Interreg
Baltic Sea Region

Co-funded by
the European Union

CIRCULAR ECONOMY
Circular spaces

Waste as a resource in Circular Economy (CE)

CLIMATE-NEUTRAL SOCIETIES

Training outcomes

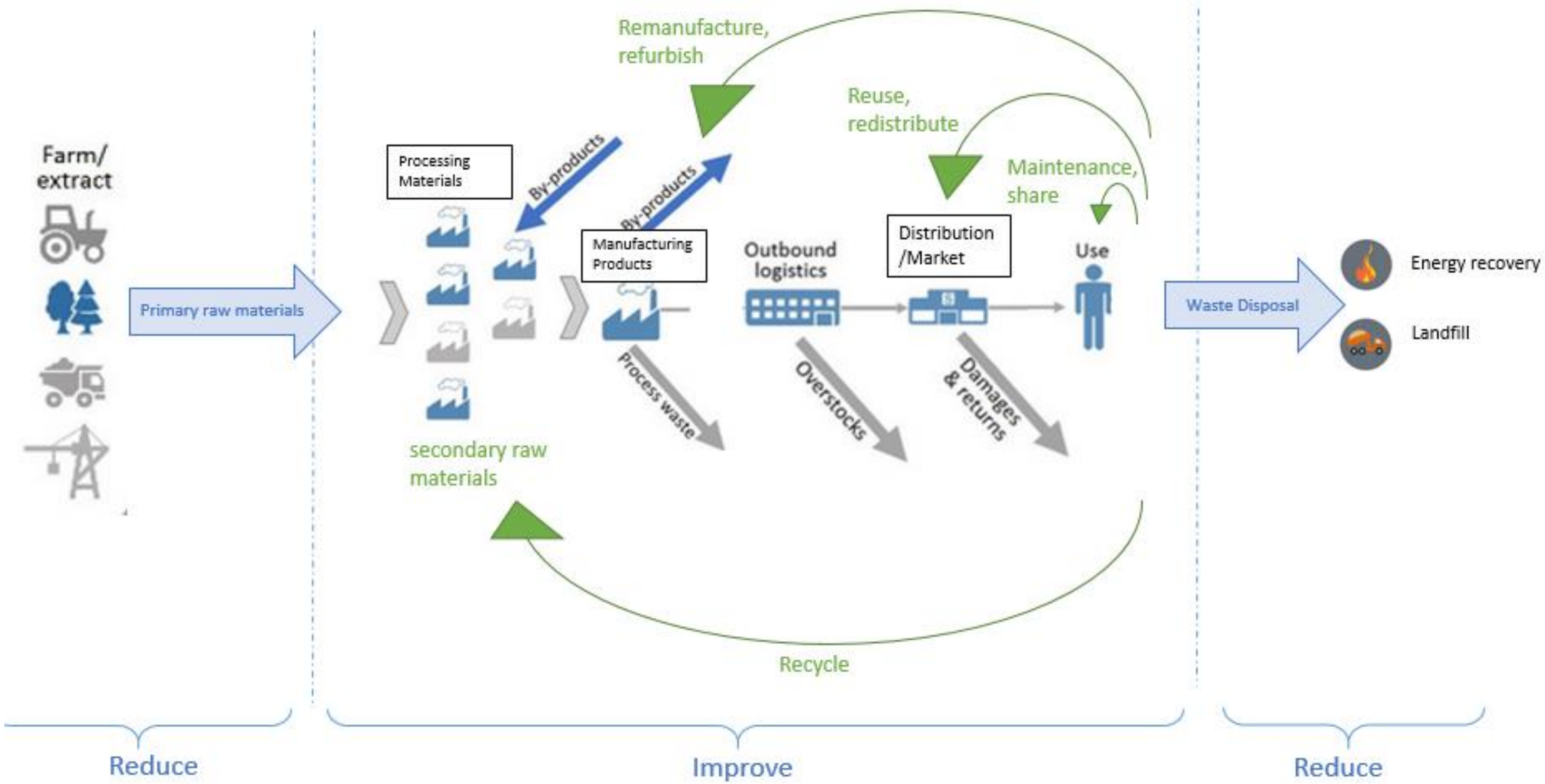
After completing the training trainees will:

- Understand and explain the role of different materials (waste as a resource) in CE.
- Understand the main principles for plastic waste use in CE.
- Understand the main principles for bioplastic use in CE.
- Understand the main principles for steel and metals use in CE.
- Understand the main principles for wood, pulp and paper use in CE.
- Understand the main principles for glass use in CE.
- Find out about Critical Materials and their role in CE.

Training Plan

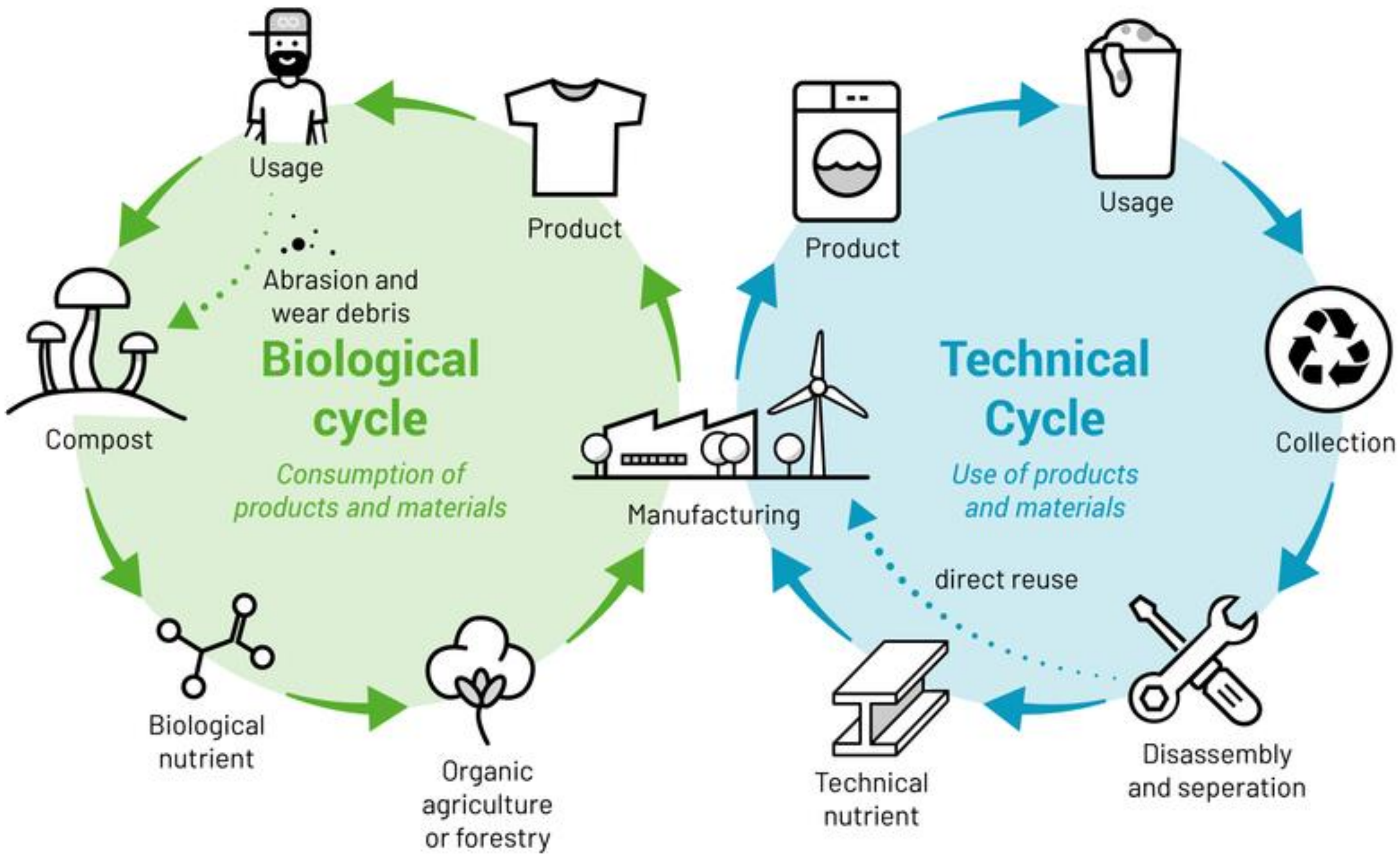
Introduction	**Introduction topic - Role of waste as a resource in CE**
Main part	1. **Technical and organic materials in waste** 2. **Plastic waste in** CE (structure of plastic waste, different types of plastic and its recyclability properties, pollution prevention and eliminating possibilities) 3. **Bioplastics in CE** (types, modifications, labeling and potential in CE) 4. **Steel and metals in CE** (types and potential in CE) 5. **Wood, pulp and paper in CE** (types, labelling and potential in CE) 6. **Glass in CE** (types, labelling and potential in CE) 7. **Critical materials and their role in CE** (what is "critical material" impact and possibilities to eliminate) 8. **What are eco-materials?** (Definition of superior properties of eco-materials)
Conclusion	**Practical Recommendations and Tips - Selection of low-impact materials as resources (from waste) in Circular Economy** **How to choose**: Cleaner materials, Renewable materials, Lower energy content materials, Recycled materials, Recyclable materials, Materials with positive social impact, i.e., generating local income, Reduction of materials usage.

Introduction –
Role of waste as a resource in CE



Conceptual scheme of the components of a circular economy (Circular Economy: a smart way of using materials, materialflows.net)

