

RECYCLING AND REUSE OF RAW MATERIALS

BACKGROUND ON MATERIALS

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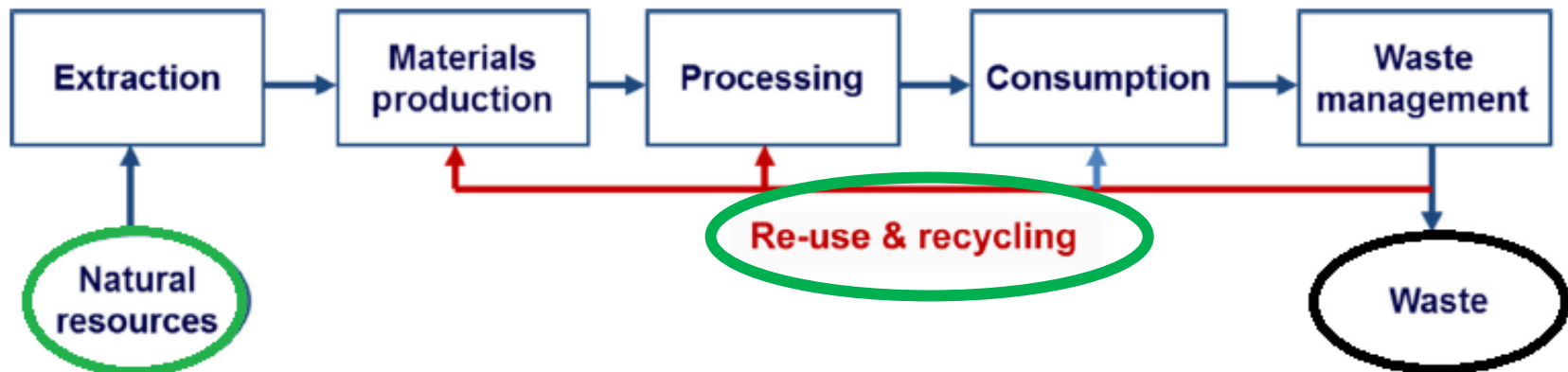
BACKGROUND

- Materials are everywhere in our lives.
- Our world would be impossible without them.
- The massive use of materials results in increasing amounts of solid wastes, which are discarded or incinerated:
 - loss of valuable materials;
 - negative environmental and health effects.

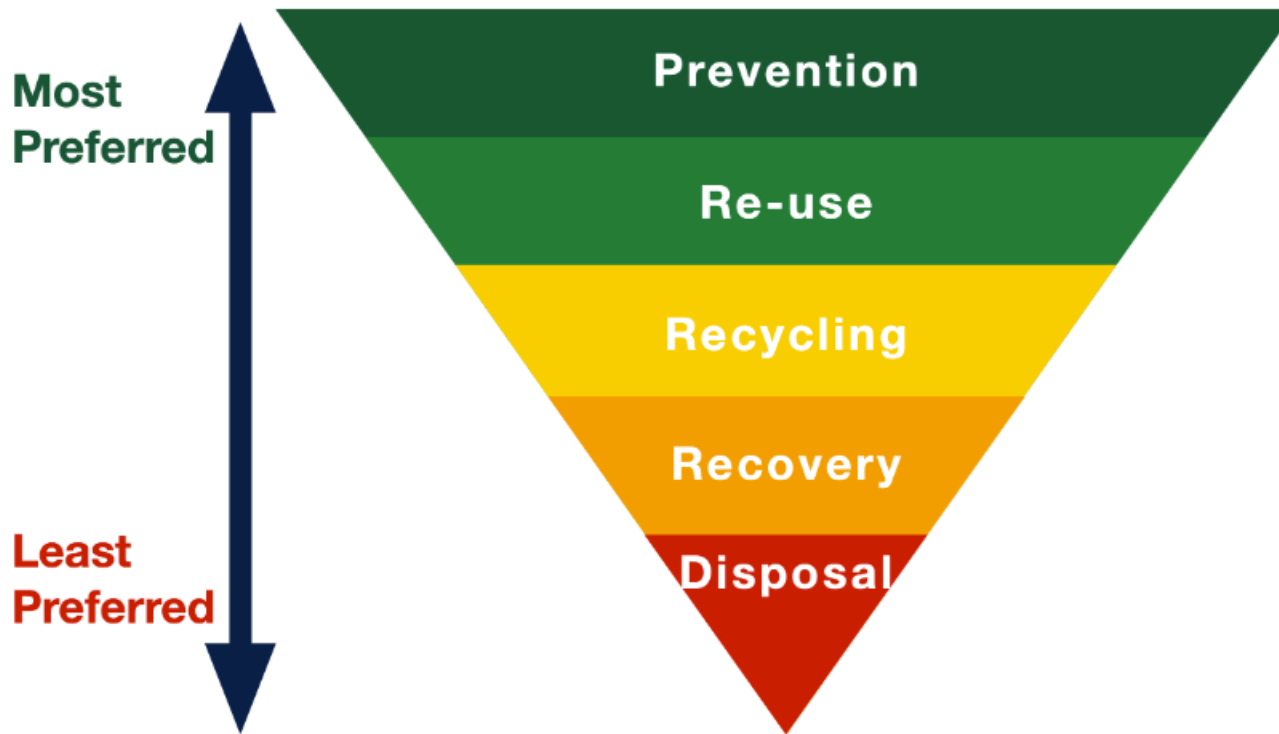
BACKGROUND

Recycling is the reprocessing of recovered materials at the end of product life, returning them into the supply chain.

