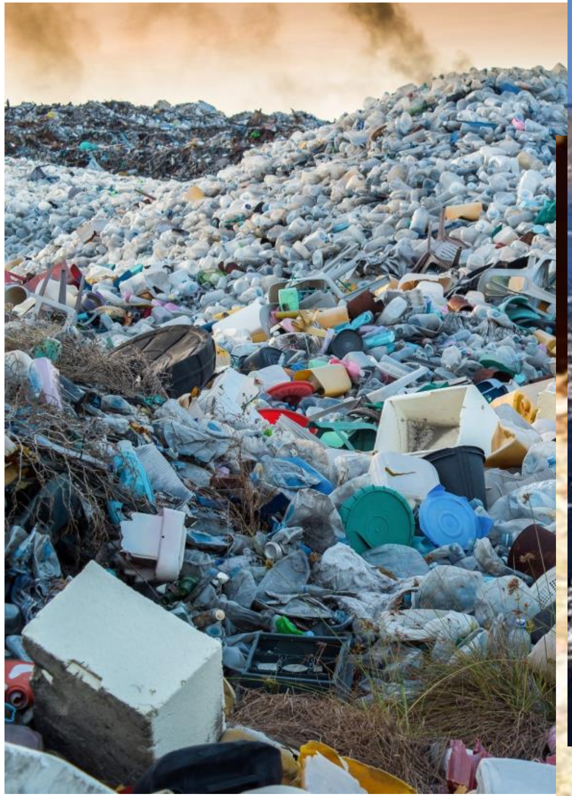
Images of plastic

Images of plastic



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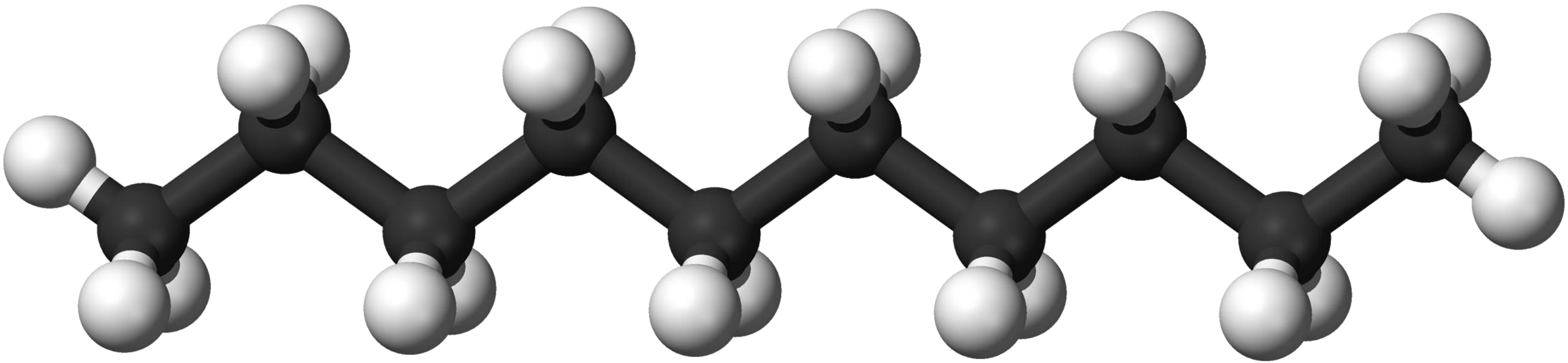
Polymer

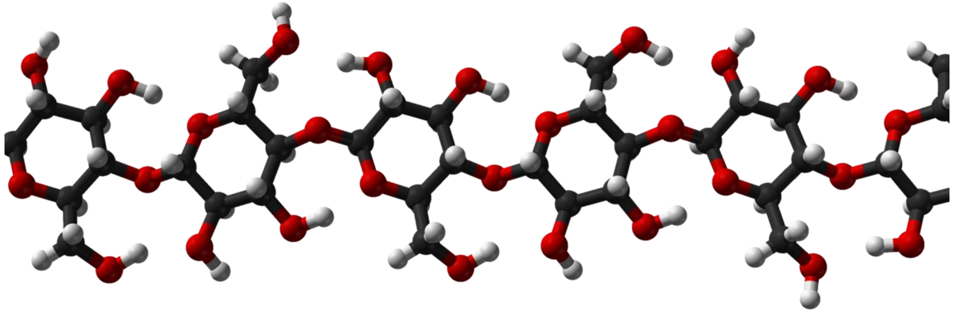
- From the Greek: *polus* = many and *meros* = parts
- The carbon atom can form long chain molecules which are the basis of life on earth

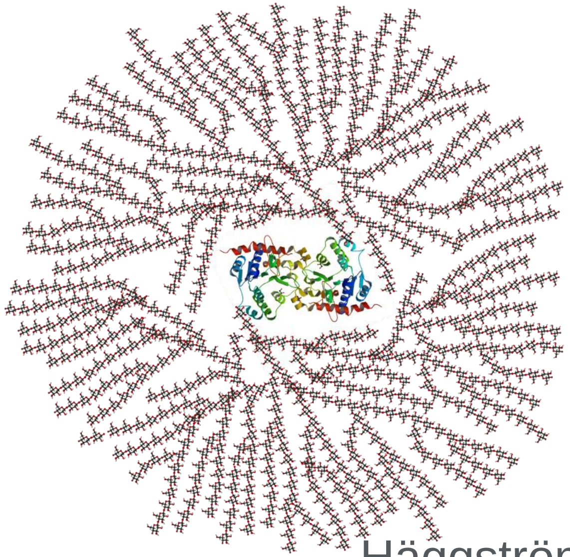


Bio Polymers

Polysaccharides – Structure and energy

- Cellulose
    - Plant cell walls
- Chitin
    - Exo skeletons
- Starch
    - Amylose - plants
- Glycogen
    - Animal starch





Häggström, Mikael (2014)

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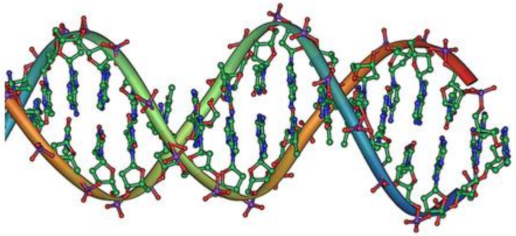
Bio Polymers

Polypeptides

- Proteins – long chains of amino acids (polyamides)