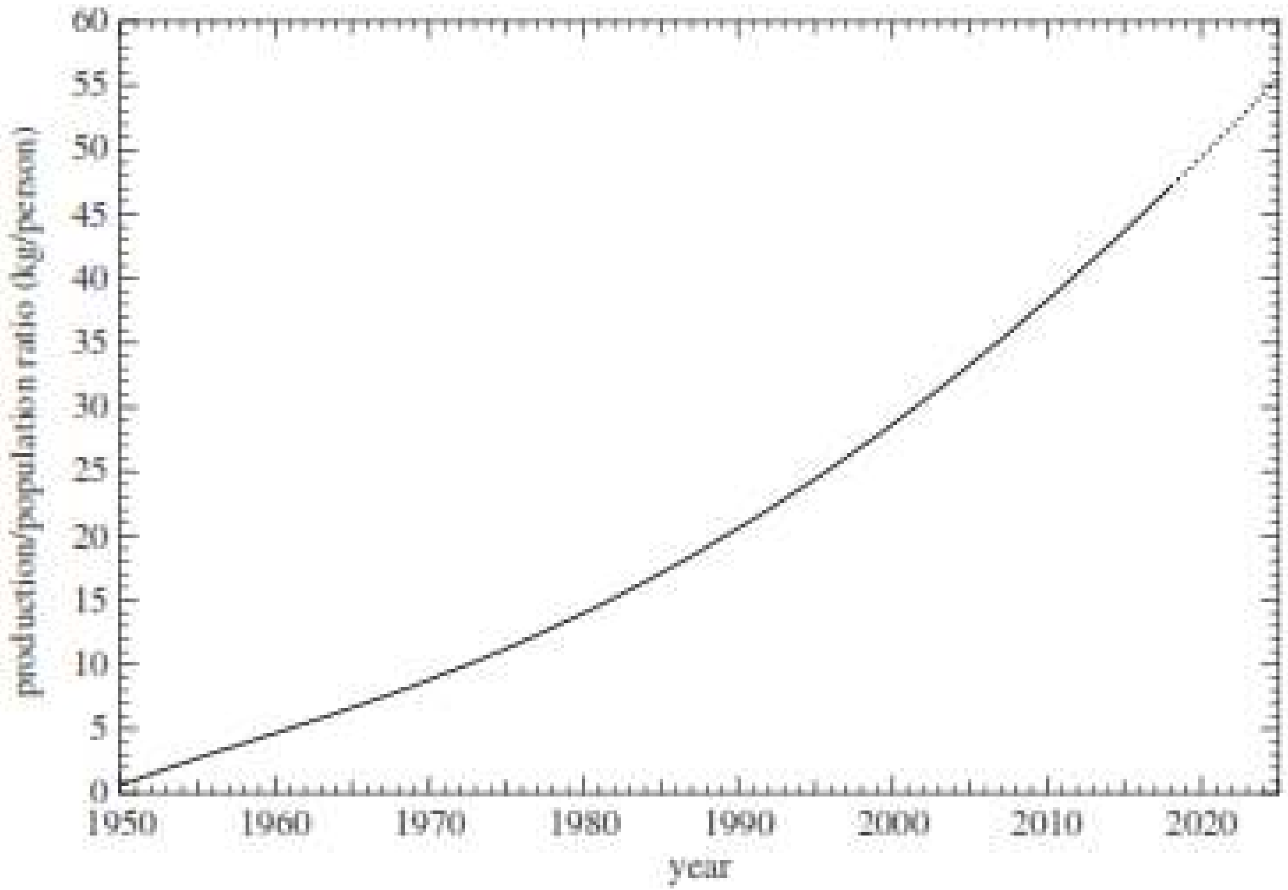
Technical and organic materials



Cradle to Cradle concept by M. Braungart and W. McDonough

Plastic in Circular Economy

Plastic in Circular Economy

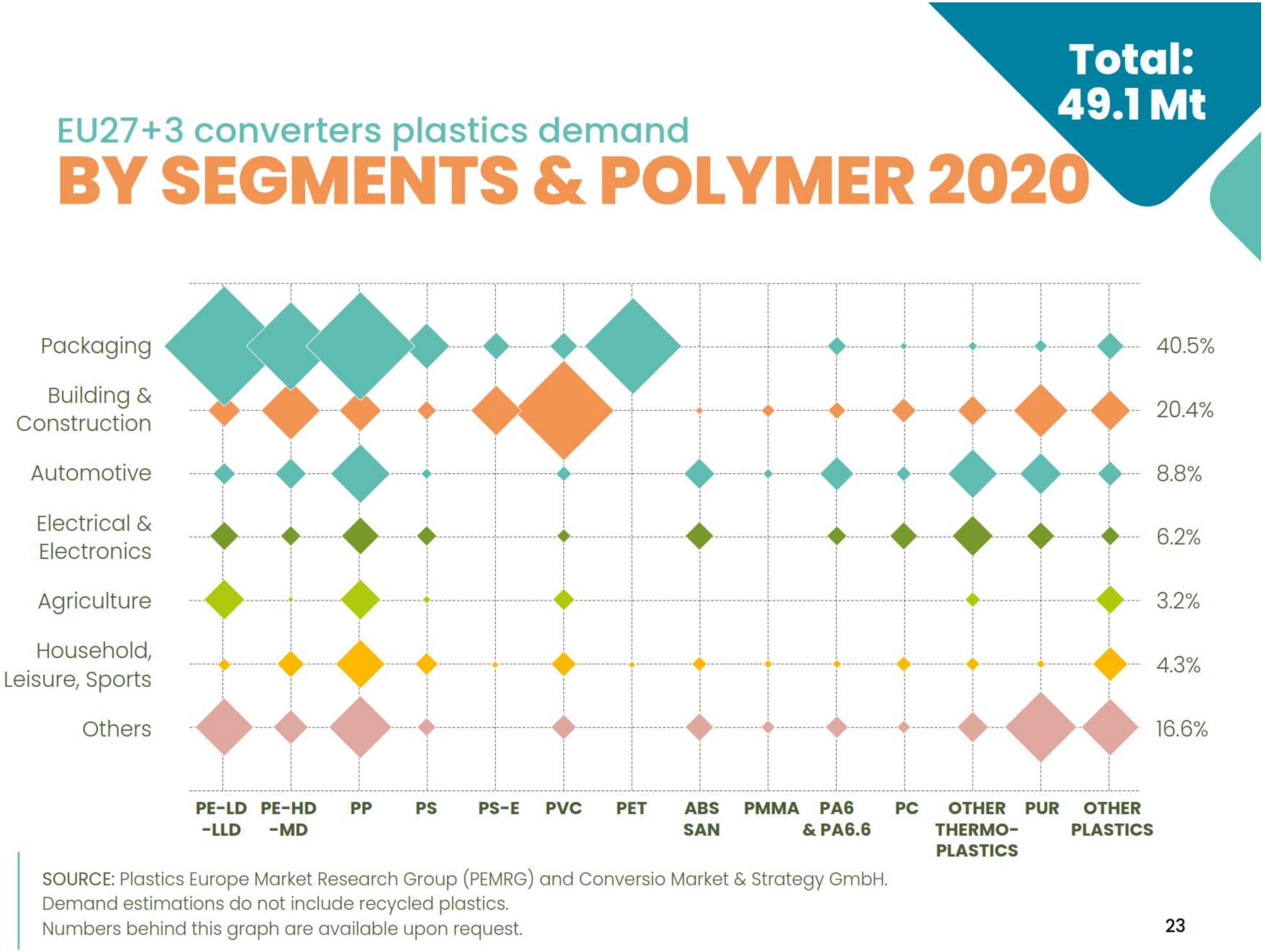


Normalized global total plastics production per person as a function of year. The dashed line represents a polynomial extrapolation of both production and population figures (Bucknall, 2020).

Plastic in Circular Economy

- The global population has increased from about 2.5 billion in 1950 to 7.7 billion people today, i.e., a threefold increase.
- By comparison, the normalized plastics production, i.e., the mass produced per capita per year averaged across the global population, shows that there has been an almost 50-fold increase in the mass of plastics per capita generated over this period.
- Even with the rise in recycling practices over recent years, most end-of-life plastics are currently either still sent to landfill or increasingly incinerated for energy recovery, both practices that not only damage the environment in different ways, but also represent an enormous loss of a valuable resource.

Plastic in Circular Economy



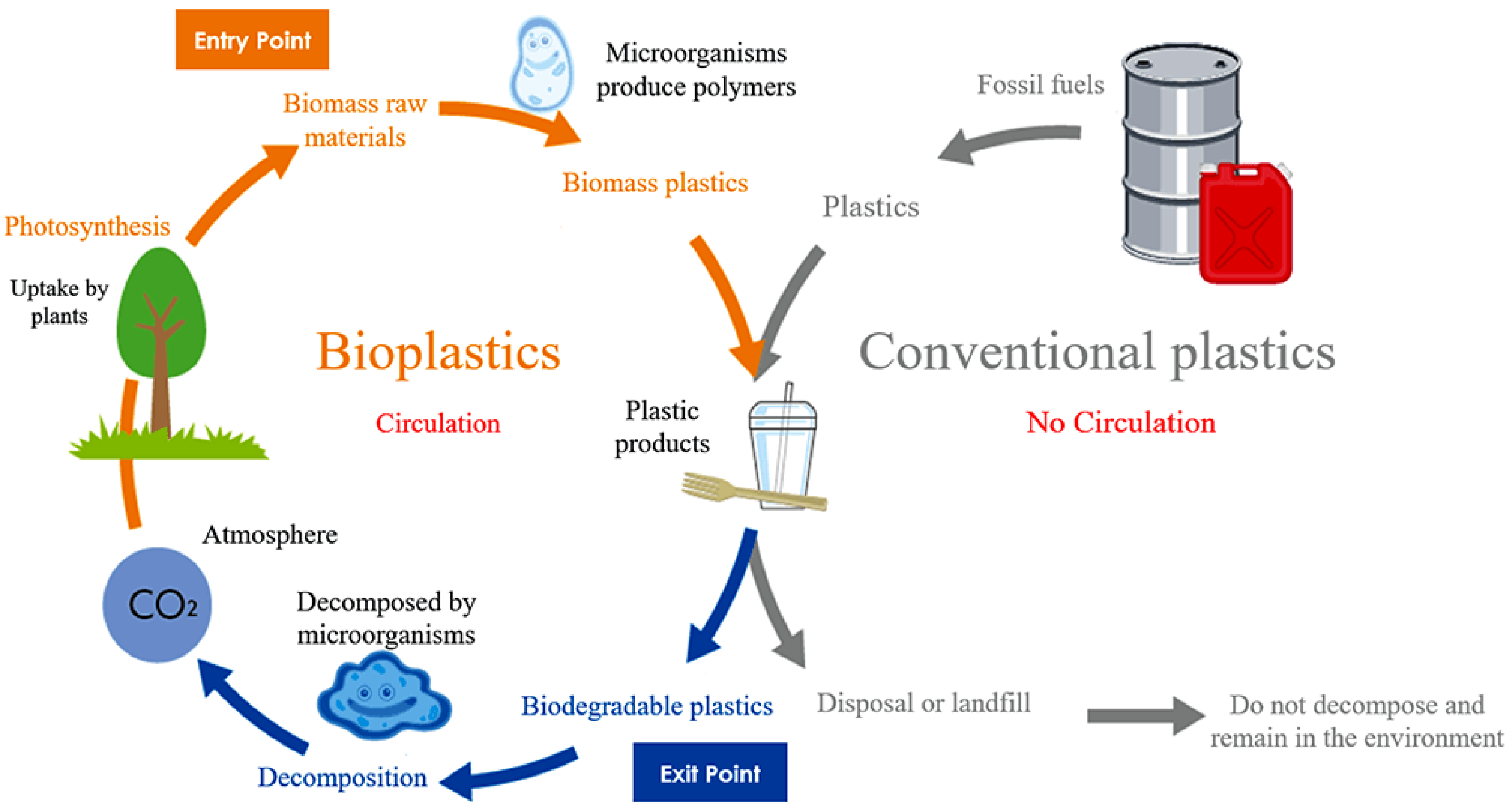
Eliminate the plastics we don’t need

The vision for a circular economy for plastic has six key points:

1. Elimination of problematic or unnecessary plastic packaging through redesign, innovation, and new delivery models is a priority
2. Reuse models are applied where relevant, reducing the need for single-use packaging
3. All plastic packaging is 100% reusable, recyclable, or compostable
4. All plastic packaging is reused, recycled, or composted in practice
5. The use of plastic is fully decoupled from the consumption of finite resources
6. All plastic packaging is free of hazardous chemicals, and the health, safety, and rights of all people involved are respected.