Recycled material may also be called “*secondary*” in contrast to “primary” material that is extracted from the environment.



A COMMON LANGUAGE



WASTE HIERARCHY: RECYCLING IS DIFFERENT FROM RECOVERY AND REUSE!

A COMMON LANGUAGE

Prevention

- The idea of avoiding things becoming waste in the first place is essential and the most preferred option in the waste hierarchy.
- When we take action to **prevent waste from arising in the first place**, there is simply less waste.
- Less waste means
 - less need to reuse products,
 - less disposal
 - and most importantly, less waste at landfill sites.

A COMMON LANGUAGE

Reuse (R1)

When waste is created, reusing products and materials before it becomes waste is the next best option.

By cleaning, repairing and refurbishing items, we can significantly increase the number of things we reuse.

Common examples include **reusable bottles/cups for takeaway drinks and reusable shopping bags.**

A COMMON LANGUAGE

Recycling (R2)

Recycling is the most environmentally friendly solution to waste disposal.

Recycling essentially turns our waste into a new item or product, reducing the amount of raw materials required. Today, the majority of items we use can now be recycled. Everyday products that we can recycle include:

- **metals, paper, cardboard, glass, wood, and most plastics.**

A COMMON LANGUAGE

Recovery (R3)

Recovery is the third best option.

For waste that we can't recycle, it may be possible to recover energy in the form of "waste to energy".

Waste to energy is the process of incinerating non-recyclable waste to produce electricity.

Composting is also a method we use when we can't recycle materials. Composting turns organic wastes into nutrient-rich food for plants.

A COMMON LANGUAGE

Disposal

The least sustainable option in the waste hierarchy and our last resort is **landfill**.

In the UK for instance, landfill is highly taxed by the government to help promote more sustainable methods in the waste hierarchy. Landfill tax sees yearly increases in April, and as of April 2024, landfill tax is £103.70 per tonne of waste.

Not only is landfill unsustainable, but it is also by far the most expensive method in the waste hierarchy. In Italy, taxes depend on the waste type and even on the location.

MATERIALS

Over 160.000 materials are available today!!!

The materials have to:

- support loads,
- insulate or conduct heat and electricity,
- accept or reject magnetic flux,
- transmit or reflect light,
- survive in often-hostile surroundings,

and to do all this without damage to the environment or costing too much.

MATERIALS

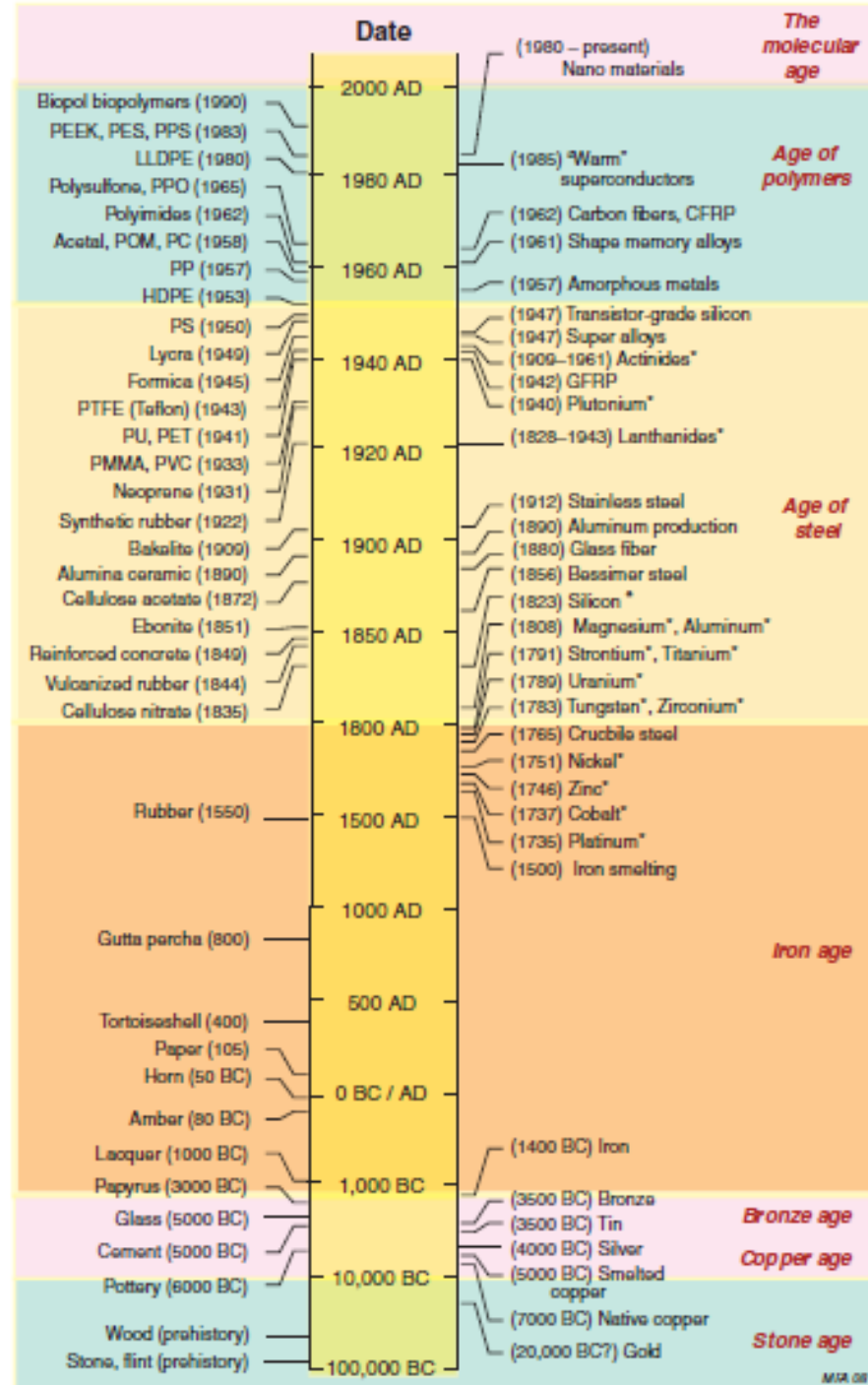
Materials have enabled the advance of mankind from its earliest beginnings.

