Circular Economy: What Does 'Closing the Loop' Mean in €18 Billion of Investments by 2027?

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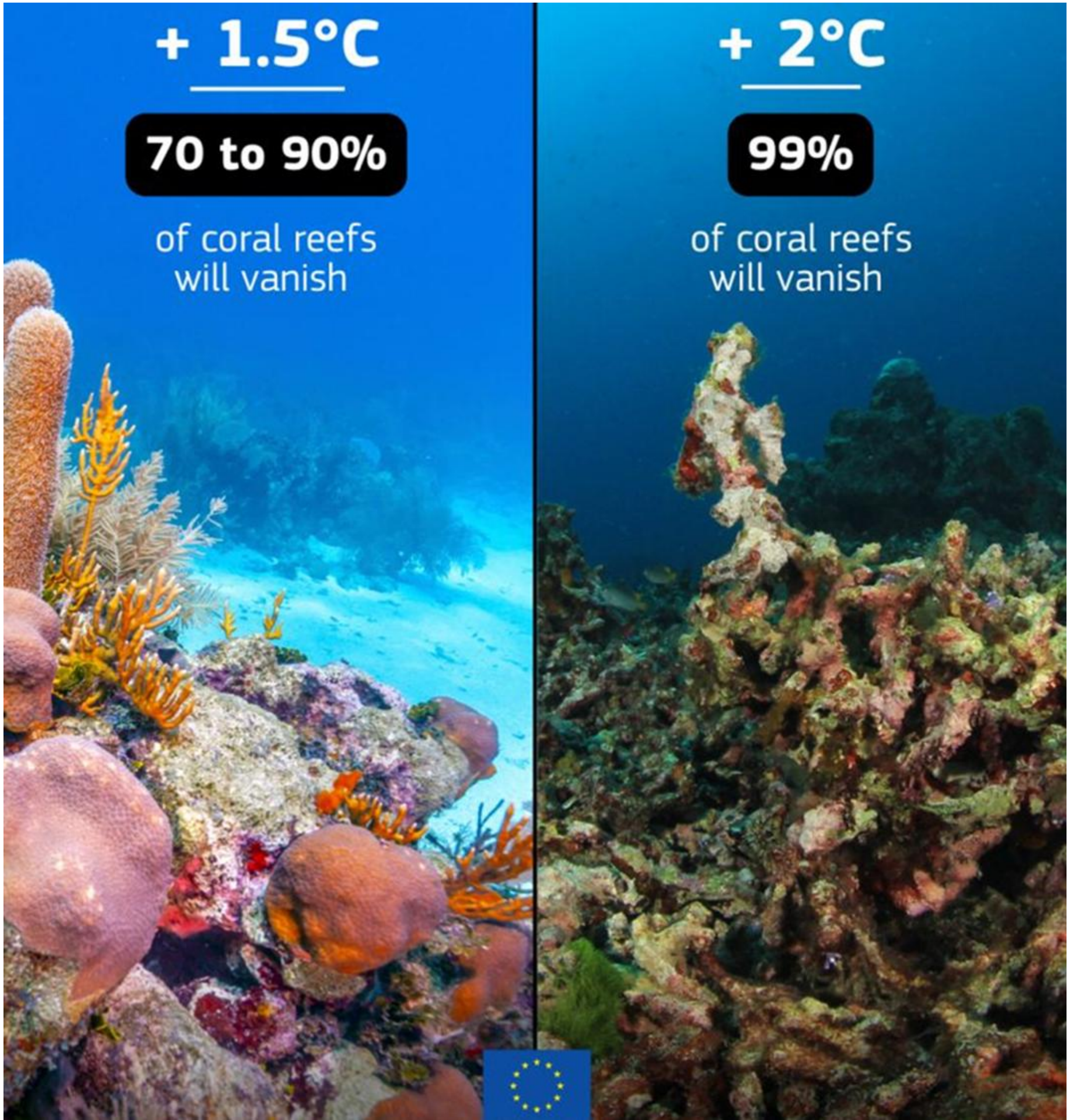
Short intro

In this lecture, you will:

- explore the **foundational principles** of the circular economy;
- examine **key models**, that drive circularity within companies and across the entire value chain;
- gain insight into how **CO_2 emissions** influence investment decisions.
- learn why **collaboration** is crucial for the successful implementation of circular economy initiatives;

THE NEED FOR CIRCULAR ECONOMY

How does climate change affect economies?



What is the EU's strategic goal for 2050?

Home > EU Action > Climate strategies & targets > 2050 long-term strategy

2050 long-term strategy

Striving to become the world's first climate-neutral continent by 2050.

The EU aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions. This objective is at the heart of the European Green Deal, and is a legally binding target thanks to the European Climate Law.

The transition to a climate-neutral society is an opportunity to build a better future for all, while leaving no one behind.

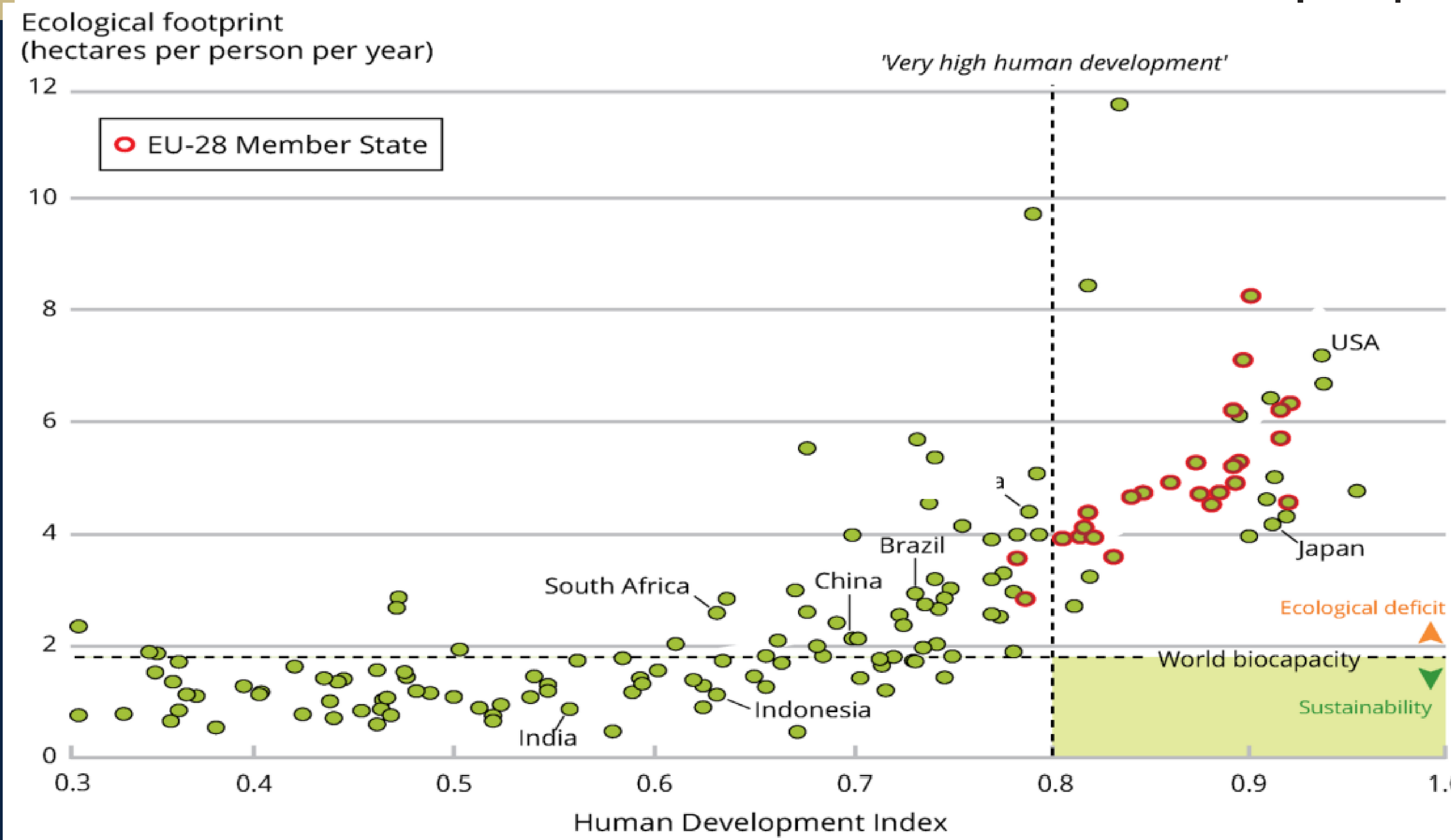
All parts of society and economic sectors will play a role – from the power sector to industry, transport, buildings, agriculture and forestry.

The EU can lead the way by investing in technological solutions, empowering citizens and ensuring action to support a smooth and just transition in key areas such as industrial policy, finance, and research.

