Introduction to sustainability strategies and the circular economy, or the challenge for the composites industry

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Learning objectives

- Primer on sustainability, decarbonization
- Understand why we need a circular economy
- Describe the limits of linear economic models
- Explain how we can change to a circular economy in engineered products
- Design your own circular initiatives

Now is the most exhilarating time to be an innovator.

Wakeman

Now your turn

Group Project: Content

1. **Composite material selection**
   - Justify why you have selected particular fibers / textiles / resins
2. **Design and structural feasibility established**
   - Identify load case, generate design (CAD), structural analysis (of key elements, FEA ideal, 3D printed demo interesting (but not required)
3. **Clear value proposition (incl. performance, cost, …)**
   - Understand how the problem is solved today
   - How your idea will meet customer needs
   - Why should a customer "get out of bed" for your product
4. **Composites manufacturing process identified**
   - How will you convert your composite constituents into parts?
   - How many part will you make per year?
   - Will process change with time (scale-up)?
5. **Cost per part modelled**
   - Investments required in equipment and tooling, cost/part calculated
   - Extrapolation to price interesting (but not required)
   - Scaling and industrialization: discussion of next steps/strategy
6. **Sustainability positioning**
   - Give a sustainability statement regarding your product
   - Give 3 SMART initiatives to reduce impact (short, medium, long term)

2/3 of the grade

LPAC Laboratory for Processing of Advanced Composites

10 page maximum report, 15 minute presentation (max)

Overview

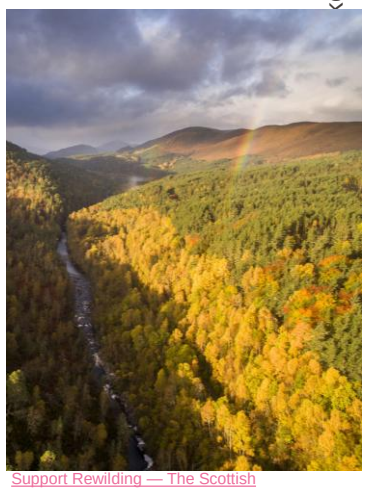
- Sustainability
- NetZero transition
- Linear vs. circular economy
- Circular economy frameworks
- Materials and engineered product examples
- Enablers to a CE
- Initiatives

NetZero 2050: what is your vision?

AP to set up solar-wind hybrid project with battery back-up – The Leading Solar Magazine In India (eqmagpro.com)

Daily Mail Online

EV World Record: Mercedes Benz Vision EQXX Travels 1,000 Km On A Single Charge (forbes.com)



Support Rewilding — The Scottish Rewilding Alliance

ZEROe on the Rise at Airbus - CAFE Foundation Blog

[기업소개] 수소연료탱크 제조사 '일진다이아' : 네이버 블로그 (naver.com)

Child Fun Outdoors - Free photo on Pixabay

4 NetZero Energy Lessons | NetZero Buildings

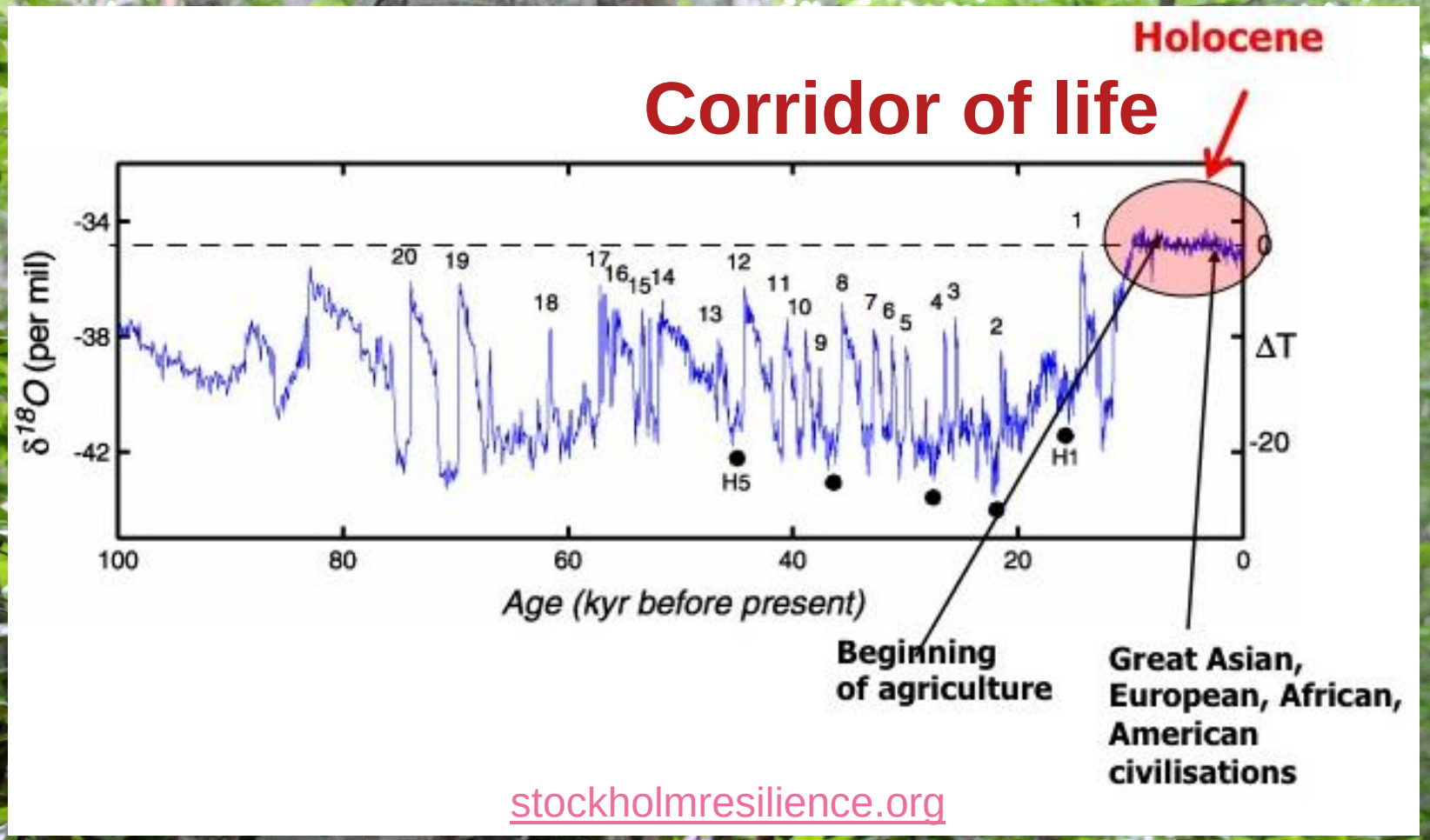
People Group Many - Free photo on Pixabay

Sustainability can be defined as:

"Avoiding the depletion of our natural resources in order to maintain a balanced ecosystem and preserve natural capital *while* meeting the needs (wants?) of the present without compromising the ability of future generations to meet their own needs".

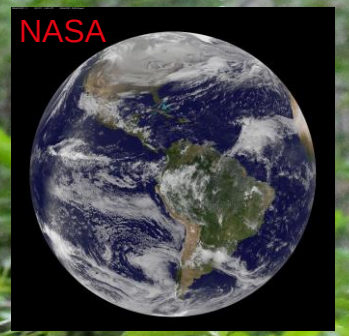
Holocene

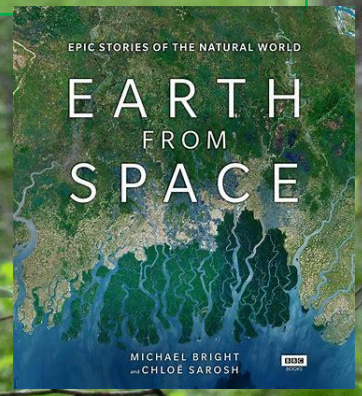
the stable geological epoch in the earth history that has lead to our blue and green planet



stockholmresilience.org

- Relatively stable Holocene climate during the past ca. 10,000 years
- Record from Greenland Ice Sheet, proxy for atmospheric temperature over Greenland

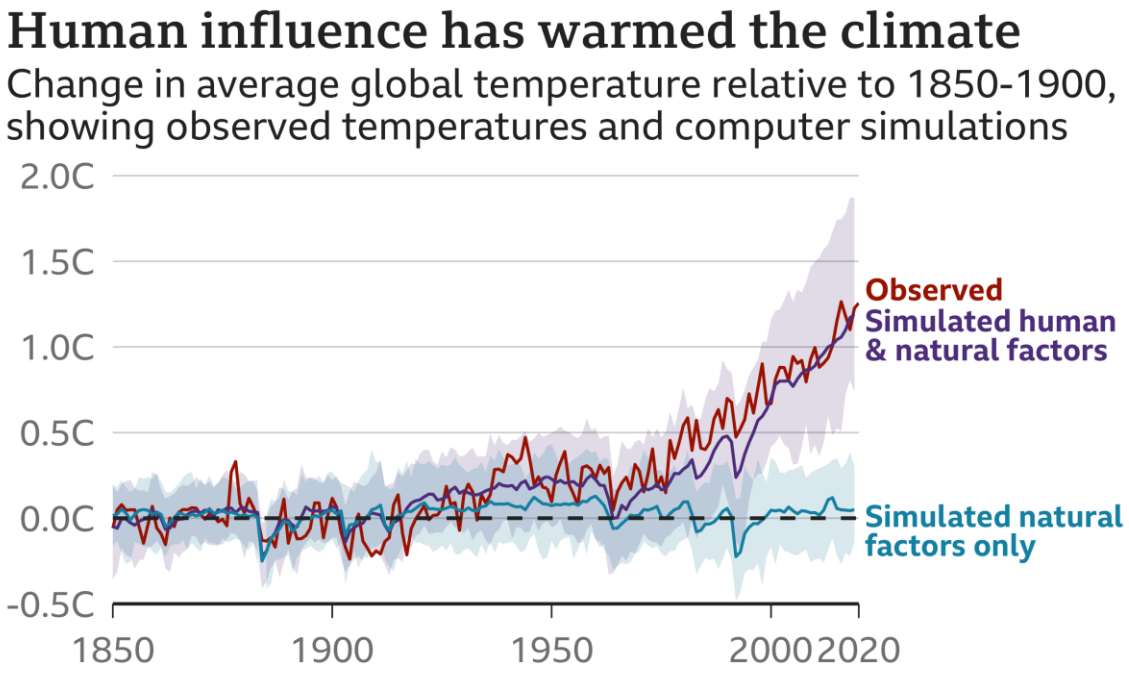




Virgin Forests: WWF Saving the Last Remaining in Europe, Part 1 | WWF (panda.org)

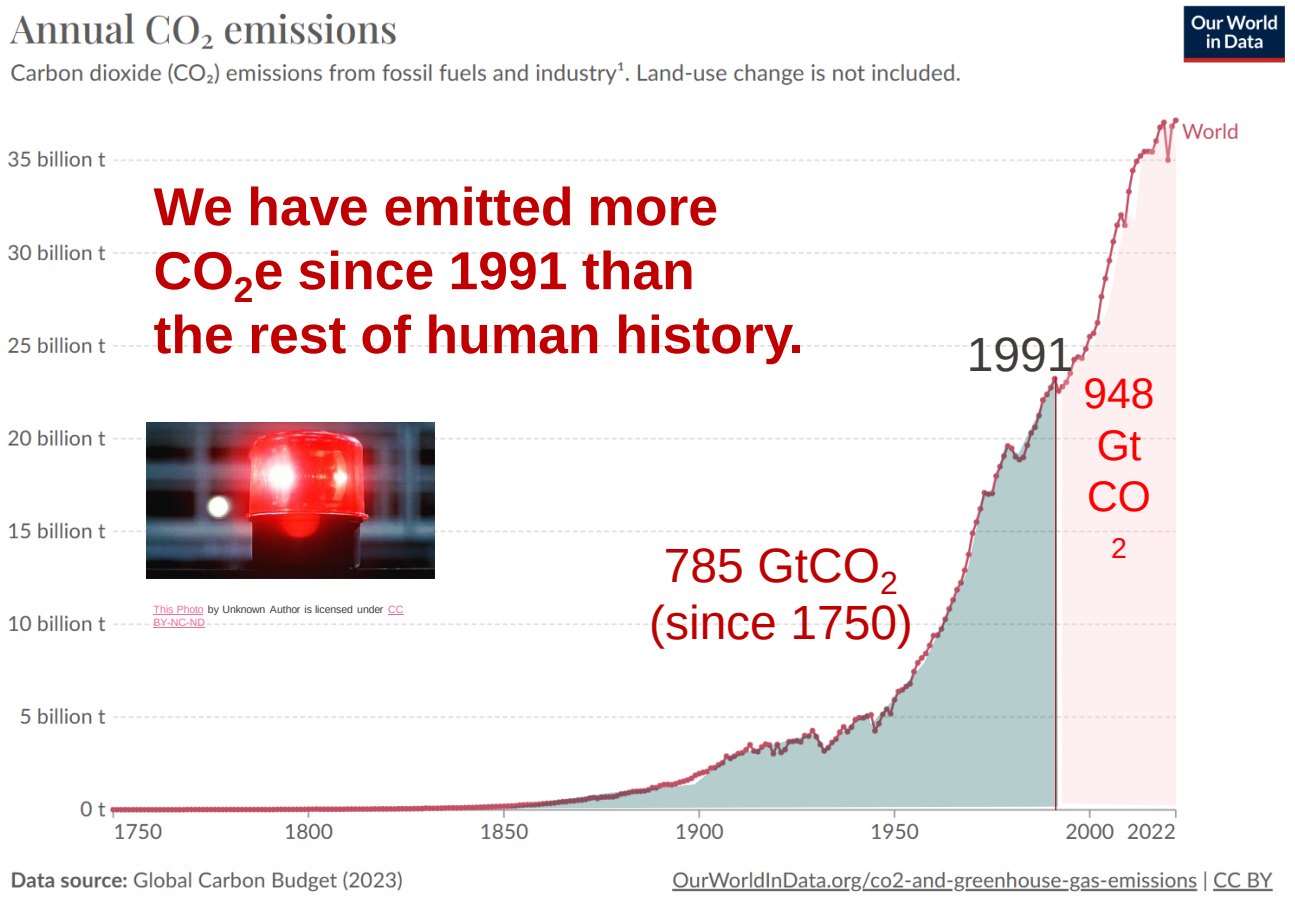
Our planet is getting warmer, CO2e driven

- Unequivocal warming through human activity



IPCC_AR6_SYR_SPM.pdf

Climate change: UN warning over nations' climate plans - BBC News



1. **Fossil emissions**: Fossil emissions measure the quantity of carbon dioxide (CO_2) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO_2 includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.

CO_2 emissions - Our World in Data

Arrhenius 1896

ARRHENIUS EQUATION

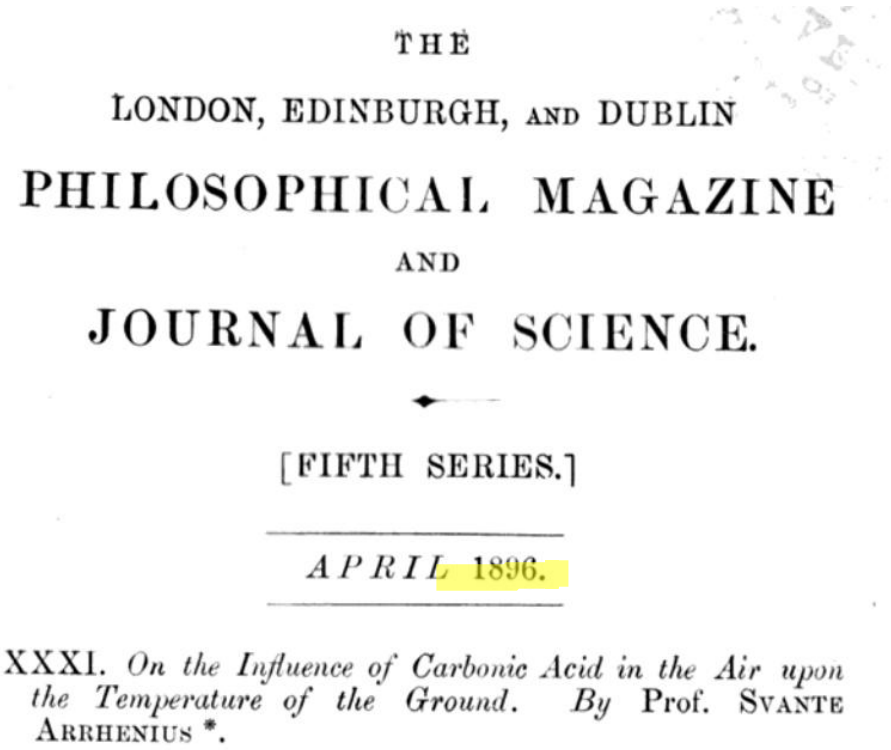
$$k = A e^{\frac{-E_a}{RT}}$$

On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground

Svante Arrhenius

Philosophical Magazine and Journal of Science
Series 5, Volume 41, April 1896, pages 237-276.

Arrhenius's paper is the first to quantify the contribution of carbon dioxide to the greenhouse effect (Sections I-IV) and to speculate about whether variations in the atmospheric concentration of carbon dioxide have contributed to long-term variations in climate (Section V). Throughout this paper, Arrhenius refers to carbon dioxide as "carbonic acid" in accordance with the convention at the time he was writing.



THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

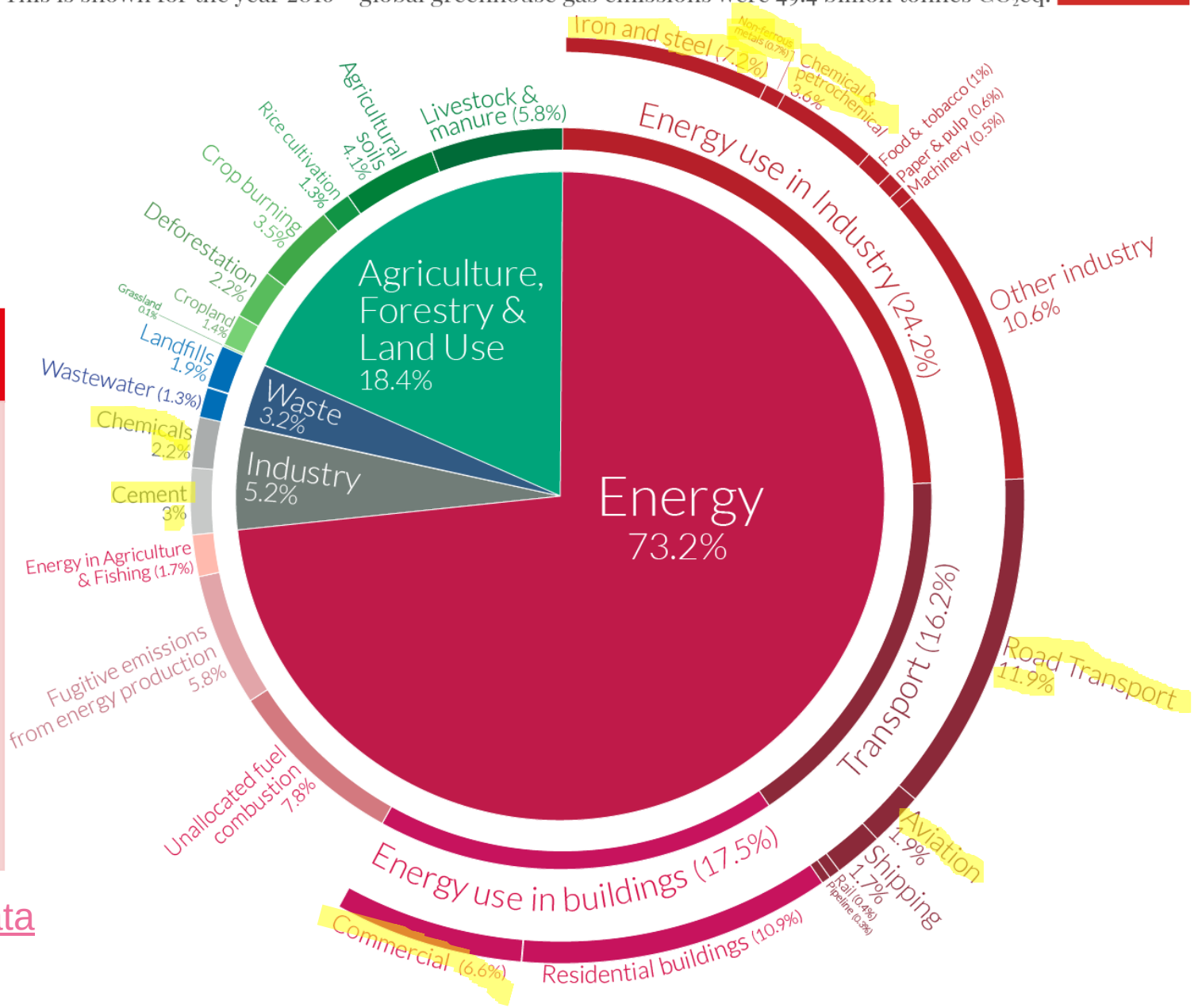
On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground (rsc.org)

Major GHG contributors

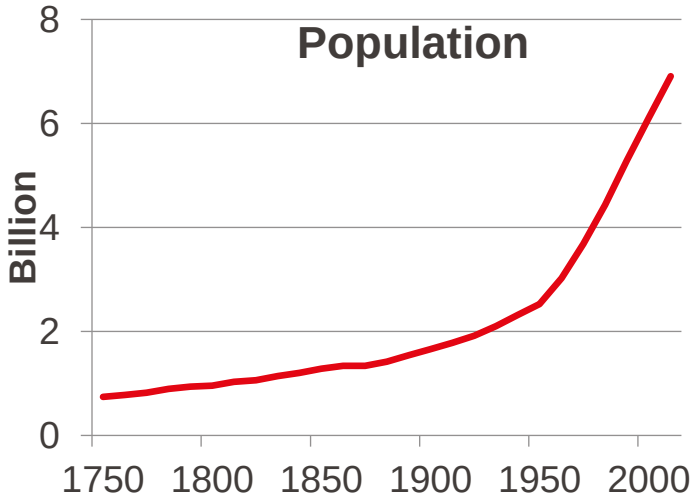
- Engineered products touch

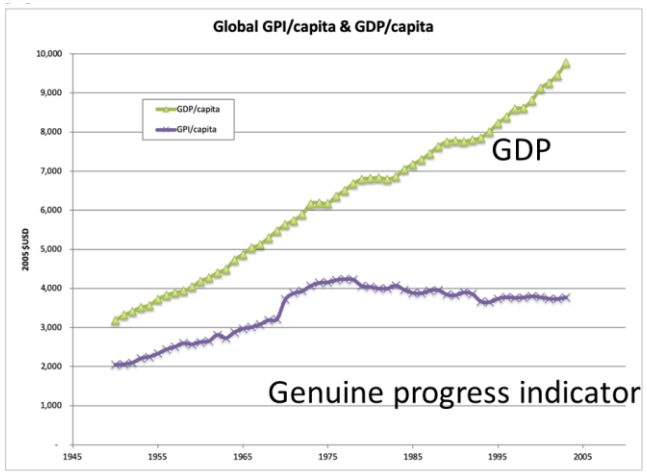
Transport 16%	Chemicals 5.8%	Materials 20%
• a leading source of greenhouse gas emissions • Road 12% • Aviation 1.9% • Shipping 1.7%	• 2.2% manufacturing • 3.6% powering chemical industry	• Steel 7% • Plastic 3% • Aluminum 0.5% • Copper 0.1% • Cement 3-5% • Battery materials 0.1% • Coal/energy mining 3-4% • Other metals 1%

Emissions by sector - Our World in Data

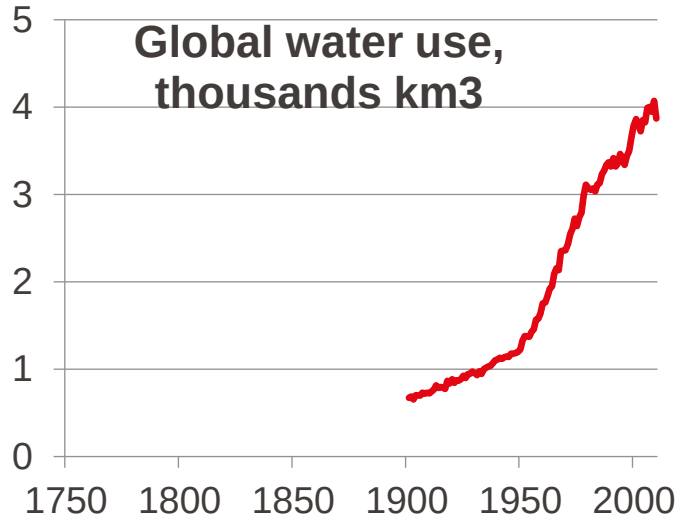


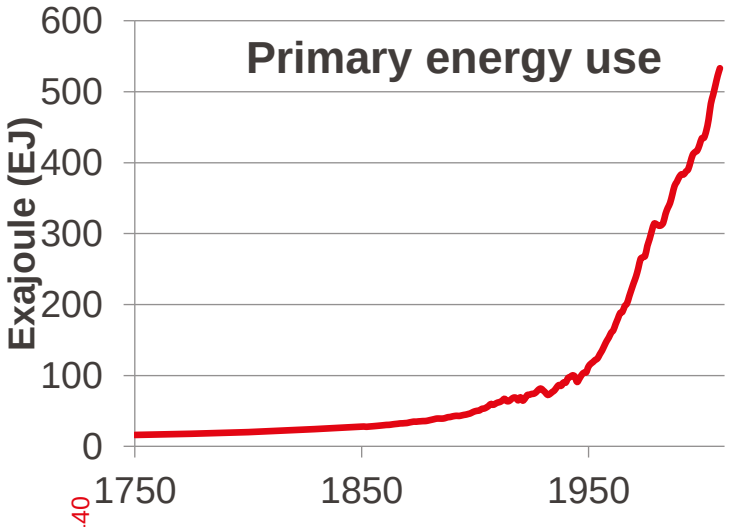
The great acceleration: Socio-economic trends (6 of 12)

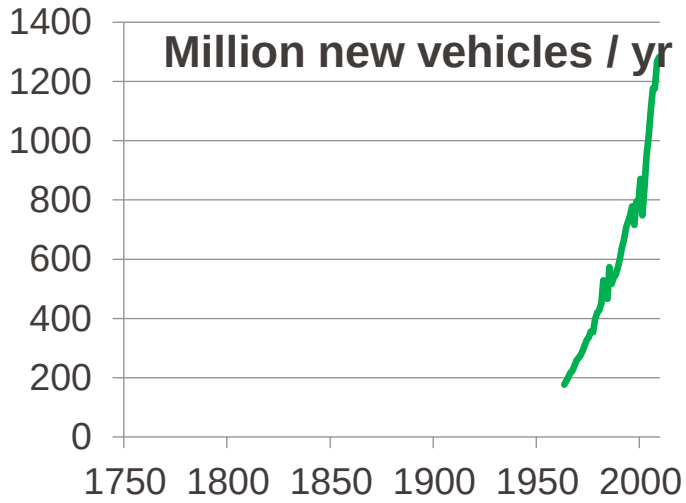


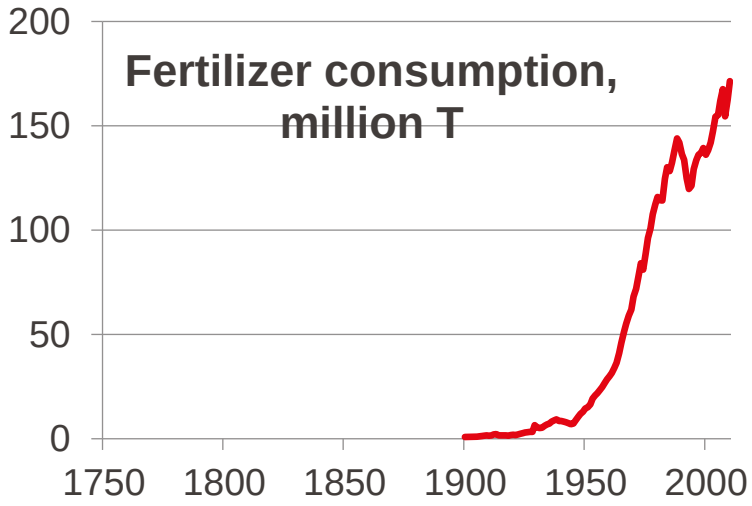


Since 1978, Genuine Progress has been falling even while GDP continues to increase. Credit: Kubiszewski et al., Beyond GDP: Measuring and achieving global genuine progress





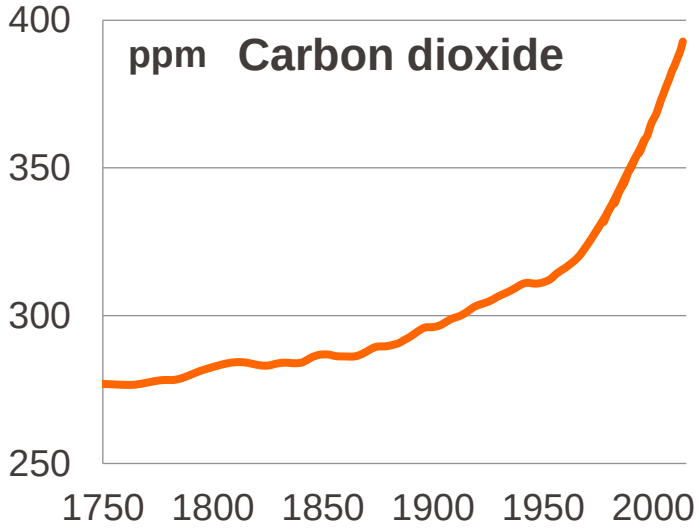


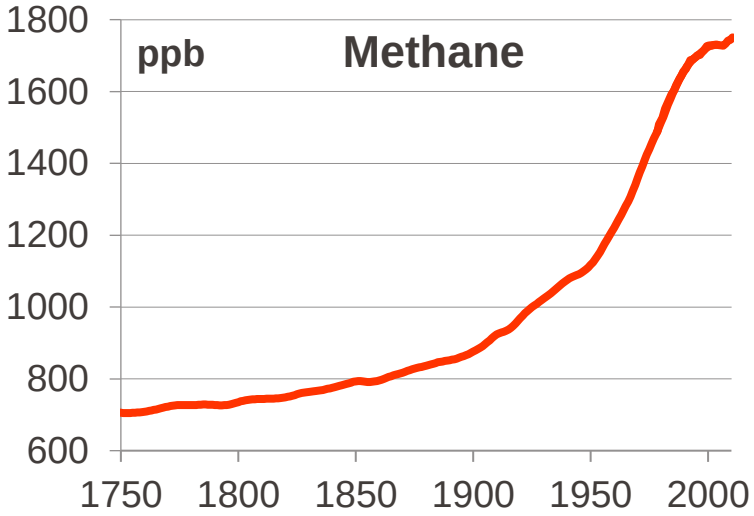


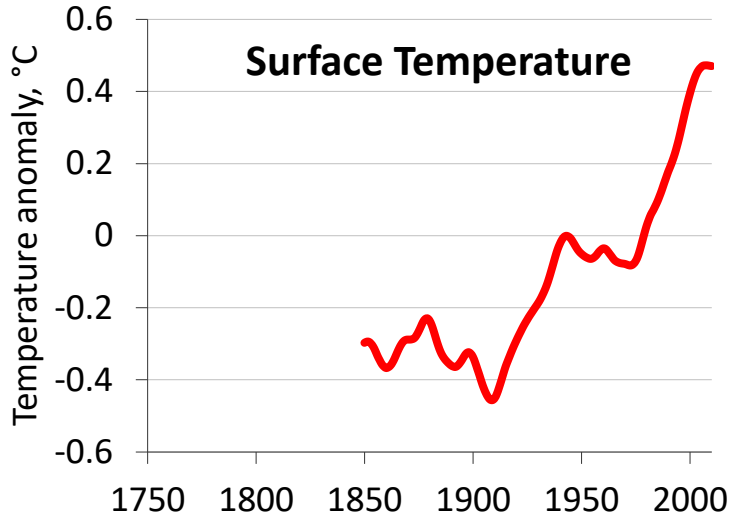
IGBPGreatAccelerationdatacollection.xlsx (live.com)

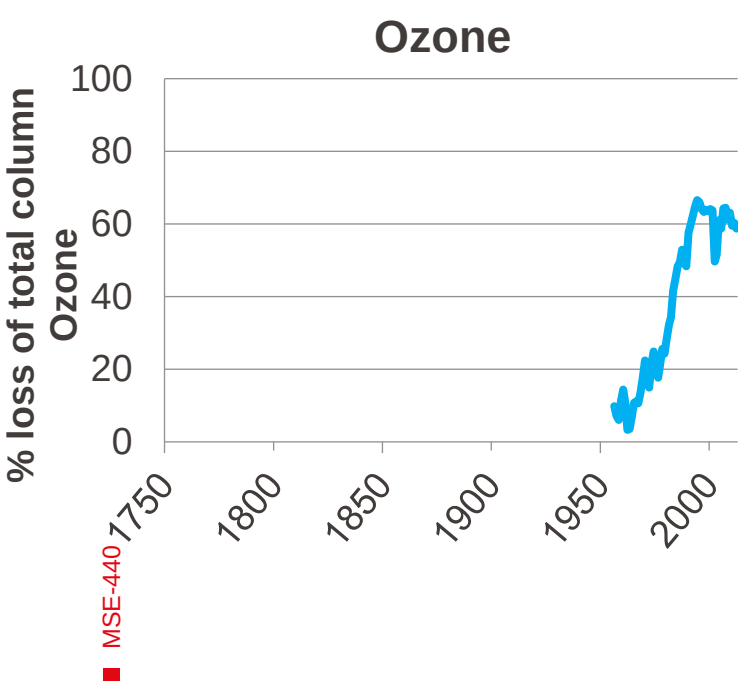
GPI = GDP (value of all goods and services produced) minus the environmental and social costs

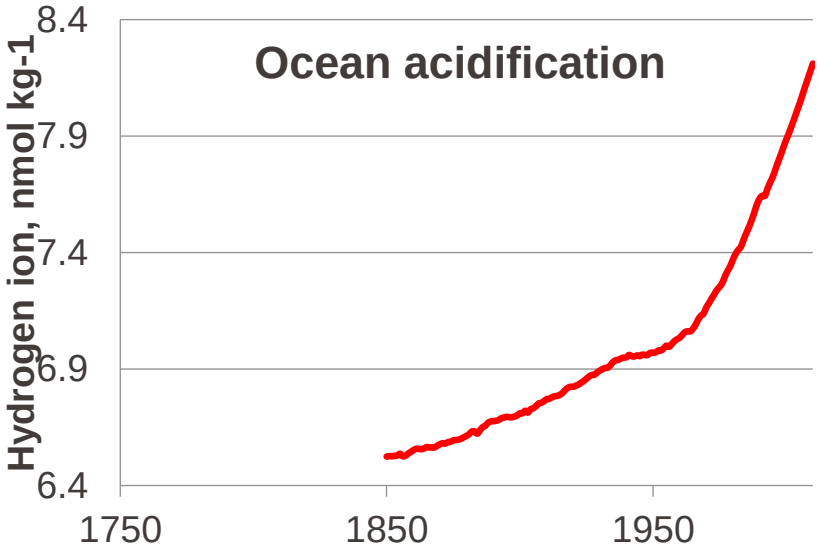
The great acceleration: Earth System trends (6 of 12)

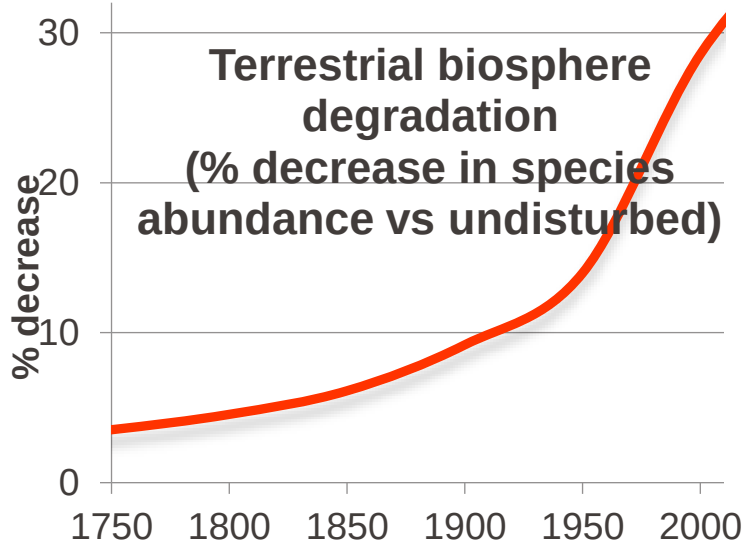






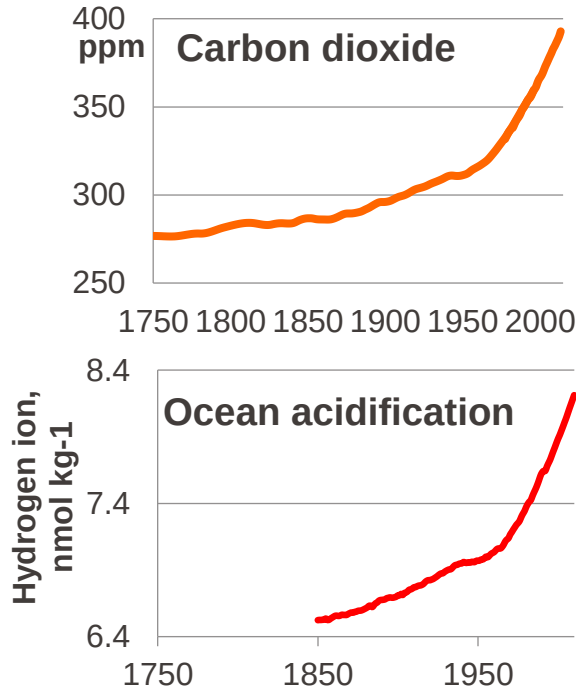






IGBPGreatAccelerationdatacollection.xlsx (live.com)