The ages of mankind are named after the dominant material of the day:

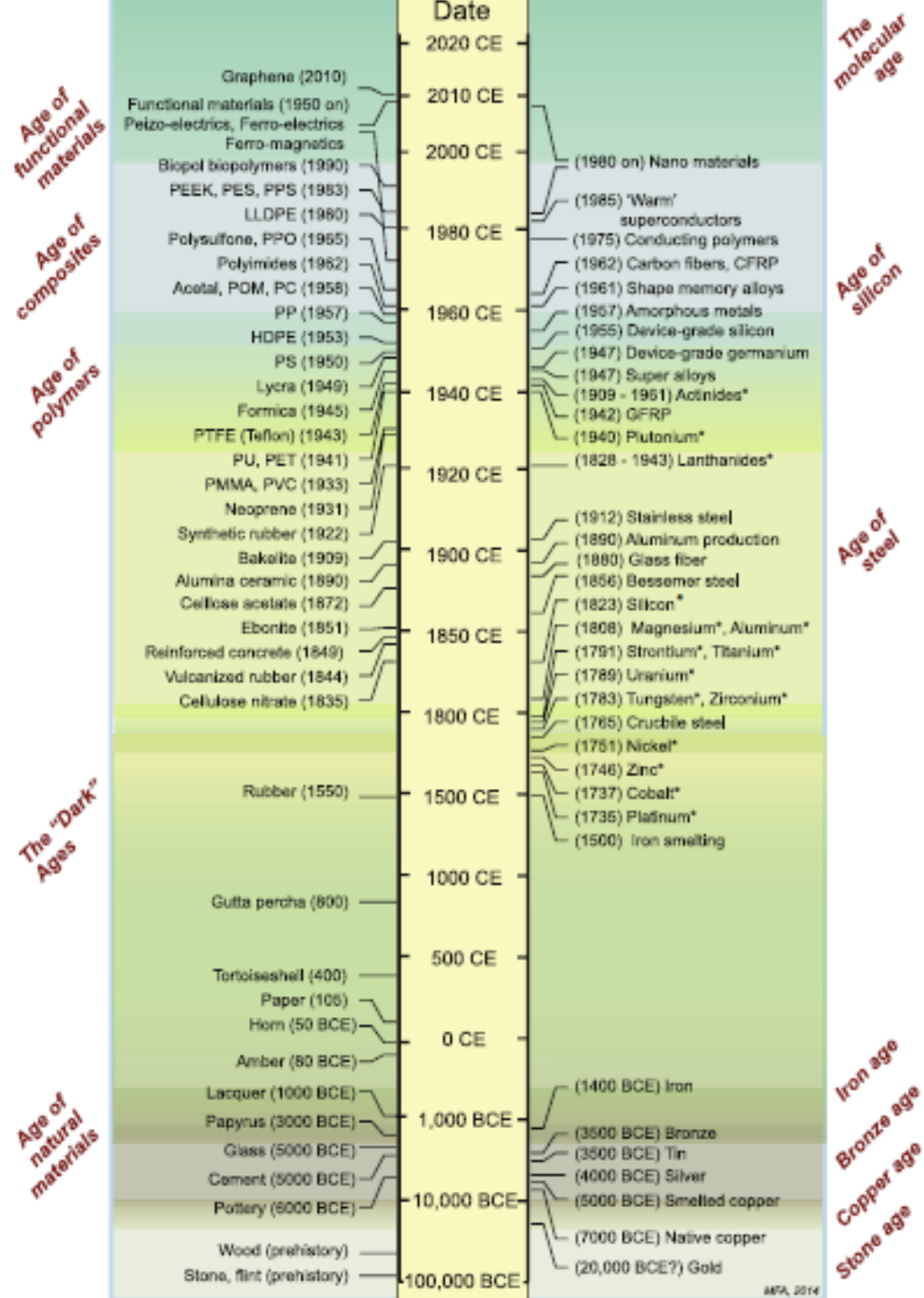
- the Stone Age,
- the Age of Copper,
- the Bronze Age,
- the Iron Age.



