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SCOTLAND MANUFACTURING & SUPPLY CHAIN CONFERENCE & EXHIBITION
In Partnership With Scottish Engineering

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# Investigating the Circular Economy of PET in Food Packaging

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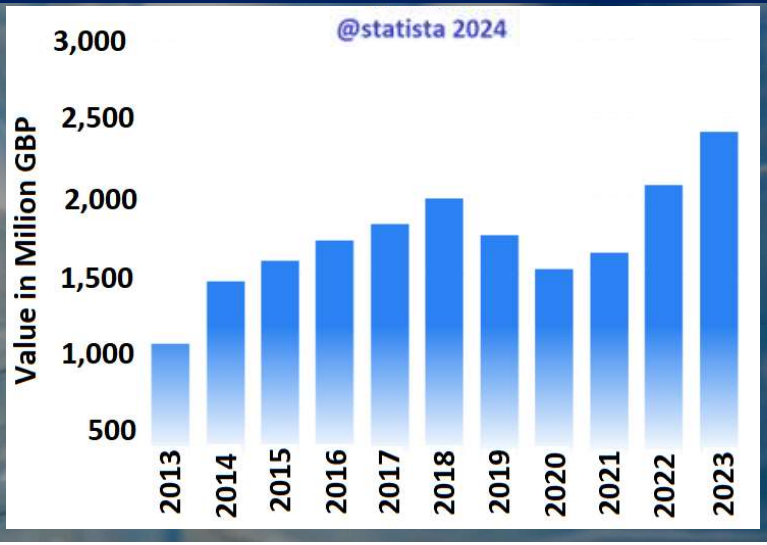
# PET bottled water




**Value of the bottled water market in the United Kingdom from 2013 to 2023**

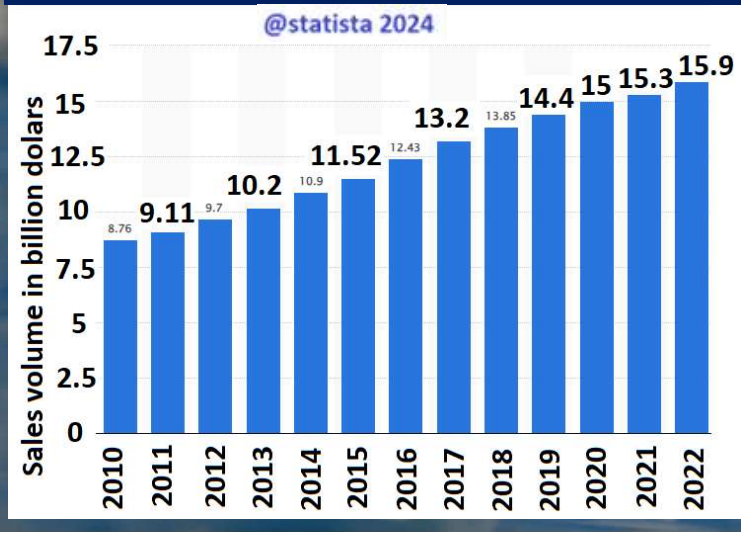



7.7 billion single-use plastic water bottles are bought in the UK every year.

(source: London's government)

In fact, it's estimated 1.3 billion plastic bottles are used each day across the world, which is about 1 million per minute.
(Source: https://www.aquasana.co)

Sales volume of bottled water in the United States from 2010 to 2022



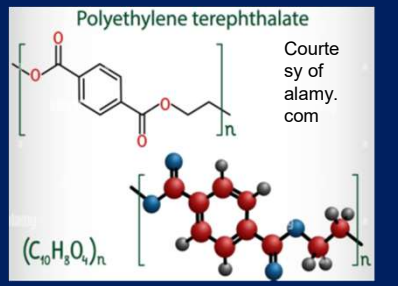
# What is PET?

- Polyethylene terephthalate (PET) is a thermoplastic polymer resin of the polyester family.
- PET is made from petroleum hydrocarbons with the polymer chain form of $(C_{10}H_8O_4)_n$ through the polymerization of monomers ethylene glycol and terephthalic acid (PTA).