The pursuit of climate neutrality is also in line with the EU's commitment to global climate action under the Paris Agreement. The EU submitted its long-term strategy to the United Nations Framework Convention on Climate Change (UNFCCC) in March 2020.

https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en

Goal: climate neutral (low carbon) economy



https://www.eea.europa.eu/en/analysis/maps-and-charts/correlation-between-ecological-footprint-and

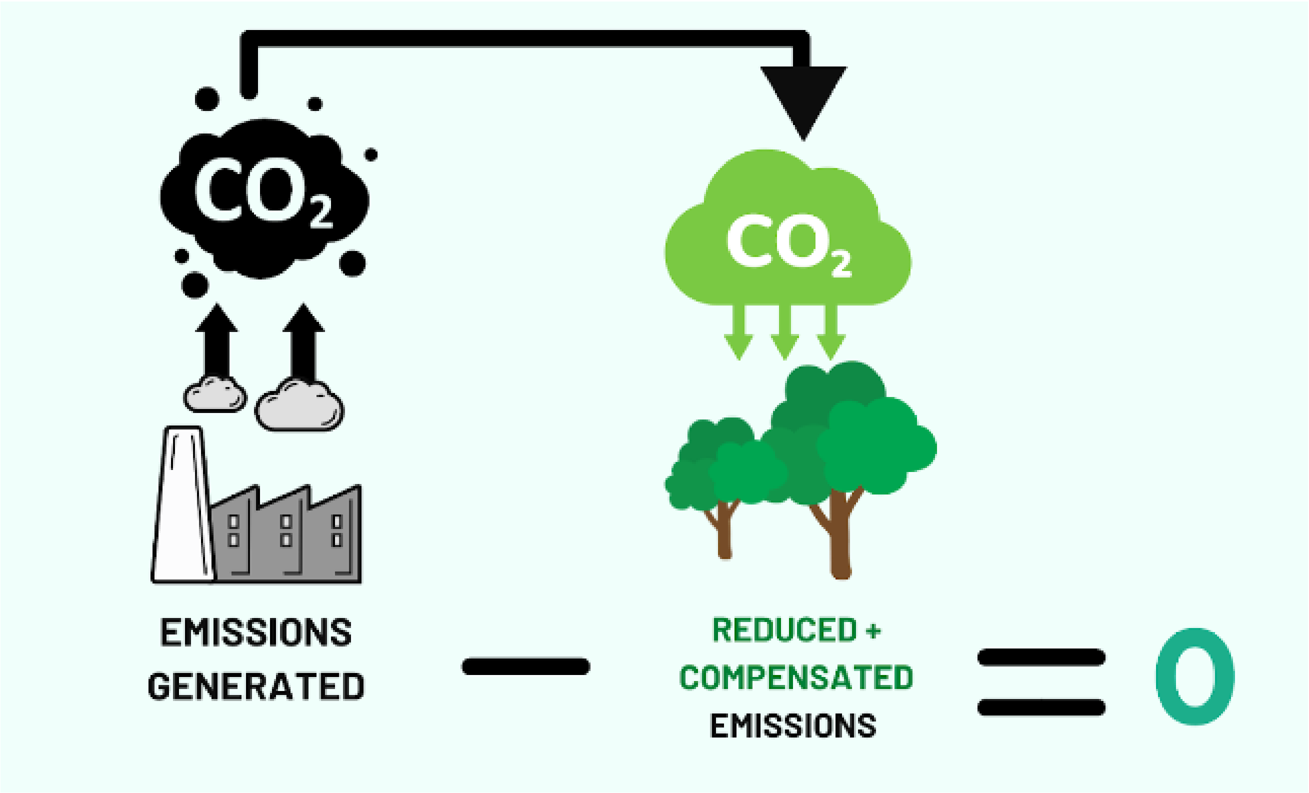
Greenhouse gas emissions

Type of gas	Share gas in GHG	Main source drivers/ Other source drivers	Share in gas total	Year of statistics
CO_2	72%	**Coal combustion**	39%	2018
		Oil combustion	31%	2018
		Natural gas combustion	18%	2018
		Cement clinker production	4%	2017
		Subtotal drivers of CO_2	**92%**	
CH_4	19%	**Cattle**	21%	2017
		Rice production	10%	2018
		Natural gas production (including distribution)	14%	2018
		Oil production (including associated gas venting)	9%	2018
		Coal mining	10%	2018
		Landfill: municipal solid waste generation ~ food consumption	10%	2013
		Waste water	11%	
		Subtotal drivers of CH_4	**85%**	
N_2O	6%	**Cattle** (droppings on pasture, range and paddock) *	23%	2017
		Synthetic fertilisers (N content) *	13%	2017
		Animal manure applied to soils *	5%	2017
		Crops (share of N-fixing crops, crop residues and histosols)	11%	2017
		Fossil fuel combustion	11%	2018
		Manure management (confined)	4%	2017
		Indirect: atmospheric deposition & leaching and run-off (NH_3)*	9%	2017
		Indirect: atmospheric deposition (NO_x from fuel combustion)	7%	2018
		Subtotal drivers of N_2O, incl. other, related drivers (*)	**83%**	
F-gases	3%	HFC use (emissions in CO_2 eq)	61%	NA/2017 **
		HFC-23 from HCFC-22 production (emissions in CO_2 eq)	22%	NA/2017 **
		SF_6 use (emissions in CO_2 eq)	14%	NA/2017 **
		PFC use and by-product (emissions in CO_2 eq)	3%	NA/2017 **
		Subtotal drivers of F-gases	**100%**	

Goal: net zero economy/carbon neutrality

Net zero: focuses on neutralizing all GHG emissions.

Carbon neutrality: focuses on neutralizing CO2 emissions.



https://en.carbonneutralplus.com/what-is-and-how-to-achieve-carbon-neutrality/

Goal: net zero economy/carbon neutrality

The main natural CO_2 absorbents are:

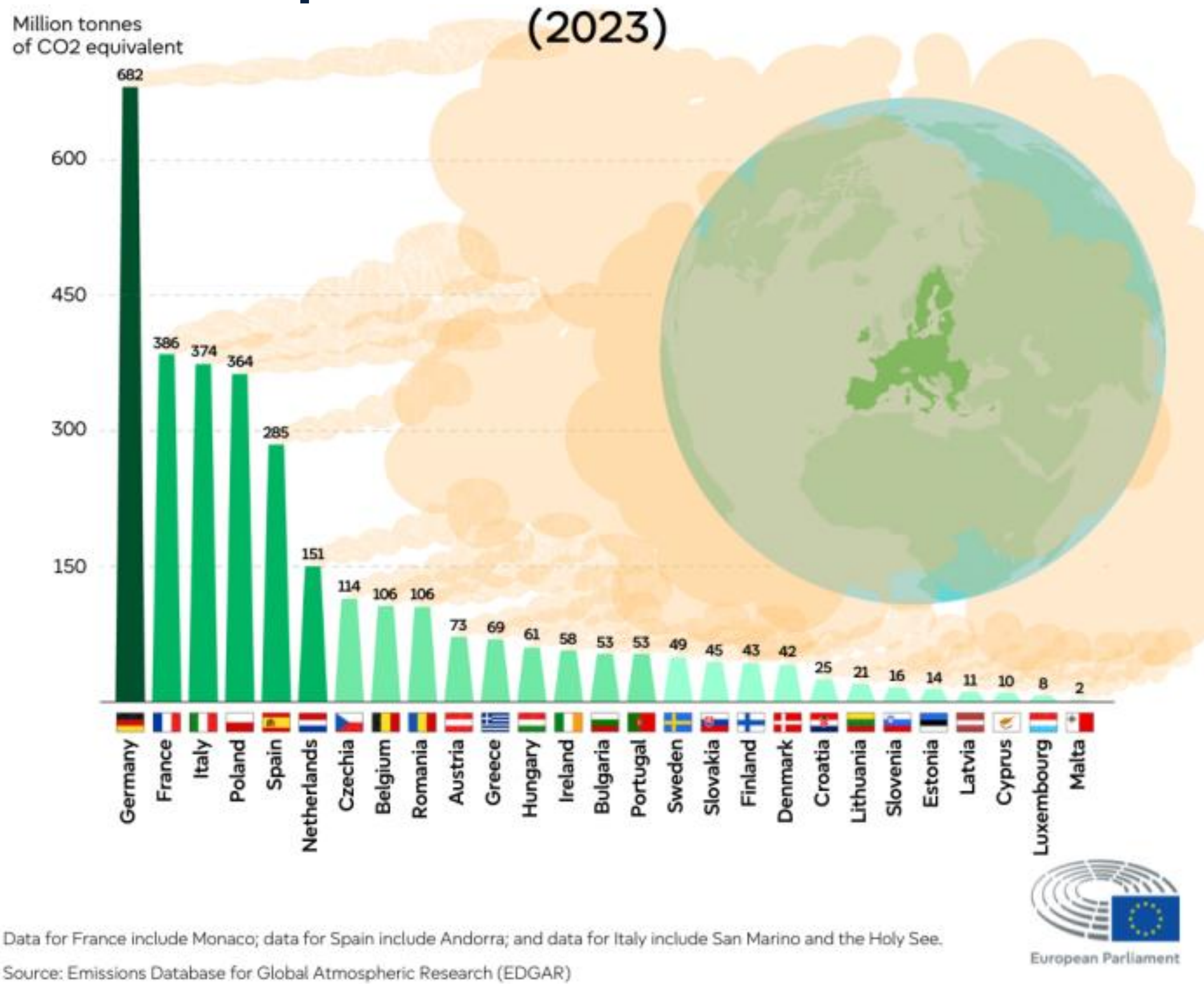
- soil,
- forests,
- oceans.

Natural absorbents remove 9.5 - 11 gigatons of CO_2 annually.