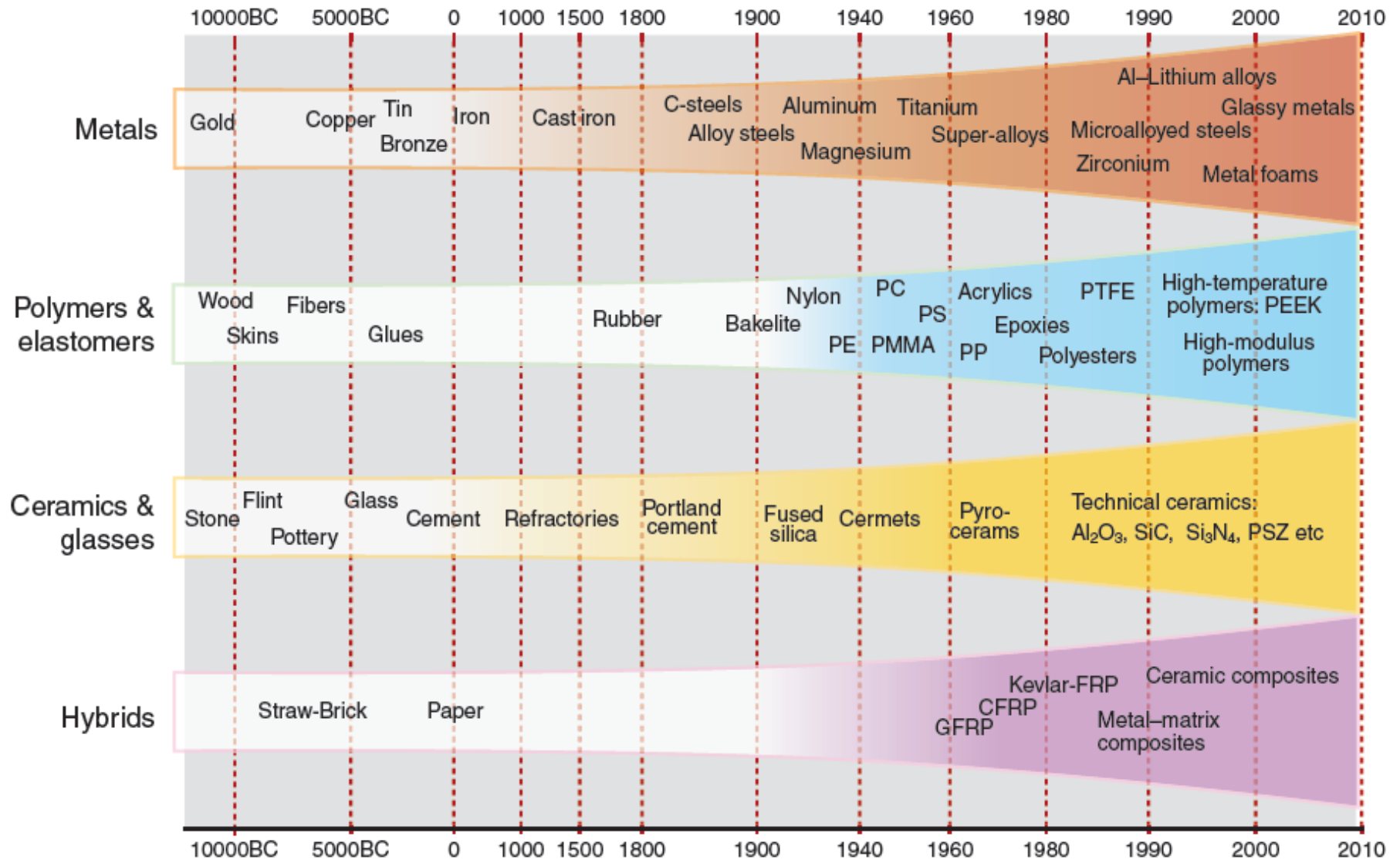
MATERIALS



MATERIALS



MATERIALS



MATERIALS AND IMPACTS

The materials (and the energy needed to make and shape them) are drawn from *natural resources*:

- ores;
- fossil hydrocarbons.



Escondida (Cile), mine of copper



Super Pit, mine of gold

MATERIALS AND IMPACTS

The Earth's resources are not infinite.

The research center "Global Footprint Network" calculates each year the date when renewable natural resources are exhausted, known as the **overshoot day**: from that point on, it's as if we're drawing on resources by taking them from subsequent years and thus from future generations.

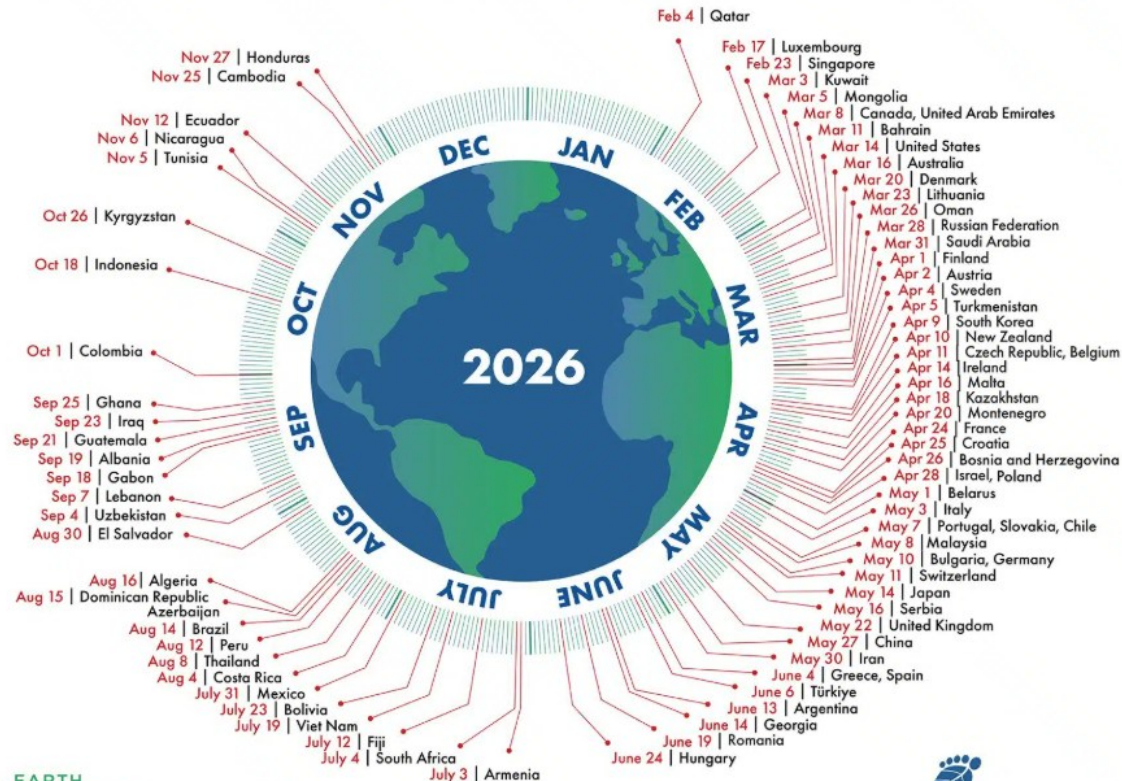
For the European Union, the overshoot day has been calculated as May 3th.