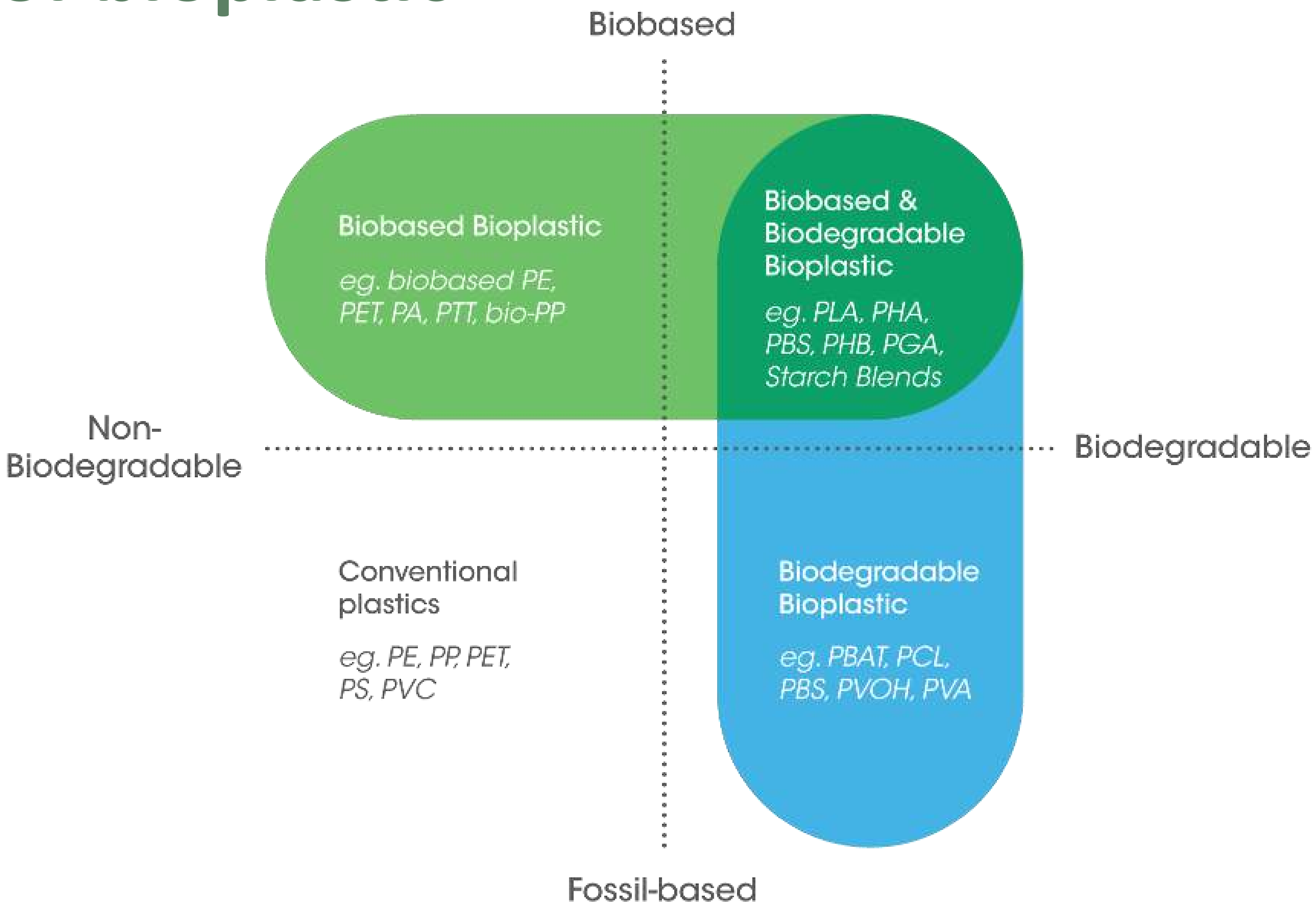
Bioplastic in Circular Economy

Bioplastic in Circular Economy



Bioplastic cycle. There are two types of bioplastics, biomass plastics and biodegradable plastics. Plastics made from biomass are called biomass plastics. Plastics that can be decomposed by microorganisms after use are called biodegradable plastics. If biodegradable plastics comprising biomass can be developed, plastic substances can circulate from entry to exit through the cycle, further reducing their impact on the environment.

Types of bioplastic



Types of bioplastic

Bioplastics are a large family of different materials

According to European Bioplastics, a plastic material is defined as a bioplastic if it is either biobased, biodegradable, or features both properties.

Biobased

The term 'biobased' means that the material or product is (partly) derived from biomass or biowaste. Biomass used for bioplastics stems from e.g. corn, sugarcane or cellulose. Bioplastics can also be produced by microbes or based on CO2 or methane.

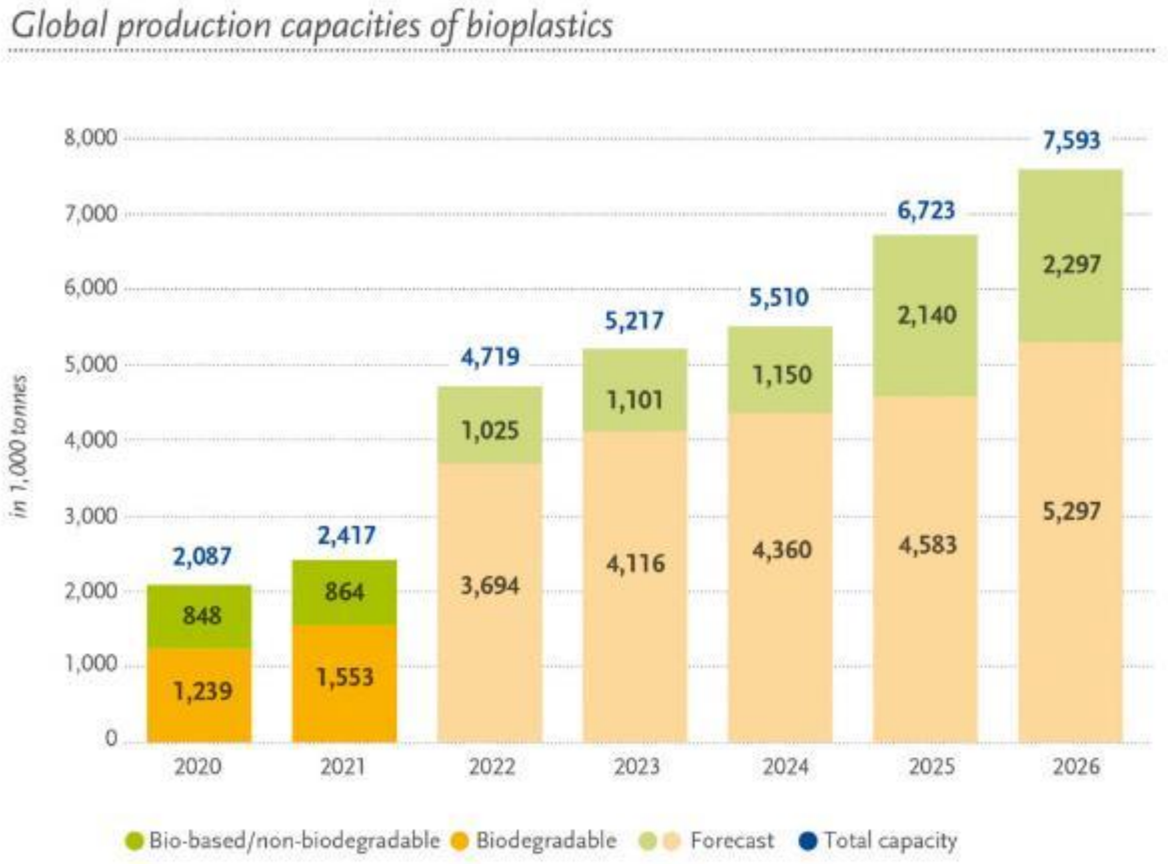
Biodegradable

Biodegradation is a chemical process during which microorganisms that are available in the environment convert materials into natural substances such as water, carbon dioxide, and compost (artificial additives are not needed). The process of biodegradation depends on the surrounding environmental conditions (e.g. location or temperature), on the material and on the application.

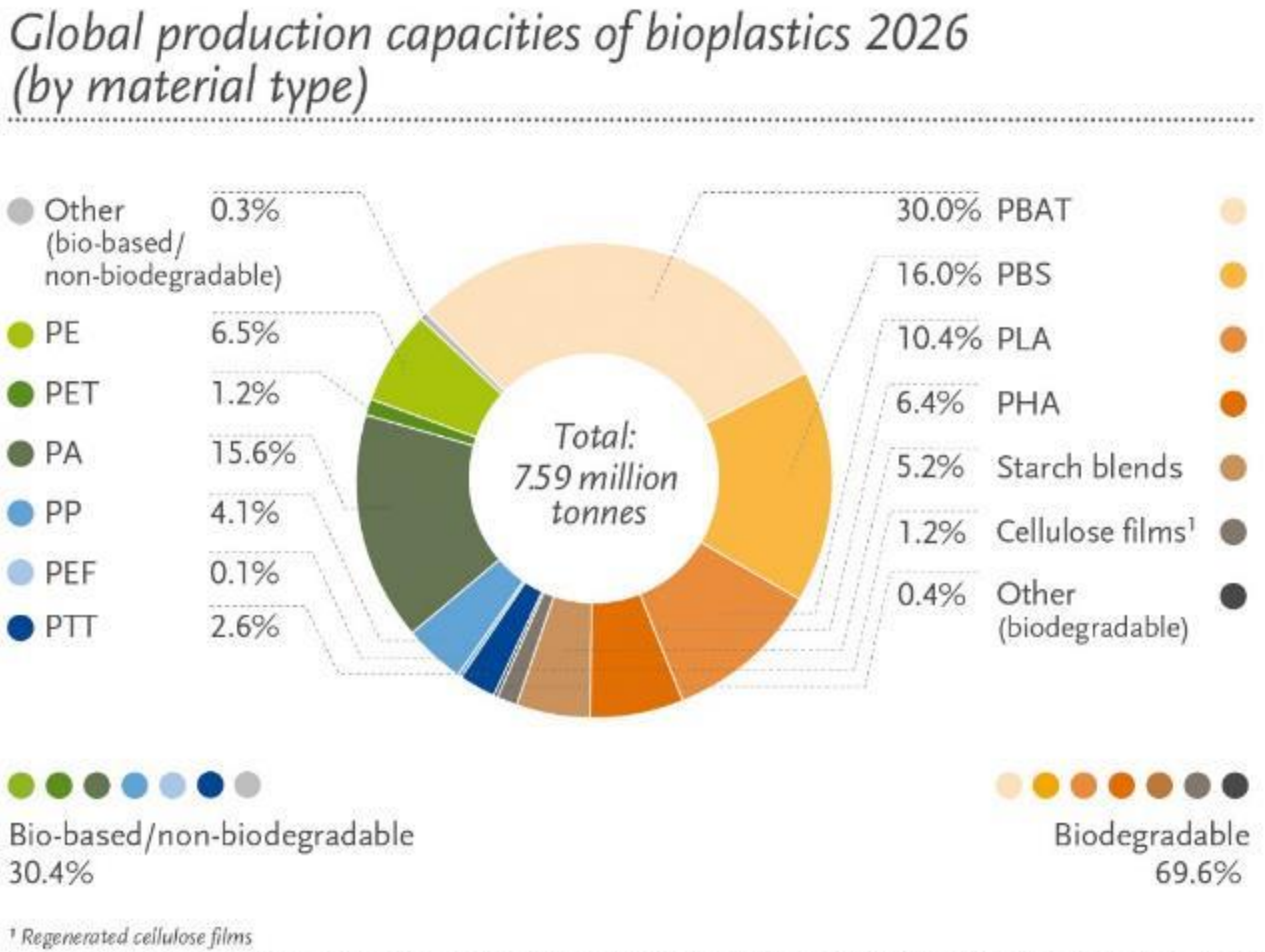
'Biobased' does not equal 'biodegradable'

The property of biodegradation does not depend on the resource basis of a material but is rather linked to its chemical structure. In other words, 100 percent biobased plastics may be non-biodegradable, and 100 percent fossil-based plastics can biodegrade.