**Ethylene Glycol [C2H6O2] + Terephthalic Acid (PTA) [C8H6O4]**

**$\rightarrow$(C10H8O4)n+H2O$C_2H_6O_2$ + $C_8H_6O_4$ $\rightarrow$ $(C_{10}H_8O_4)$_n +$H_2$OC2H6O2+C8H6O4**

**$\rightarrow$PET [(C10H8O4)n]+H2O**




- The raw materials for PET are made from crude oil and natural gas.
- Majority of plastics are made from natural gas feedstock.
- In the USA, they are manufactured from petroleum products, which include liquid petroleum gases (LPG) and natural gas liquids (NGL), and natural gas. (source: Beston Machinery)

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# Why PET in food packaging?

- PET is extensively utilized in food-grade applications because:
  - its high strength-to-weight ratio makes it ideal choice for its robustness and light weight.
  - its high resistance to breakage ensures that products are securely contained, reducing the risk of spillage and waste.
  - its excellent chemical resistance provides effective protection against moisture and gases.
  - its relatively low melting point, between 250°C and 260°C, makes its products have energy-efficient production.
  - its minimal additional formulation beyond the use of optical brighteners makes it a cost-effective and versatile material for packaging.

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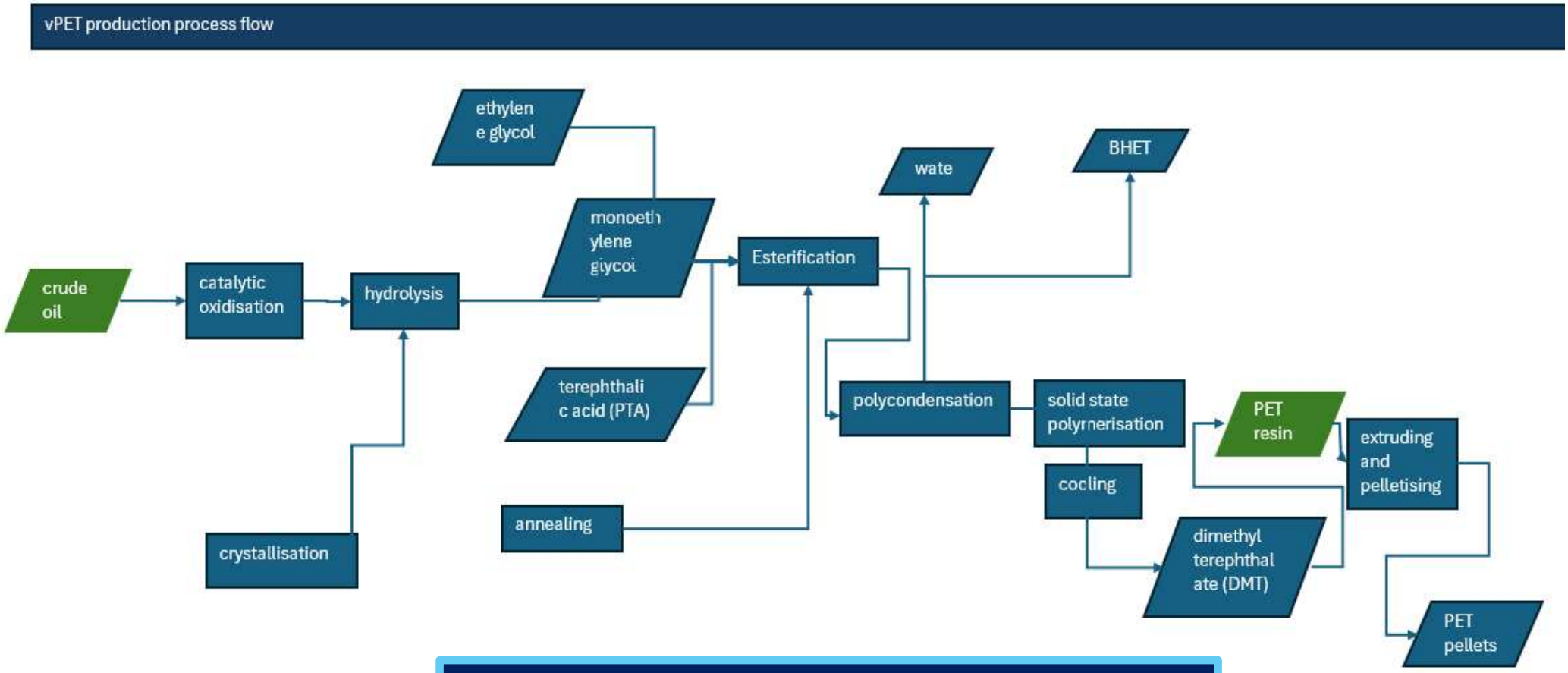
# vPET production process flow