MATERIALS AND IMPACTS

The Earth's resources are not infinite.

Country Overshoot Days 2026

When Earth Overshoot Day would land if all the people around the world lived like...



EARTH
OVERSHOOT
DAY

For more information, visit:

<https://overshootday.org/newsroom/country-overshoot-days>

Source: Country Overshoot Days 2026 are calculated using the National Footprint and Biocapacity Accounts' 2025 Edition (Lo et al. 2025), produced by York University for FoDaFo and Global Footprint Network, available at data.footprintnetwork.org



Global Footprint Network
Advancing the Science of Sustainability

RESOURCES

All natural resources (also known as natural capital) can be divided into two categories:

- **non-renewable**
- **renewable.**

Non-renewable resources are present in a finite quantity and do not regenerate after they are harvested and used. Consequently:

- as non-renewable resources are used, their remaining stocks in the environment are depleted.

This means that:

- non-renewable resources can never be used in a sustainable fashion – they can only be “mined.”

Examples of non-renewable resources include metal ores, petroleum, coal, and natural gas.

RESOURCES

Renewables

Renewable resources are capable of regenerating after harvesting. Consequently:

Potentially, their stocks can be utilized forever.

Most renewable resources are biological, although some are non-biological.

Biological Renewable Resources:

- wild animals that are hunted as food or for bio-materials, such as deer, moose, hare, ducks, fish, lobster, and seals;
- forest biomass that is harvested for lumber, fiber, or energy;
- wild plants that are gathered as sources of food, plants cultivated as sources of food, etc.

Non-Biological Renewable Resources:

- sunlight, water and groundwater, cycle winds, etc.

RESOURCES

Some considerations:

- **The life cycle** of some non-renewable resources, particularly metals, can be **extended by recycling**.
- There are **thermodynamic and economic limits to recycling**, which means the process cannot be 100% **efficient**.
- **The demand for non-renewable resources is increasing rapidly** (population growth, spreading industrialization, and improving standards of living).
- Accelerating demand for non-renewables resources that must be satisfied by mining additional quantities from the environment.

RESOURCES

Some considerations:

- **Changes in the value of non-renewable metals** also affect the sizes of their economically recoverable reserves.
- For example, if the value of gold increases in its marketplace, then it may become profitable to prospect for new stocks in remote places, to mine lower-grade ores, and to reprocess “waste” materials containing small quantities of this valuable metal.
- **An improvement of technology may have the same effect**, for instance, by making it profitable to process ores mine that were previously non-economic.

RESOURCES

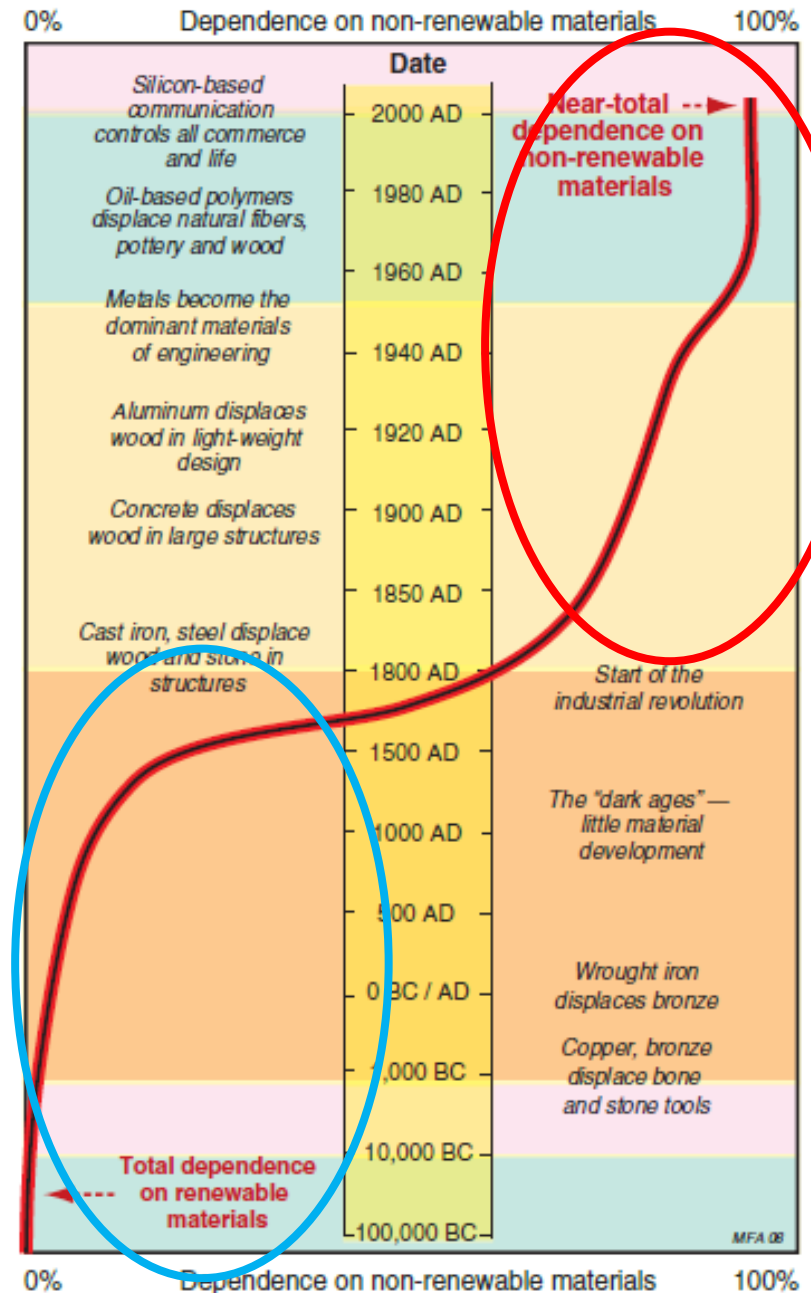
300 years ago, human activity subsisted almost entirely on renewables: stone, wood, leather, bone, natural fibers.