The great acceleration: Socio-economic and earth system trends



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- **Up to 80% of a product's lifetime emissions (environmental and social impacts) are determined by decisions made during the design and material selection stage**

https://www.ellenmacarthurfoundation.org/news/an-introduction-to-circular-design

- **Stripping ratio (over-burden) to extract is approx. 2x increasing to 2.4x by 2050**
- **Systemic change is needed**

- **Past 6 years: have consumed 500 BT of raws, ≈ cumulative total since 1900**

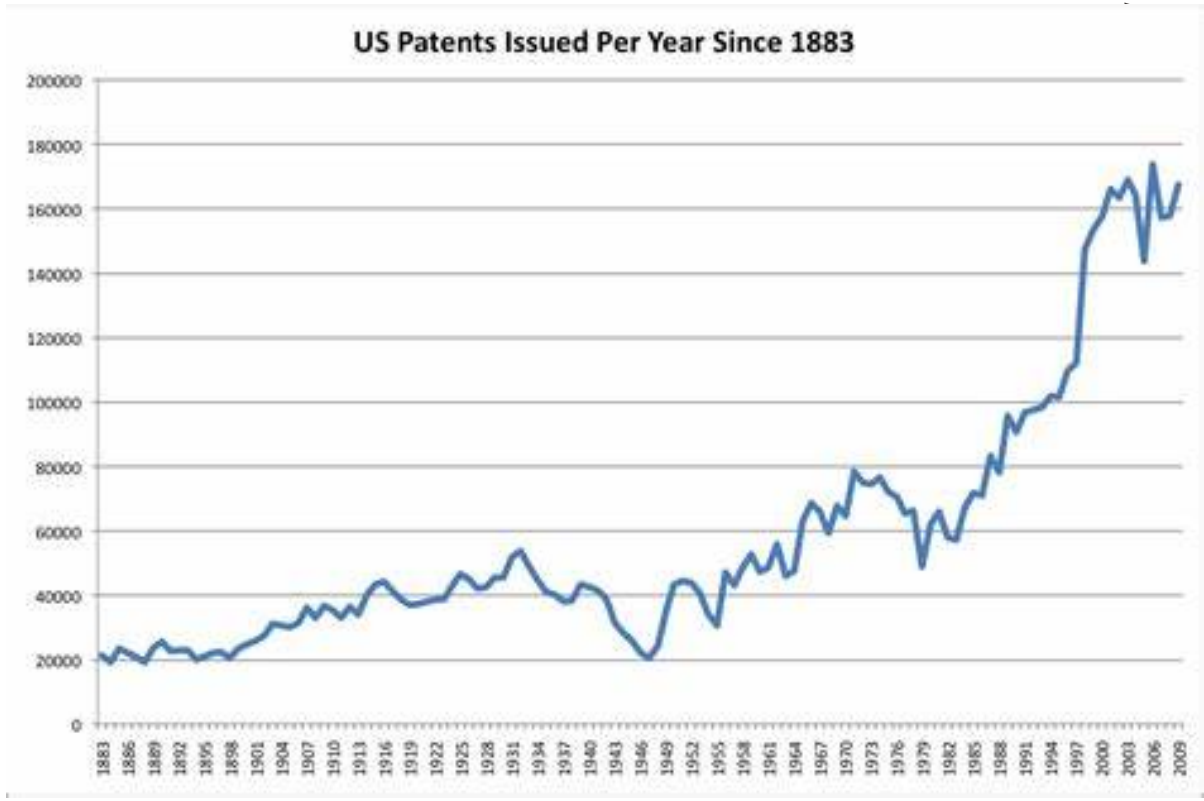
IGBPGreatAccelerationdatacollection.xlsx (live.com) Circularity Gap Report 2018_0.pdf

Continued advancing … but in a sustainable way

- Find a way to capture the amazing advances we have made as a human society (health, longevity, science, technology, travel, art …)

but

- in a sustainable way ***(without taking a mortgage on future generations)***

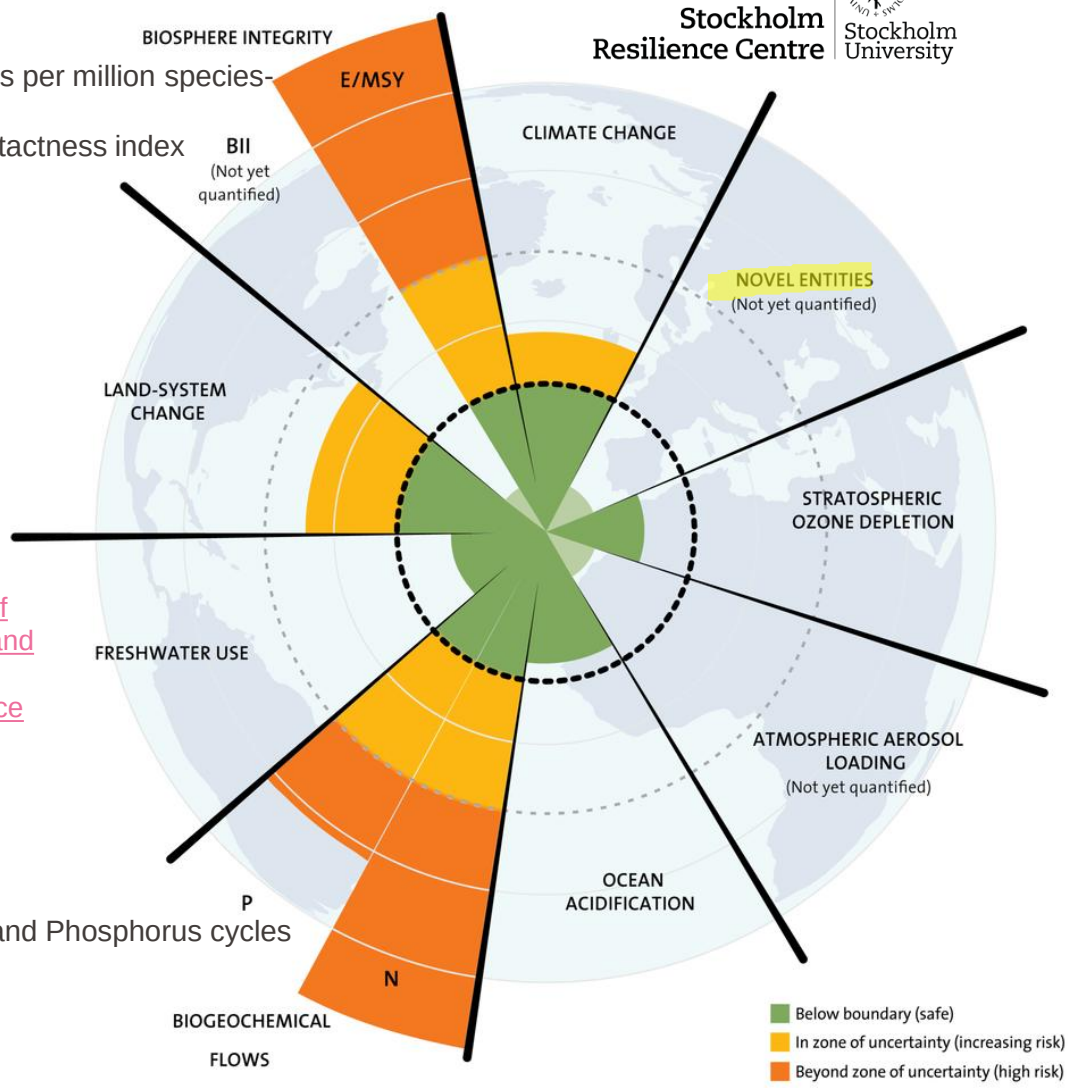


Research: part of the great acceleration

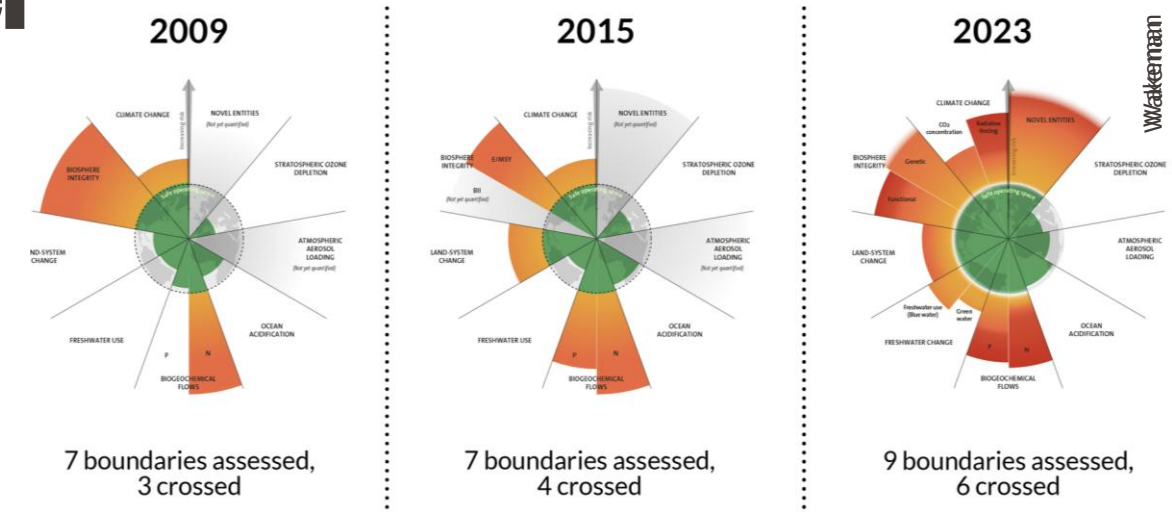
- Value our own mental and physical health
- A remapping of we how we become more advanced as a society

Planetary boundary model

E/MSY = extinctions per million species-years
BII = biodiversity intactness index



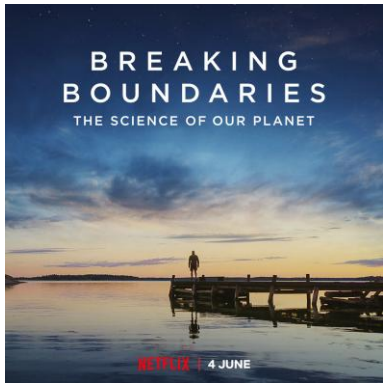
Steffen et. al, 16 January 2015, Science



PB over time. 2009, 2015, 2023.jpg | Powered by Box

The tipping points of climate change — and where we stand - Stockholm Resilience Centre

Nitrogen and Phosphorus cycles



Let the environment guide our development | Johan Rockstrom - YouTube

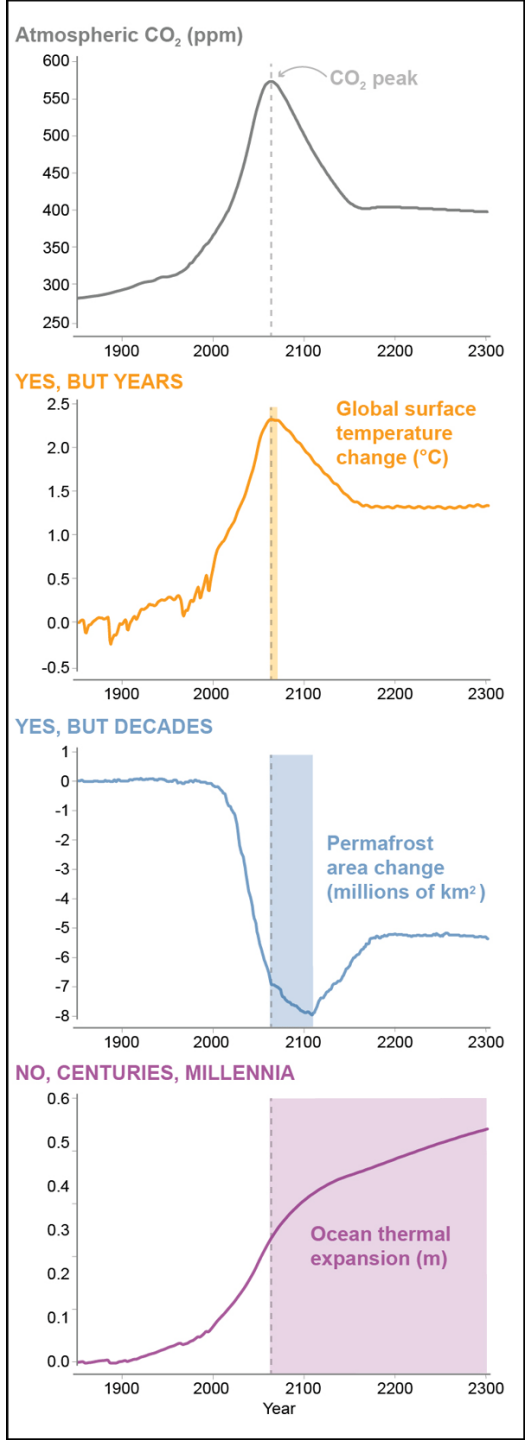
Planetary boundaries - Stockholm Resilience Centre

Time lines of reversal

- Global surface temperature: years
- Permafrost: decades
- Ocean expansion: millennia

Reversal outside of pricing and economics (Significant non-trivial externalities not considered by economics)

Carbon dioxide stays in atmosphere for centuries to millennia, but carbon removal accelerates the natural cycle to store excess carbon in soil, plants, or water.



A simplified computer model shows how long Earth systems take (years to centuries) to rebound
following peak CO_2 emissions (vertical gray dashed lines in each plot). Credit: *IPCC* [2021], FAQ 5.3

new-ipcc-2021-figure-5.png (600×1669) (wp.com)

Mark Carney, ex governor of the bank of England

- climate change is the **"Tragedy of the Horizon"**
- The catastrophic effects of climate change will be felt (well) beyond the traditional horizons of most (financial) actors

Anthropocene

Proposed geological epoch dating from the commencement of significant human impact on Earth's geology and ecosystems, including, but not limited to, anthropogenic climate change

- Start date peak in radionuclides fallout from atomic bomb testing in 1950s coinciding with the Great Acceleration, and the Atomic Age.
- Ratification rejected yet being opposed

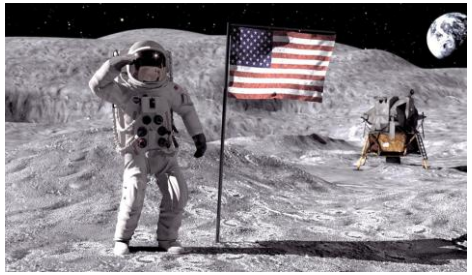
Terraforming: Largest Mines in the World (911metallurgist.com)
The Diavik diamond mine, Canada (Rio Tinto)

2.4 million

A 1991 study by the International Physicians for the Prevention of Nuclear War (IPPNW) predicted that some **2.4 million** people would eventually die from cancer as a result of atmospheric testing globally.

75 YEARS LATER, NUCLEAR WEAPONS STILL KILL | Geneva Centr...
www.gcsp.ch/global-insights/75-years-later-nuclear-weapons-still-kill

Trinity was the code name of the first detonation of a nuclear device. It was conducted by the United States Army at 5:29 a.m. on July 16, 1945, as part of the Manhattan Project.



maxresdefault.jpg (1280×720) (ytimg.com)

surgery-header.jpg (1100×385) (utmb.edu)

Anthropocene - Wikipedia

Earth overshoot day

- Date humanity's resource consumption for year exceeds Earth's capacity to regenerate those resources that year.
- "Overshoot" represents level by which human population exceeds sustainable amount of resources
- Day in which humanity enters environmental **deficit spending**

world biocapacity

(the amount of natural resources generated by Earth that year)

EOD =

world ecological footprint

(humanity's consumption of Earth's natural resources for that year), and multiplying by 365, the number of days in a year.