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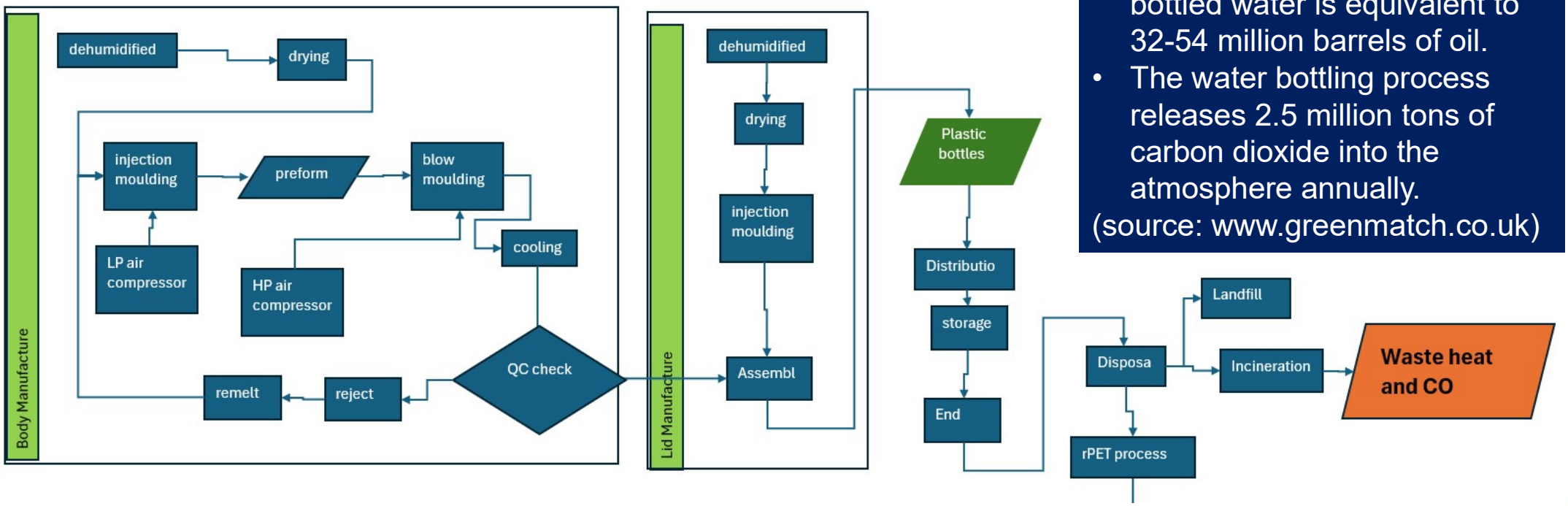
Producing PET enough for annual bottled water production demands 17 million barrels of oil per year

# Process flow to manufacture plastic bottle




- The total energy required to produce 33 billion litters of bottled water is equivalent to 32-54 million barrels of oil.
- The water bottling process releases 2.5 million tons of carbon dioxide into the atmosphere annually.

(source: www.greenmatch.co.uk)

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# Life of a Plastic Bottle


- Two different recycling pathways
  1. Bottle-to-Bottle (closed-loop recycling) and
  2. Bottle-to-Fiber (open-loop recycling)
- Recycling requires Intense washing and hydrolysis reaction
- Other options end up incinerated, landfill, and recycled non-bottle grade.

At least 14 million tons of plastic ending up in the oceans every year.