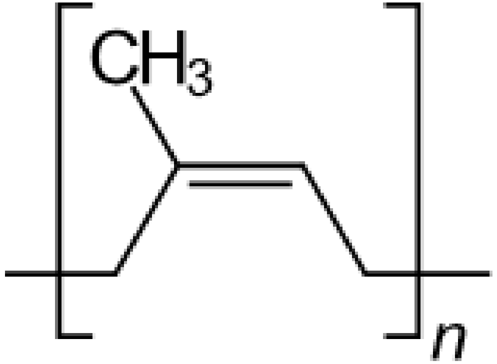
Polynucleotides

- RNA and DNA



Natural rubber

- Polyisoprene



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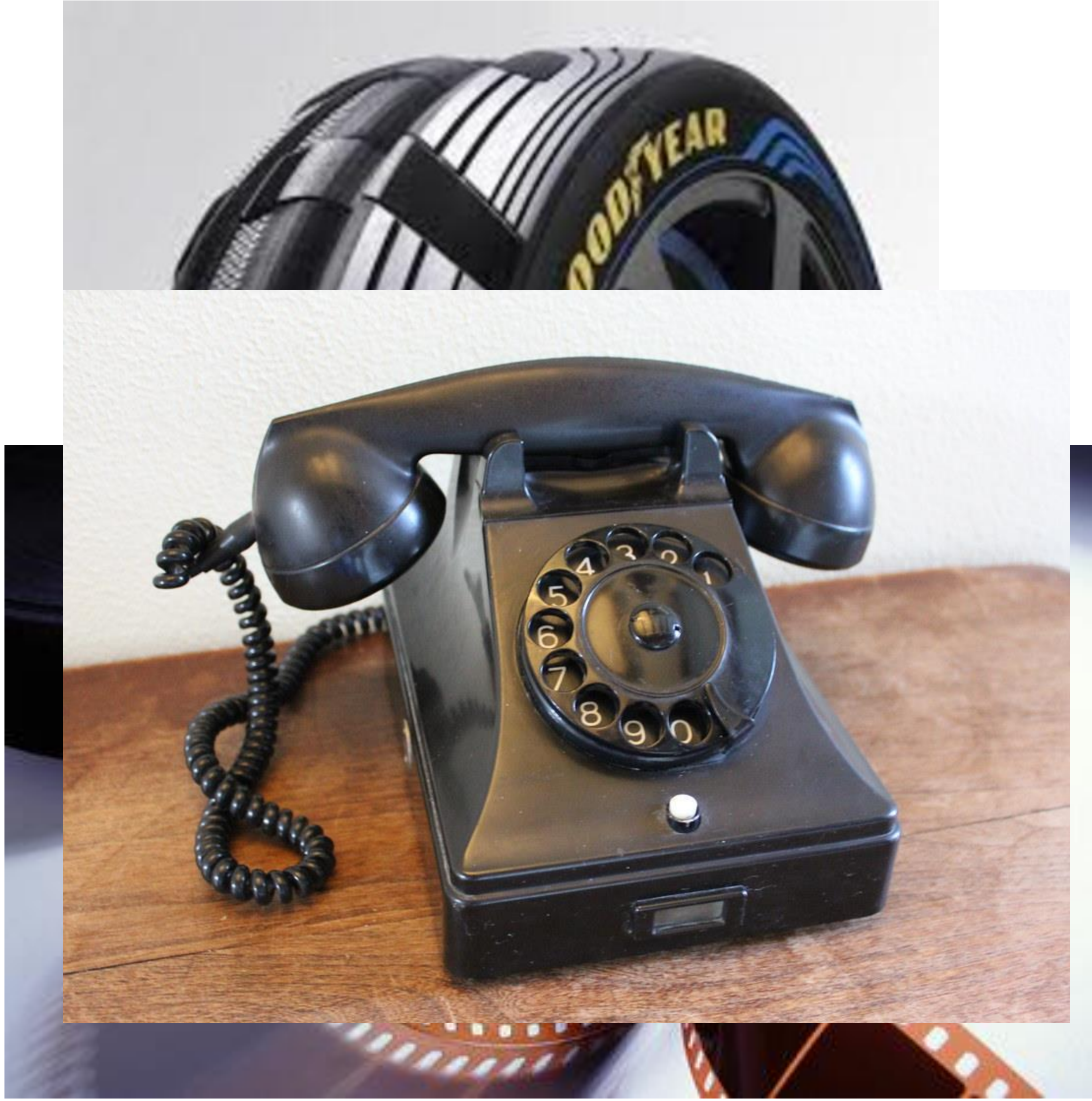
Synthetic Polymers

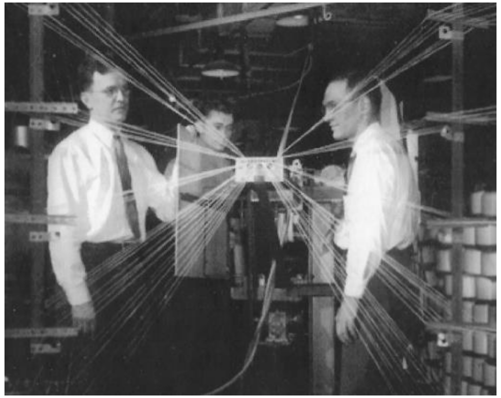
Early plastics were modified natural polymers

- Vulcanised rubber
- Celluloid

The first fully synthetic polymer was Bakelite in 1907



Early thermoplastics



Nylon (DuPont)

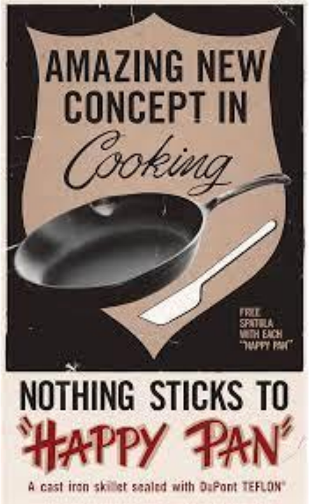
1935

Polyethylene (ICI)

1937

Teflon (DuPont)

1938



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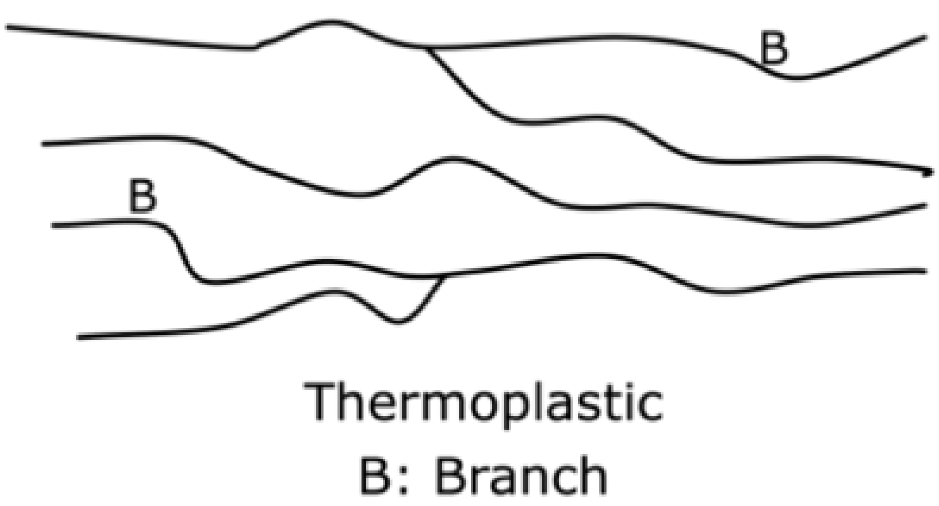
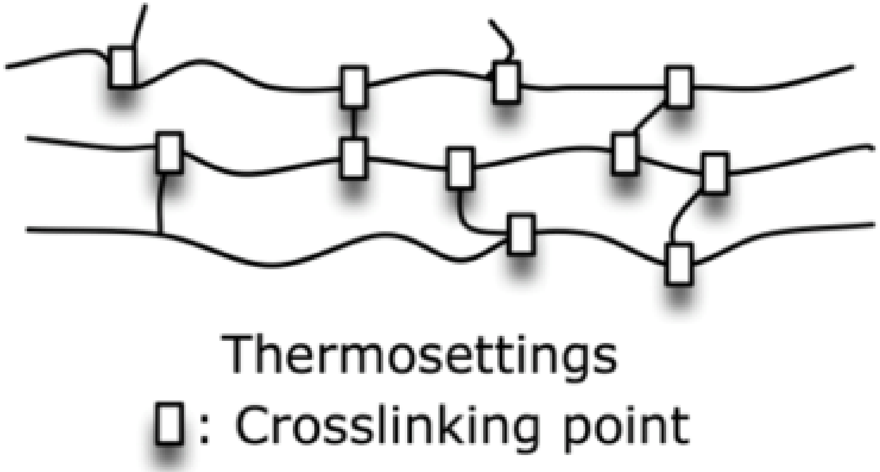
Thermoplastic	Thermoset
Fibre, film, 3D shapes	3D shapes and sheet
Can be molten and reused	Chemical reaction during forming
High elasticity and strength	Structural integrity and heat resistance
Deform at high temperature	Degrade before melting