In 2023, global CO_2 emissions from fossil fuels and industrial processes reached a record high of 37.8 gigatons (Statista, 2024)

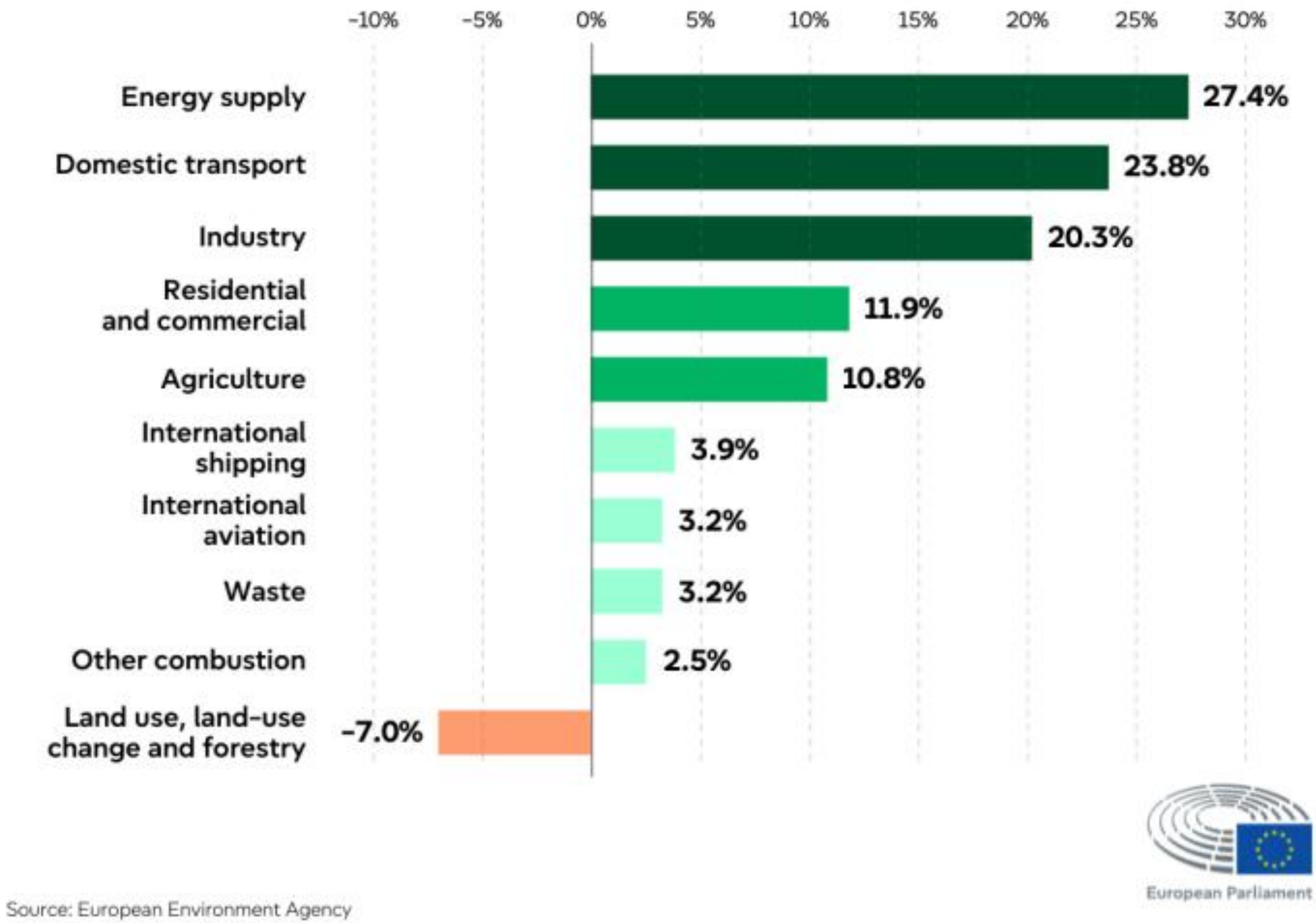
Gap: 28,9 – 26,8 gigatons of CO_2 per year

Total GHG per EU countries



GHG in the EU by sectors

(share of total emmisions estimated in CO2 equivalent, 2022)



Economics resilience

Europe depends on other countries for most critical raw materials (CRMs)

Countries accounting for largest share of EU supply of CRMs

Source: European Commission 2017

ING Economics Department 5

Economics resilience

Strategic raw materials exports from Russia
(percentage share out of total world and EU imports)

Material	EU	World	3D printing	Batteries	Drones	Fuel cells	ICT (Semi conductor..	Motors	Robotics	Fertilizer
			Selected uses							
Vanadium	60.1	21.2	●		●	●	●		●	
Cobalt	51.4	22.9	●	●	●	●	●	●	●	
REE	35.2	1.3			●	●	●	●	●	
Phoshpate rock	25.0	13.3		●	●		●		●	●
Coking coal	22.8	14.4								
Sulphlur	15.6	14								●
Nickel	14.2	9.0	●	●	●	●	●		●	
Potash	14.1	19.9								●
PGMs	13.9	12.5			●	●	●		●	
Iron ore	11.9	5.7	●	●	●	●	●	●	●	
Selenium	9.7	3.6			●	●	●		●	
Aluminium and bauxite	9.1	7.8	●	●	●	●	●	●	●	
Copper	8.7	4.2	●	●	●	●	●	●	●	
Lithium	6.5	3.4		●	●	●			●	
Boron and Tellurium	4.4	1.0			●		●		●	
Chromium	3.5	4.8	●		●	●	●		●	
Ga/Ge/Hf/In/Nb	3.2	5.2	●		●		●		●	
Strontium and Barium	2.9	13.0			●	●			●	
Cadmium/Beryllium/Tun..	2.7	1.8			●		●		●	

€18 Billion of Investments by 2027 to Circular Economy

absolute decoupling

In certain cases, technological progress cannot ensure a complete circular economy (Giampietro et al., 2019).

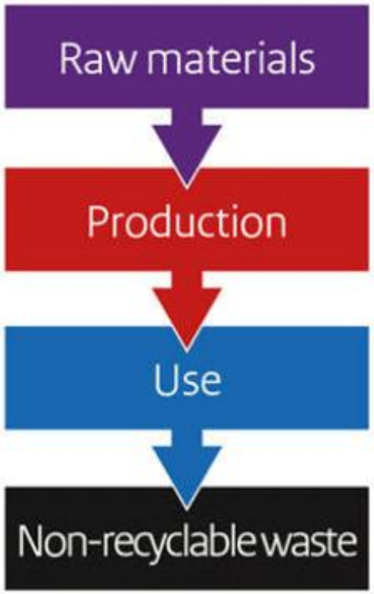
relative decoupling

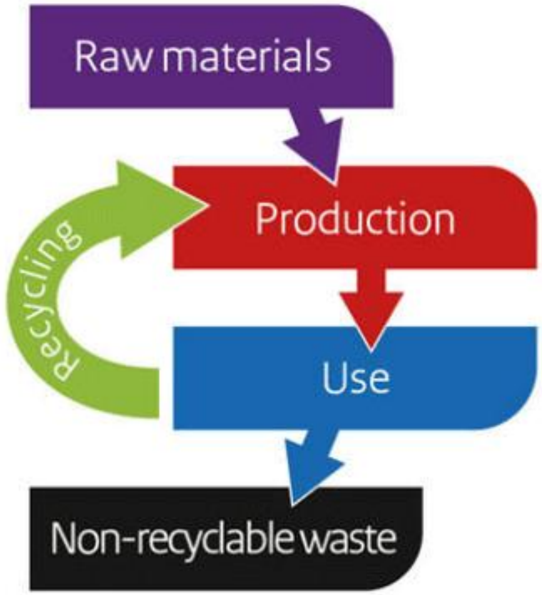
However, recent studies are optimistic (Sanyé-Mengual et al., 2019), showing a positive trend in EU (28) countries moving from relative to absolute decoupling.

UNDERSTANDING CIRCULAR ECONOMY

From linear to circular economy

Linear economy ≠ Recycling economy ≠ Circular economy





https://www.government.nl

What is circular economy?