Global production capacities of bioplastic

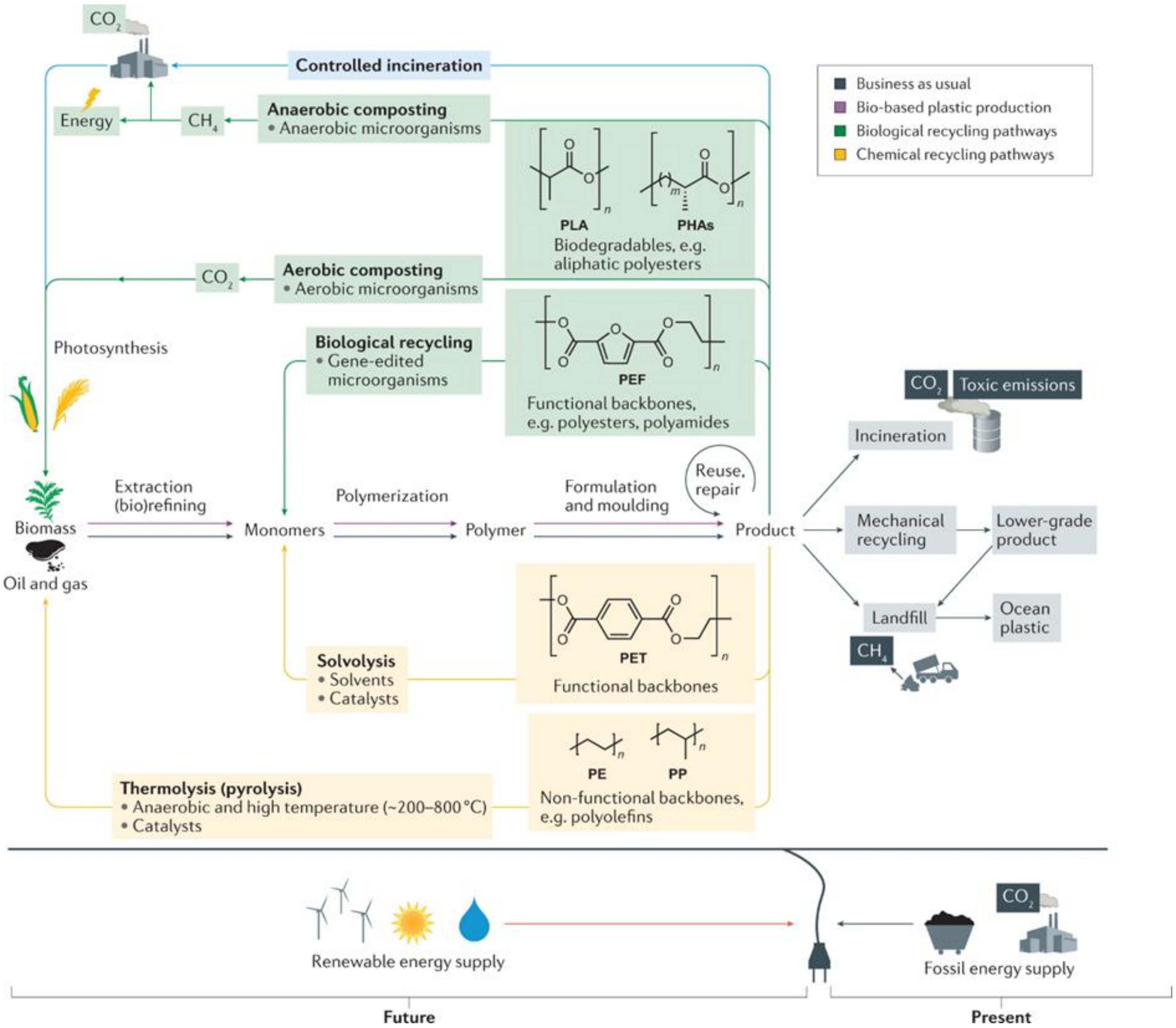


Source: European Bioplastics, nova-Institute (2021)
More information: **www.european-bioplastics.org/market** and **www.bio-based.eu/markets**



¹ Regenerated cellulose films

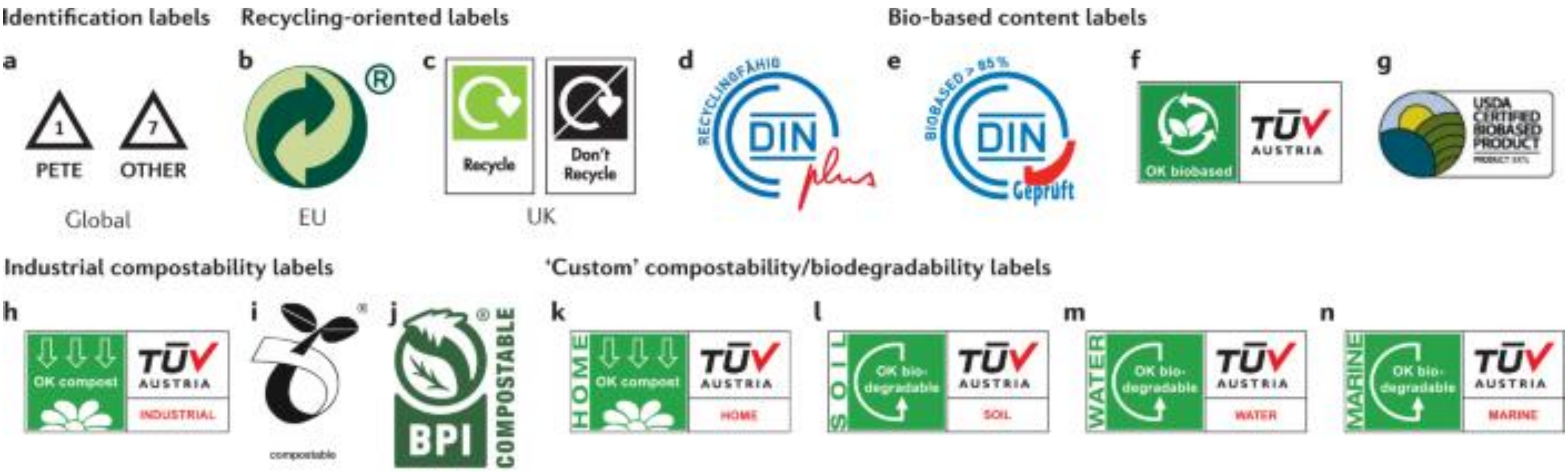
Source: European Bioplastics, nova-Institute (2021)
More information: **www.european-bioplastics.org/market** and **www.bio-based.eu/markets**



The circular plastic economy.

(Rosenboom, JG., et al., 2022)

'Custom' compostability/biodegradability labels



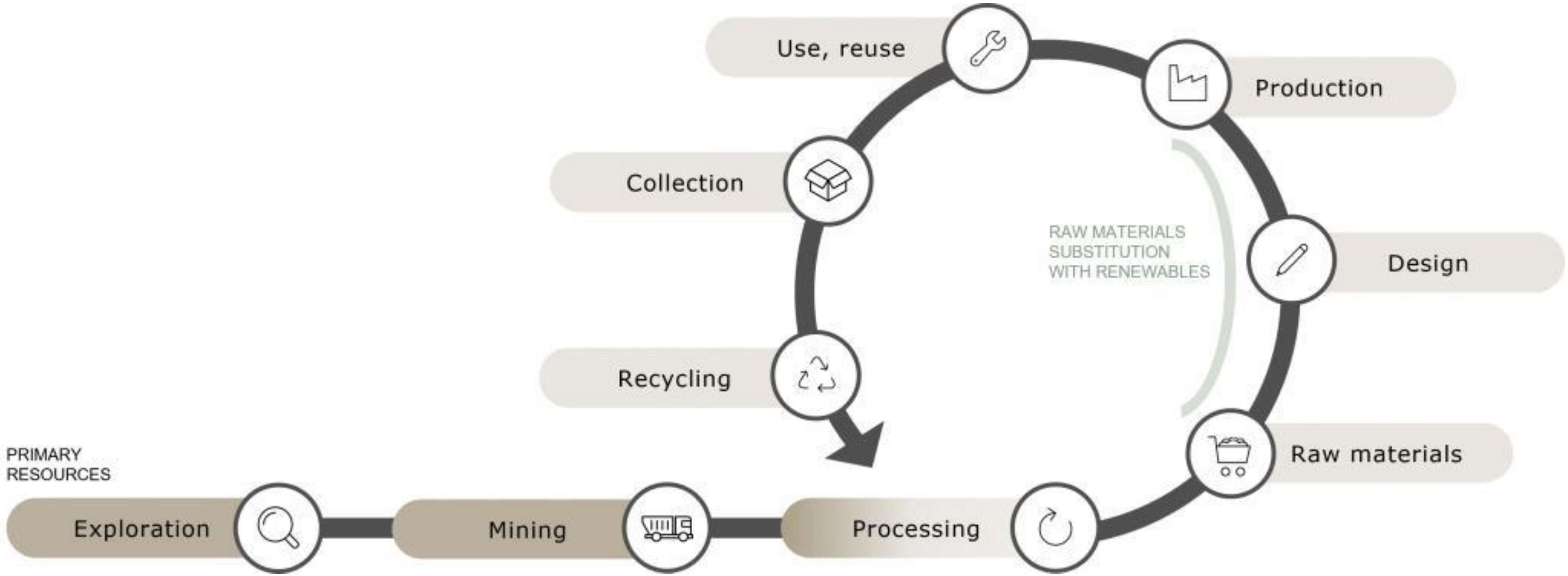
Examples of different biodegradability labelling (Rosenboom, JG., et al.2022)

Labelling bioplastics

- Identification labels
- Recycling-oriented labels
- Bio-based content labels
- Industrial compostability labels
- ‘Custom’ compostability/ biodegradability labels

Steel and metals in CE

Steel and metals in CE

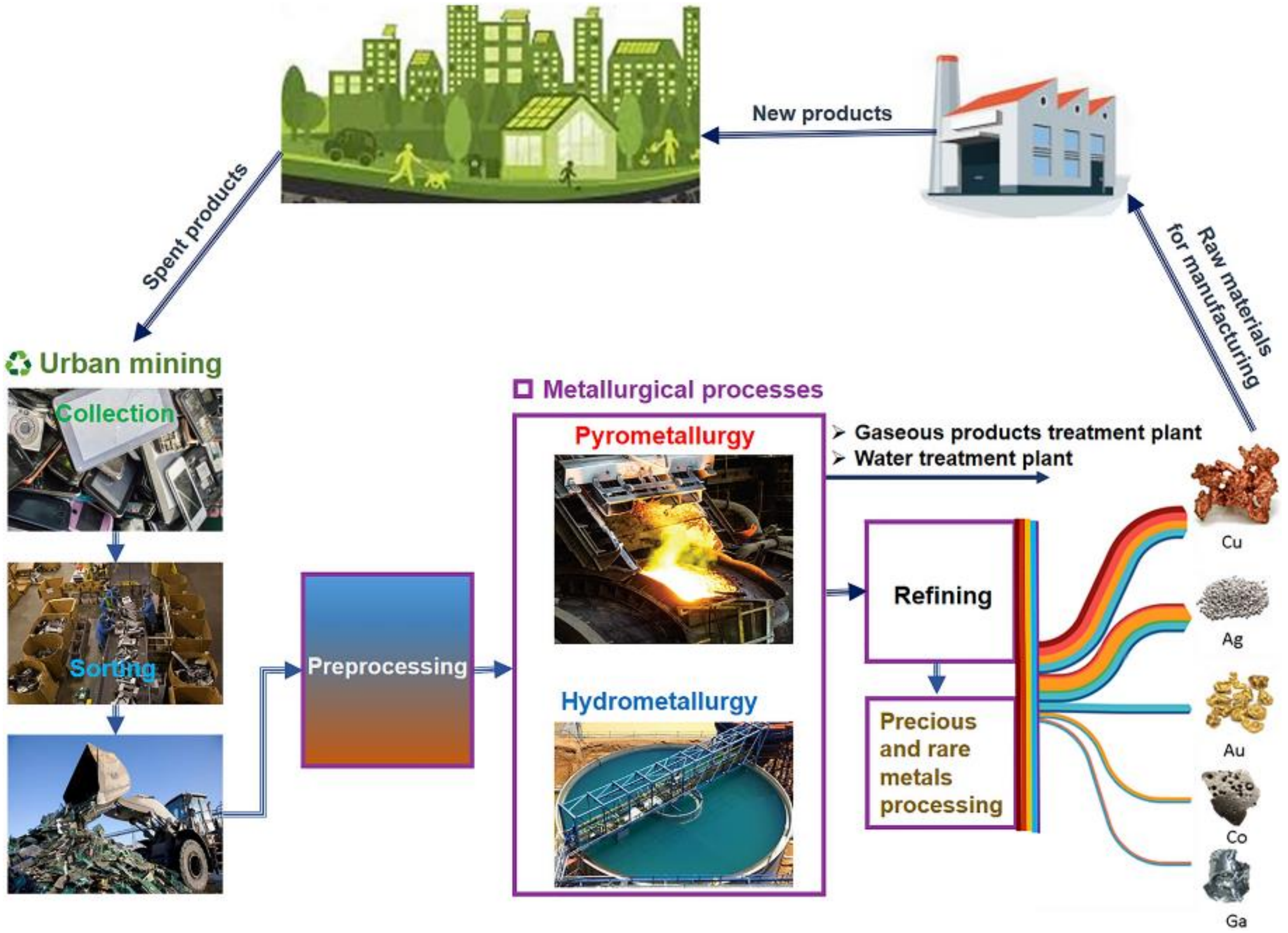


Recycling enables the creation of new goods with a far smaller carbon footprint than by extracting virgin resources; therefore, it is vital to change present practices.

Steel and metals in CE

- In theory, all new steel can be made from recycled steel.
- Around 75 % of steel products ever made are still in use today.
- Buildings and other structures made from steel can last from 40 to 100 years or longer if proper maintenance is carried out.
- Large, heavy structural steel components need planning for end-of-life management.