Country-Overshoot-Days-2024

Our socio-economic model also affects us as humans

- Ecological ceiling (and boundaries)
- Social foundation (and shortfalls)
- **Need the safe and just space between these social and planetary boundaries**
- Humanity's 21st century goal

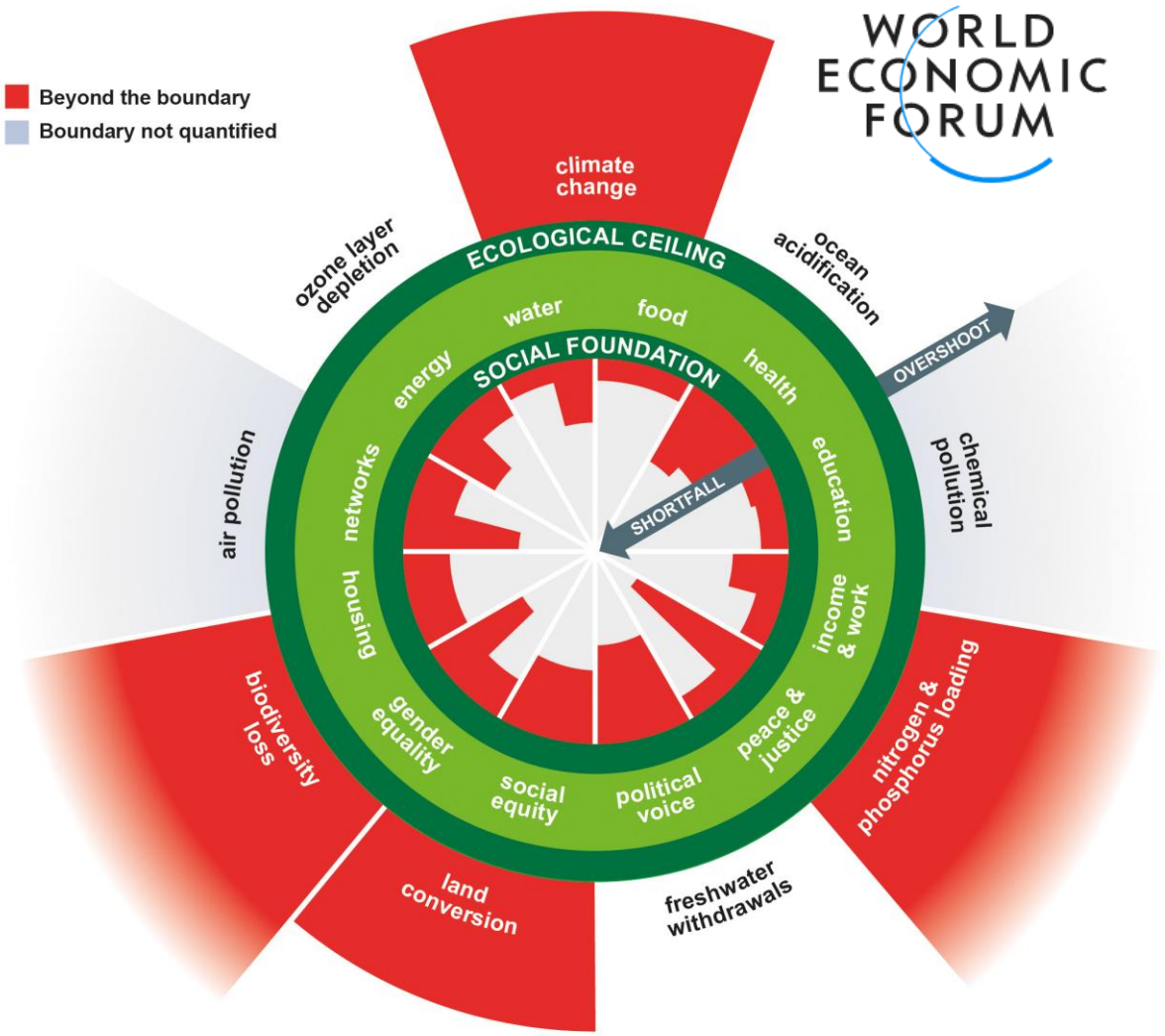


Image: Kate Raworth and Christian Guthier/The Lancet Planetary Health

Meet the doughnut: the new economic model that could help end inequality | World Economic Forum (weforum.org)

Doughnut | Kate Raworth

Wealth inequality

Richest 1% own half the world's wealth, study finds

Credit Suisse report highlights increasing gap between the super-rich and the remainder of the globe's population

▲ The Credit Suisse report found 2.3 million new dollar millionaires were created over the past year, taking the total to 36 million. Photograph: Carl Court/Getty Images

The globe's richest 1% own half the world's wealth, according to a new report highlighting the growing gap between the super-rich and everyone else.

World's 26 richest people own as much as poorest 50%, says Oxfam

Charity calls for 1% wealth tax, saying it would raise enough to educate every child not in school

▲ The Oxfam report says that between 2017 and 2018 a new billionaire was created every two days. Photograph: Bloomberg via Getty Images

The growing concentration of the world's wealth has been highlighted by a report showing that the 26 richest billionaires own as many assets as the 3.8 billion people who make up the poorest half of the planet's population

World's 26 richest people own as much as poorest 50%, says Oxfam | The super-rich | The Guardian

Confronting Carbon Inequality: Putting climate justice at the heart of the COVID-19 recovery (openrepository.com)

Of the 1%, by the 1%, for the 1% | Vanity Fair

Richest 1% own half the world's wealth, study finds | Inequality | The Guardian

Carbon emissions correlate to wealth

- The richest **1%** of the world have used two times as much carbon as the poorest **50%** of the population over the last 25 years

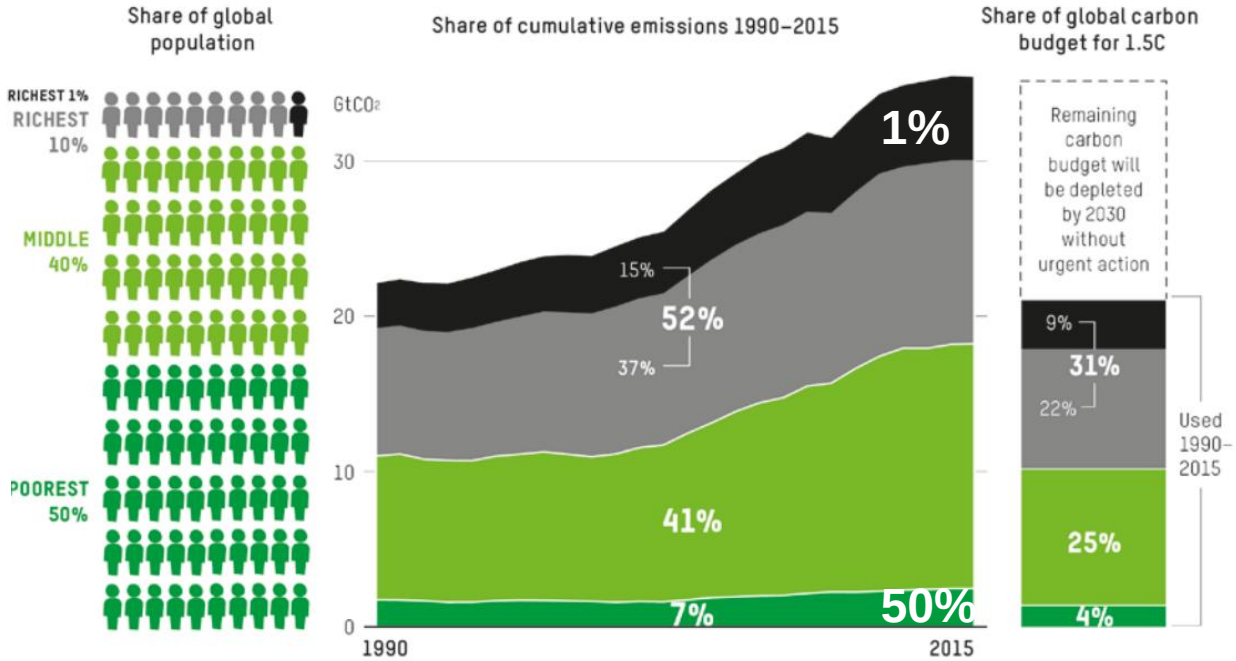
OXFAM

Just how much money do you need to be among the global 1 percent?

According to the 2018 Global Wealth Report from Credit Suisse Research Institute, you need a net worth of $871,320 U.S. Credit Suisse defines net worth, or "wealth," as "the value of financial assets plus real assets (principally housing) owned by households, minus their debts."

Figure 5: Main categories of consumption among highest emitters in the EU (2010)[30]

Figure 1: Share of cumulative emissions from 1990 to 2015 and use of the global carbon budget for 1.5C linked to consumption by different global income groups



Per capita income threshold [SPPP2011] of richest 1%: $109k; richest 10%: $38k; middle 40%: $6k; and bottom 50%: less than $6k. Global carbon budget from 1990 for 33% risk of exceeding 1.5C: 1,205Gt.

Confronting Carbon Inequality: Putting climate justice at the heart of the COVID-19 recovery (openrepository.com)

Carbon emissions correlate to wealth

‘As Oxfam's new report shows,

Our current (neo-liberal) economic model has been an enabler of catastrophic climate change and equally catastrophic inequality.

Ban Ki-moon, Deputy Chair of The Elders, former Secretary-General of the United Nations

COVID-19 pandemic provides an incontestable imperative to rebuild better and place the global economy on a more sustainable, resilient and fairer footing.

Addressing the disproportionate carbon emissions from the wealthiest in society must be a key priority as part of this collective commitment.’

Confronting Carbon Inequality: Putting climate justice at the heart of the COVID-19 recovery (openrepository.com)

UN 2030 sustainable development goals

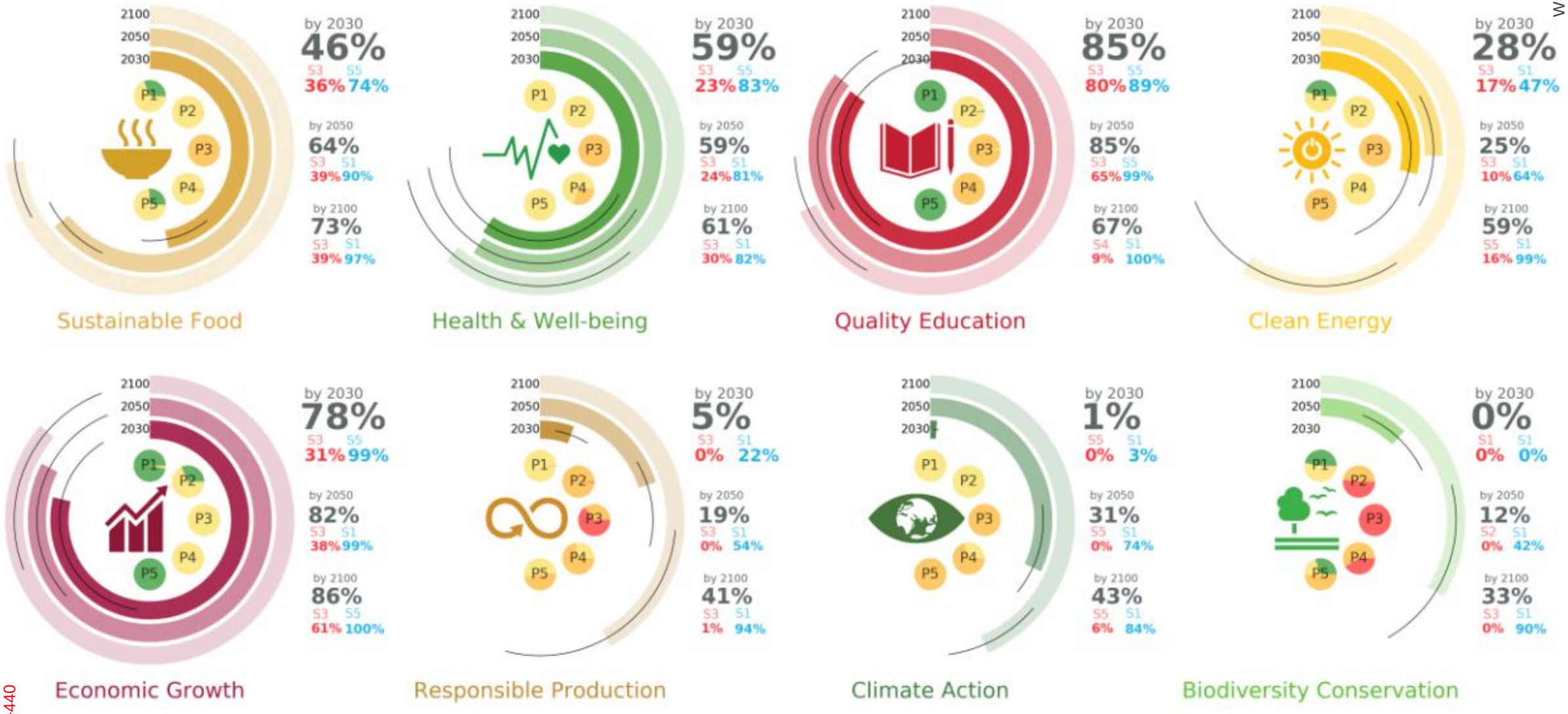
[Transforming our world: the 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs (un.org)]

[Home | Sustainable Development (un.org)]

The Doughnut economy and circularity in business models – Best For The World

SDG progress

Countries are making incremental progress on strengthening their NDCs, but what we really need to achieve the goals of the Paris Agreement is urgent transformational change.



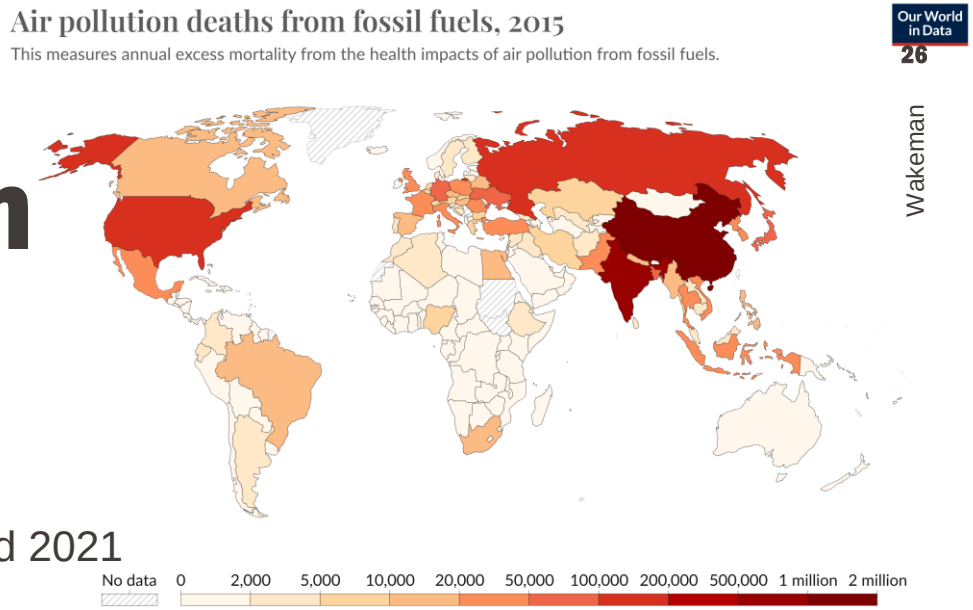
(15) (PDF) Global pathways to sustainable development to 2030 and beyond (researchgate.net)

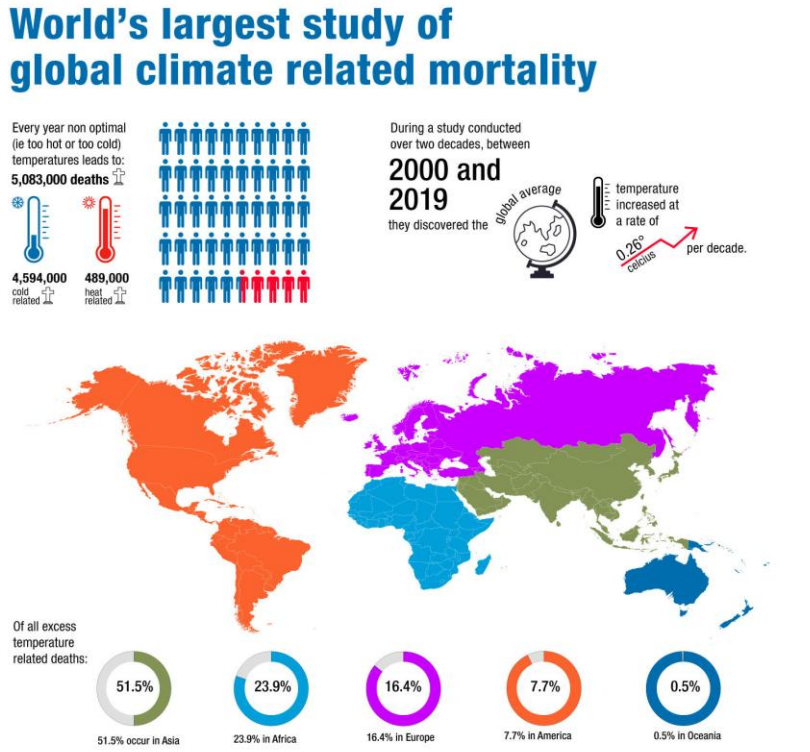
SDG Tracker: Measuring progress towards the Sustainable Development Goals - Our World in Data

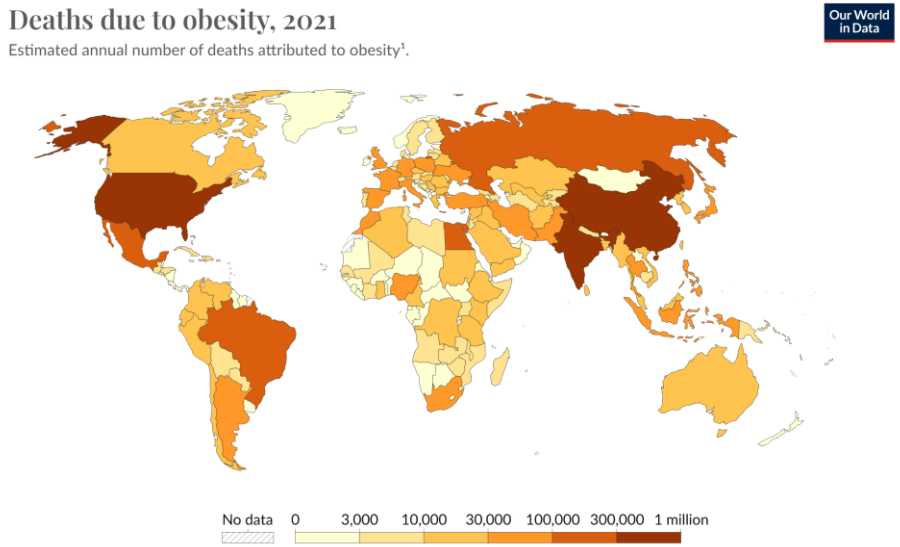
state-of-ndcs-2022.pdf (wri.org)

Our current Petro-chemical economy, diet, & human health

- ~ 15 million / yr of our own cause
  - Air pollution: 7 million, of which 3.6 million fossil fuel
  - Obesity: 2.8 million
  - Temperature: 5 million from excessive temperatures
- Around same as Covid-19: 14.9 million excess deaths in 2020 and 2021







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how many people die from air pollution