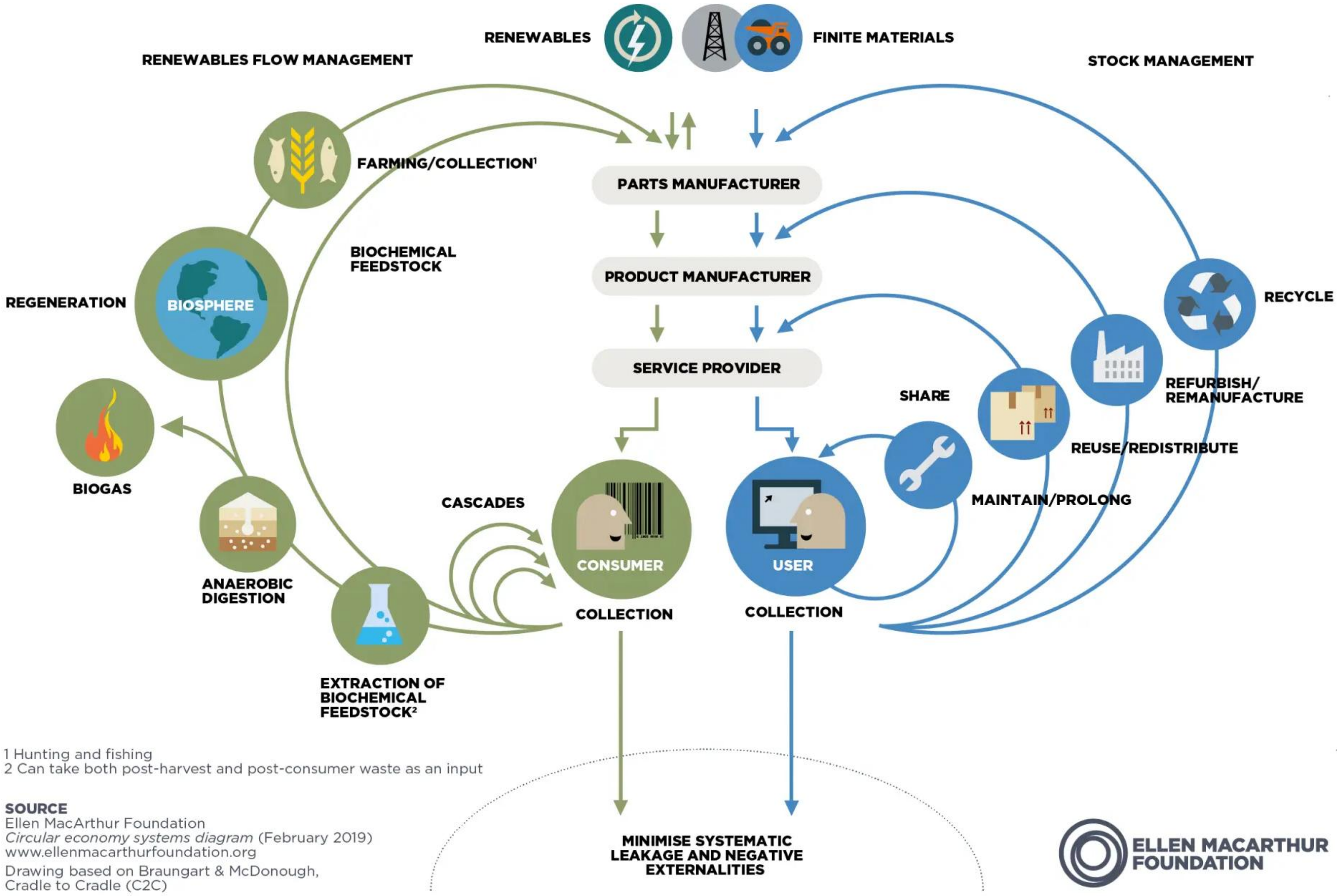
The **circular economy** is a system where **materials never become waste** and nature is **regenerated**. In a circular economy, products and materials are kept in circulation through processes like **maintenance, reuse, refurbishment, remanufacture, recycling, and composting** (The Ellen MacArthur Foundation).

The **circular economy** is an **industrial economy** in which resource use, waste costs, emissions levels, and energy losses, are reduced through proper management and integration **into a closed chain of energy and materials** (Geissdoerfer et al., 2017).

In a circular economy the **value** of products and materials is maintained for **as long as possible**; waste and resource use are **minimised**, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to **create further value** (European Commission).

Basics of the circular economy: https://www.youtube.com/watch?v=NBEvJwTxs4w

The butterfly diagram



https://www.youtube.com/watch?v=Lc-FQvPO89Y&t=14s

3 key principles to a circular economy

- Design out waste & pollution
- Keep products & materials in use
- Regenerate natural systems

Meeting these principles is all about design.
So, the circular economy is a design problem.

https://www.ellenmacarthurfoundation.org/circular-economy-principles

Strategies in a circular economy

Circular economy ↑

Smarter product use and manufacture	R0 Refuse	Make a product redundant: abandon function or use different product
	R1 Rethink	Make product use more intensive: sharing or multi-functional products
	R2 Reduce	Consume less through efficient manufacturing or use
Extend lifespan of products and its parts	R3 Re-use	Re-use of functioning discarded products by another use
	R4 Repair	Repair and maintenance of defects to keep original function
	R5 Refurbish	Restore and update
	R6 Remanufacture	Use parts in a new product with the same function
	R7 Repurpose	Use products or parts in a new product with a different function
Useful application of materials	R8 Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
	R9 Recover	Incineration of materials with energy recovery

Linear economy

Source: PBL (2017). Circular economy: measuring innovation in the product chain, J.Potting, M. Hekkert, E. Worrell et al.

Examples

R0 Refuse

R1 Rethink

R2 Reduce

Examples

- R3 Re-use
- R4 Repair
- R5 Refurbish
- R6 Remanufacture
- R7 Repurpose

Examples

R8 Recycle

R9 Recover

Fundamental approaches in circular economy

To become ‘circular’, firms need to implement new ways of doing business

- to **narrow** (use less material and energy),
- to **slow** (use products and components longer),
- to **close** (use products, components and material again),
- to **intensify** (maximize the utility of products through shared use)
- to **dematerialize** (use fewer or no physical materials)
- to **regenerate** (use non-toxic material, renewable energy and regenerate natural ecosystems)

their material and energy flows.

Konietzko, J. N., Bocken, N., & Hultink, E. J. (2020). Circular ecosystem innovation: An initial set of principles. *Journal of Cleaner Production, 253*, 119942. https://doi.org/10.1016/j.jclepro.2019.119942

Circular business models

There is no clear consensus on what is and is not a circular business model. It is about:

- Value creation for stakeholders *(company, customers, society and natural environment (non-human stakeholder)).*
- Innovations
- Collaboration among different stakeholders
- Efficient use of natural resource
- Close interrelation between production & consumption.

Circular business models

- Circular supplies
- Resource recovery
- Product life extension
- Sharing platform
- Product as a service

There are various classifications for business models.

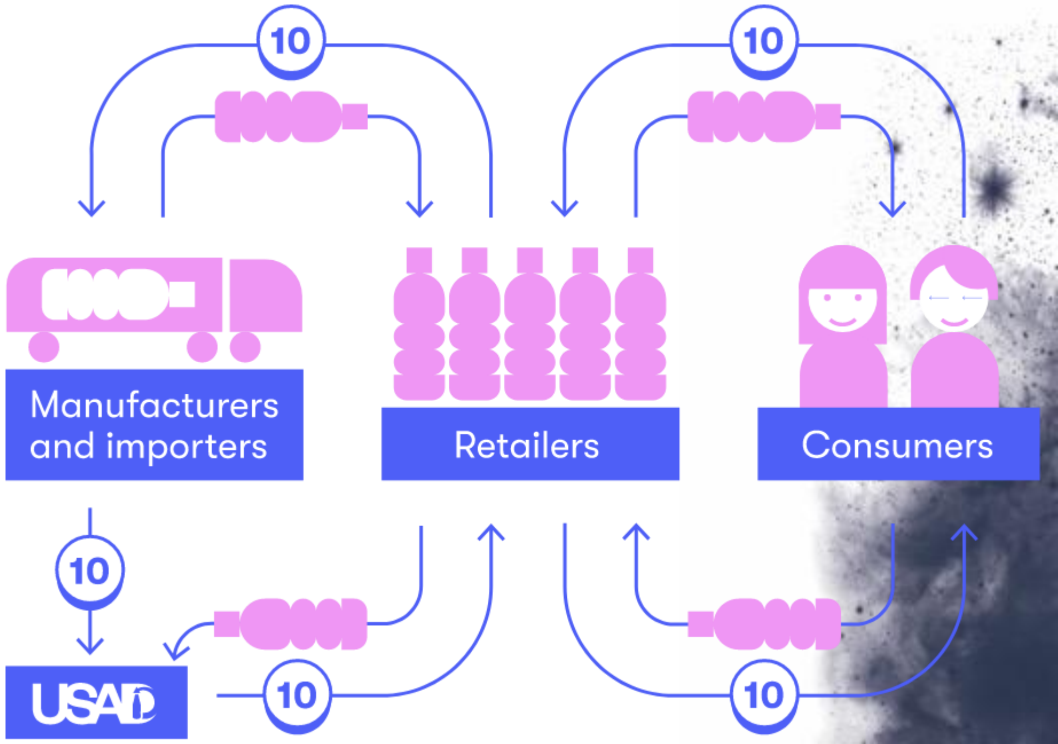
Circular supplies

Close material loops

Replacing "linear" resources in the supply chain with renewable energy, renewable, bio-based materials or recovered materials.

Inputs that are adopted must be good substitutes for the traditional materials that they replace;

Sufficient demand/economies of scale.