Steel and metals in CE



Tesfaye, F., Hamuyuni, J., Iloeje, C.O. et al. Technology Metals in the Circular Economy of Cities. JOM **74**, 596–598 (2022)

Processing of Metals in Makerspace

Common Ferrous Metals:

- **Alloy Steel** – such as stainless steel and core-ten.
- **Carbon Steel** – commonly used in fabrication.
- Mild Steel or Carbon Steel is manufactured in two ways:
- **Hot Rolled** – Typically used for making larger structural members, it is cheaper but less dimensionally stable.
- **Cold Rolled** – Very dimensionally consistent, it has sharper corners and cleaner finish quality. Typically used for detailed applications and furniture.

Common Non-Ferrous Metals:

- Aluminium
- Brass
- Copper
- Titanium
- Gold
- Silver

Which metals can be welded?

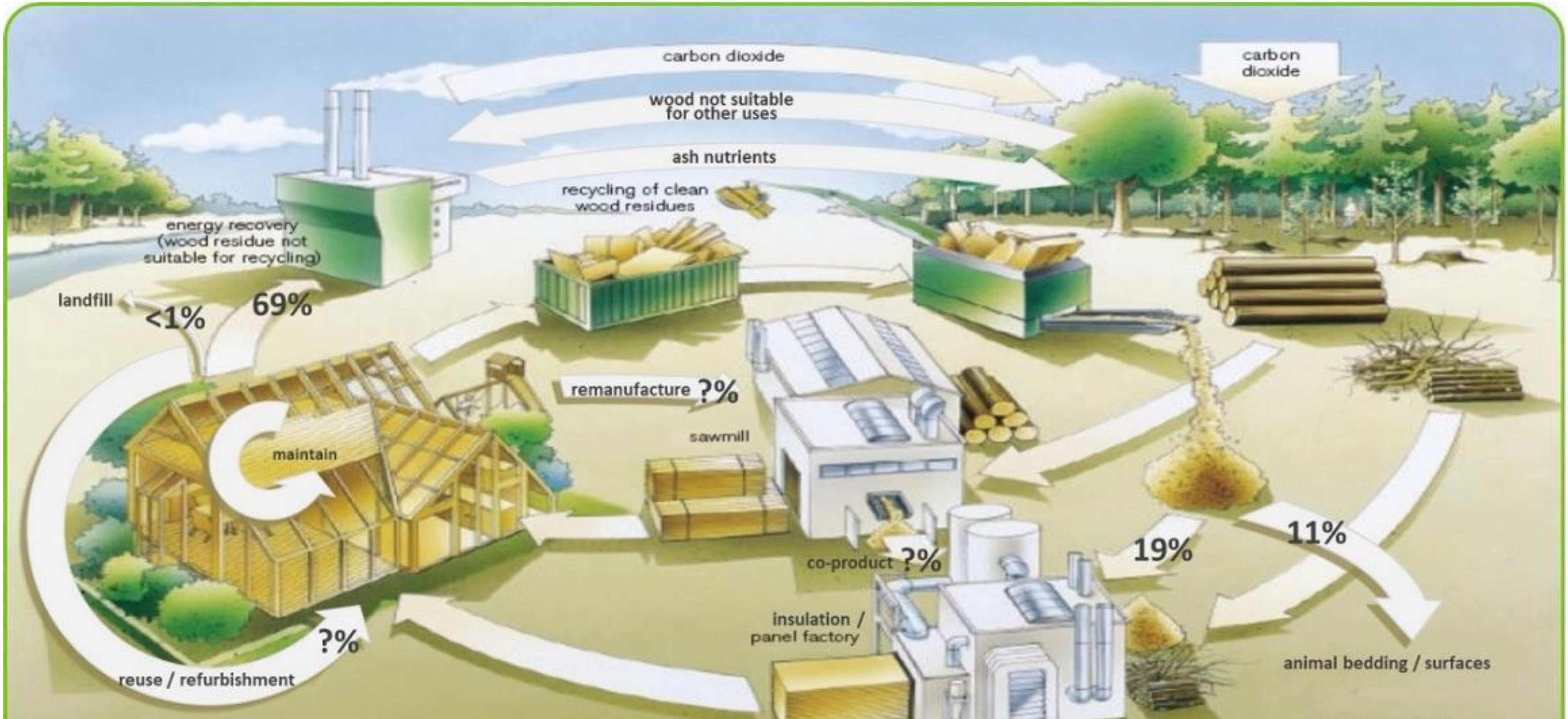
Mild Steel (Hot/Cold Rolled)
•Comes in a large selection of dimensions and profiles.
•Typically requires minimal preparation if the material is new.
•Large pieces can be cut to length by the supplier where needed.
•Ideal for structural components or details which are hidden.
•The best choice if you have bends in your design.
•Cost effective and easy to work with.
•Easy to clean and finish.
•It will oxidise (rust) if left unfinished, so this is a good choice if you plan to powder-coat or paint the component.
•Can be welded with MIG or TIG

Stainless Steel (304 and 316)
•Comes in a limited selection of dimensions and profiles.
•Requires minimal prep.
•Ideal for components which can be seen, or where a raw metal finish is desired.
•Does not oxidise, ideal for outdoor applications.
•Harder and more challenging to work than mild steel.
•More susceptible to distortion when heated.
•More expensive than mild steel.
•More challenging to weld.
•Can be Tig or Mig welded.

Aluminium
•Difficult to weld
Titanium
•Difficult to weld

Wood, pulp and paper in CE

Timber in CE



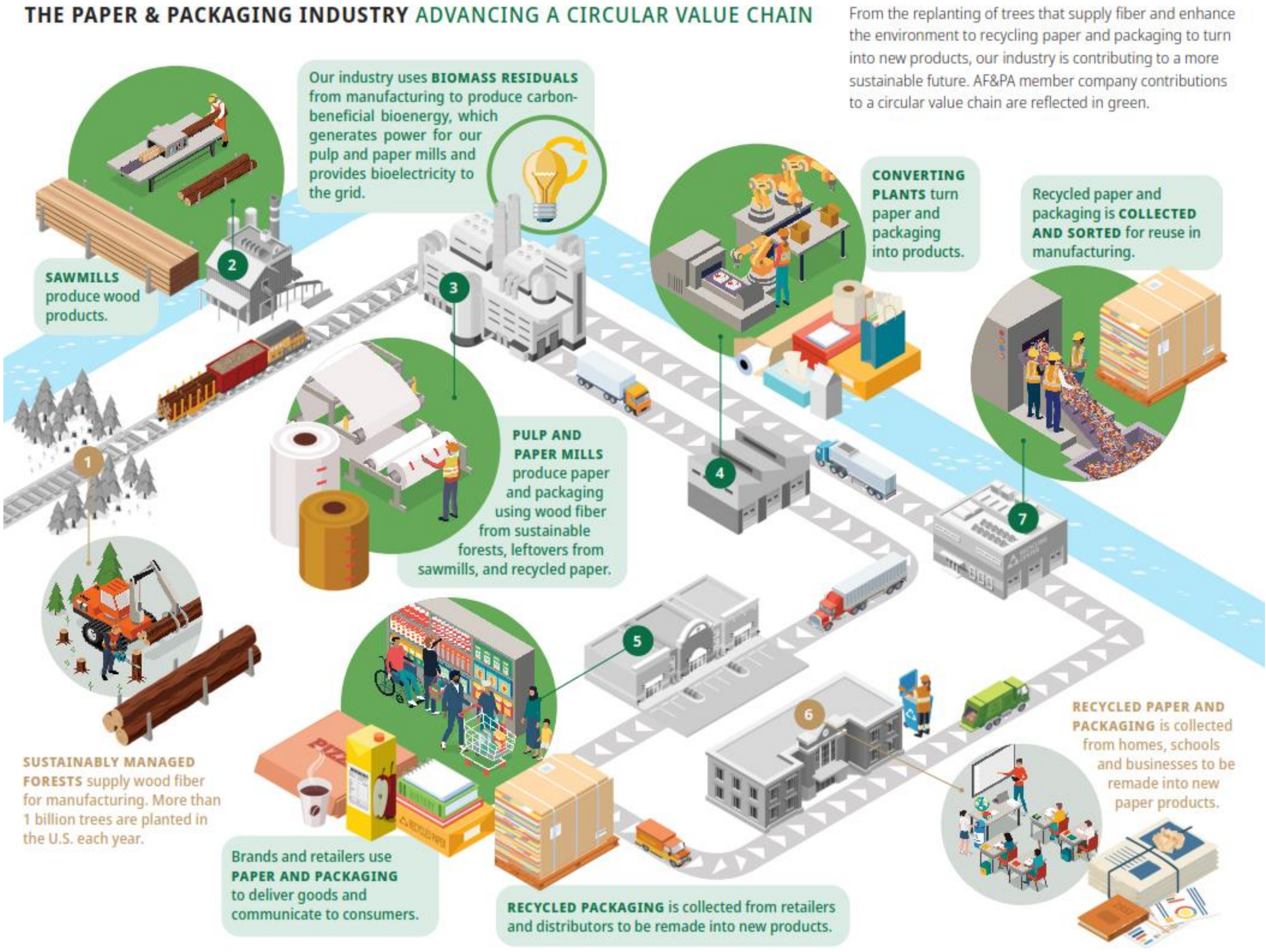
Adapted from CEI Bois – Tackle Climate Change 2009

Timber in CE

With ever-increasing energy and resources going into timber production generally, and engineered timber products, should designers look at how these products could be developed to follow the technical cycle, at least initially, and aim to:

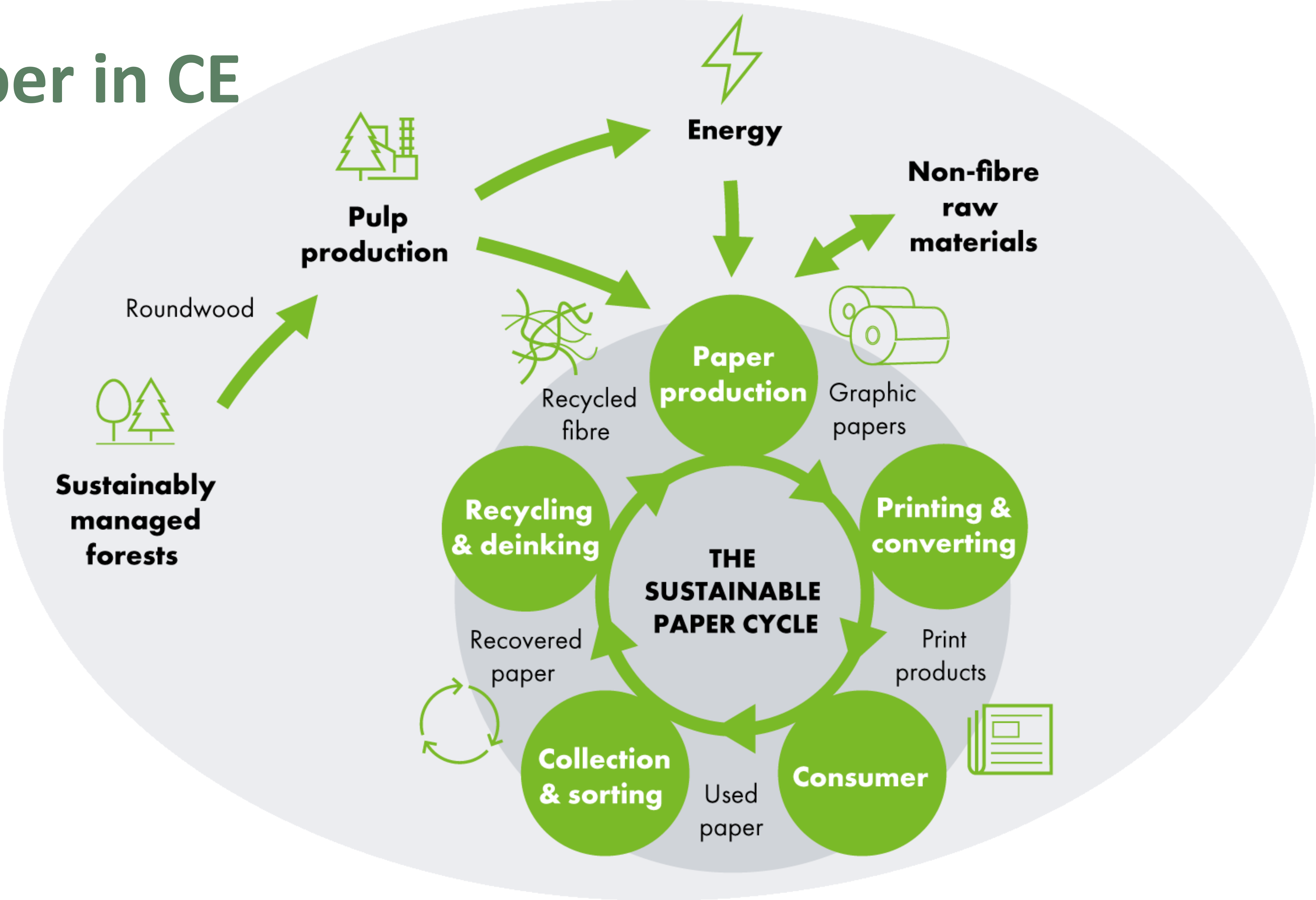
- maintain timber products in place for longer,
- refurbish and reuse timber components,
- look at how certain components could be remanufactured.