Paula Ferreira

Common thermoplastics

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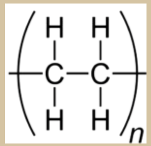
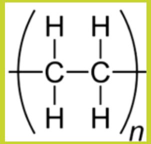
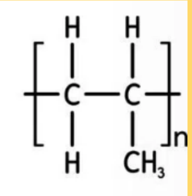
Polyolefins

High density HDPE Linear 	Excellent tensile strength and abrasion resistance Chemical resistance Highly recyclable Jerricans, household, play		02 HDPE
Low density LDPE Branched 	Tough and weatherproof Cheap – most widely used Low melting point Bottles, film, toys		04 LDPE
PP Low density Linear 	Dimensionally stable High melting point Degrades under UV – harder to recycle Fibre, film, mouldings		05 PP

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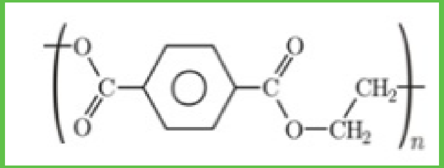
Polyesters and polyamides

Polyester
PET
Polyethylene terephthalate

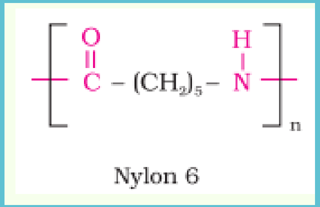


Semi crystalline

Gas and moisture barrier
Shatter resistant
Shrink resistant fibre
Recyclable

01 PET

Polyamide
Nylon 6; 6,6; 6,10



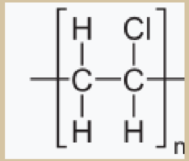
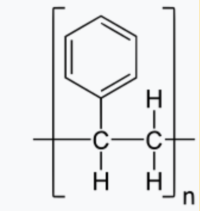
Semi crystalline

Tough
Takes colour
Waterproof
Heat resistant
Low gas permeability

07 O

Miscellaneous

Versatile polymers

Polyvinyl Chloride PVC Plasticised or rigid  Linear, high density	Flexible and transparent film Gas and moisture barrier UV and chemical resistant UPVC tough and impact resistant and readily recyclable Monomer is carcinogenic	  	
Polystyrene General purpose GPPS High impact HIPS Expanded EPS 	GPPS is hard, brittle and transparent but cheap HIPS is copolymerised with rubber and is rigid and translucent EPS is 89% air and is a thermal insulator and cushioning material	  	

Speciality plastics

ABS	Acrylonitrile butadiene styrene	Telephone handsets, rigid luggage, computer housings
EVA	Ethylene vinyl acetate	Bottle teats, flexible tubing, vacuum cleaner hoses
PTFE	Polytetrafluoroethylene	Coating for non-stick, gaskets, medical and electrical, thread seal tape
PB-1	Polybutene-1	Peelable seal films for cartons and deli products such as cold meat
PC	Polycarbonate	Glass replacement – roofing, glazing etc
PVOH	Polyvinyl alcohol	Layer in food packaging, contact lens solution
TPE	Thermoplastic elastomers	Trainer soles, gaskets, skateboard wheels
MF	Melamines	Dinnerware, heavy duty electrical equipment, toilet seats

Summary – miracle materials

Packaging

- Prevents food waste
- Extends shelf life
- Ensures food safety
- Easy to transport
- Domestic, industrial and medical

Medical

- Tubing – pumps, catheters, oxygen delivery
- Protection – masks, gloves, aprons
- Equipment – syringes, thermometers, blood and IV bags

Textiles

- Waterproofs
- Clothing
- Shoes
- Home furnishing

Automotive

- Bumpers
- Seats and fabrics
- Seat belts
- Interior panels
- Mechanical parts

Engineering and construction

- Appliance housing
- Windows and doors
- Cables and pipes
- Gears and mechanical components

Agriculture

- Mulch bags
- Crates and storage
- Irrigation

Impacts of plastic pollution

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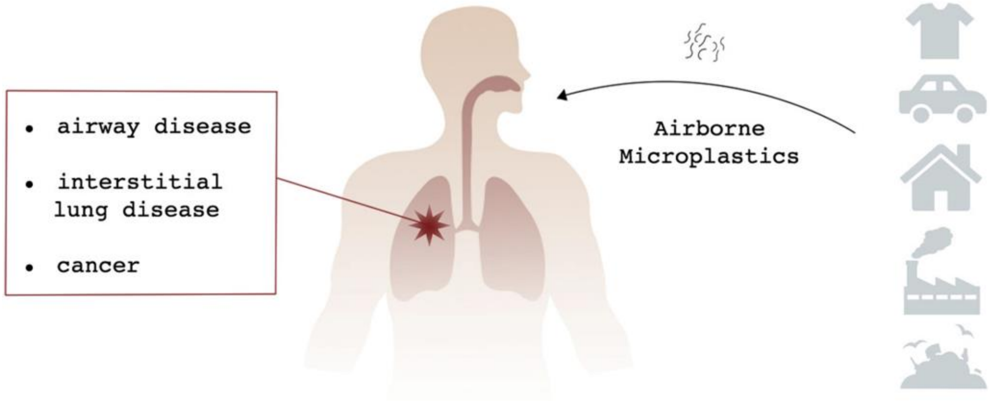
Hazards of plastic waste

- **Entanglement**
  - Particularly sea creatures caught in rope and netting
  - 344 species recorded to date including all marine turtles and 25% of sea birds
- **Ingestion**
  - Starvation due to feeling of a full stomach
  - Perforation of the gut
  - Endocrine disruption
  - 194 plastic fragments found in the stomach of this Great Shearwater