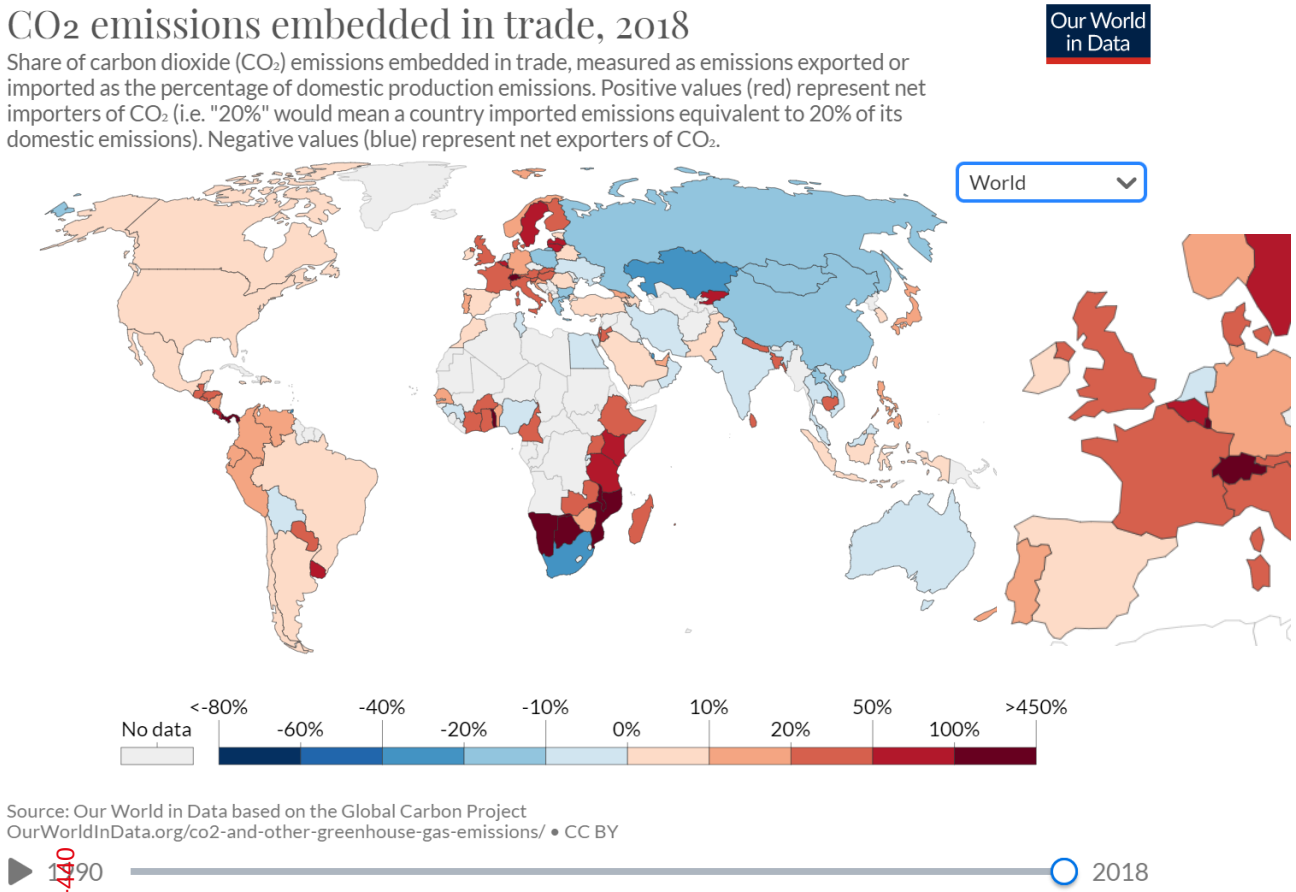
Obesity (who.int)

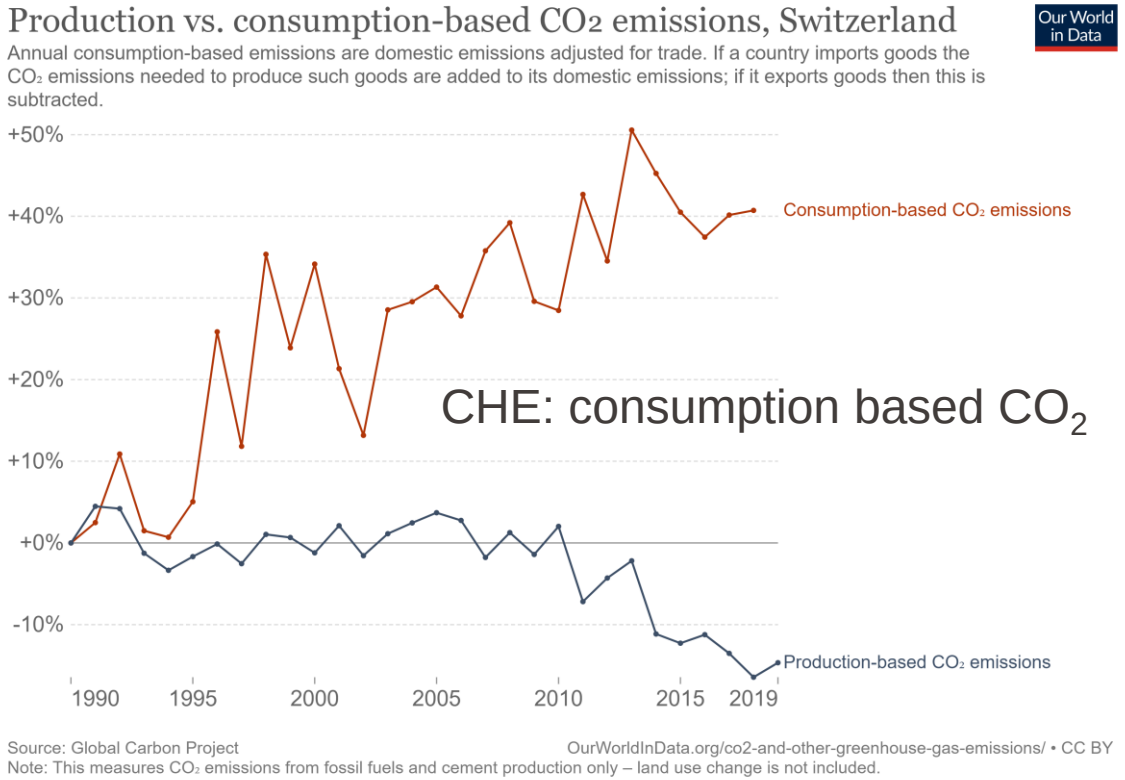
global climate related mortality 5 million deaths a year to abnormal temperatures

COVID-19 pandemic (who.int)

Key issues for Switzerland

- Net importers of CO_2
- High standard of living & wealth drive consumption based CO_2 emissions





[Climat: Holcim et Lonza, les plus gros pollueurs en Suisse - rts.ch - Suisse]

[How do CO2 emissions compare when we adjust for trade? - Our World in Data]

Shifting baseline syndrome (Daniel Pauly in 1995)

Negative externalities

125 M CHF clean up cost (700 CHF/working person in Valais)

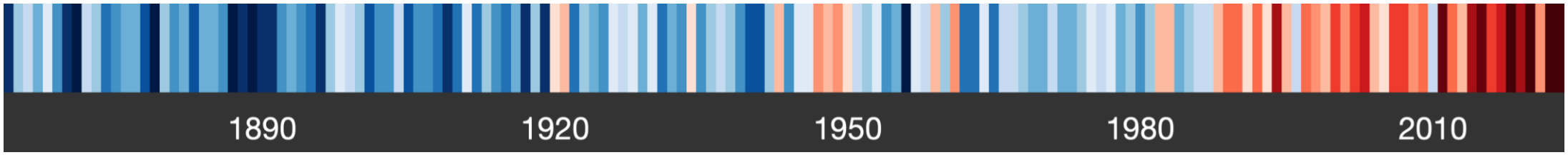
Wakeman

SWI swissinfo.ch — Swiss perspectives in 10 languages

Swiss Alps Slammed by More Severe Flooding, Landslides

June 30, 2024 - 19:36 — 2 minutes

menu RTS Info Sport Culture

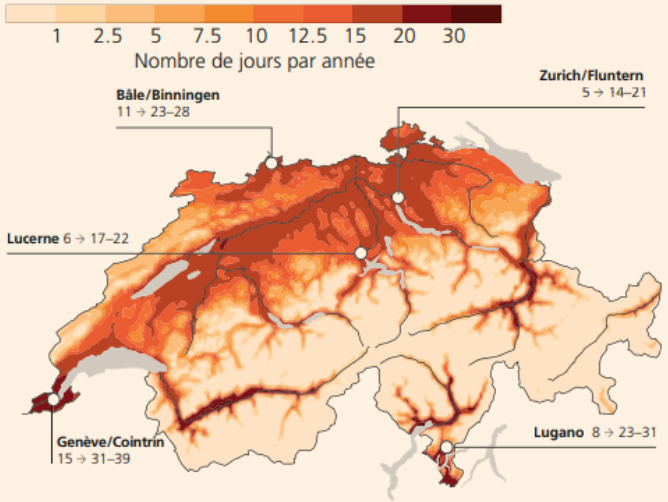


#ShowYourStripes

Switzerland forecast to 2085

Évolution du nombre de journées tropicales

Évolution attendue du nombre de jours avec des températures supérieures à 30 degrés Celsius vers 2060 par rapport à 1981–2010 (moyenne sur 30 ans) sans mesures de protection du climat. Les valeurs correspondent à la période de référence 1981–2010 et les changements possibles vers 2060.

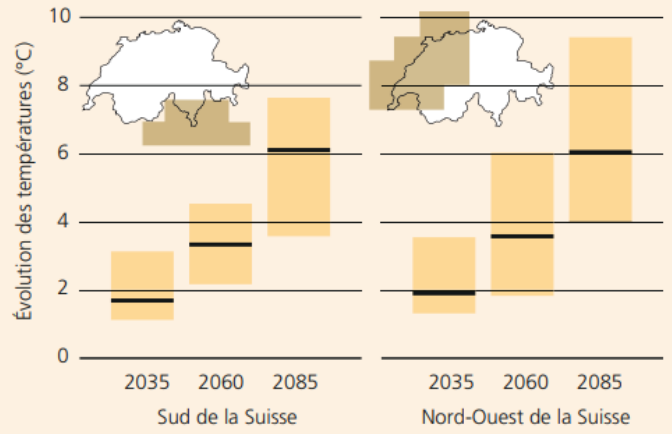


Évolution des températures maximales annuelles

Évolution moyenne vers 2035, 2060 et 2085 par rapport à la période de référence 1981–2010 (moyenne sur 30 ans) sans mesures de protection de climat.

Valeur attendue (valeur médiane de l'ensemble des simulations)

Valeurs possibles (plage des valeurs possibles sur l'ensemble des simulations)



Plus de journées tropicales

Les régions urbaines situées à basse altitude seront particulièrement touchées par des canicules. Sur le Plateau et dans les vallées alpines, le thermomètre grimpera plus fréquemment au-dessus de la barre des 30 degrés Celsius qui caractérise une « journée tropicale ». On attend le plus grand nombre de journées tropicales supplémentaires pour les régions de Genève, du Valais et du Sud de la Suisse.

Les températures maximales augmenteront particulièrement

Les températures maximales annuelles augmenteront fortement. D'ici le milieu du siècle, le jour le plus chaud de l'année pourra atteindre jusqu'à 4 degrés Celsius de plus au Sud des Alpes et même jusqu'à 6 degrés Celsius de plus au Nord des Alpes par rapport à aujourd'hui. À Genève, par exemple, le jour le plus chaud d'une année moyenne pourrait atteindre environ les 40 degrés Celsius.

Median

+4ºC Lausanne 2060

+6ºC Lausanne 2085 (my Kids)

Rapport technique CH2018 (admin.ch)

Brochure CH2018 (admin.ch)

The Economist

Menu | Weekly edition | Search

Briefing

Jul 24th 2021 edition ›

What's the worst that could happen

Three degrees of global warming is quite plausible and truly disastrous

Rapid emission cuts can reduce the risks but not eliminate them

Three degrees of global warming is quite plausible and truly disastrous | The Economist

Fight, flight, or freeze

- **Fight:** Aim is to help you generate initiatives, to fight
- Not freeze in data overload
- Not flight, run away and ignore the issue

peter rabbit GIF (giphy.com)

The future is not automatically predetermined.

Every day we decide tomorrow's future, one decision at a time

Overview

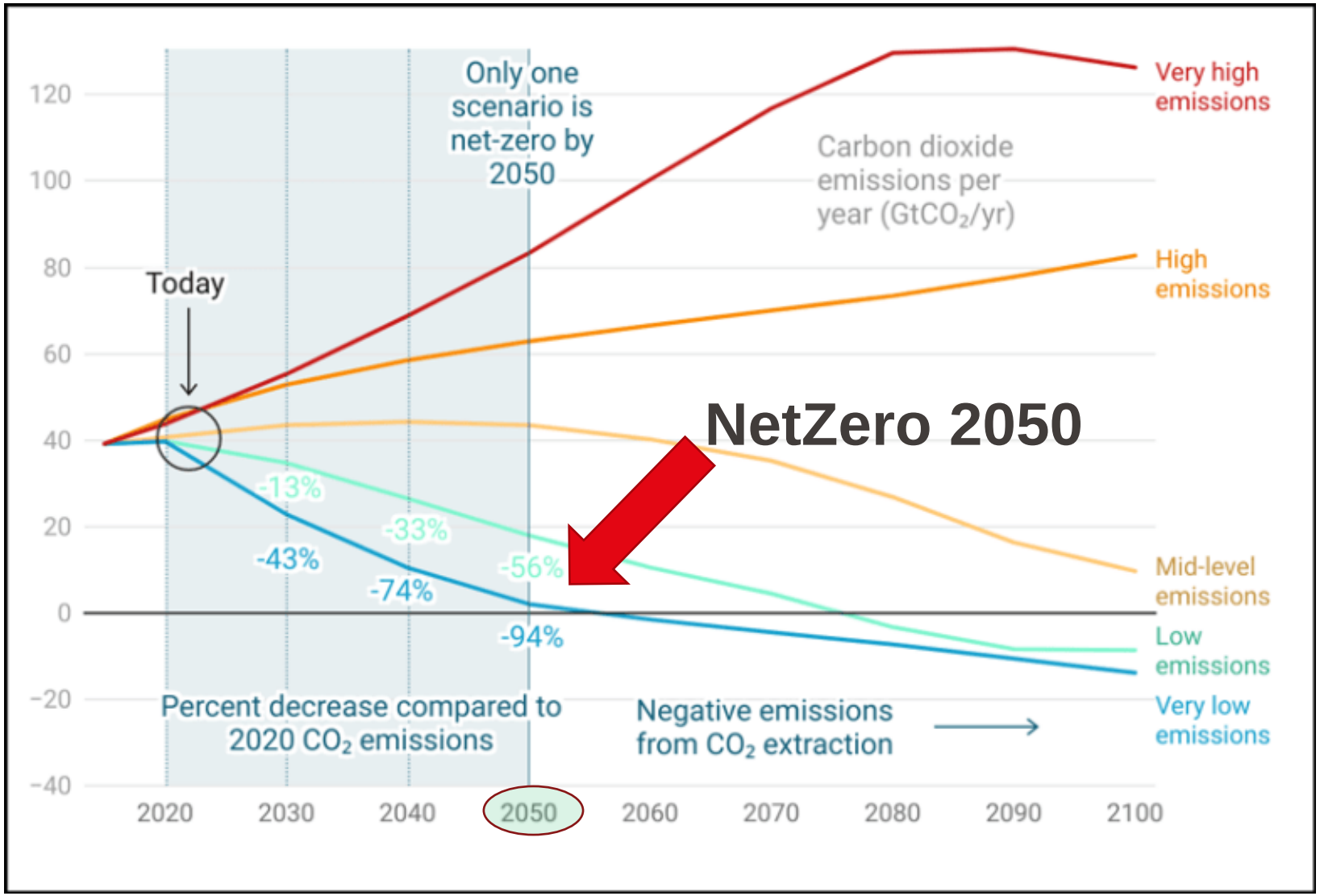
- Sustainability
- NetZero transition
- Linear vs. circular economy
- Circular economy frameworks
- Materials and engineered product examples
- Enablers to a CE
- Initiatives

CO_2 emissions reduction scenarios

Requires sharp CO_2 cuts per decade, net zero CO_2 by 2050, and carbon capture.

Needs systemic change.

- **In industry**
- **In government**
- **In academia**
- **In our own lives**

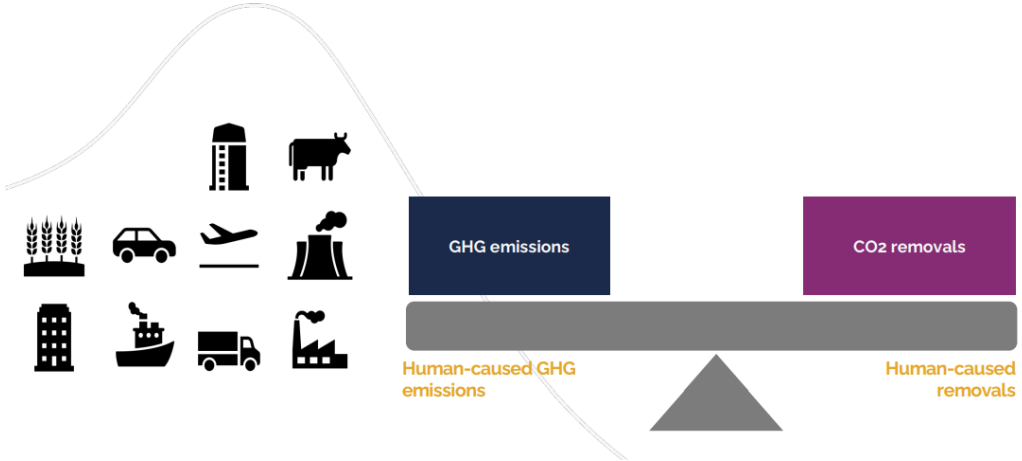


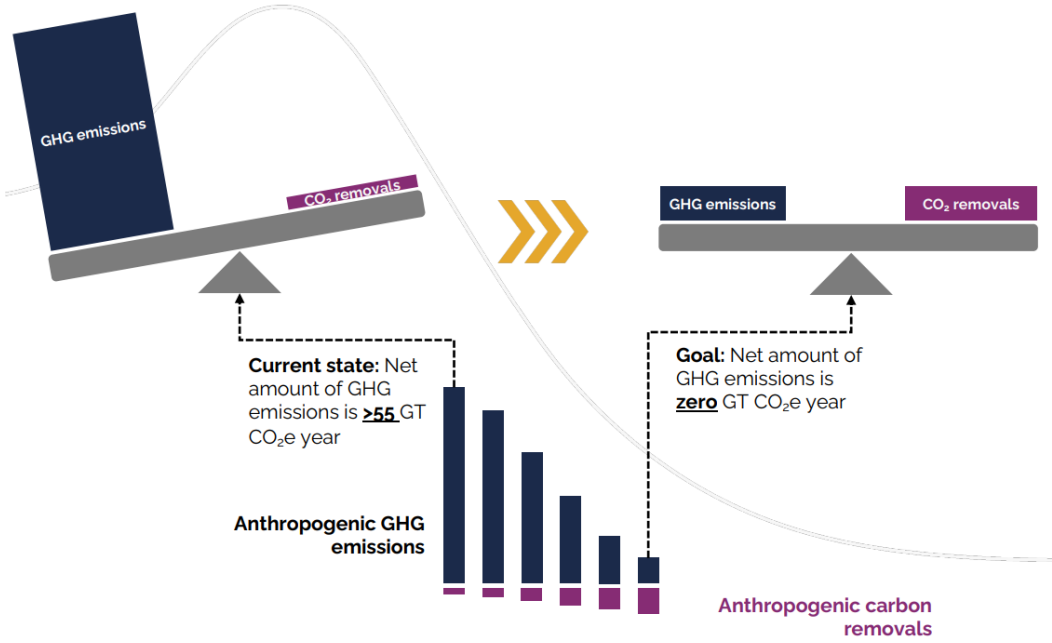
Credit: Jenessa Duncombe.
Source: *IPCC* [2021]

What Five Graphs from the U.N. Climate Report Reveal About Our Path to Halting Climate Change - Eos

Towards a net-zero economy

To limit global warming to 1.5°C, we must reach net-zero carbon emissions **no later than 2050**.