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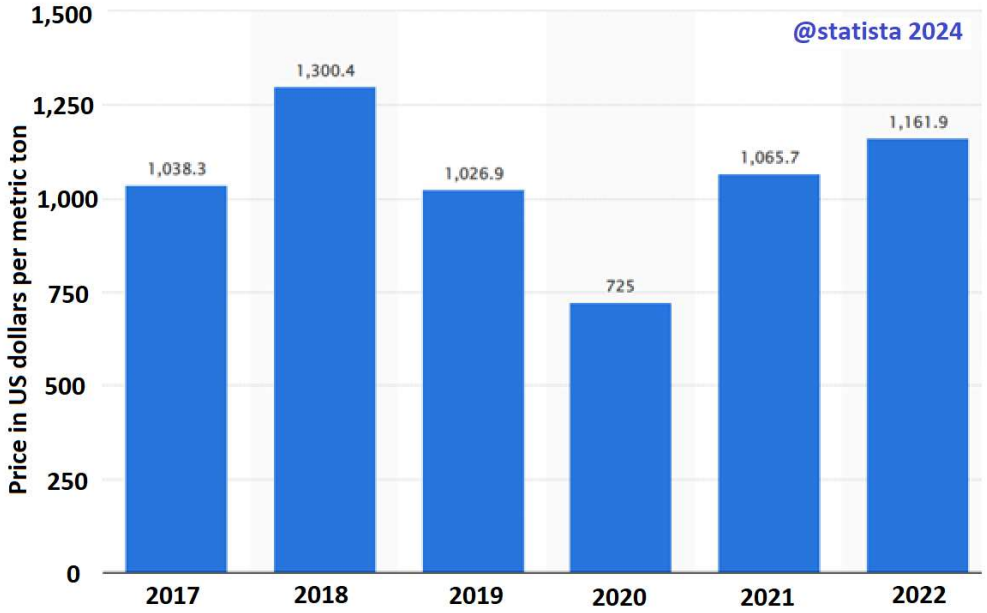
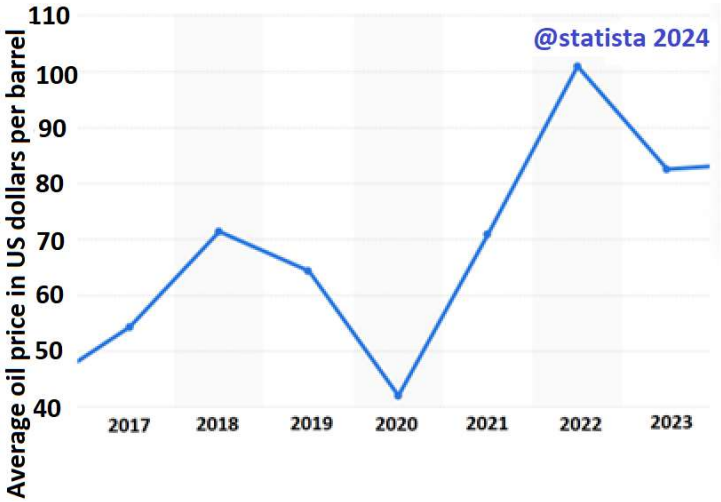
# Price of PET worldwide from 2017 to 2022




PET price in the US dollar per metric ton




Oil price in the US dollar per barrel

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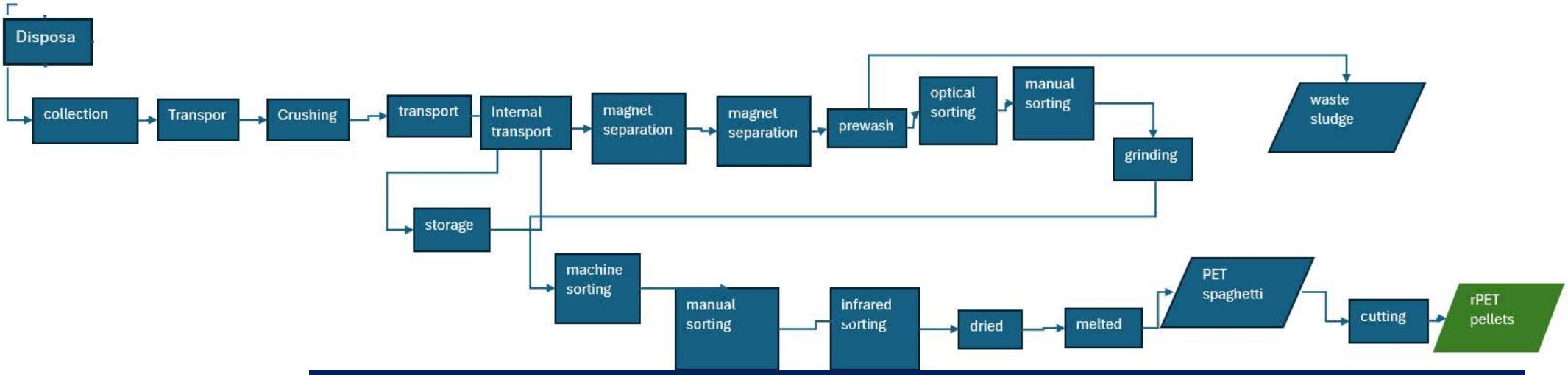
# PET recycling process (rPET)