In a 2021 study, scientists found 194 plastic fragments in the stomach of this great shearwater (*Ardenna gravis*). Yamashita et al., 2021, CC BY-ND

Hazards of plastic waste

- **Habitat destruction**
  - Leaching of plasticisers and monomers
  - Displacement by degradation of environment and attraction of animals to non-viable habitats such as landfill sites
  - Microplastics (<5mm) from breakdown of larger pieces of plastic can act as a carrier for organic contaminants and toxins
- **Inhalation**
  - Small particles (<0.01mm) from fibre and tyre shedding can travel deep into the lungs and cause disease



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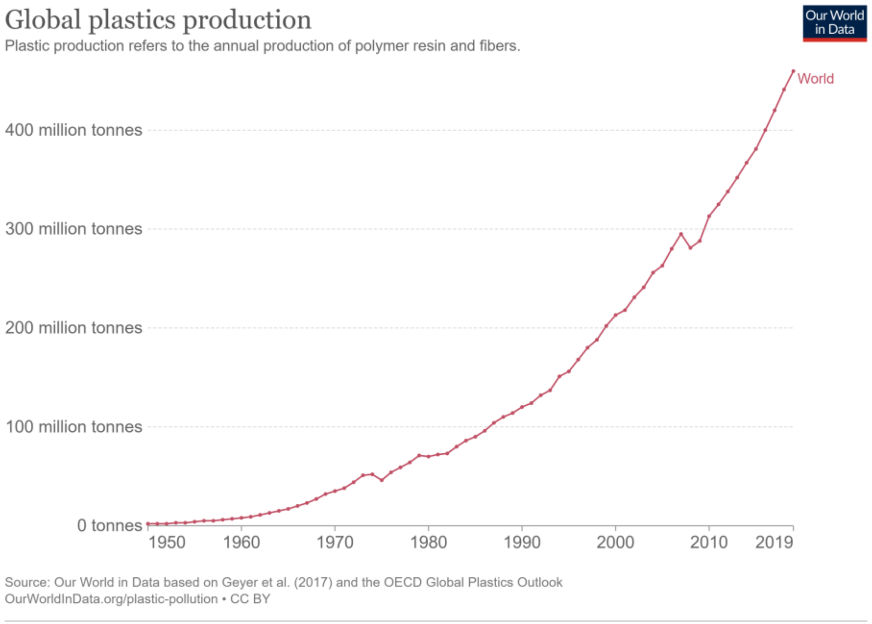
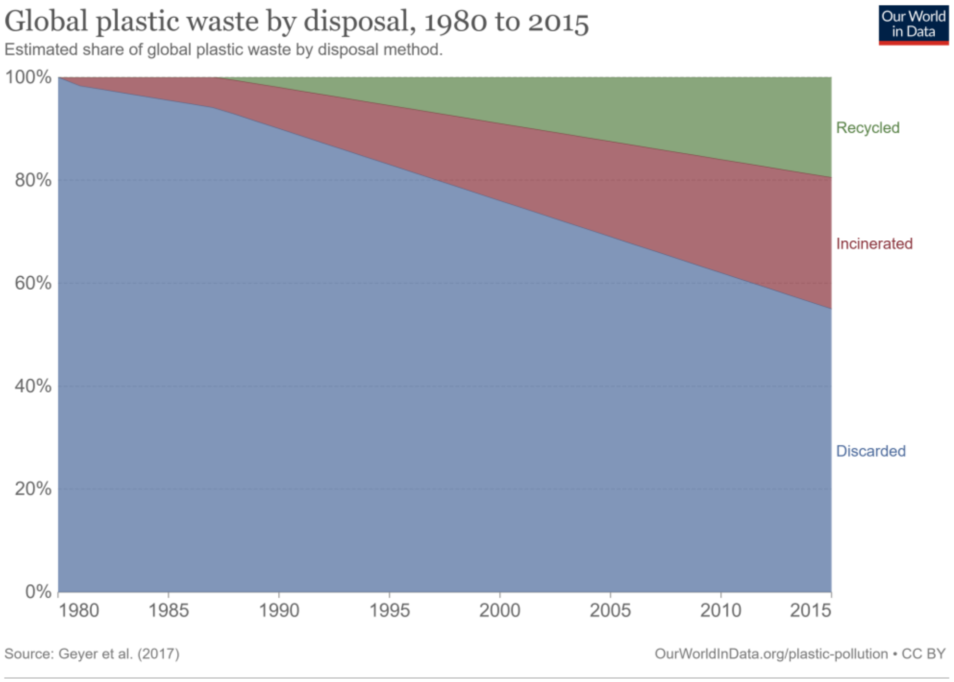
Growth in production and waste





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Options for handling waste

Recycling has the lowest global warming potential and from the environmental perspective is usually the best option but not always the best economic choice

BUT

Materials are often downcycled rather than re-used for the same purpose and many plastics can only be recycled once or twice

Globally
9%

Incineration reduces landfill

BUT

Adds to greenhouse gases and can produce toxic emissions if not regulated

Globally
19%

Landfill at least puts the carbon back in the ground and in high-income countries landfills are well-managed and effectively regulated

BUT

Landfill resources can be poorly-managed, dumped in open pits and consume land which is in short supply

Globally
50%

Globally 22% evades waste management and ends up in uncontrolled dumps or burnt in open pits

Plastic pollution is growing relentlessly as waste management and recycling fall short, says OECD

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Domestic recycling

Possible vs actual

Which plastics are recyclable?

Our World in Data

Summary of plastic polymer groups, their common uses, properties and recyclability. Numerical coding (from 1-7) is typically provided on plastic items and gives information of their polymer grouping below. Recyclability is based on common recycling schemes but can vary between countries as well as regionally within countries; check local recycling guidelines for further clarification.

Symbol	Polymer	Common Uses	Properties	Recyclable?
1 PETE	Polyethylene terephthalate	Plastic bottles (water, soft drinks, cooking oil)	Clear, strong and lightweight	Yes; widely recycled
2 HDPE	High-density polyethylene	Milk containers, cleaning agents, shampoo bottles, bleach bottles	Stiff and hardwearing; hard to breakdown in sunlight	Yes; widely recycled
3 PVC	Polyvinyl chloride	Plastic piping, vinyl flooring, cabling insulation, roof sheeting	Can be rigid or soft via plasticizers; used in construction, healthcare, electronics	Often not recyclable due to chemical properties; check local recycling
4 LDPE	Low-density polyethylene	Plastic bags, food wrapping (e.g. bread, fruit, vegetables)	Lightweight, low-cost, versatile; fails under mechanical and thermal stress	No; failure under stress makes it hard to recycle
5 PP	Polypropylene	Bottle lids, food tubs, furniture, houseware, medical, rope, automobile parts	Tough and resistant; effective barrier against water and chemicals	Often not recyclable; available in some locations; check local recycling
6 PS	Polystyrene	Food takeway containers, plastic cutlery, egg tray	Lightweight; structurally weak; easily dispersed	No; rarely recycled but check local recycling
7 OTHER	Other plastics (e.g. acrylic, polycarbonate, polyactic fibres)	Water cooler bottles, baby cups, fiberglass	Diverse in nature with various properties	No; diversity of materials risks contamination of recycling

Source: based on general US & UK guidelines, and chemical polymer properties. Icon graphics from Noun Project.
This is a visualization from OurWorldinData.org, where find data and research on how the world is changing.