The few non-renewables (iron, copper, tin, zinc)

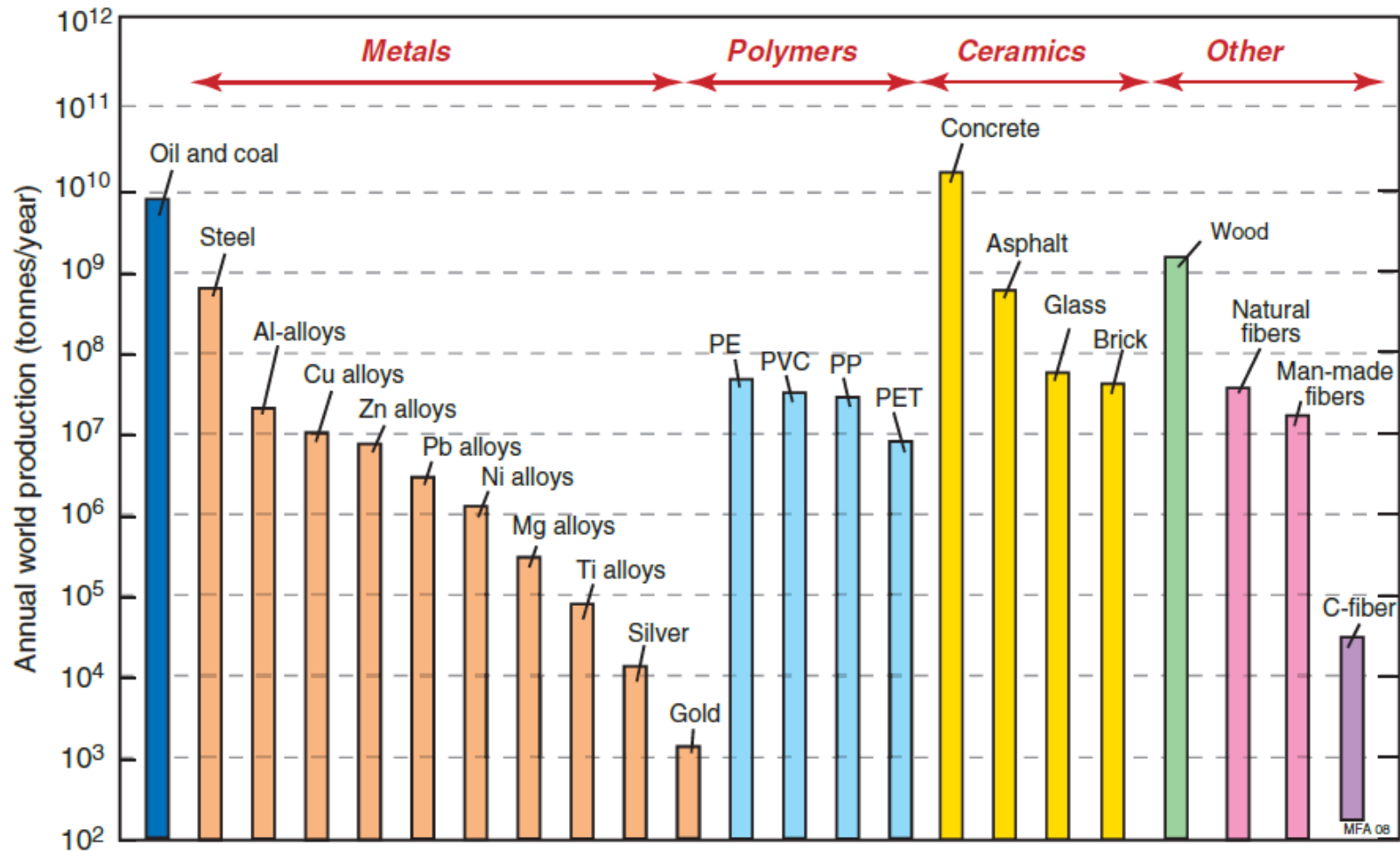
were used in such small quantities that the resources from which they were drawn were, for practical purposes, inexhaustible.

Then, progressively, the nature of the dependence changed:

- by the end of the 20th century, our dependence on non-renewable was almost total.