- 44% of 2.5mt plastic bottles was sent to recycling in the UK but very little of that 44% will be reused as bottle grade and even if they are – there is a limit to the number of times it is possible!
  - Some companies , e.g. Nestlé® Pure Life and South Downs Water, claim to use rPET to make their single use water bottles.
- However, rPET is currently more expensive than vPET, since high quality granulate is in lower supply.
- The quality of rPET can go down with the addition of colours and additives (e.g. UV barrier additive), so they are  mainly downcycled to be transformed into valuable materials or reused in other products.
- The more colouring in a bottle, the fewer applications the recycled plastic can be used for.

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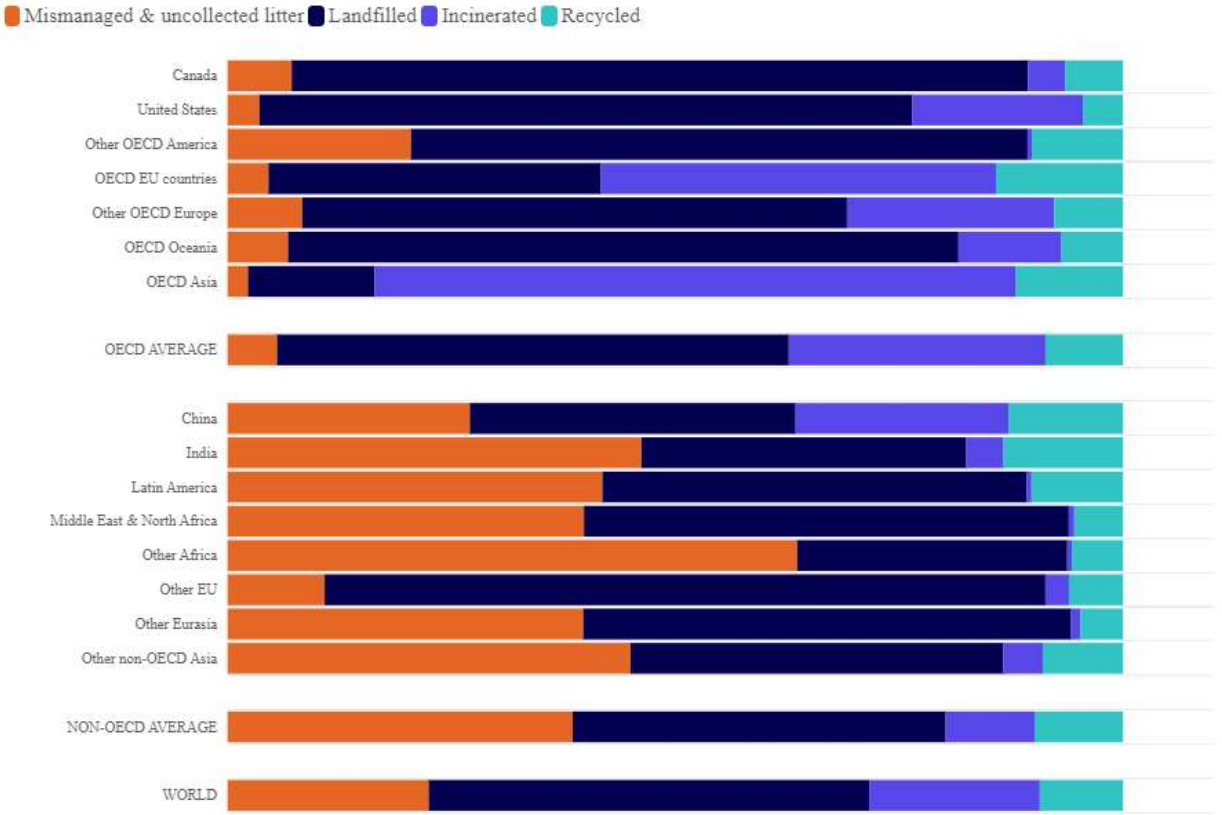
# Burning/ incineration of plastic waste

Organisation for Economic Co-operation and Development (OECD) reported that only 9% of plastic is recycled in the world (as of 2019) 22% is mismanaged - ending up in nature, 49% landfilled and 19% incinerated.