Mechanical recycling

- Shredded, washed and melted
  - Retains chemical structure of polymer
  - Good for pure materials like HDPE and PET
- Solvent based dissolution
  - Can be used for mixed polymers and laminates
  - Dissolves some polymers so that separation can take place

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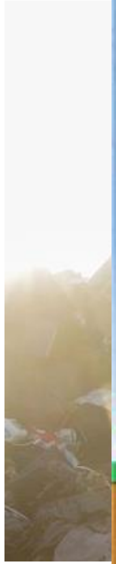
Incineration

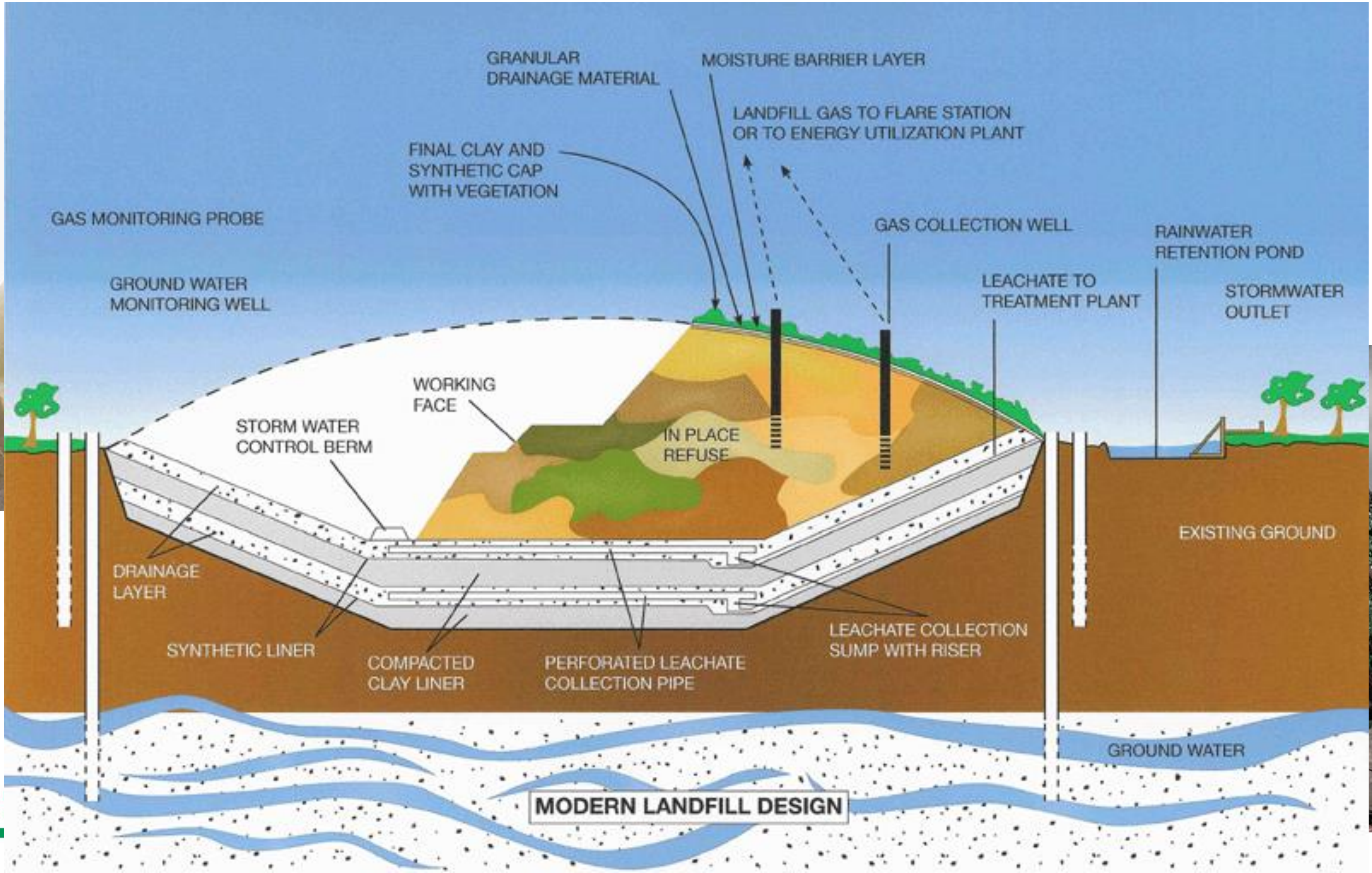
Waste to energy

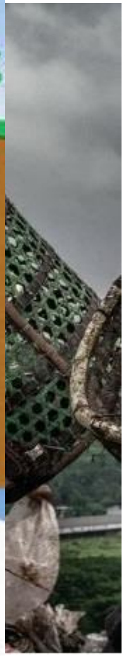
- Reclaims the energy stored in the polymer molecules
- Relative gain depends on mix of energy it replaces
- If local energy is produced from fossil fuels incineration can reduce greenhouse gas emissions
- If more renewable energy being used it will increase GHG

Incineration without energy recovery is never good, especially if open, uncontrolled burning

- High income countries have strict regulations on emissions from incineration
- Studies from India, Kenya and Thailand show pollution from toxic gases such as carbon monoxide from polyolefins and dioxins from PVC




GRANULAR DRAINAGE MATERIAL
MOISTURE BARRIER LAYER
LANDFILL GAS TO FLARE STATION OR TO ENERGY UTILIZATION PLANT
FINAL CLAY AND SYNTHETIC CAP WITH VEGETATION
GAS MONITORING PROBE
GAS COLLECTION WELL
RAINWATER RETENTION POND
GROUND WATER MONITORING WELL
LEACHATE TO TREATMENT PLANT
STORMWATER OUTLET
WORKING FACE
STORM WATER CONTROL BERM
IN PLACE REFUSE
EXISTING GROUND
DRAINAGE LAYER
SYNTHETIC LINER
COMPACTED CLAY LINER
PERFORATED LEACHATE COLLECTION PIPE
LEACHATE COLLECTION SUMP WITH RISER
GROUND WATER
MODERN LANDFILL DESIGN



Sources of ocean pollution

- 82 million tonnes of macro plastic and 40 million tonnes of microplastic is washed up, buried or resurfaced along the world’s shorelines
- 80% of the macroplastic onshore is from the past 5 years , most of the rest is from the past 15 years but some is much older and shows it can last several decades before breaking down to microplastic
- Offshore the macroplastic dates back further – even to the 50s and 60s - and 75% of the microplastic is pre 1990
- 80% of the plastic waste in the ocean enters from rivers – the rest comes from fishing nets, ropes and fleets