Wood and paper in CE



Source: The American Forest & Paper Association (AF&PA)

Paper in CE



Energy
Non-fibre raw materials
Pulp production
Roundwood
Sustainably managed forests
Recycled fibre
Paper production
Graphic papers
Recycling & deinking
Printing & converting
THE SUSTAINABLE PAPER CYCLE
Recovered paper
Print products
Collection & sorting
Used paper
Consumer

FSC® (Forest Stewardship Council) and PEFC™ (the Programme for the Endorsement of Forest Certification) labels

Glass in CE

Circularity of Glass

Circularity of Glass

- Once produced, glass is one of those rare materials that can be 100% and infinitely recycled in a bottle-to-bottle loop without any loss of quality: recycled glass is not waste, but a precious resource the industry requires to replace virgin raw materials.
- Glass recycling has many benefits: more than 70% of all post-consumer glass packaging is recycled in the EU, thus keeping valuable resources out of landfills.
- One ton of recycled glass saves 1.2 tons of virgin raw materials and cuts CO2 emissions by 60%.
- The container glass manufacturing model fits perfectly with the EU’s ambition to build a circular economy.

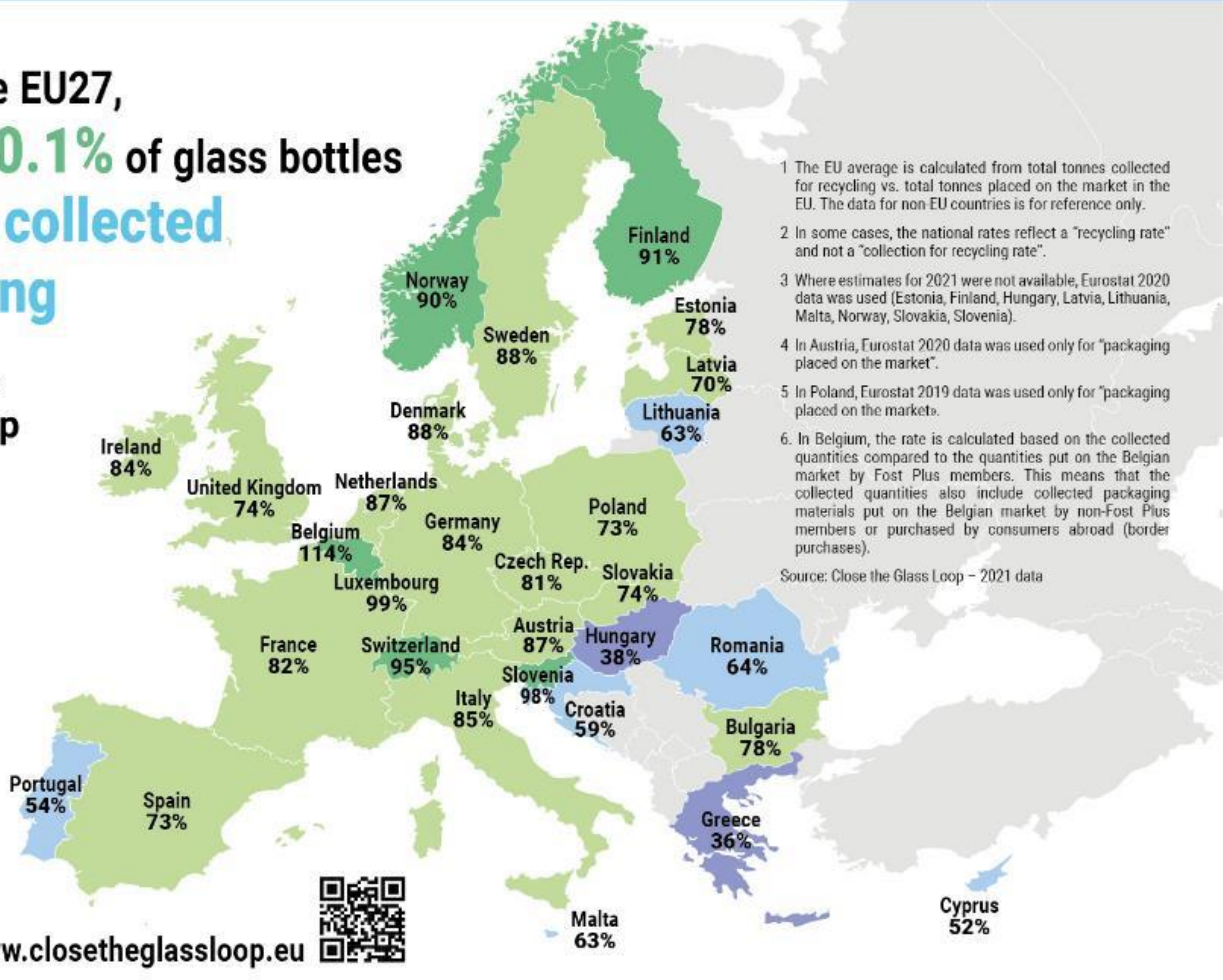
Container glass collection for recycling in Europe

Collection and Recycling

In 2021, in the EU27, on average 80.1% of glass bottles and jars were collected for recycling

close the glass loop

- > 90%
- 70-90%
- 50-70%
- < 50%

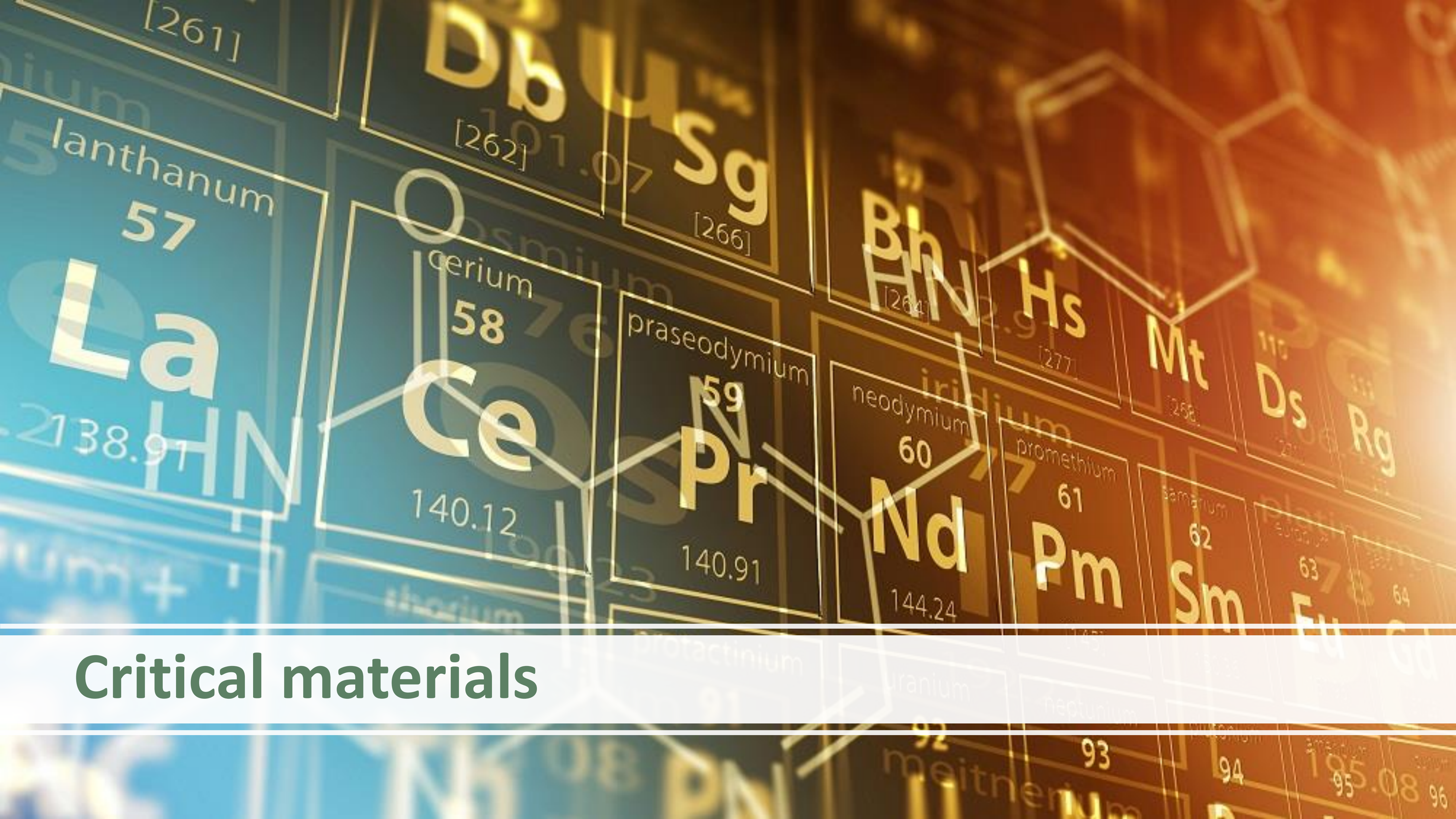


More details on **www.closetheglassloop.eu**

Glass in CE

To close the loop and achieve a complete circular economy for glass packaging in Europe, the European container glass industry calls on the European Institutions to consider the following points as essentials for a Circular Economy:

- Multiple recycling of a permanent material is the best option for resource efficiency.
- Separate collection and a ban on backfilling for recyclable materials are key to ensure that the best quality recycles are re-introduced into the production process.
- Manufacturing industries, such as glass packaging which produce sustainable products, create jobs and bring added value to Europe, and need to be supported as they already are successful examples of a European Circular Economy.