SBTi-Net-Zero-Standard-Event-slides.pdf (sciencebasedtargets.org)

Decarbonization – battle of high school math

If we multiply a linearly increasing function (market demand) by a linear decreasing function (kgCO2e/kg) of the same gradient what is the resulting function?

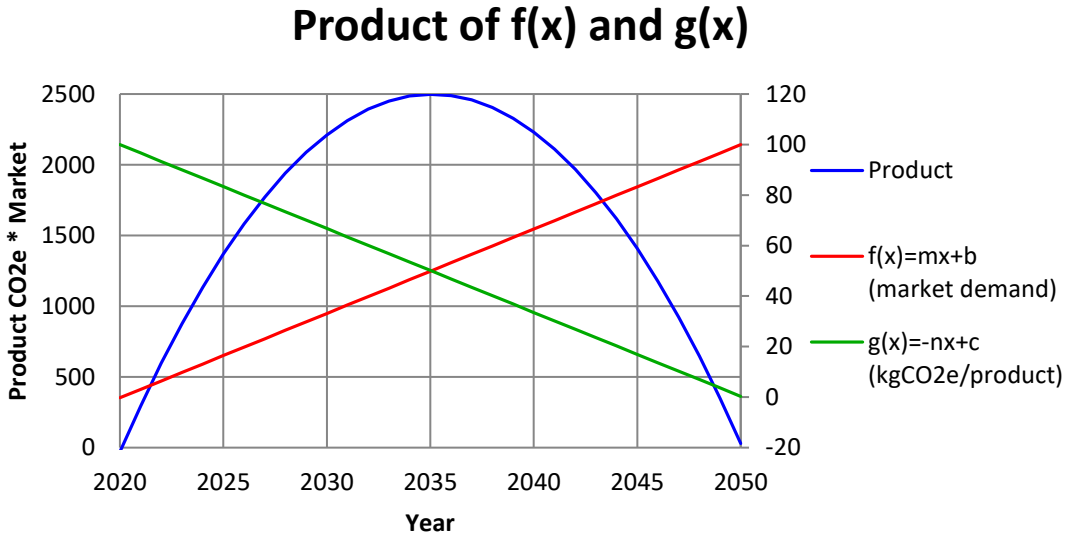
Linearly increasing function
Market demand (parts)
$f(x) = mx + b$

Linearly decreasing function
Product kgCO2e
$g(x) = -mx + c$

$$h(x) = f(x) \cdot g(x) = (mx+b)(-mx+c)$$

h(x) = Market demand (parts) * Product kgCO2e
h(x) = MTCO2e emitted by total products in market

NetZero



Constraints
Market demand
2020 = ~ 0
2050 = 100

CO2e
2020 = 100
2050 = ~ 0
Ideal case

Decarbonization – battle of high school math

$$h(t) = f(t) \,.\, g(t) = (ae^{kt}(-mt+b) = abe^{kt}\text{-}amte^{kt}$$

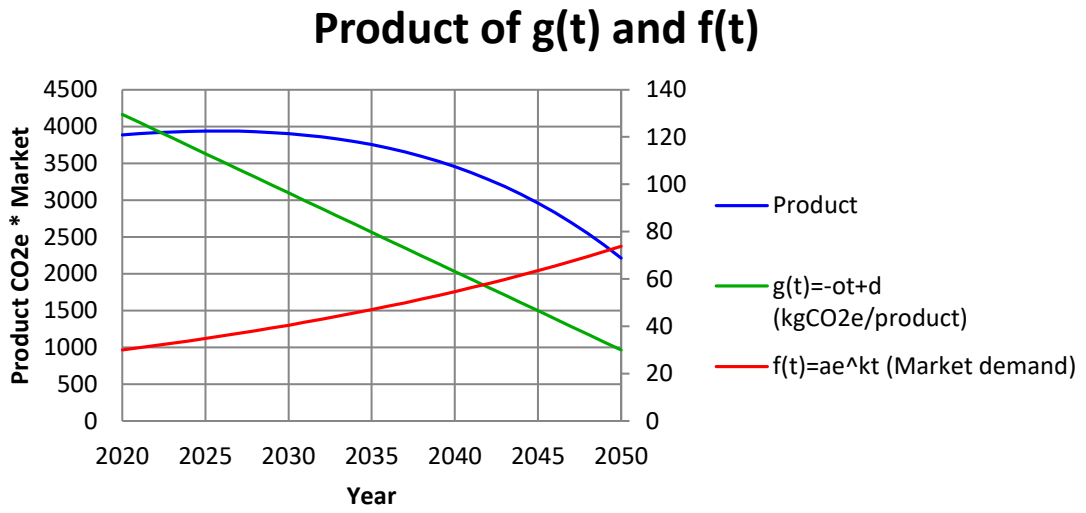
h(t) = Market demand (parts) * Product kgCO2e

h(t) = MTCO2e emitted by total products in market

Expected GDP 3% to 2030 (IEA)

Net Zero by 2050 – Analysis - IEA

NetZero



Constraints
Market demand
2020 = 30
k = 0.03 (CAGR 3.05%)

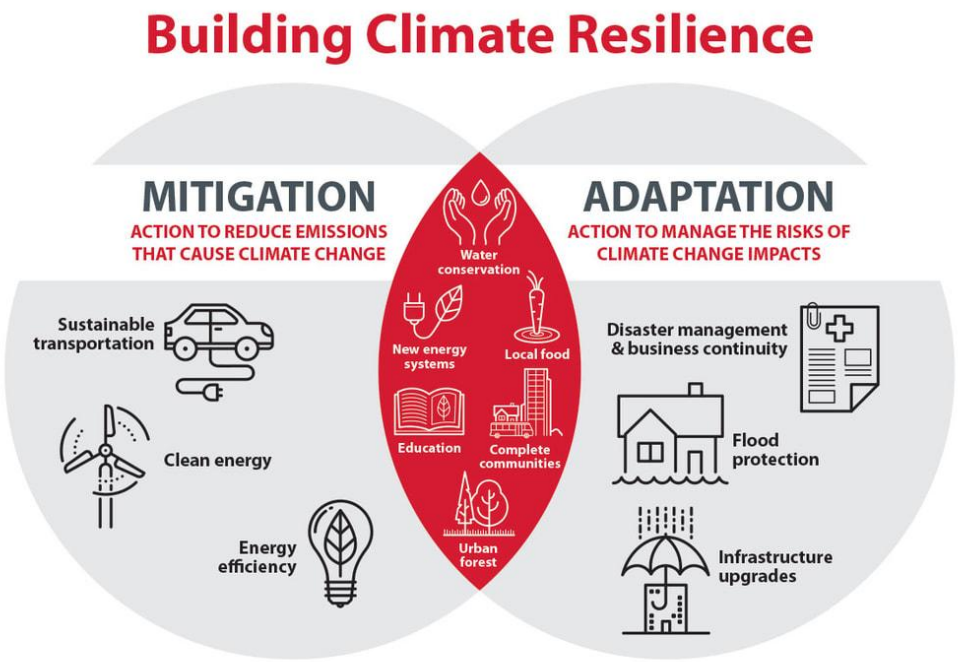
CO2e
2020 ~130
2050 = 30

A linear reduction in hypothetical product CO2e can flatten a 3% GDP curve but not bring it to zero

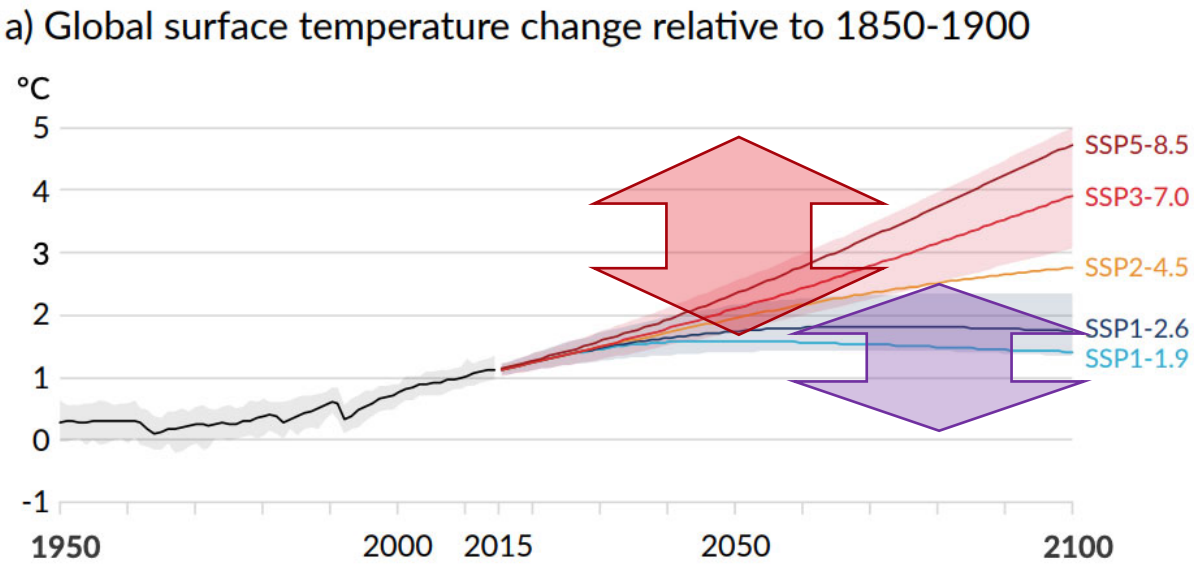
- We need dematerialization, societal adaptation, and a circular economy to shift the curve

Mitigation versus adaption

- Mitigation and adaptation are two different approaches to deal with climate change.
- **Mitigation** refers to the efforts to **reduce** greenhouse gas emissions (abatement) and slow the rate of climate change.
- **Adaptation** refers to the efforts to **adjust** to the current and future effects of climate change.
- **Mitigation** tackles the causes of climate change, whereas **adaptation** tackles the effects.



ESS Topic 7.3: Climate change – Mitigation and Adaptation - AMAZING WORLD OF SCIENCE WITH MR.



Sixth Assessment Report — IPCC

Mitigation

World's first high-altitude floating solar farm – in the Swiss Alps | House of Switzerland

Adaptation

Storm Éowyn, photos Reuters and Steve H

Sept. 2024: Pledges and targets, Policies and actions …

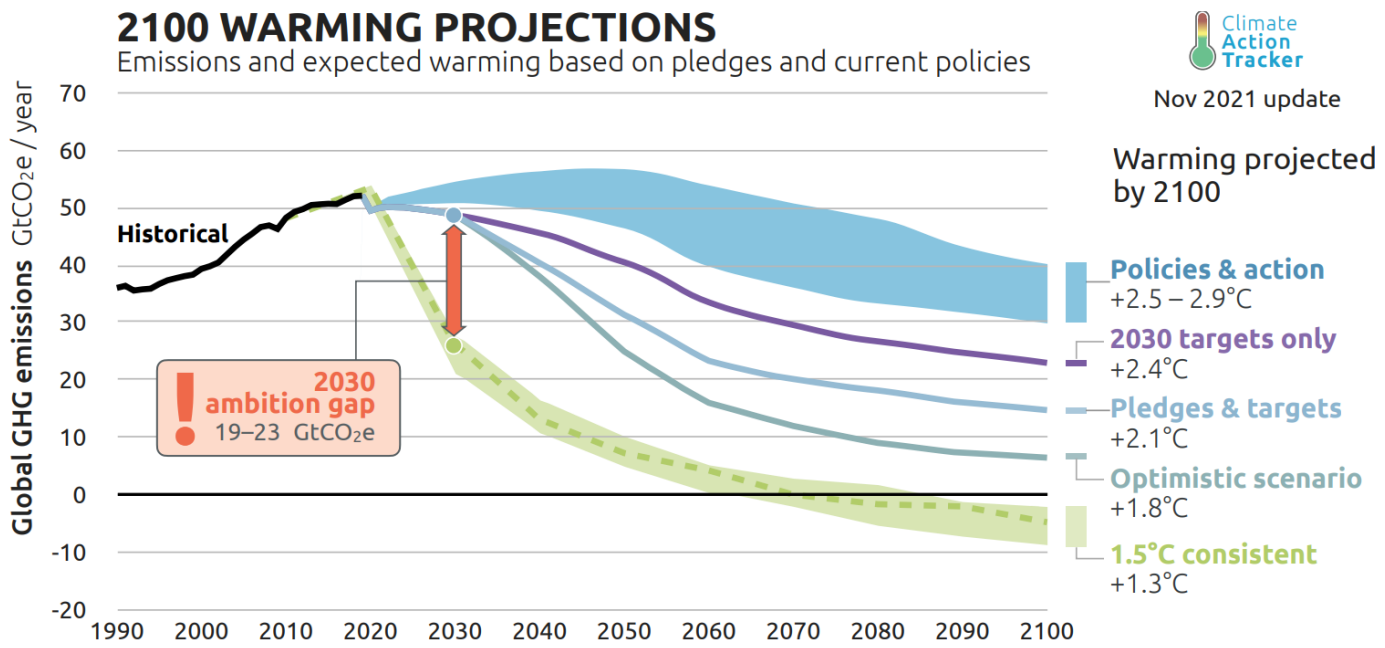
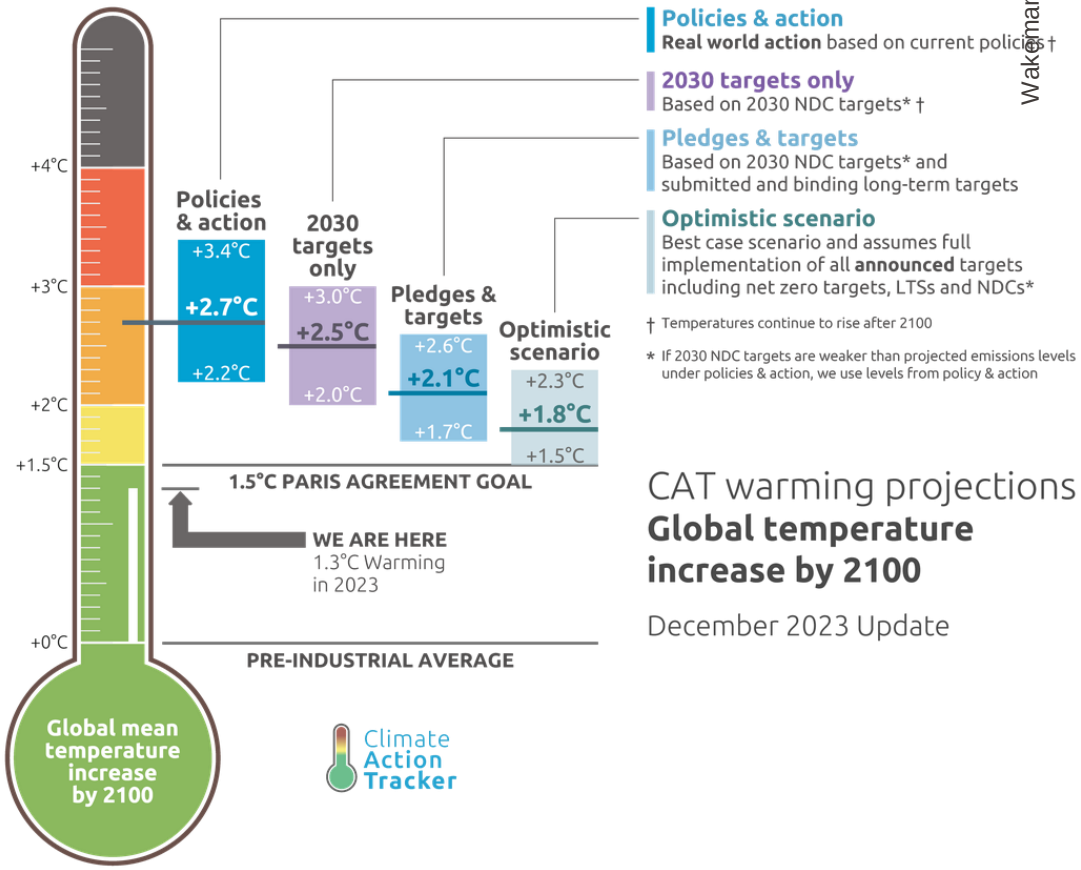


Figure 2 Global greenhouse gas emission pathways for CAT estimates of policies and action, 2030 targets only, 2030 and binding long-term targets and an optimistic pathway based on net zero targets of over 140 countries in comparison to a 1.5°C consistent pathway.



Leaves a <u>remaining carbon budget</u>

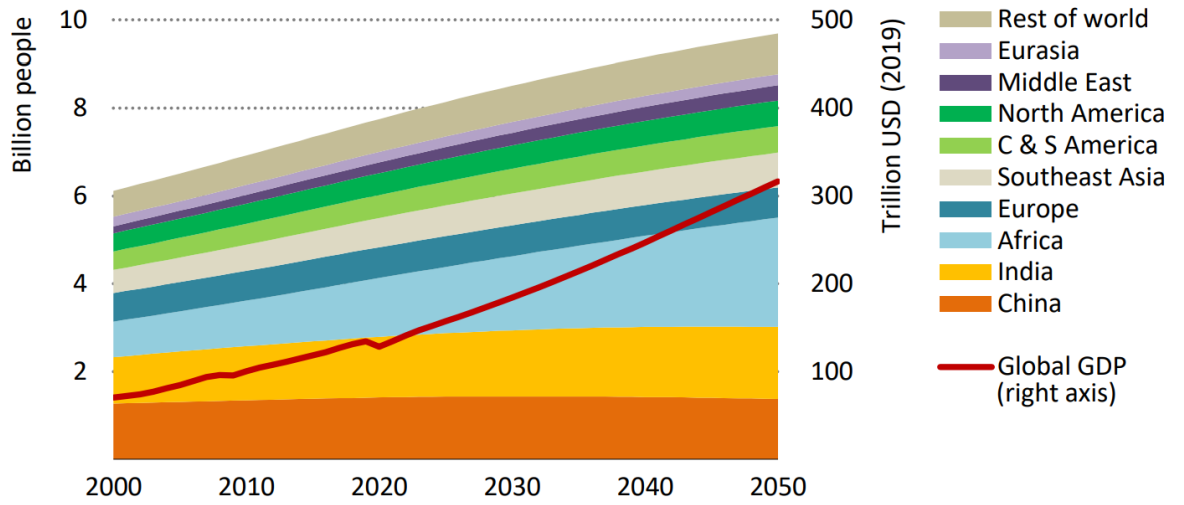
∑ anthropogenic CO_2e that can still be emitted into the atmosphere while holding the global average temperature increase to 1.5°C

200 $GtCO_2$ as of 2024, equal to around six years of current CO_2 emissions.