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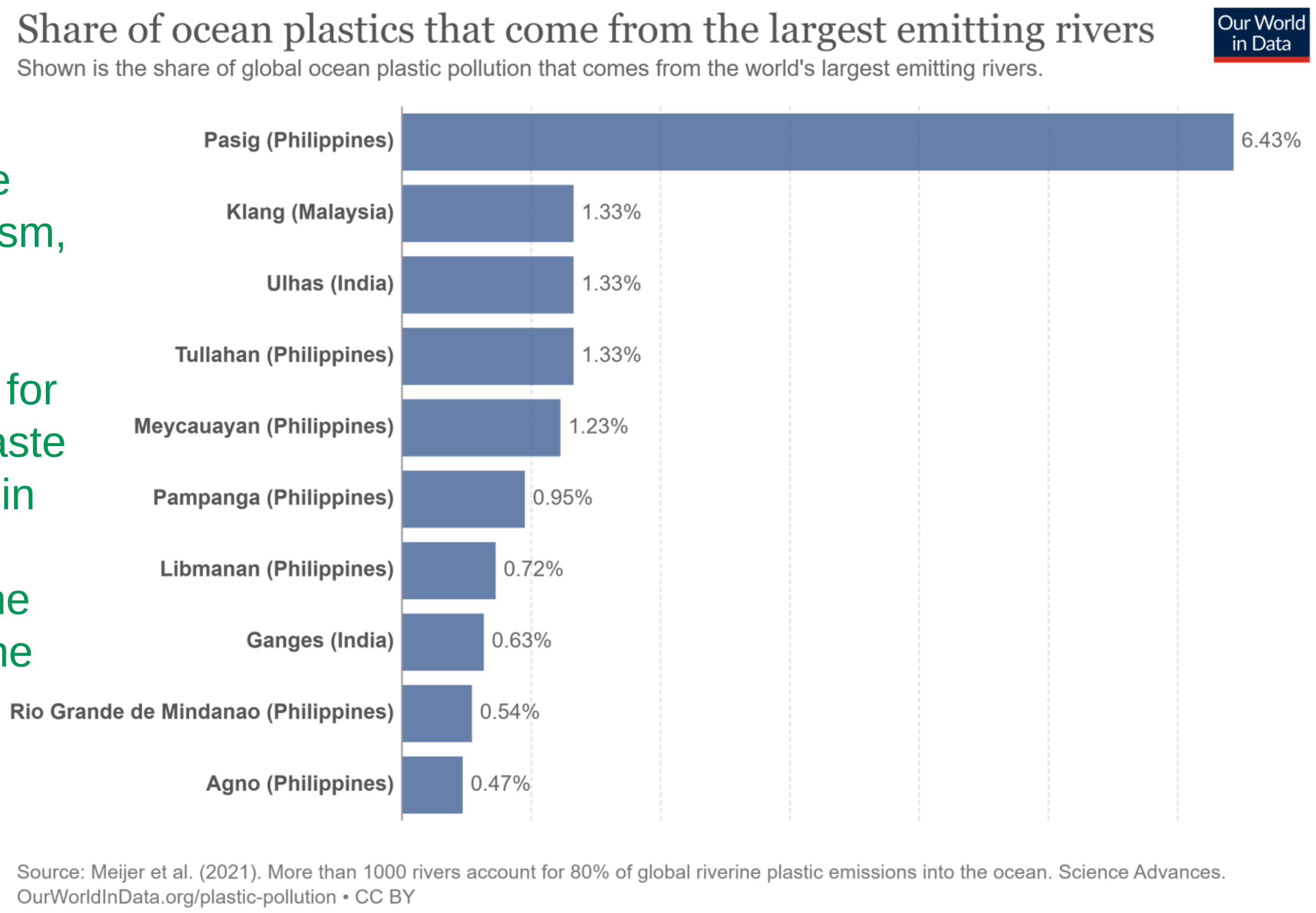
The great pacific garbage patch

The Great Pacific Garbage Patch • The Ocean Cleanup

The great Pacific garbage patch

GPGP T J Watson

- As well as the environment, marine plastic impacts tourism, fisheries and aquaculture
- 1000 rivers account for 80% of all plastic waste in the ocean mostly in Asia
- The Philippines alone contributes about one third of the total



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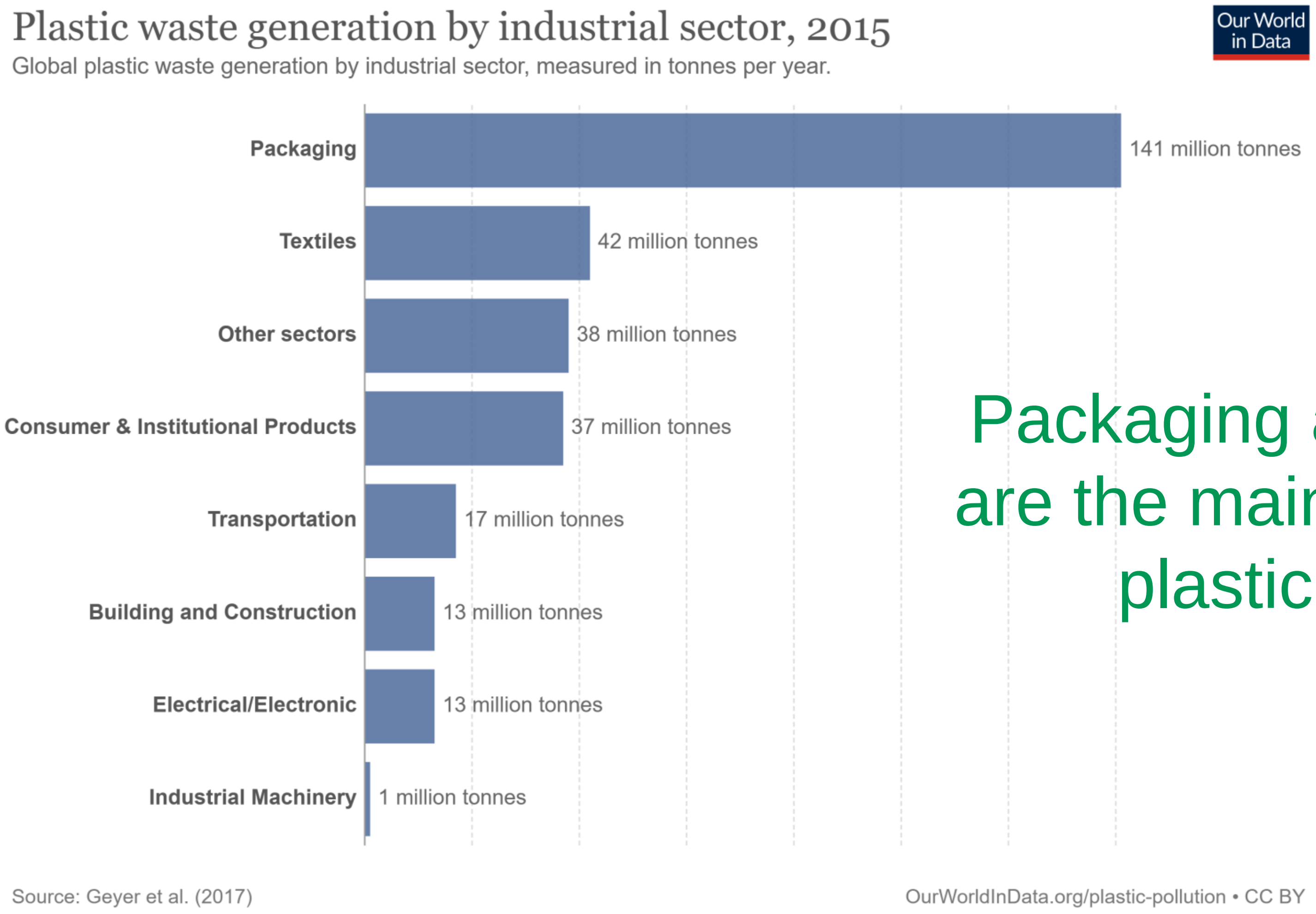