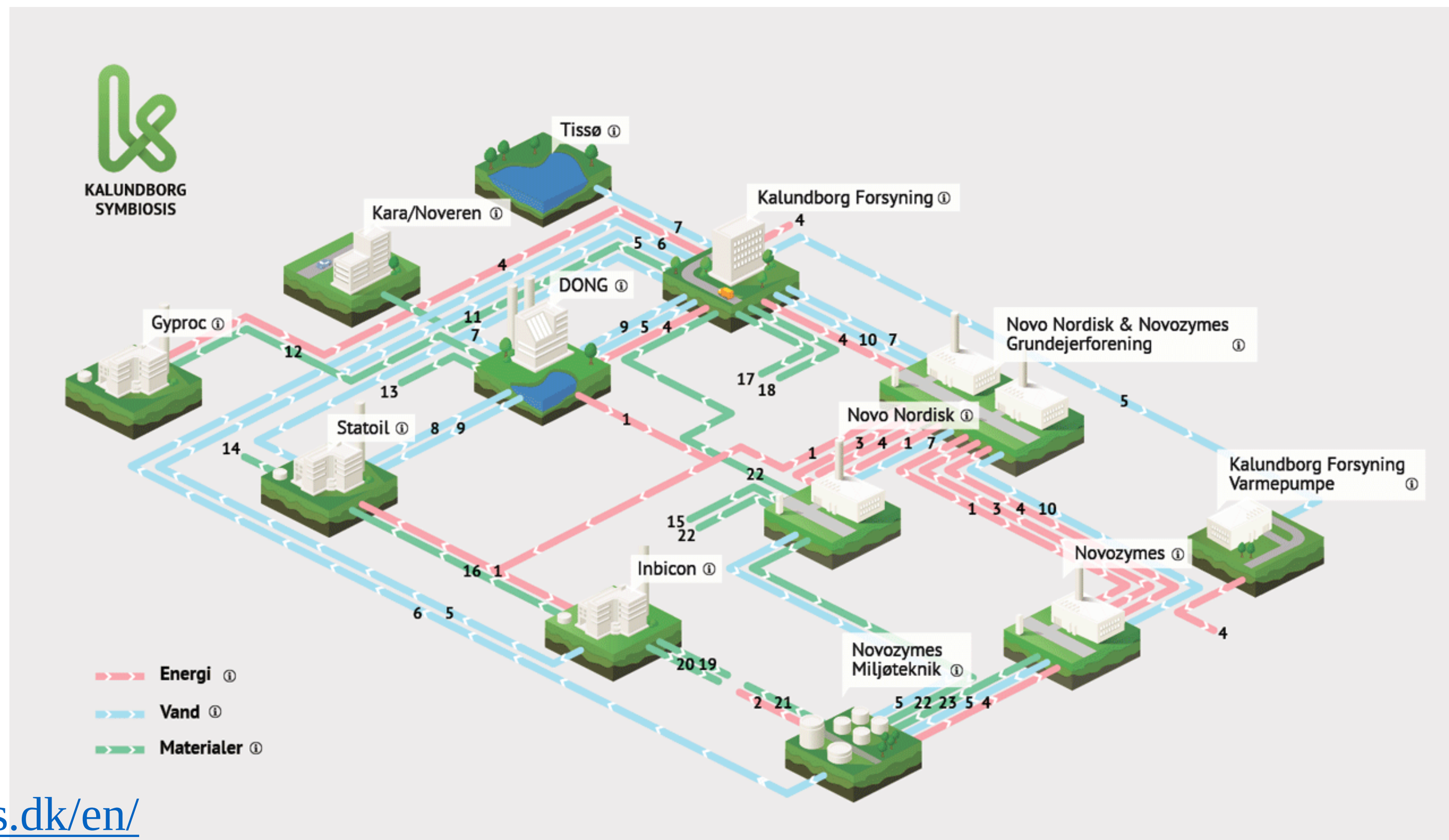


https://grazintiverta.lt/en/system/75

Resource recovery

Close material loops

Secondary raw materials from waste streams
Collection, sorting, and secondary production
Downcycling, upcycling, and industrial symbiosis



http://www.symbiosis.dk/en/

Product life extension

Slow material loops

Focus on extending the intended use and life of a product.
Classic long-life, direct reuse, repair, remanufacture.

Sharing platform

Increase utilization of existing products and assets via lending or pooling.
Promotes collaboration between users of products;
The use of platforms is common.

Product as a service

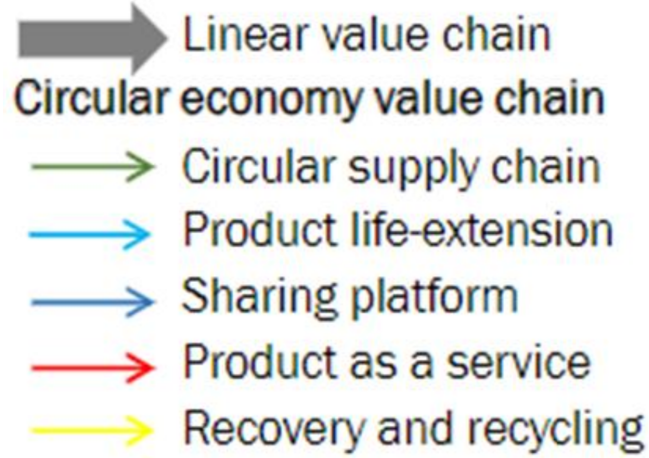
Slow material loops, narrow resource flows
Promotes a focus shift from selling products to selling functions through a mix of products and services while fulfilling the same user demands with less environmental impact.