RESOURCES



The annual world production of 23 materials on which industrialized society depends. The scale is logarithmic.

RESOURCES

On the extreme left are **hydrocarbon fuels** —oil and coal —of which we currently consume a colossal 9 billion tonnes per year.

Next, moving to the right, are **metals**. The consumption of steel exceeds, by a factor of 10, that of all other metals combined, thanks to its versatility, strength, toughness, low cost, and wide availability.

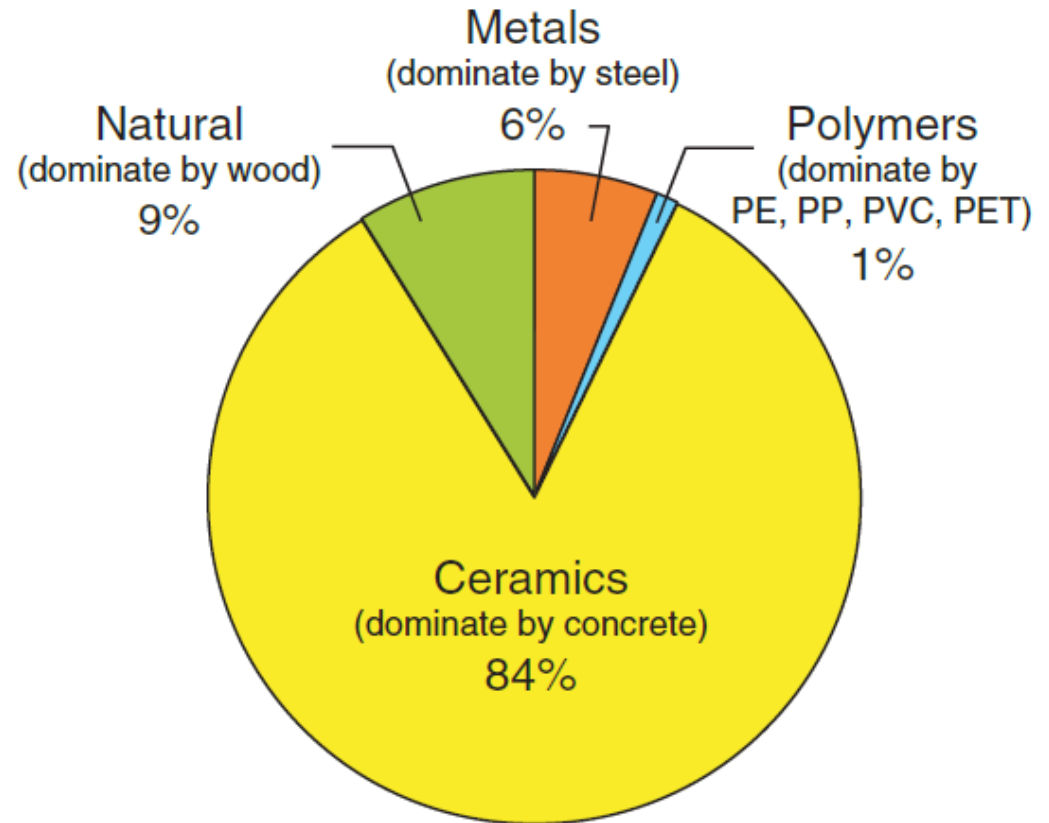
Polymers come next. Fifty years ago their consumption was tiny; today the consumption of the commodity polymers polyethylene (PE), polyvinyl chloride (PVC), polypropylene (PP), and polyethylene-terephthalate (PET) exceeds that of any metal except steel.

However, the really big ones, though, are the **materials of the construction industry**. Steel is one of these, but the consumption of wood for construction purposes exceeds even that of steel, even measured in tonnes per year and since it is a factor of 10 lighter, if measured in m³/year, wood totally eclipses steel. Bigger still is the consumption of **concrete**, which exceeds that of all other materials combined. The other big ones are **asphalt** (roads) and **glass**.

The last column of all illustrates things to come: it shows today's consumption of carbon fiber. Today its consumption is approaching that of titanium and is growing much more quickly.