Packaging and textiles are the main sources of plastic waste

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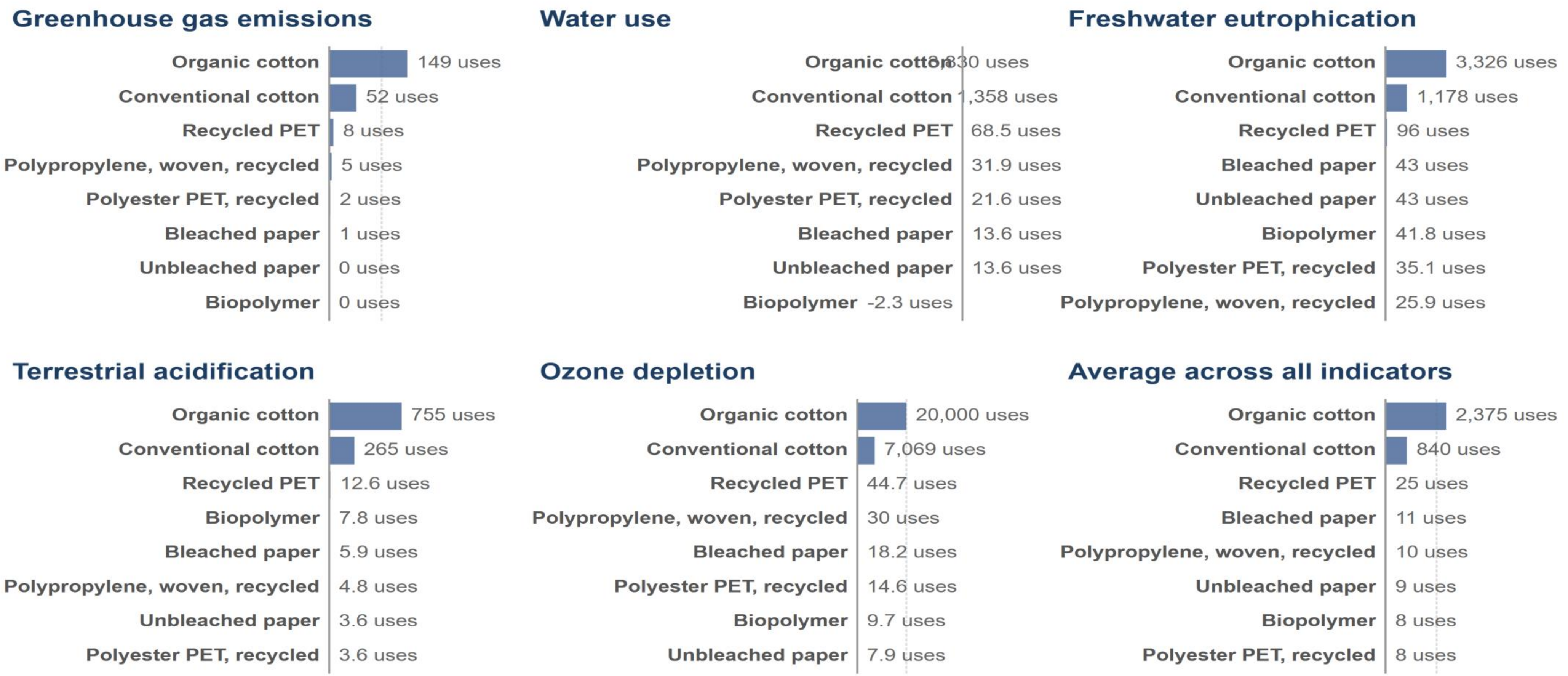
Grocery bag comparisons of environmental impact

Number of times a given grocery bag type would have to be reused to have as low an environmental impact as a standard single-use plastic bag.



Source: Danish Environmental Protection Agency (2018)

Note: Average across all indicators includes other metrics not shown here, including marine eutrophication, particulate matter, toxicity and others.

Are ‘bioplastics’ better?

Possibly but probably not

- Two different meanings
    - Made from plant based raw materials
    - Biodegradable or compostable
- Plastics can be made from non-petroleum raw material, but life cycle impacts increase
- Biodegradable materials not durable
- Compostable materials need commercial composter to fully degrade

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Actions and innovations

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Ocean Cleanup

- 2017 UN launched its clean seas platform
- 2019 Ocean Cleanup The Ocean Cleanup removed first material
  - Iterative research aiming to build and scale method
  - Version 02 – artificial coastline had removed 246 tonnes
  - Aim to remove 90% of floating ocean plastic by 2040

Material removed by Ocean Cleanup

Ocean Cleanup – stop the flow

- Rivers are the main source of ocean pollution
- Ideally we need to stop the disposal of plastic into the environment but in the meantime catching it in the river is better than letting it get into the sea
- Rivers are more complicated
  - Width, depth, flow speed, seasonality and tides make every river different
  - Ocean Cleanup are developing a range of interceptors from