Critical materials

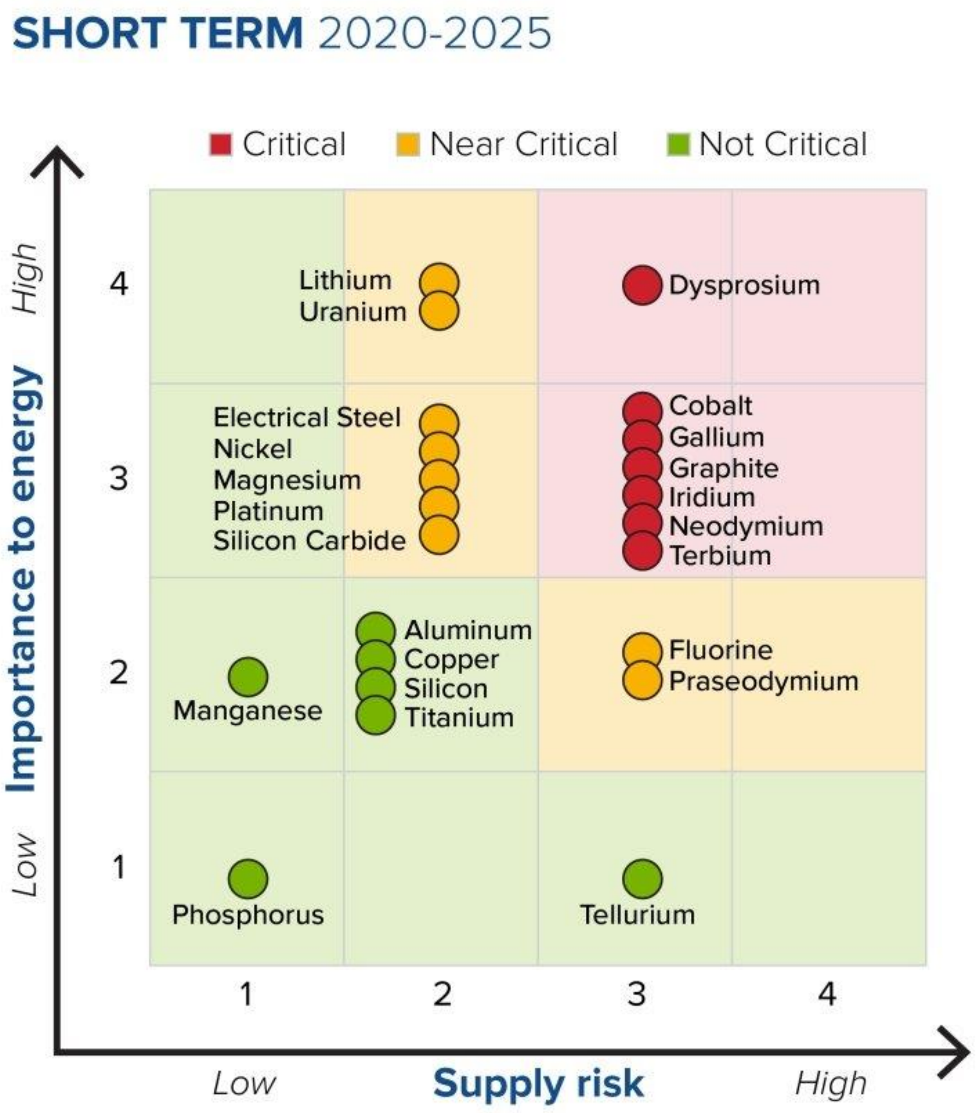
Critical materials

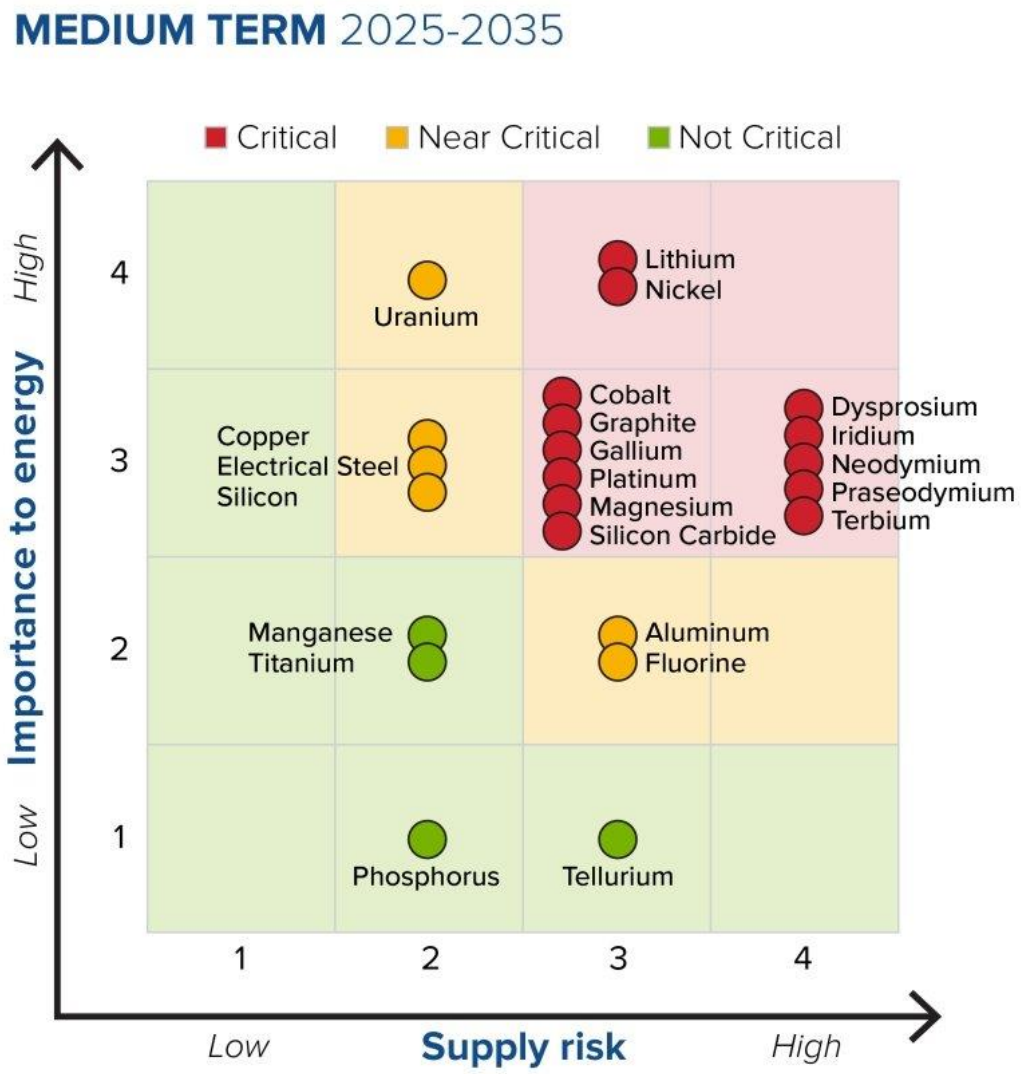
Critical materials are fundamental to both advanced and clean technologies. Access to a secure supply of these materials is key to maintaining quality of life, geopolitical and economic stability and is necessary for the transition to a climate-neutral global economy.

The 2020 EU list contains 30 materials as compared to 14 materials in 2011, 20 materials in 2014 and 27 materials in 2017. Currently, 26 materials remain on the list.

2020 EU Critical Raw Materials		
Antimony	Hafnium	Phosphorus
Baryte	Heavy Rare Earth Elements	Scandium
Beryllium	Light Rare Earth Elements	Silicon metal
Bismuth	Indium	Tantalum
Borate	Magnesium	Tungsten
Cobalt	Natural Graphite	Vanadium
Coking Coal	Natural Rubber	Bauxite
Fluorspar	Niobium	Lithium
Gallium	Platinum Group Metals	Titanium
Germanium	Phosphate rock	Strontium

Short-term (2020–2025) and Medium-term (2025–2035) U.S. criticality matrix

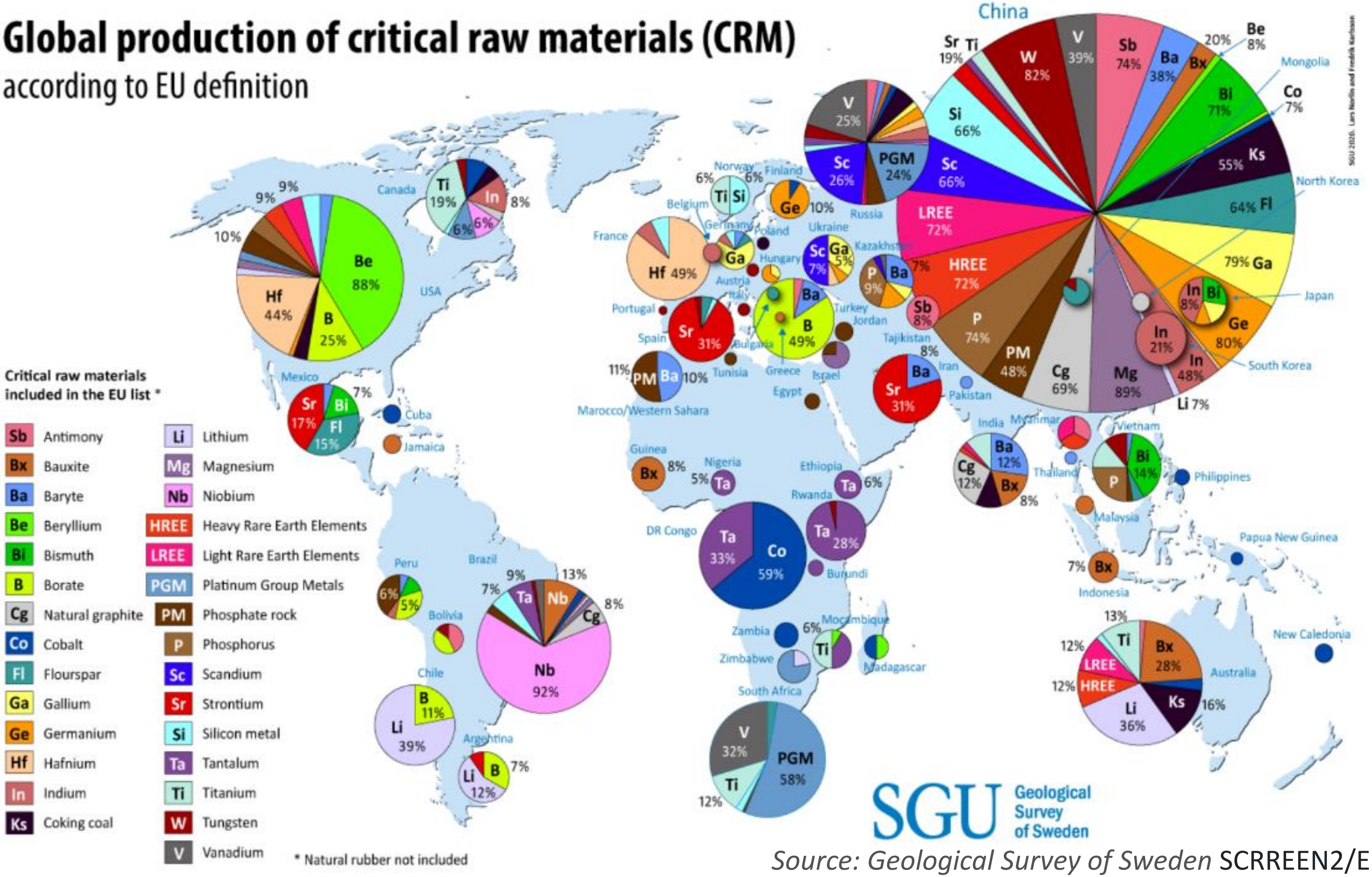




Source: U.S. Geological Survey, 2022

Global production of critical raw materials (CRM)

according to EU definition



Source: Geological Survey of Sweden SCRREEN2/EU.

Critical materials

Integration of the roles of the key stakeholders at all stages of the cradle-to-cradle cycle:

- primary metals producers of both base and rarer metals;
- product designers to optimize critical material use and recyclability into the design phase;
- retailers and local government to provide the facilities for collection and separation to provide the raw materials for recycling;
- consumers to cooperate in separation and return programs for EoL goods;
- governments to provide an appropriate societal and legislative framework to deliver high rates of recycling (e.g., Extended Producer Responsibility schemes, effective collection and sorting and public education);
- recyclers applying best available techniques (BAT) to recover critical materials from separated waste streams.

Critical materials

Seven conditions (Hagelüken (2014)) for effective recycling:

1. Technical recyclability from the source.
2. Accessibility of the source components (e.g., automotive catalysts, car battery, personal computer, mobile phone, motors).
3. Economic viability, whether by the inherent value of the extractive material or the fiscal environment established by regulation.
4. Collection mechanisms to ensure the product is available for recycling.
5. Entry into the recycling chain rather than loss due to export or improper disposal (for instance mislabeling of electronic goods as for reuse and export thereby bypassing waste export regulations).
6. Optimal technical and organizational set-up adapted to the particular product type.
7. Sufficient capacity to handle the potential supply.

Did you know?

Demand for two critical materials (Dy and Nd) could increase between 7-fold and 26-fold over the next 25 years in a business-as-usual scenario.