Copying service instead of owning a copier

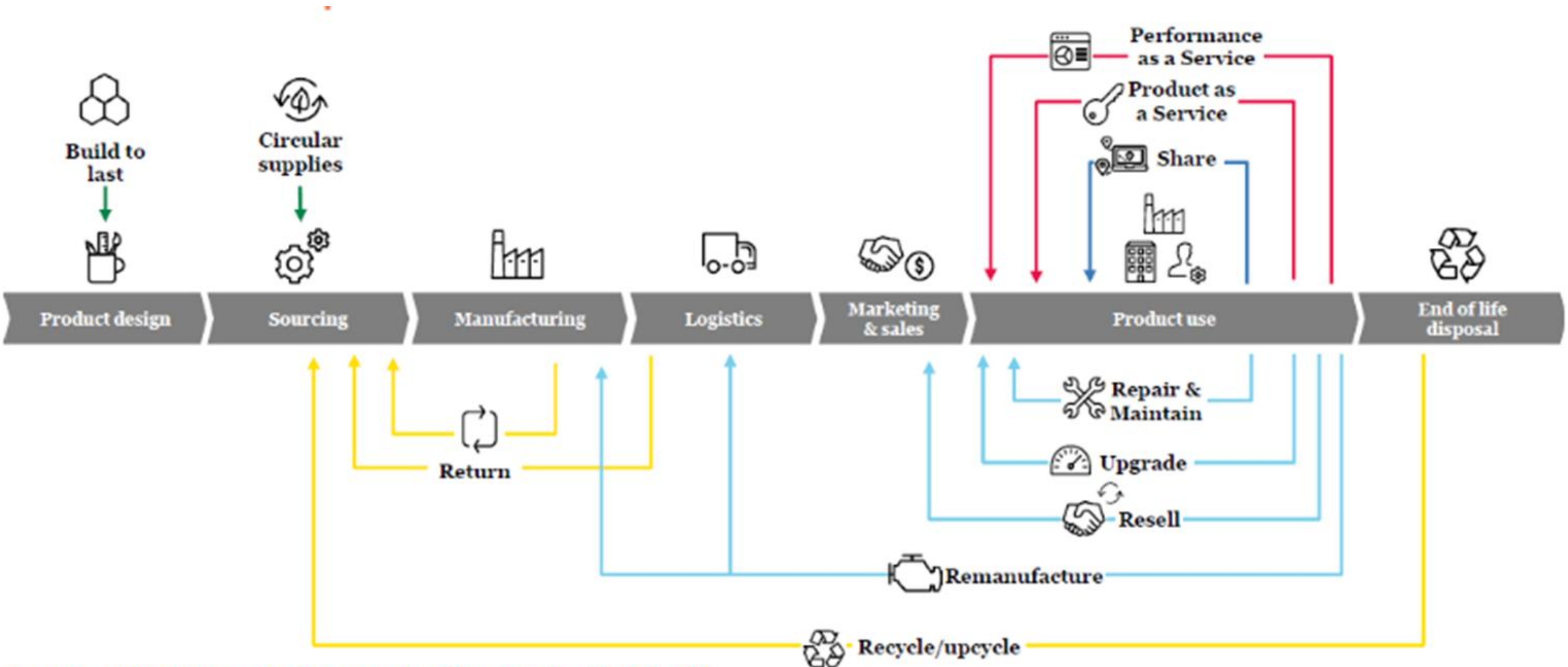
Cleanliness instead of a carpet

FROM CIRCULAR BUSINESS TO CIRCULAR VALUE CHAIN

Circular value chain

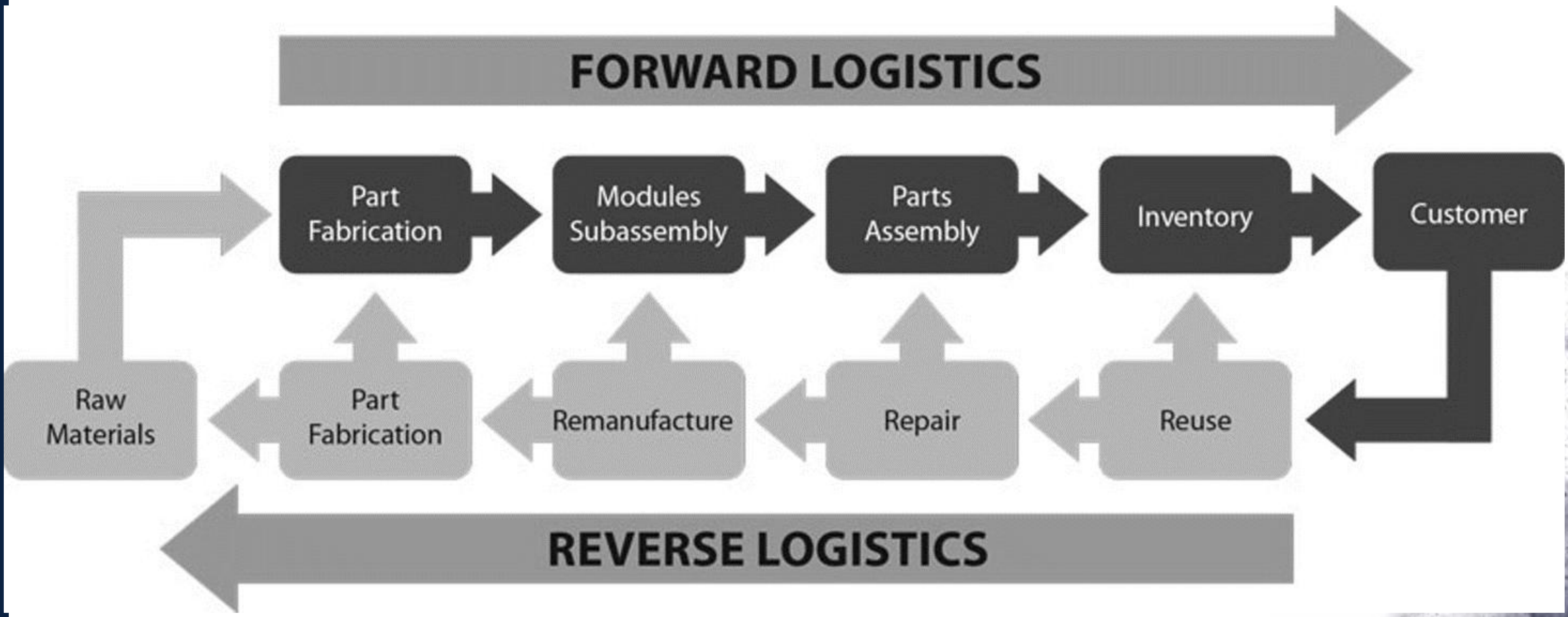


Circular economy cannot be achieved in isolation

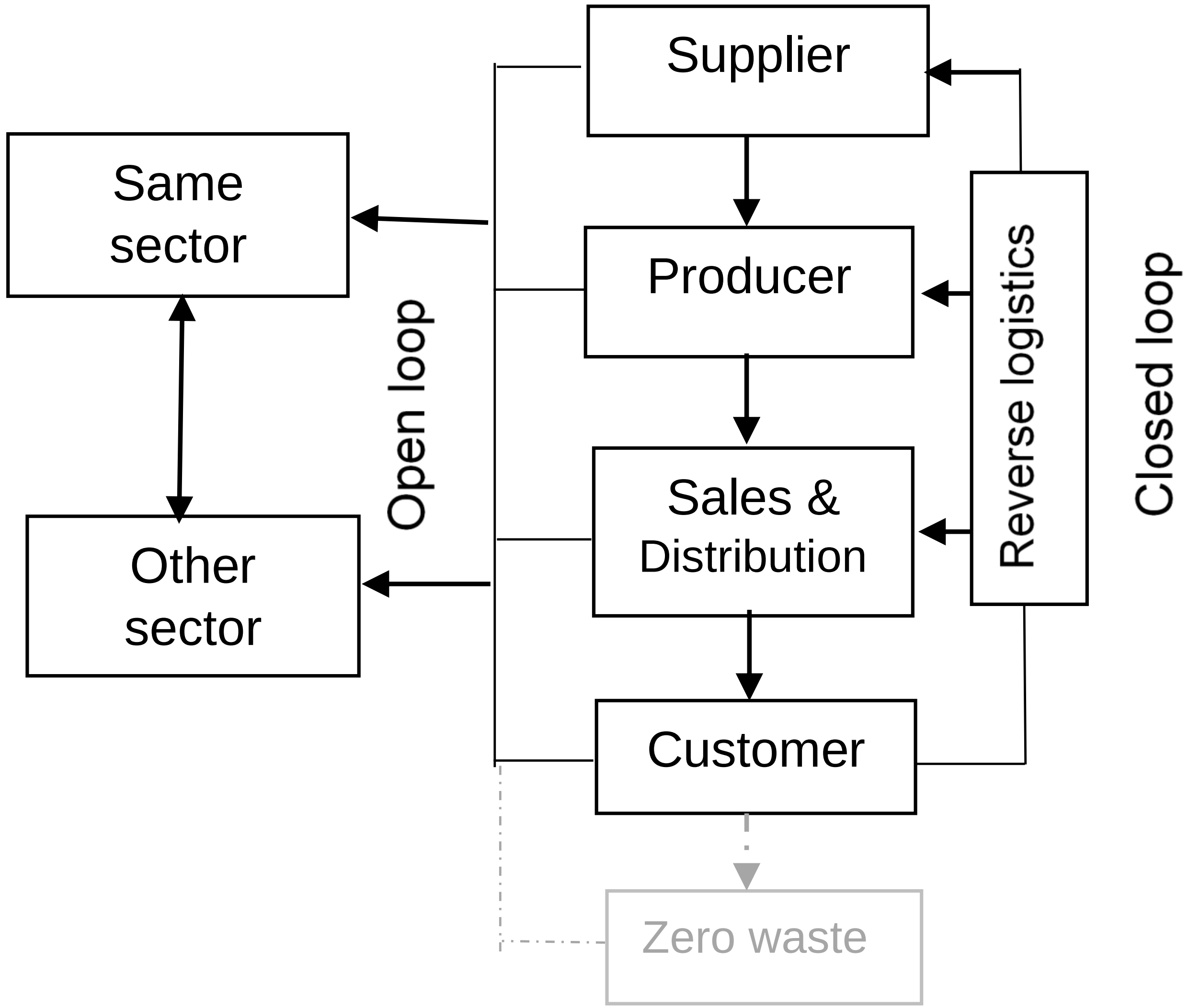


Source: The Circular Economy Playbook, 2020 [3]

Reverse logistics



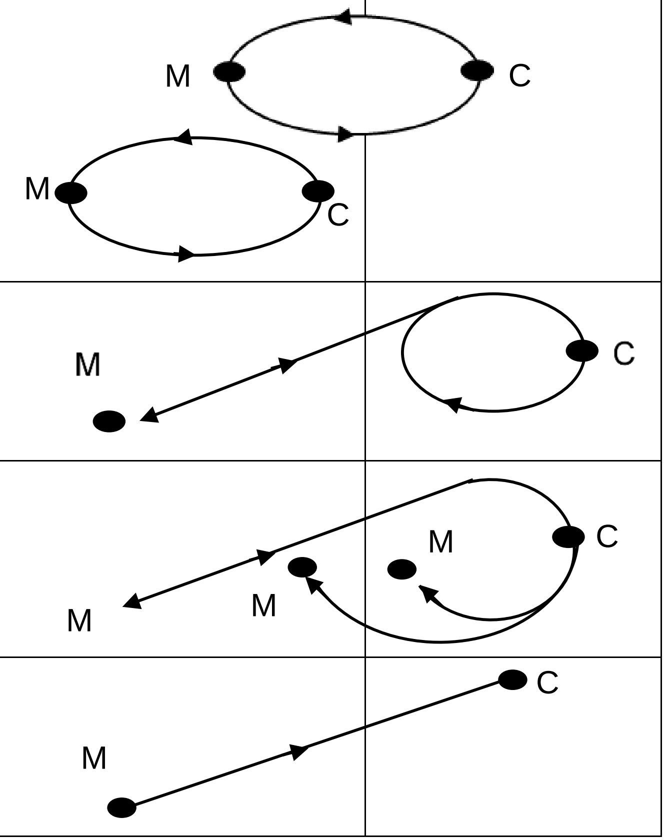
Closed and open loop



World Economic Forum and Ellen MacArthur Foundation circular economy team, 2014.

Geography and circular supply chains

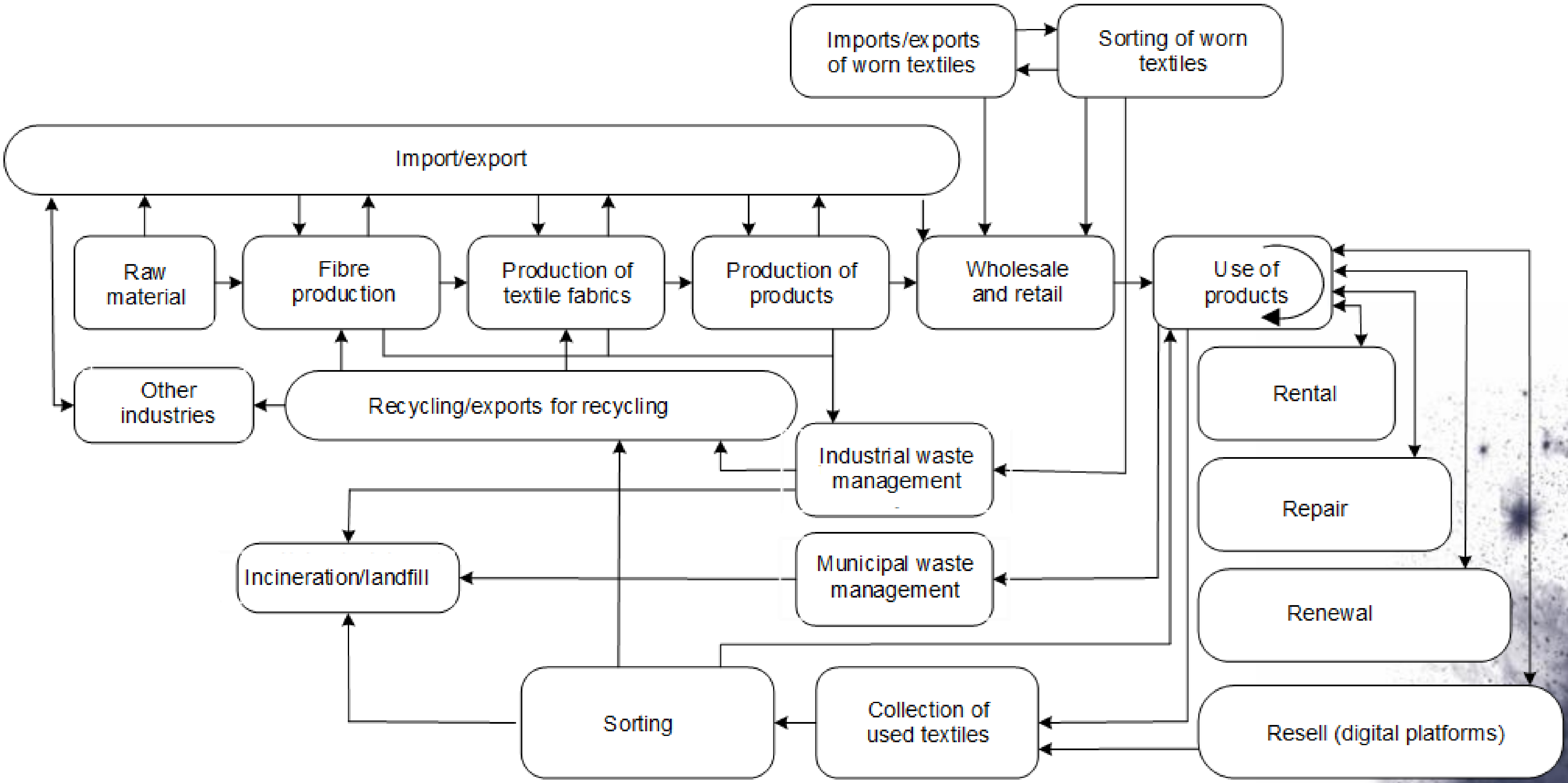
	Region 1	Region 2
Closed global/ local/ regional loop		
Partially open local/ regional loop		
Geographically open cascade		
Geographically open linear		