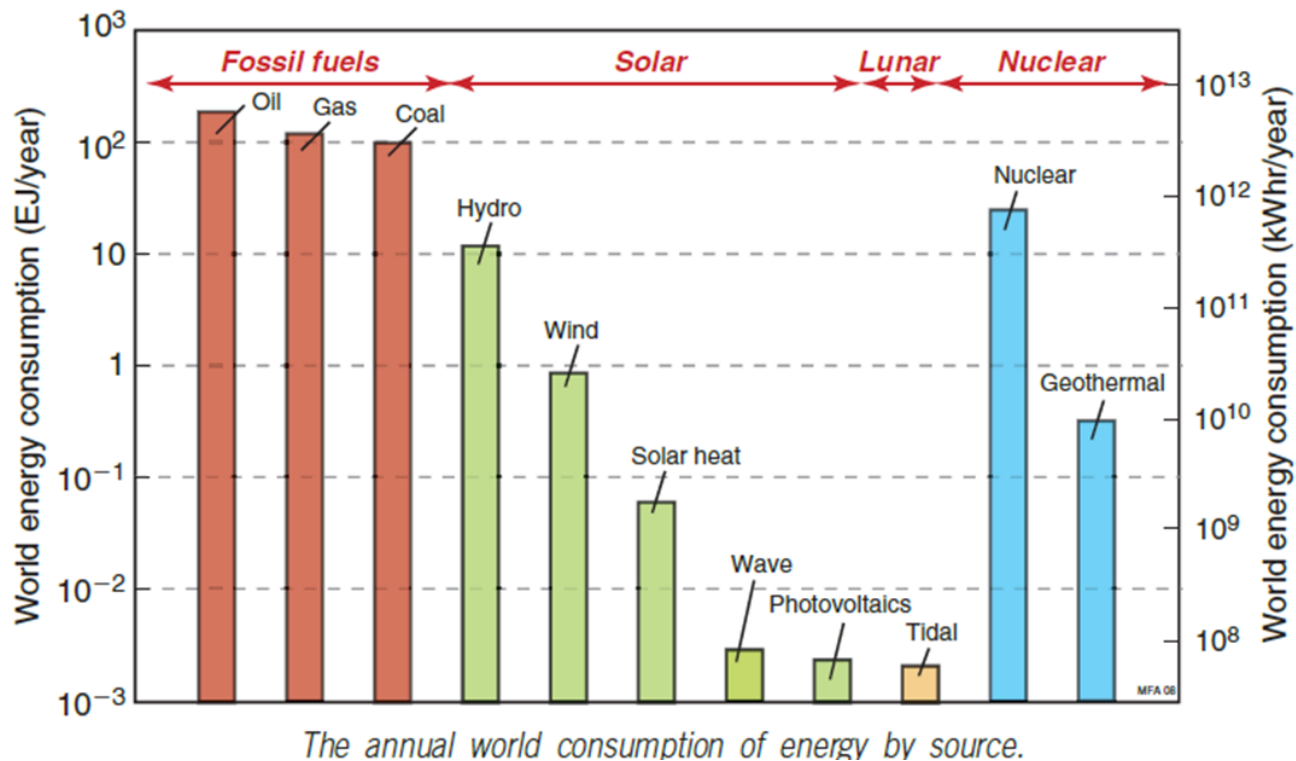
RESOURCES

A pie chart of materials usage (tonnes) by family:
Ceramics dominate because of the **enormous annual consumption of concrete**.



ENERGY

It is inseparable from the making of materials, their manufacture, their use and their disposal. **The SI unit of energy** is the joule (J), but we generally use kJ (10^3 J), MJ (10^6 J), or GJ (10^9 J) as the unit. Power is joules/sec, or watts (W), but it too is small, so we usually end up with kW, MW, or GW. The everyday unit of energy is the kW.hr, one kW drawn for 3600 seconds, so 1 kW.hr = 3.6 MJ.



Key data

STEEL

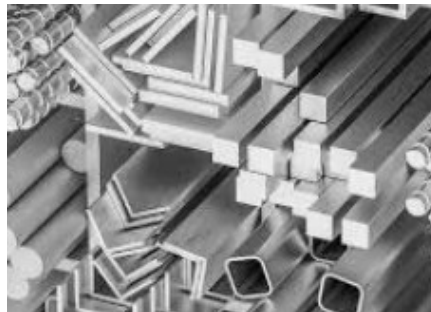
	Carbon steel	Low alloy steel	Stainless steel
Annual world production (tonne/yr)	$1.1 \times 10^9 - 1.2 \times 10^9$	$1.1 \times 10^9 - 1.2 \times 10^9$	$30 \times 10^6 - 3.1 \times 10^6$
CO ₂ footprint, primary production (kg/kg)	2.2 – 2.8	1.95 – 2.3	4.7 – 5.4
Water usage (l/kg)	23 – 69	37 – 111	112 – 336
Price (USD/kg)	0.79 – 0.90	1.0 – 1.1	7.7 – 8.5



Key data

Aluminum alloys

Annual world production (tonne/yr)	$33 \times 10^6 - 34 \times 10^6$
CO ₂ footprint, primary production (kg/kg)	11 – 13
Water usage (l/kg)	125 – 375
Price (USD/kg)	2.5 – 2.8



Key data

Copper

Annual world production (tonne/yr)	$15 \times 10^6 - 16 \times 10^6$
CO ₂ footprint, primary production (kg/kg)	4.9 – 5.6
Water usage (l/kg)	150 – 450
Price (USD/kg)	6.7 – 7.4



Key data

Polyethylene

Annual world production (tonne/yr)	68×10^6 - 69×10^6
CO ₂ footprint, primary production (kg/kg)	2.0-2.2
Water usage (l/kg)	38-110
Price (USD/kg)	1.85-1.2



Key data

Polyvinyl chloride

Annual world production (tonne/yr)	4.9×10^7 - 5.1×10^7
CO ₂ footprint, primary production (kg/kg)	2.2-2.6
Water usage (l/kg)	18-56
Price (USD/kg)	1.52-1.67



Key data

Polyethylene terephthalate

Annual world production (tonne/yr)	9.0×10^6 - 9.2×10^6
CO ₂ footprint, primary production (kg/kg)	2.21-2.45
Water usage (l/kg)	14.7-442
Price (USD/kg)	1.63-1.79



Key data

Concrete

Annual world production (tonne/yr)	15×10^9 - 15.5×10^9
CO ₂ footprint, primary production (kg/kg)	0.13-0.15
Water usage (l/kg)	1.7-5.1
Price (USD/kg)	0.041-0.062



Key data

Bricks

Annual world production (tonne/yr)	5×10^7 - 5.1×10^7
CO ₂ footprint, primary production (kg/kg)	0.22-0.23
Water usage (l/kg)	2.8-8.4
Price (USD/kg)	0.62-1.67



Key data

Soda-lime glass

Annual world production (tonne/yr)	80×10^6 - 82×10^6
CO ₂ footprint, primary production (kg/kg)	0.7-0.1
Water usage (l/kg)	6.8-20.5
Price (USD/kg)	1.41-1.66