Pledges and targets = +2.1°C; Policies and actions = +2.7°C

NetZero 2050 population, GDP, energy

Figure 2.1 ▷ World population by region and global GDP in the NZE

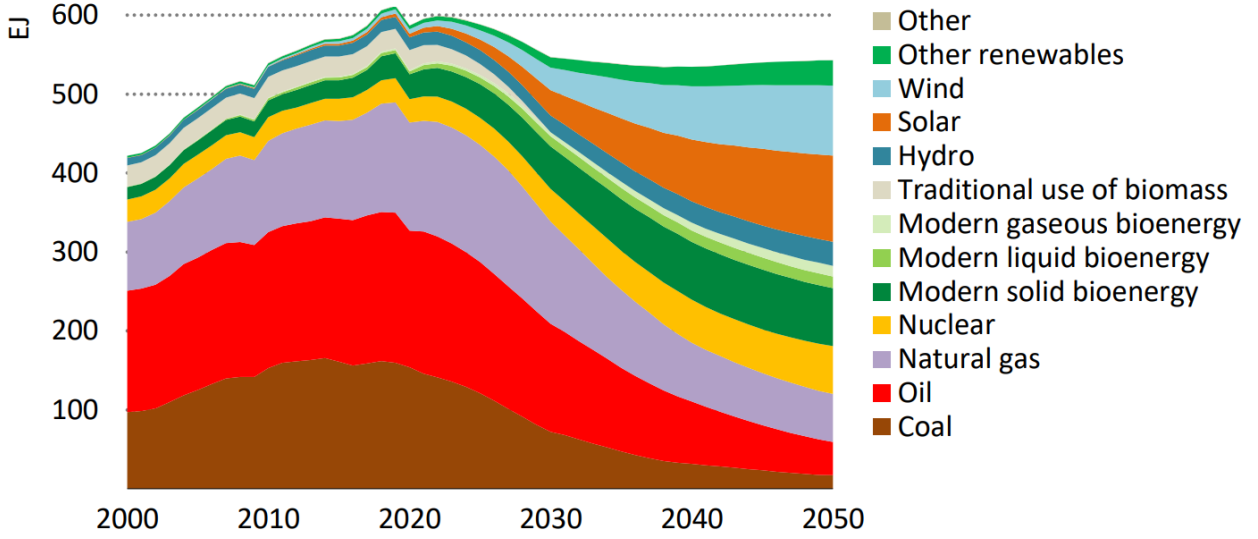


By 2050, the world's population expands to 9.7 billion people and the global economy is more than twice as large as in 2020

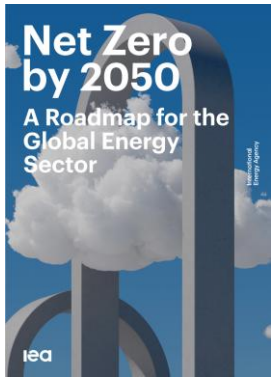
Notes: GDP = gross domestic product in purchasing power parity; C & S America = Central and South America.

Sources: IEA analysis based on UNDESA (2019); Oxford Economics (2020); IMF (2020a, 2020b).

Figure 2.5 ▷ Total energy supply in the NZE



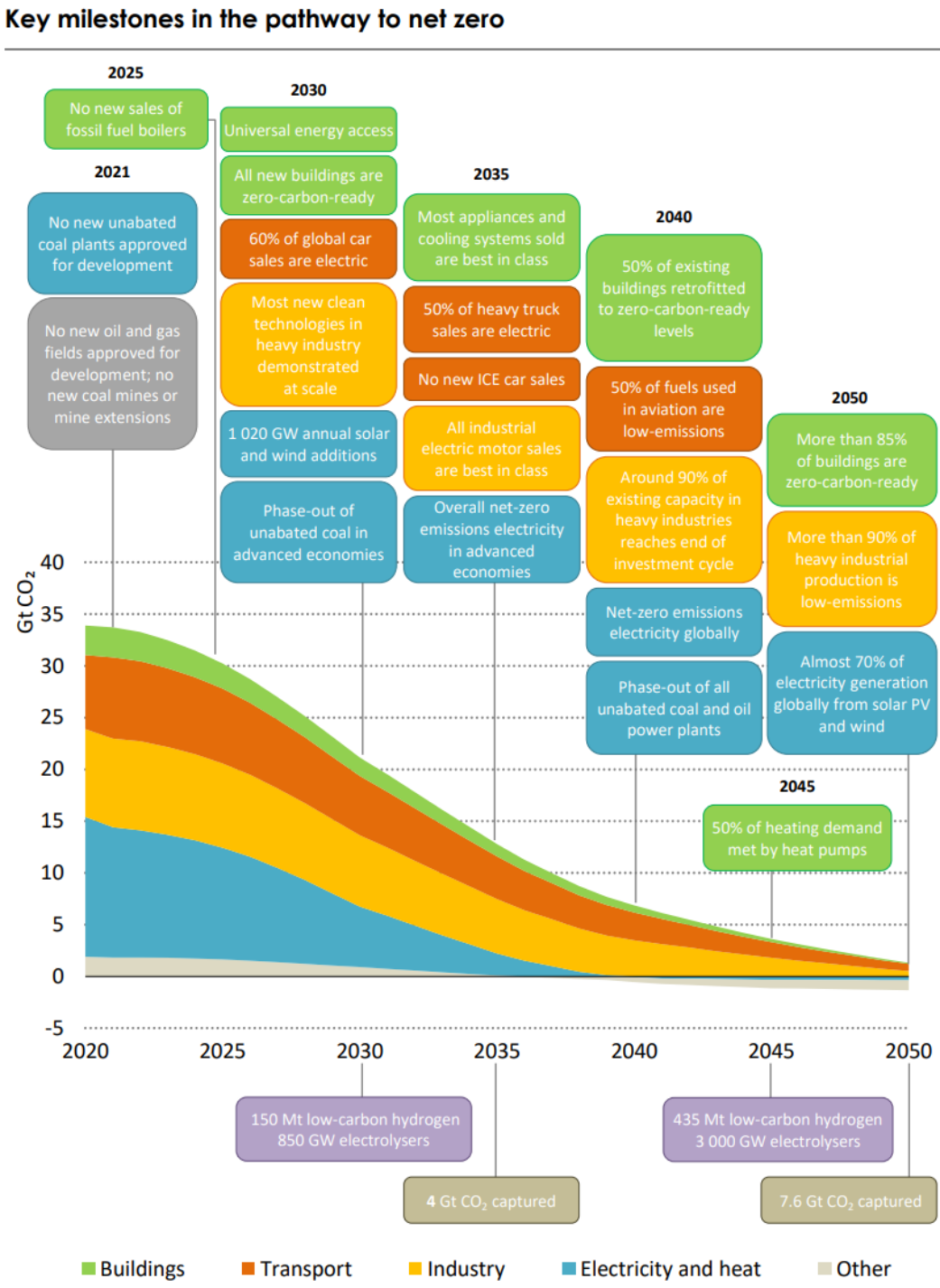
Renewables and nuclear power displace most fossil fuel use in the NZE, and the share of fossil fuels falls from 80% in 2020 to just over 20% in 2050



Net Zero by 2050 - A Roadmap for the Global Energy Sector

NetZero 2050 milestones

- 2030
  - 1TW/yr annual solar and wind additions
  - Automakers plan to build 54 million battery electric vehicles
  - >50% of total vehicle production
  - Investment of $1.2 trillion
- 2035
  - World's first zero-emission commercial aircraft
  - Net zero electricity generation in EU
- 2040
  - 39,000 new passenger & freighter aircraft
  - Coal & oil power phased out
- 2050
  - 2x automobiles, 86% electric
  - 70% power solar, PV, and wind



Exclusive: Automakers to double spending on EVs, batteries to $1.2 trillion by 2030 | Reuters

Net Zero by 2050 - A Roadmap for the Global Energy Sector

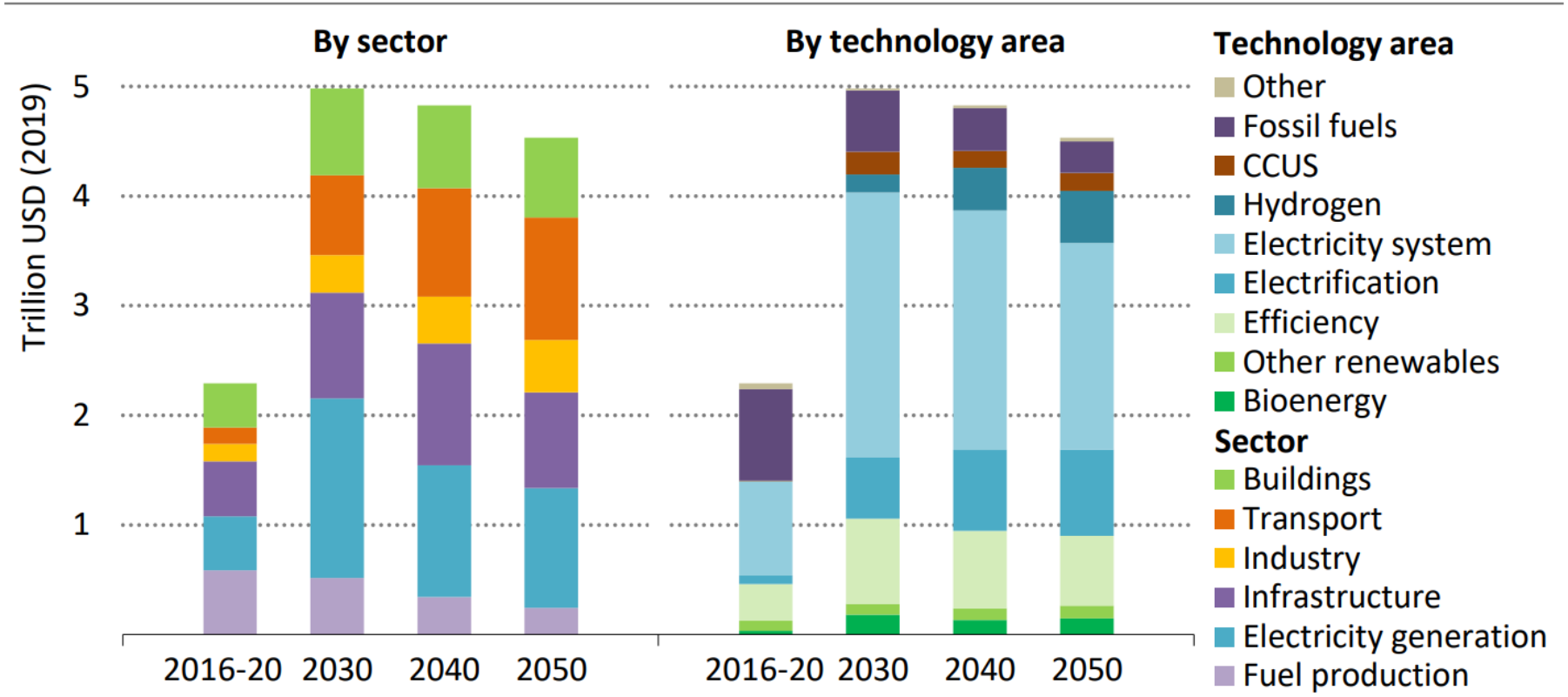
Capital investment in the NetZero economy

Growth creating (and changing) employment

- Transport
- Electrification
- Hydrogen
- Infrastructure

7.5% GDP more likely

Figure 2.22 ▷ Annual average capital investment in the NZE



Capital investment in energy rises from 2.5% of GDP in recent years to 4.5% by 2030; the majority is spent on electricity generation, networks and electric end-user equipment

Net Zero by 2050 - A Roadmap for the Global Energy Sector

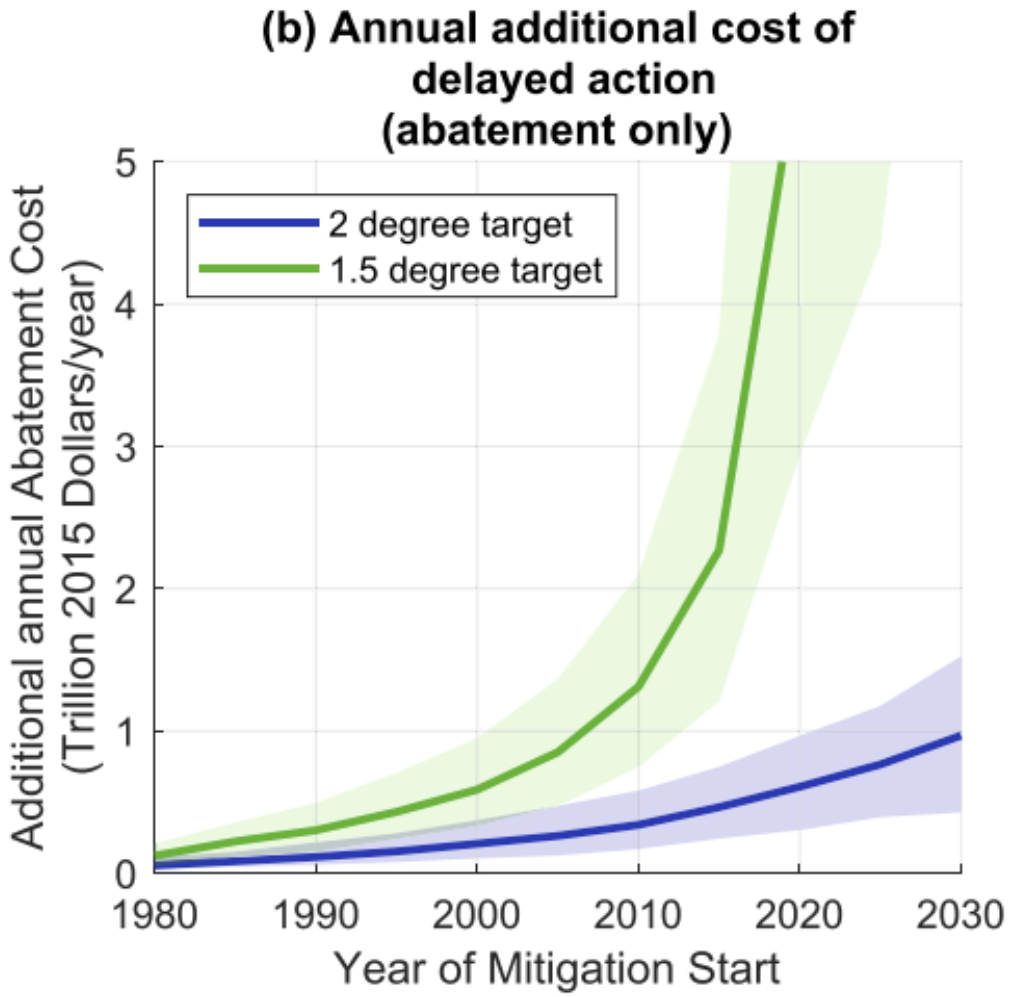
Cost now versus delayed action

- **Mitigation delay costs (excluding adaptation) additional 0.5(5) trillion $/yr**
- Could lose ~ 10% of total economic value by mid-century if climate change stays on current trajectory

  (Paris Agreement and 2050 net-zero emissions targets are not met)

The economics of climate change | Swiss Re

2023-incidences-economiques-rapport-pisani-5juin.pdf (strategie.gouv.fr)



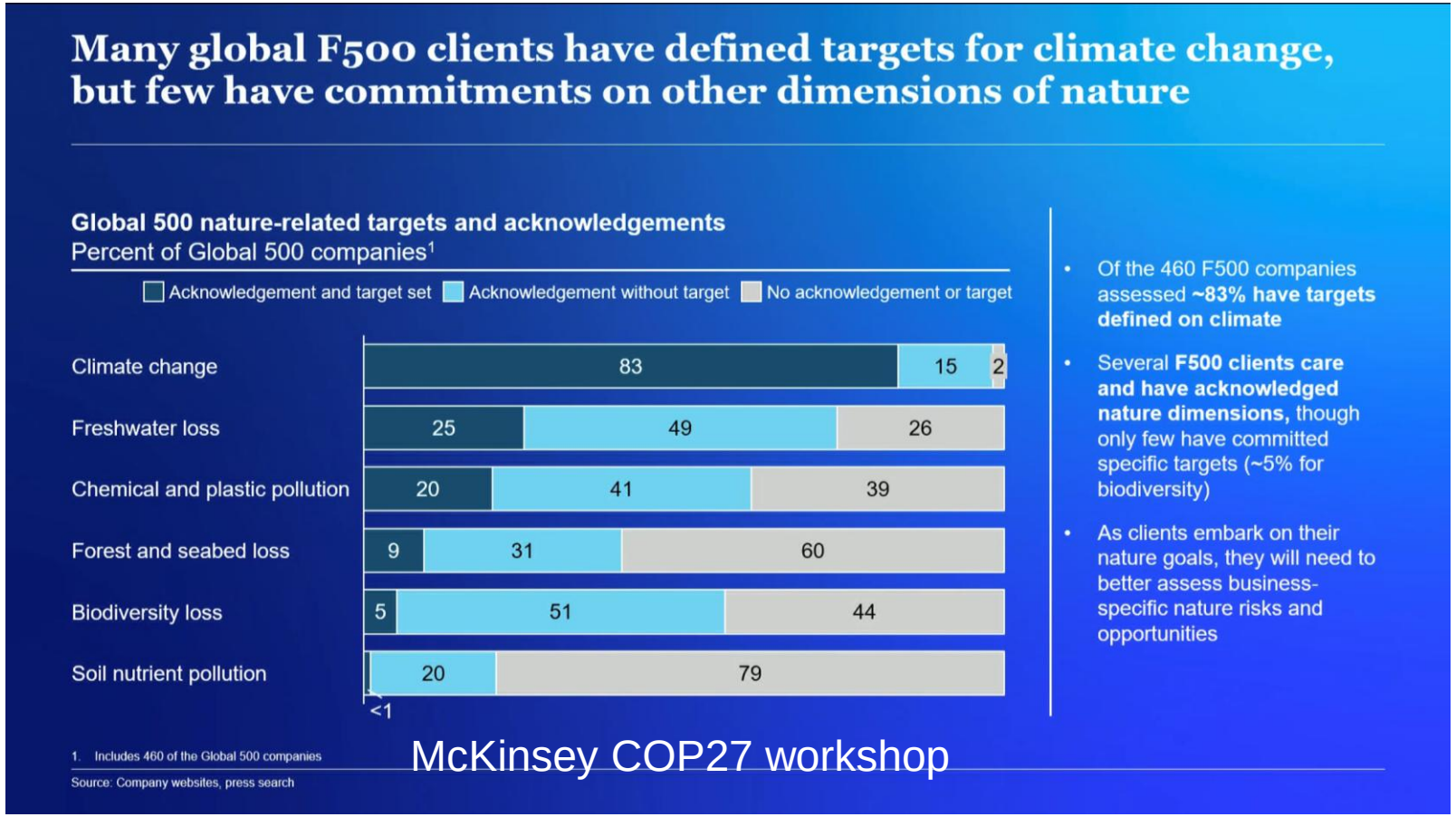
Excludes adaptation

Assessing the costs of historical inaction on climate change | Scientific Reports (nature.com)