M – Manufacturing
C – Consumption

Adapted from Farooque et al., 2019, https://doi.org/10.1016/j.jclepro.2019.04.303

The simplified Lithuanian textile and clothing value chain



Bruneckiene et al, 2021, Žiedinės ekonomikos iššūkiai ir galimybės Lietuvoje : mokslo studija. Kaunas : Technologija.
doi: 10.5755/e01.9786090217382.

IMPACT OF CIRCULAR ECONOMY

Impact of circular economy on GDP

Total 0 – 15%

Direct Benefits:

GDP growth is mainly associated with increased revenues from circular activities, higher investments and innovations, and reduced production costs.

Indirect Benefits:

- Export of circular economy expertise
- Safer (more reliable, with less price fluctuation) raw material supply
- Window to the future (new businesses, new markets, reverse logistics, etc.)

Impact of circular economy on economic structure

Cambridge Econometrics et al. (2018) forecasted that the biggest changes in employment will occur in four sectors:

- Waste management (collection, sorting, and recycling) (expected main employment growth);
- Repair and maintenance services sector (employment growth);
- Construction sector (employment decline);
- Electronics sector (employment decline).

A shift towards circular business models may drive growth in sectors focused on recycling, repair, remanufacturing, and renewable energy.
Traditional resource-extractive industries (such as mining and oil) may see a decline in demand.

What professions and competencies will emerge or be required due to the circular transformation?

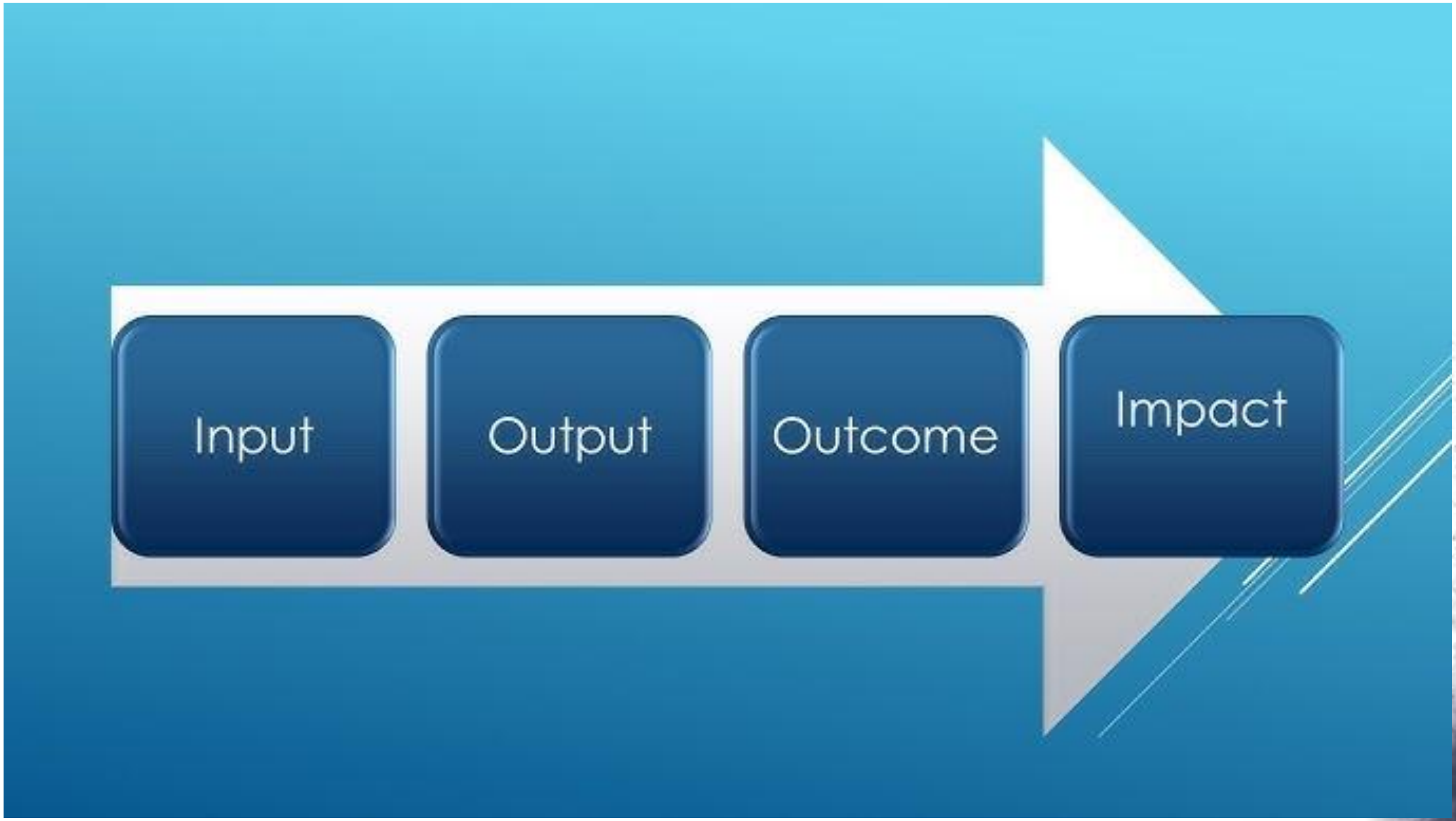
System thinking

Systems thinking is a way that states that complex phenomena or, in other words, complex systems (eg nature, society, organizations, technological systems) should not be examined in the usual way of analysis, but by combining **holistic** and **analytical** thinking ways.

https://www.youtube.com/watch?v=17BP9n6g1F0

https://insightmaker.com/insight/5SuvM72cxXLu3vbDJwZRfJ/Bird-Feeder-Dilemma

System thinking



Life cycle assessment methods

Life Cycle Assessment (LCA) is a method used to systematically analyze the full environmental impact of products across all stages of their life cycle—from raw material extraction, manufacturing process, installation, to usage and disposal or destruction. The results of this analysis include the consumption of water, energy, and fossil fuel resources, as well as the associated environmental impact, such as emissions to air (kg CO_2), waste generation, and pollution of water and soil.

Life Cycle Costing (LCC) is the process of calculating all costs associated with a product throughout its entire life cycle, from production to usage, maintenance, and disposal. It involves compiling and evaluating these costs to provide a comprehensive view of the total expenses incurred during the product's life, helping to assess the financial impact and guide decision-making regarding the product's design, maintenance, and end-of-life management.

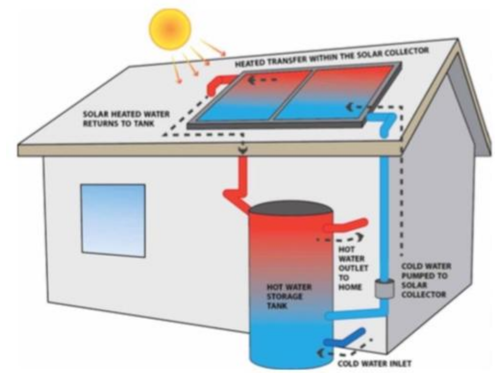
Social Life Cycle Assessment (S-LCA) is a method for assessing the social and socio-economic impacts of a product throughout its life cycle. This evaluation focuses on both the real and potential social effects of a product, aiming to understand its positive and negative social implications from production to disposal. S-LCA helps to evaluate the social aspects of products, such as labor conditions, community impacts, human rights, and local development, providing a comprehensive view of how products affect societies and economies throughout their entire life cycle.

PRACTICAL TASK 1:

SOLAR WATER HEATING AND SYSTEMS THINKING

In this task you have to apply systems thinking to a typical energy conservation situation - solar heated water. Usually, a liquid that won't freeze like a glycol and water mixture circulates through the panel, gets heated up and then flows into a water tank where the liquid's heat warms the water. In the system this pre-warmed water goes to the water heater, where it is warmed a bit more and a supply of hot water is stored for use. Here is a diagram that shows how the system works.

The table shows the estimates of savings on natural gas bill (used to heat water in the water heater) and the water usage. The numbers are monthly averages for an entire year. The estimation is based on sunny days and the rating of the solar water heating system. The estimates were based on everyone in the house (two adults and a teenage girl) using hot water as they had been; that is, there is the assumption, that the water use habits wouldn't change.



	Estimated savings	**Actual savings**
Natural Gas	**$30.00 /month**	**$25.00**
Water Use	**0**	**-$5.00**

We cut our natural gas bill almost in half, saving $24.00 a month or about $300 per year, but our water usage went up. We didn't expect this. We thought there would be no change.