Low tech → **High tech**

Kingston Harbour, Jamaica, Barnes Gully barrier

Kingston Harbour, Jamaica, Barnes Gully barrier and tender

Boyan Slat and Interceptor 004 in the Dominican Republic

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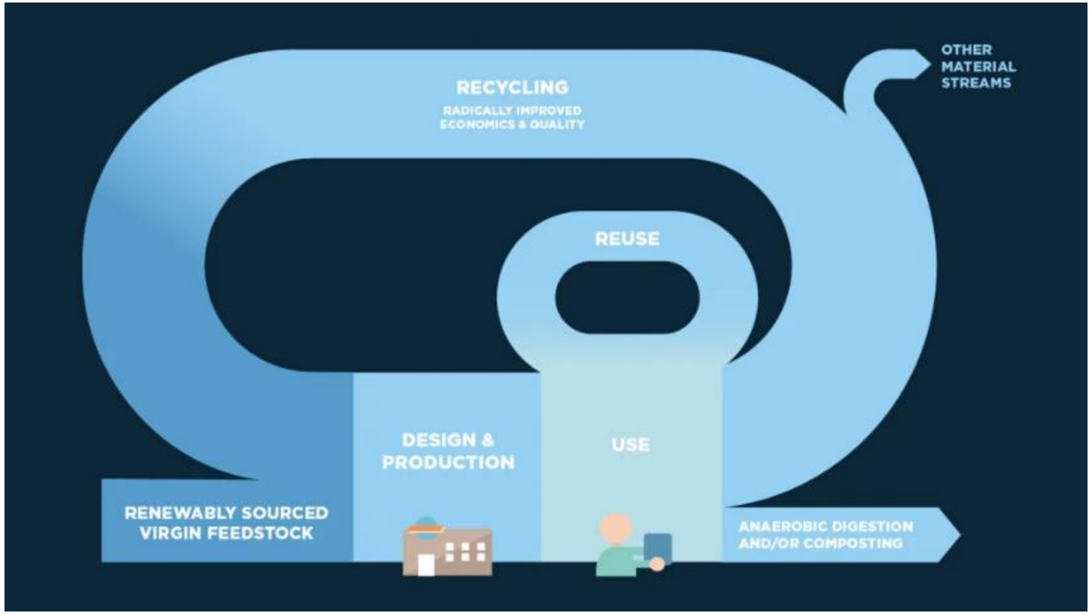
Circular economy

Ellen Macarthur Foundation

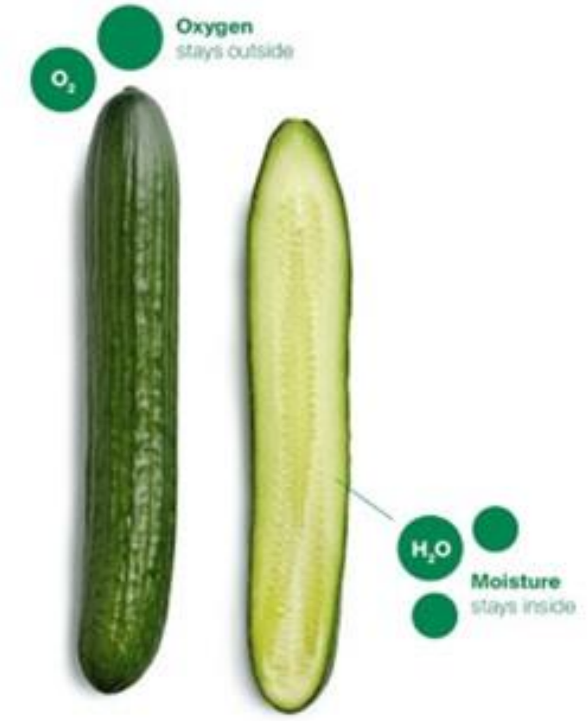
Lifecycle analysis helps

- Create a circular economy for plastics
- Ensure proper waste management and collection
- Eliminate plastics we don’t need
- Enable sustainable product design
- Keeps plastics in the economy and out of the environment



Upstream innovation - Apeel

- To extend the shelf life of fresh fruit and vegetables you need to keep the moisture in and the oxygen out
- Prevent food waste – but remove packaging
- Apeel is a coating of purified mono- and diglycerides derived from sustainably-sourced plant oils
- Edible but can be removed with washing if desired
- Full life cycle analysis of Apeel coated products shows they outperform baseline product in all cases
- Asda trialling with avocados and oranges in Oxford



Re-use in Indonesia – packaging as a service

- 76% of Indonesia's plastic waste is single use flexible sachets and pouches
- Alner – Social enterprise tech start up
- Supplies reusable PET, PP or HDPE bottles designed to be reused 10-20 times
- Brands fill the containers but Alner supplies the logistics to get the product to customers, collect the returns, clean and test before supplying back to the brand
- QR codes and the Alner app track the lifespan
- Deposit scheme means low income users can get essential products 10-15% cheaper
- Since 2020 Alner has introduced100 outlets as well as online sales

Chemical recovery

- Pyrolysis breaks down the polymer chains into Naphtha – a mixture of low molecular weight hydrocarbons, similar to the fraction of crude oil used for manufacturing plastics
- It could recycle large volumes of flexible packaging and mixed PE/PP waste
- Ambition to be industrial scale by 2025 and hitting targets for dealing with 'hard to recycle' plastic by 2030
- In Europe this would mean investment in 60-70 new plants and a secure supply of waste material
- Pyrolysis can't deal with PET

Plastic eating microbes

- Proven principle – Rhodococcus ruber
- Many other examples found

BUT

- Need low temp activity
- So far very low conversion rate
- May produce other toxins
- Specific to individual polymers

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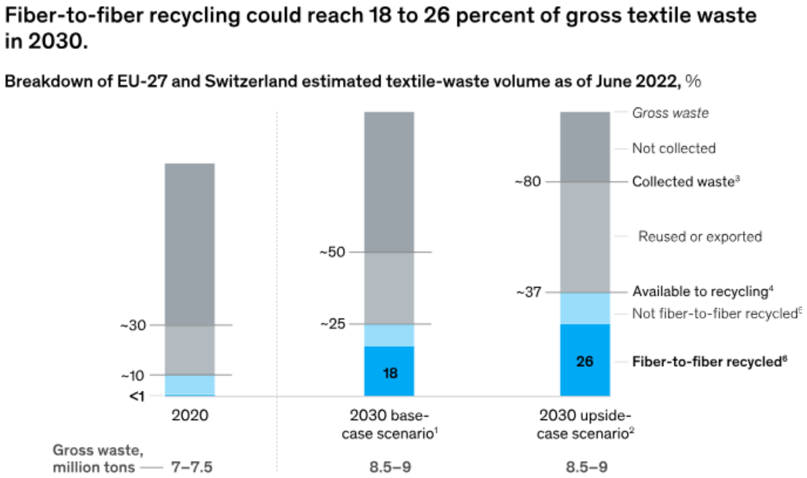
Textiles

- 85% of textiles ends up in land fill
- Synthetic fibres make up 60% of clothing and 70% of household textile
- McKinsey estimate fibre to fibre recycling could get to around 20% by 2030 (using chemical recovery)
- Patagonia (now a charitable trust) is moving toward 100% renewable and recycled raw materials - using synthetic and natural fibres from pre-consumer and postconsumer waste
- Prato, in Italy, has built its fortune on transforming old wool scraps into new clothes - 100s of companies collaborate on all the different processes



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Individual actions

- Behaviour change
  - Reusable drinks containers
  - Reduce food waste – one third never consumed
  - Buy fresh and local food - avoid ultra processed foods which are usually in ‘hard to recycle’ packaging
  - Use solid product - reduce water consumption and transport
  - Start washing hands again – reduce PPE
  - Buy second hand
- Campaign and lobby
  - Local government
  - MPs
  - Retailers

Policy change

- Systemic policies that treat plastic as one of the many resources in the economy
- Support global infrastructure for recycling and waste management
- Improve food distribution with appropriate packaging in low-income countries
- Standardise packaging to make recycling easier
- Use regulation and financial incentives to reduce landfill
- Finance innovation – high and low tech – by investing in developing technology
- Enforce life cycle analysis on all products, regardless of whether they contain plastic - plastic can be a sustainable alternative to glass, metals and paper and has an important role in promoting sustainability as part of a circular economy.

Thank you

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