Burning PET needs 24MJ/kg which is 6.66 kWh /kg – more energy used than manufacturing into bottles




Source: OECD Global Plastics Outlook Database

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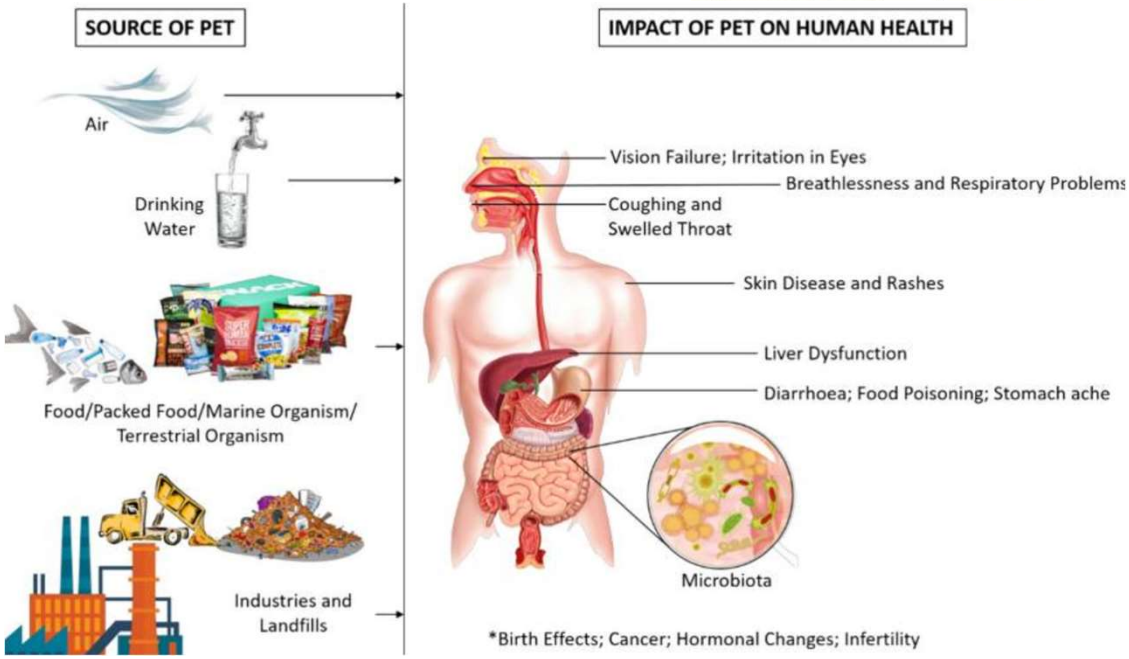
OECD

# Potential toxic effect of PET on human well-being

Courtesy of who.int

Courtesy of shutterstock.com

- The antimony (Sb 51) goes as a conceivable cancer-causing agent in the human body.
- Long contact between PET and water (Dhak et al., 2022)→
  - The probability of antimony discharge increases,
  - It is leading to dermatitis, irritation in the respiratory tract, changes in electrocardiograms, and gastritis in humans.
  - It has toxic effects proliferation and migration of mesenchymal and endothelial cells, important for making and repairing skeletal tissues.
- Illegal open burning of PET waste- open burning releases carcinogenic PAHs (Polycyclic aromatic hydrocarbons) which pose serious human health risks such as acute and chronic respiratory disease, or heart diseases (Das et al., 2018).




Source doi:10.1007/s10311-021-01384-8

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# Alternative technology and material

- It is possible to implement an advanced hybrid gas - press forming method to leverages benefits of gas forming and conventional manufacturing methods in forming sheet to produce complex shape containers and cheap multiple or single use aluminium bottles.
- The novelty of this would be to create resealable, available in multiple sizes, aluminium (closed loop recycle) beverage package that is cheaper than aluminium packaged bottle on the market to increase the industry and user incentive for sustainable practices.


Courtesy of x.com


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# Summary

- vPET is cheaper to buy than rPET so the trend will continue to buy vPET.
- There are challenges to use PET in bottled water, e.g. contamination/complex sorting and cleaning, degradation, and low recycling rate.
- Single used bottled water have raised concern regarding potential risks to zero carbon emission strategy and human well-being.
- Hybrid press-gas aluminium forming is suggested to encourage the supply chain of single use plastic bottles for replacing PET with aluminium!
- Introducing alternative design for bottled water may incentivise supply chain stakeholders including the end users to replace PET with better sustainable material.

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# Thank you for your kind attention!

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