Questions

1. Were our original savings estimates based on a ***linear*** model? Explain why.
2. What did we miss when we made our estimates? What does the fact that more water is being used suggest?

Rebound effect

the **rebound effect** is the reduction in expected gains from new technologies that increase the efficiency of resource use, because of behavioral or other systemic responses. These responses usually tend to offset the beneficial effects of the new technology or other measures taken.

Partial rebound (0 < RE < 1): The actual resource savings are less than expected savings.

Full rebound (RE = 1): The actual resource savings are equal to the increase in usage – the rebound effect is at 100%.

Backfire (RE > 1): The actual resource savings are negative because usage increased beyond potential savings – the rebound effect is higher than 100%. This situation is commonly known as the **Jevons paradox.**

Externalities

Externalities occur when producing or consuming a good cause an impact (negative and positive) on third parties not directly related to the transaction.

Externalities can be categorized in terms of four economic functions of the environment and the economic concept of sustainability:

- to negatively impact the **value of services and products**;
- to induce **excess extraction of resources**, leading to exhaustion;
- to cause **harmful waste** output beyond the assimilation capacity of biological systems;
- to reduce the regenerative capacity of life support systems (Stiglitz, 2000).

https://doi.org/10.1016/j.jclepro.2019.06.091

Externalities of circular economy

Positive

- Reduced pollution
- Improved energy efficiency
- Conservation of natural resources and the environment
- Creation of new jobs
- Development of innovations
- Better public health and quality of life
- Emergence of new resources (e.g., alternatives to natural raw materials)

Negative

- Price increases, income reduction
- Job relocation/decline of certain industries
- High initial investments
- Resource shortages
- Environmental conflicts (may lead to more intensive resource use)
- Market shifts (e.g., disappearance of certain products)
- Feelings of uncertainty/ambiguity
- Increased waste generation
- Growing social inequality and technological divide
- Complexity of regulation

Externalities of value chains

Externalities also arise when the actions of one supply chain affect another supply chain (Cachon, 1999).

The waste created by unwanted IKEA furniture most often ends up in local landfills, and the negative externalities of this waste disposal fall on residents, who pay for municipal waste collection and disposal through their taxes. IKEA does not bear the costs associated with the disposal of its unwanted products (Buckley, Liesch, 2022).

Food intended for human consumption and its waste (i.e., suboptimal use) are rarely considered in the context of global supply chains. In supermarkets, imperfect potatoes are often treated as surplus and are frequently discarded or, in some cases, used as animal feed (Buckley, Liesch, 2022).

PRACTICAL TASK 2:

CO_2 CALCULATION FROM TRANSPORTATION

CO2 calculation in the context of the value chain

Businesses must monitor and report their CO_2 emissions.

According to the leading GHG Protocol corporate standard, a company's greenhouse gas emissions are classified into **three scopes:**

Scope 1 + Scope 2 + Scope 3 = Total Emissions

Scope 1 and 2 are mandatory to report, whereas scope 3 is voluntary in some cases and is the hardest to monitor.

Source: https://plana.earth/academy/what-are-scope-1-2-3-emissions#scope-1-direct-emissions

CO2 calculation in the context of the value chain

ktu
1922

Scope 1 Direct emissions	Scope 2 Indirect emissions	Scope 3 Indirect emissions
Direct emissions that are owned or controlled by a company.	**Indirect emissions that are a consequence of a company's activities but occur from sources not owned or controlled by it.**	
Emissions from sources that an organisation owns or controls directly.	Emissions a company causes indirectly that come from where the energy it purchases and uses is produced.	All emissions not covered in scope 1 or 2, created by a company's value chain.
Example From burning fuel in the company's fleet of vehicles (if they're not electrically powered).	**Example** The emissions caused by the generation of electricity that's used in the company's buildings.	**Example** When the company buys, uses and disposes of products from suppliers.

Source: https://plana.earth/academy/what-are-scope-1-2-3-emissions#scope-1-direct-emissions

Recommended Average Emission factors

recommended average CO_2 emission factors
can vary depending on the mode of transport and the specific conditions. Here are some general guidelines:

Road Freight: Approximately 62-105 gCO_2/tonne-km for heavy-duty trucks.

Rail Freight: Around 14-30 gCO_2/tonne-km.

Sea Freight: Typically between 3-15 gCO_2/tonne-km for large container ships.

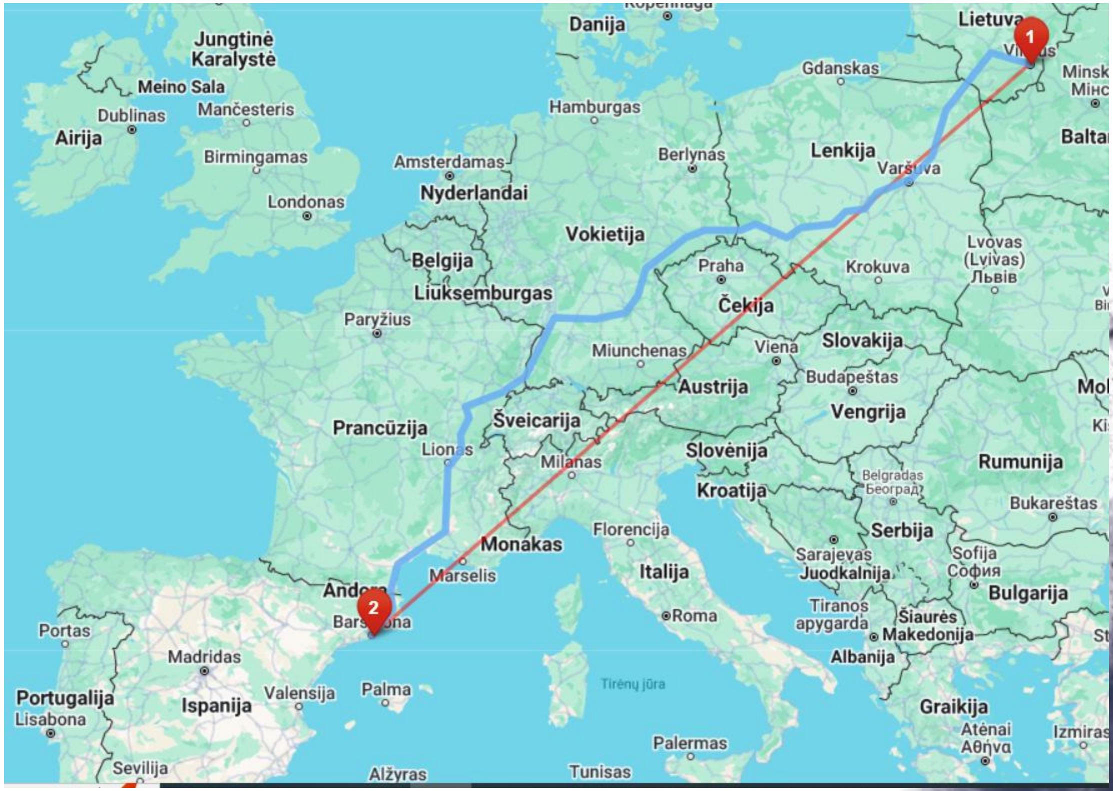
Air Freight: Significantly higher, ranging from 500-1500 gCO_2/tonne-km.

CO2 footprint of freight transportation

From Vilnius – to Barcelona: cargo weight 11 tone

Calculate CO_2 from Vilnius to Barcelona and choose the transportation way.

Distance between Vilnius and Barcelona: 2800 km



CO2 footprint of freight transportation

Calculate CO_2 from Klaipėda to New York by sea.

Distance: 6950 km.

20” container (20 t) cargoweight

PRACTICAL TASK 3:

CO_2 CALCULATION RELATED TO ENERGY

The company is young, founded two years ago. The office space is rented in a building constructed in 1970. The office space is not modern, but the rental price is attractive. The company rents 278 square meters of space. The windows in the rented premises are small, making the space quite dark. Currently, the lighting consists of a combination of incandescent long fluorescent tube ceiling lights and a few compact fluorescent bulbs. There are about 100 light fixtures in total.

You plan to replace the old lighting with LED counterparts. The new LED bulbs will emit the same amount of light but will consume less electricity. The current lights are on for 10 to 14 hours a day, as employees have flexible work schedules (some arrive early in the morning, others work late into the evening). Some employees come to the office on weekends, and a few security lights are left on 24 hours a day. Thus, on average, the lights are on about 12 hours a day for 330 days a year. The average power consumption of the bulbs is about 60 watts. The company pays 11.2 Euro cents per kWh for electricity.

On average, the new LED lighting system bulbs will use 32 watts.

1. Calculate how much electricity (kWh) the company consumes and how much it pays for it annually and monthly.

2. Evaluate the savings, i.e., how many kWh and euros were saved due to the switch to LED lighting annually and monthly, assuming all current bulbs are replaced with LED equivalents.

3. Evaluate the reduction in CO_2 emissions. Social benefit arises when less electricity is consumed, resulting in less CO_2 being emitted. Based on "CarbonFund" (https://carbonfund.org/how-we-calculate/), On average, electricity sources emit 1.222 lbs of CO_2 / kWh (0.0005925 tons of CO_2 / kWh). To calculate the amount of CO_2 emitted, use this conversion factor.

4. If a carbon tax is implemented, economists estimate it will be around 30–40 Eur per ton of CO_2 emitted. Using the average of these possible tax rates, 35 Eur, what could be the potential savings from the carbon tax when switching to LED bulbs?

COLLABORATION TASK:

Draw circular value chain based on the selected product/service

Thanks