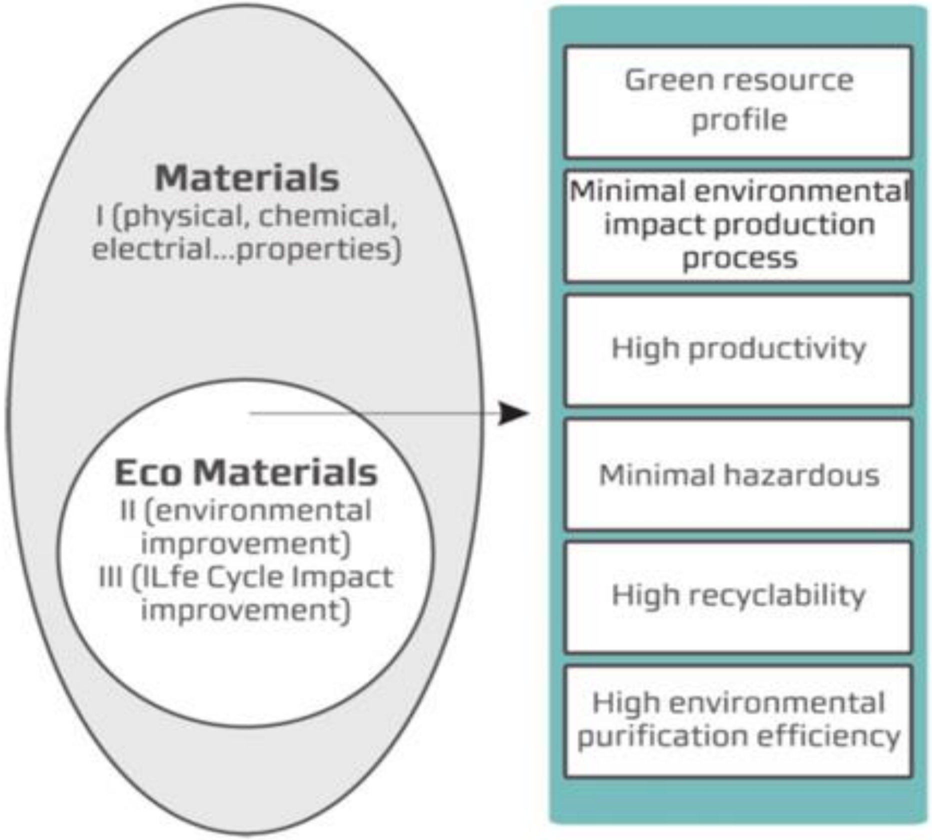
What are eco-materials?

Eco-materials

Definition of superior properties of eco-materials:

1. ***Energy saving ability*** to reduce total life cycle energy consumption of a system or device.
2. ***Resource saving ability*** to reduce the total life cycle material consumption of a system or device.
3. ***Reusability*** to allow the reuse of collected products as similar functions.
4. ***Recyclability*** to allow the use of collected product of material as a raw material.
5. ***Structural reliability*** to be used on the basis of its reliable mechanical properties.
6. ***Chemical stability*** to be used over the long term without chemical degradation.
7. ***Biological safety ability*** to be used without causing negative effects to the ecological system.
8. ***Substitutability*** to be used as an alternative to ‘bad’ materials.
9. ***Amenity*** to ensure the comfort of working environment
10. ***Cleanability*** to separate, fix, remove and detoxify a pollutant for the environmental treatment process.

Eco-materials



- Eco-materials are those that can contribute to reduction of environmental burden through their life cycles.
- In other words, any material could be an eco-material as long as it satisfies the pre-requisites (I) and necessary conditions of eco-materials (II and/or III).
- The pre-requisites of eco-materials include the optimization of physical and/or chemical properties and best technical performance (I).

Conceptual model of eco-materials within the context of material science (Nguyen, X. H.,T. Honda, et al. (2003)).

Sub-categories	Examples
I A: Recycled Materials	Eco-cement. Coal ash concrete, glass ceramics from wastes, recycled plastics, silica fertilizer, marine block.
I B: Renewable materials	Wood ceramics, wood based materials, soil ceramics, biodegradable plastic made of vegetable base.
I C: Material for efficiency	Wasre reduction materials, wear resistant metals and alloys, pre-paint steel and alloy.
II A: Materials for waste treatment	Membranes for exhausted gas separation, ion-exchange resins, microbial enzymes, absorbement materials for oil and grease removal.
II B: Materials for reduction of environment load	Catalysts and biological membrane materials for fuel cells, carbon-fiber composites, photo-catalyst coating materials for construction.
II C: Materials for easy disposal or recicle	Biodegradable plastics, functionally graded material, colorbetos which replace asbestos, TSOP.
III A: Hazardous free materials	Lead-free solder, halogen flame retardant-free plastics, chromium-free steel, VOCs-free adhesive, heavy metals free polyesters.
III B: Materials for reducing human health impacts	Vibration damping steel sheet, sound proof panels, anti-bacteria coating materials, bone-cream for orthopedic surgery and brain surgery.
IV A: Materials for energy efficiency	Ultra-ligh steel, Al-Mg lightweight alloys, heat resistant alooy for turbines, high magnetic induction steel sheets, highly endothermic steel, chromo phobic fibers, heat mirror film for household energy saving.
IV B: Materials for green energy	High grade silicon for solar cells, thermoelectric conversion materials, selective transparent glass, highly durable sealing sheets for solar batteries.

Some examples of eco-materials which are currently commercialized .

Source: (Nguyen, X. H.,T. Honda, et al. (2003))

Practical Recommendations and Tips:

Selection of low-impact materials in Circular Design

How to select:
Cleaner materials?

1. Do not use materials or additives which are prohibited due to their toxicity. These include PCBs (polychlorinated biphenyls), PCTs (polychlorinated terphenyls), lead (in PVC, electronics, dyes, and batteries), cadmium (in dyes and batteries), and mercury (in thermometers, switches, fluorescent tubes).
2. Avoid materials and additives that deplete the ozone layer such as chlorine, fluorine, bromine, methyl bromide, halons and aerosols, foams, refrigerants, and solvents that contain CFCs.
3. Avoid the use of summer smog-causing hydrocarbons.
4. Find alternatives for surface treatment techniques such as hot-dip galvanization, electrolytic zinc plating and electrolytic chromium plating.
5. Find alternatives for non-ferrous metals such as cop- per, zinc, brass, chromium, and nickel because of the harmful emissions that occur during their production.

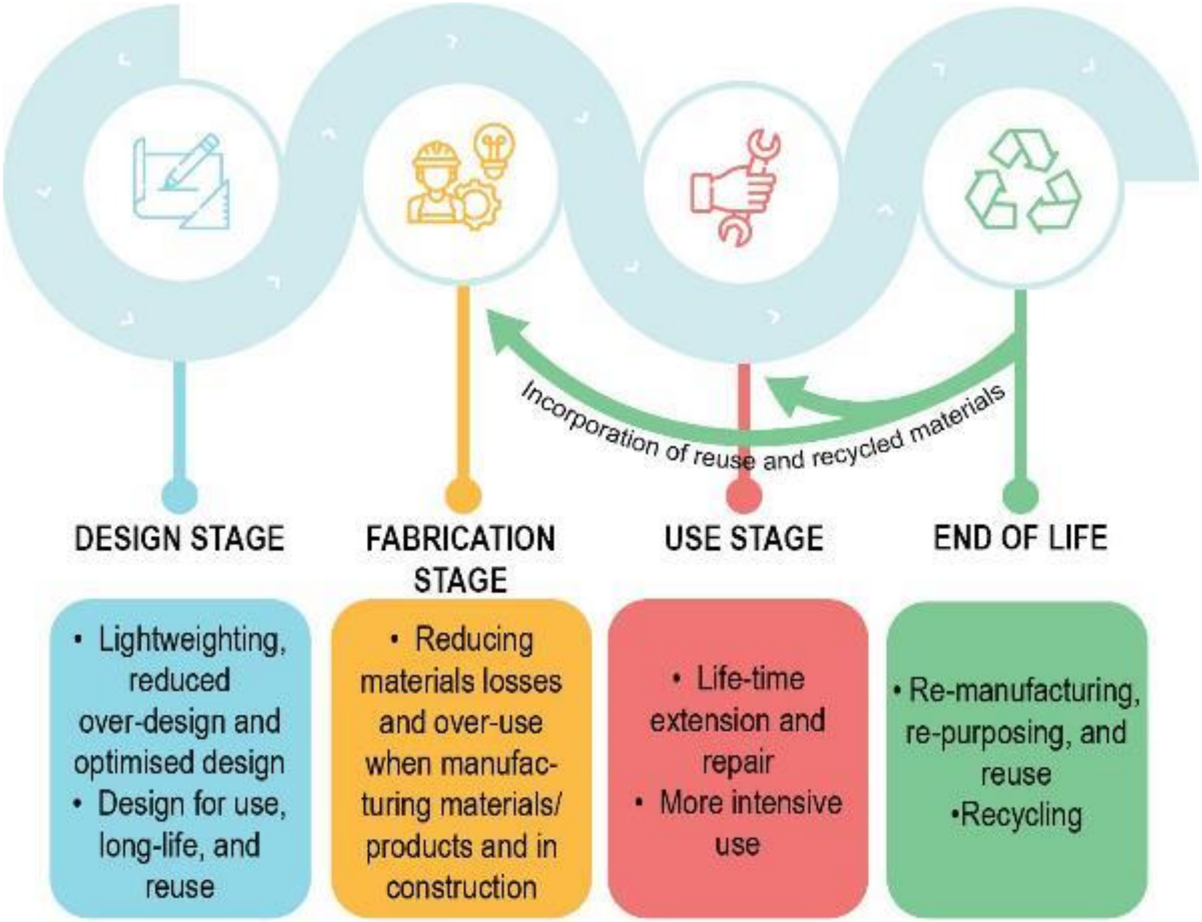
How to select:

Renewable materials?

6. Find alternatives for exhaustible materials.

Lower energy content materials?

7. Avoid energy-intensive materials such as aluminum in products with a short lifetime.
8. Avoid raw materials produced from intensive agriculture.



How to select:
Recycled materials?

9. Use recycled materials wherever possible, to increase the market demand for recycled materials.
10. Use secondary metals such as secondary aluminum and copper instead of their virgin (primary) equivalents.
11. Use recycled plastics for the inner parts of products which have only a supportive function and do not require a high mechanical, hygienic or tolerance quality.
12. When hygiene is important (as in coffee cups and some packaging) a laminate can be applied, the center of which is made from recycled plastic, covered with or surrounded by virgin plastic.
13. Make use of the unique features (such as variations in color and texture) of recycled materials in the design process.

How to select:
Recyclable materials?

14. Select just one type of material for the product as a whole and for the various sub-assemblies.
15. When this is not possible, select mutually compatible materials.
16. Avoid materials which are difficult to separate such as compound materials, laminates, fillers, fire retardants and fiberglass reinforcements.
17. Preferably use recyclable materials for which a market already exists.
18. Avoid the use of polluting elements such as stickers, which interfere with recycling.

How to select:
Materials with positive social impact, i.e., generating local income?

19. Make use of materials supplied by local producers.
20. Stimulate arrangements for recycling of materials by local companies which can substitute (part of) the raw materials of the company.

How to select:
Reduction of materials usage ?

Reduction in weight

21. Aim for rigidity through construction techniques such as reinforcement ribs rather than ‘over dimensioning’ the product.
22. Aim to express quality through good design rather than over dimensioning the product.

Reduction in (transport) volume

23. Aim at reducing the amount of space required for transport and storage by decreasing the product’s size and total volume.
24. Make the product foldable and/or suitable for nesting.
25. Consider transporting the product in loose components that can be nested, leaving the final assembly up to a third party or even the end user.

External resources:

- https://www.circulardesignguide.com/post/material-selection
- https://www.c2ccertified.org/assets/uploads/Herman_Miller_Journal_Of_Industrial_Ecology.pdf
- http://www.planningnotepad.com/2013/01/sustainability-design-3-redesigning.html
- https://blogs.helsinki.fi/inventionsforcirculareconomy/circular-economy/biological-and-technical-cycles/
- https://simplicable.com/new/upcycling-vs-downcycling
- https://www.conserve-energy-future.com/recyclingmaterial.php
- https://www.goodstartpackaging.com/biodegradable-vs-compostable-what-is-the-difference/
- https://www.ecoenclose.com/blog/8-things-to-know-about-compost-facilities-and-6-tips-to-be-a-responsible-composter/
- https://www.geeksforgeeks.org/biodegradable-and-non-biodegradable-materials/

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