We need wider IMPACT metrics

Wider metrics beyond climate change: environment and society

Redirect capital to locations which will see the strongest effects of climate change yet have contributed less towards cumulative emissions



McKinsey COP27 workshop

Overview

- Sustainability
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- Initiatives

Economics definition: "Efficient allocation of scarce resources"

- The current economic model has failed* in that resources are not efficiently allocated

Over-production

Overproduction - Lean Strategies International

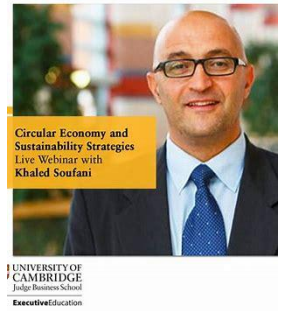
Over-consumption

Overconsumption – HiSoUR – Hi So You Are

Over-trading

How to Avoid Overtrading | by TradersAsset

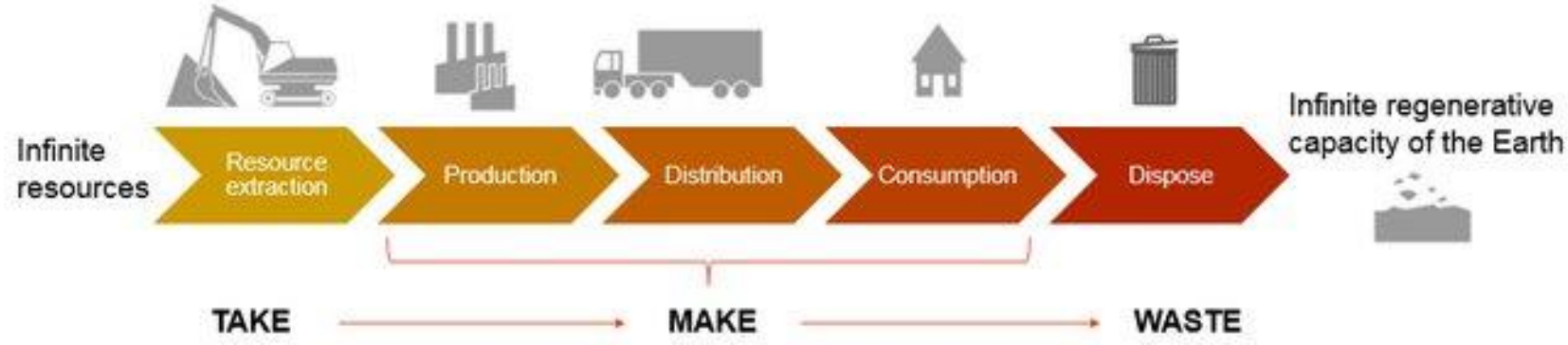
- **We need a new economic model**



* Failure means that are current system is not the optimum solution

An issue: our linear economy

- A uni-directional approach of extract, make, use, and dispose.



- Linear models can be seen in economic terms as a market failure (we have not yet found and applied models where we as society can reflect the hidden environmental costs in market prices)

have caused significant impacts on the environment such that serious changes are needed

(18) (PDF) Exploring the role of independent retailers in the circular economy: a case study approach (researchgate.net)

Shocking statistics (in the EU)

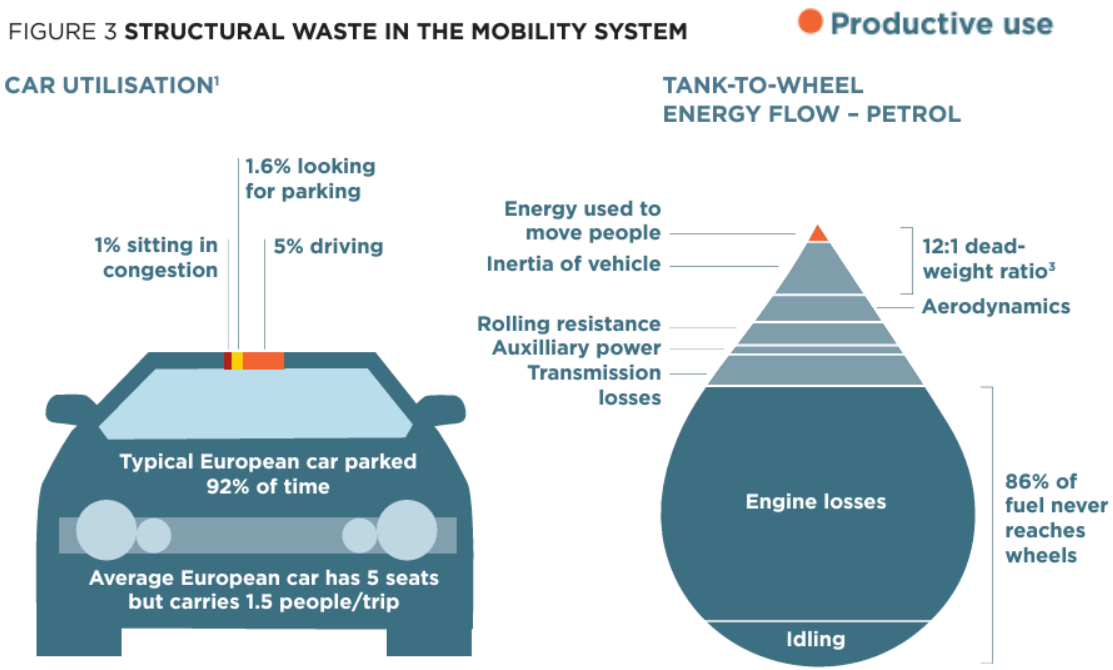
- Agriculture uses 70% global water consumption.
- 46% fruit & vegetable still useful edible mass is lost,
- 60-75% of packaging is lost after 1st use cycle,
- 8 million T of plastic floods into ocean/yr.

How Online Marketplace is Reducing Food Waste (morgonprojecting)

- 90% of time our cars are idle,
- 60% office space is not used in daytime
- Fast fashion = 10% of global CO_2 emissions.

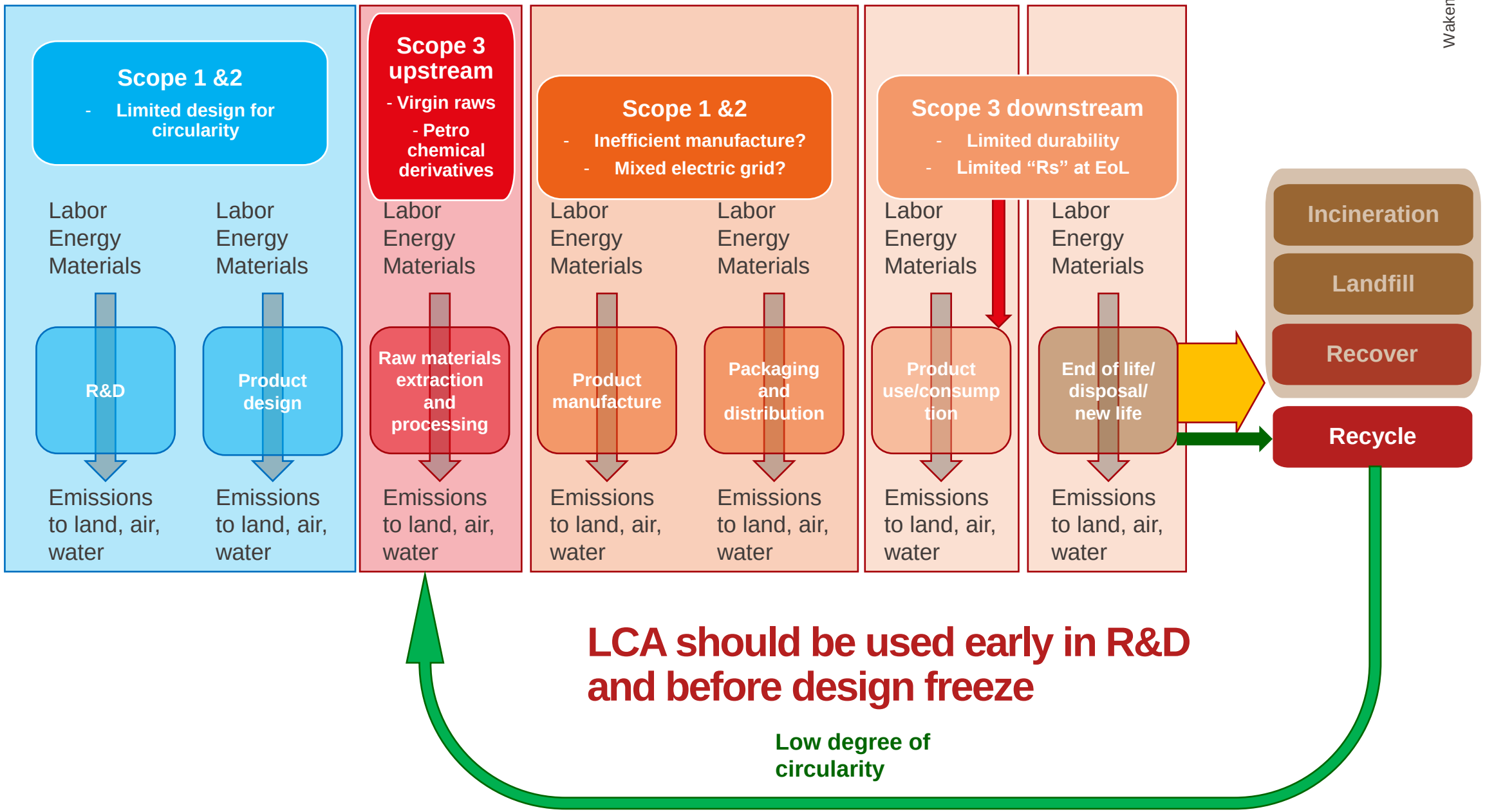
72% of all economic activity is related to the end user

What we buy will drive what people produce



We are inefficient as a society and need to improve this. Many inefficiencies are money lying on the floor, which if we pick up will hugely benefit the environment.

Product life cycle and LCA



slido

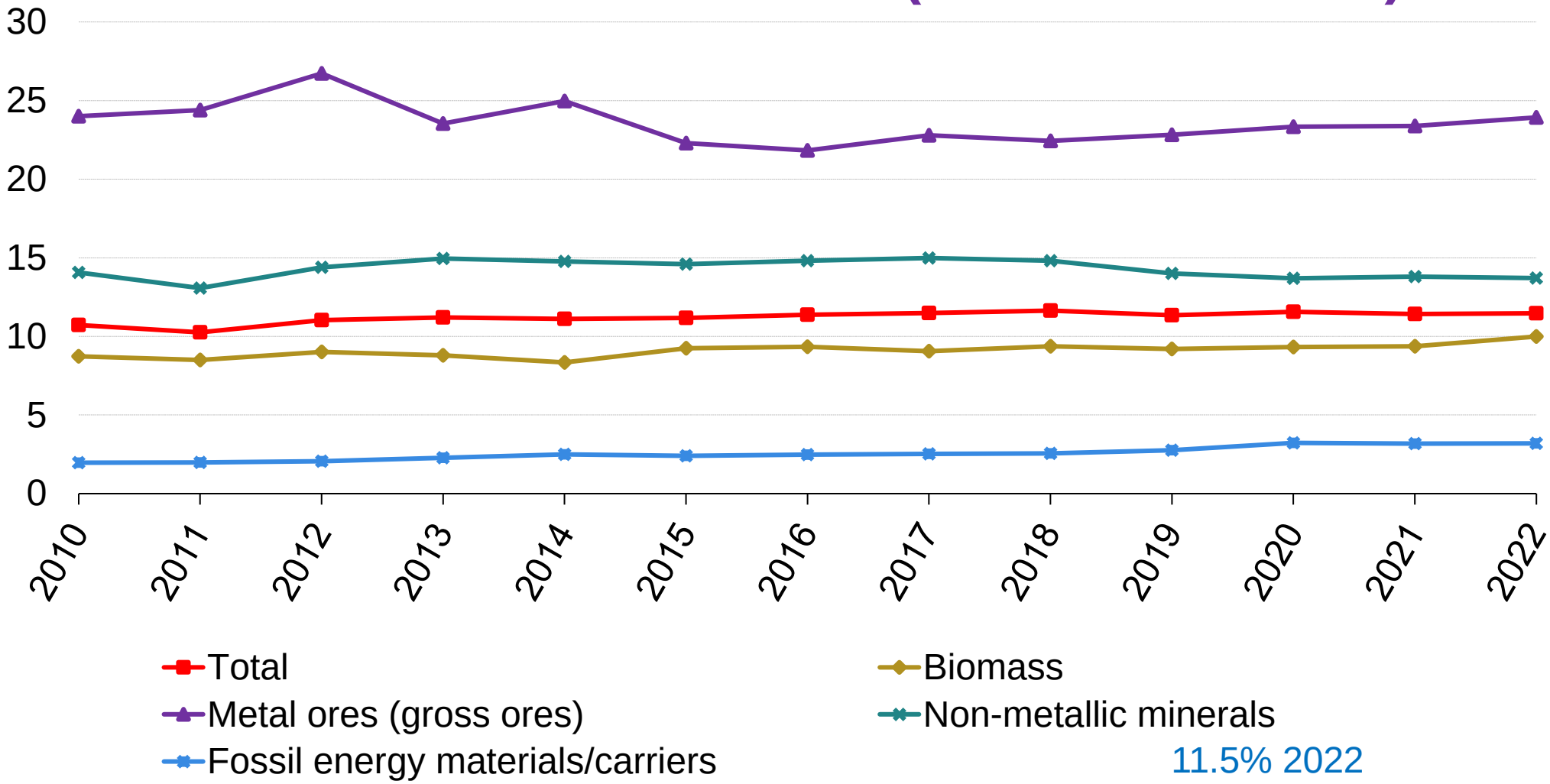
Please download and install the Slido app on all computers you use

How circular are we, mass basis, globally, (%)?

ⓘ Start presenting to display the poll results on this slide.

Circularity rate by main type of material, EU, 2010-2022 (%)

Global rate is 7.2% in 2023 (was 9.1% in 2018)



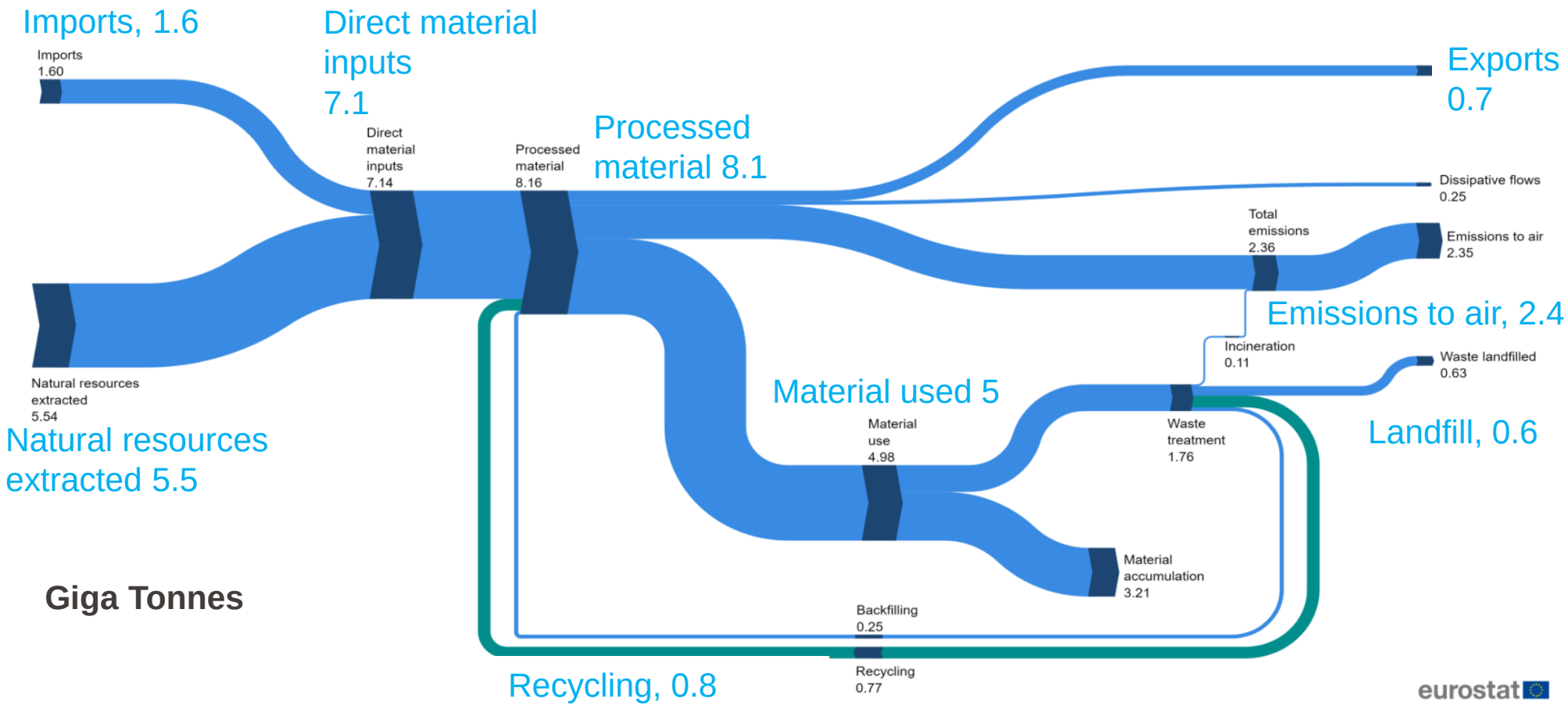
Source: Eurostat (online data code: env_ac_curm)

11.5% 2022
Circularity rate, EU (Eurostat), 2004-2022 (%)

CGR 2024 (circularity-gap.world)

Material flows in EU, 2022

- raw materials processed in the EU (8.16 Gt)
  - 68 % (5.54 Gt) domestic extraction,
  - 20 % from imports (1.60 Gt)
  - 12 % from recycling and backfilling (1.02 Gt),
  - 61 % used to make products (4.98 Gt).
  - The rest were mainly exported or used for producing energy.

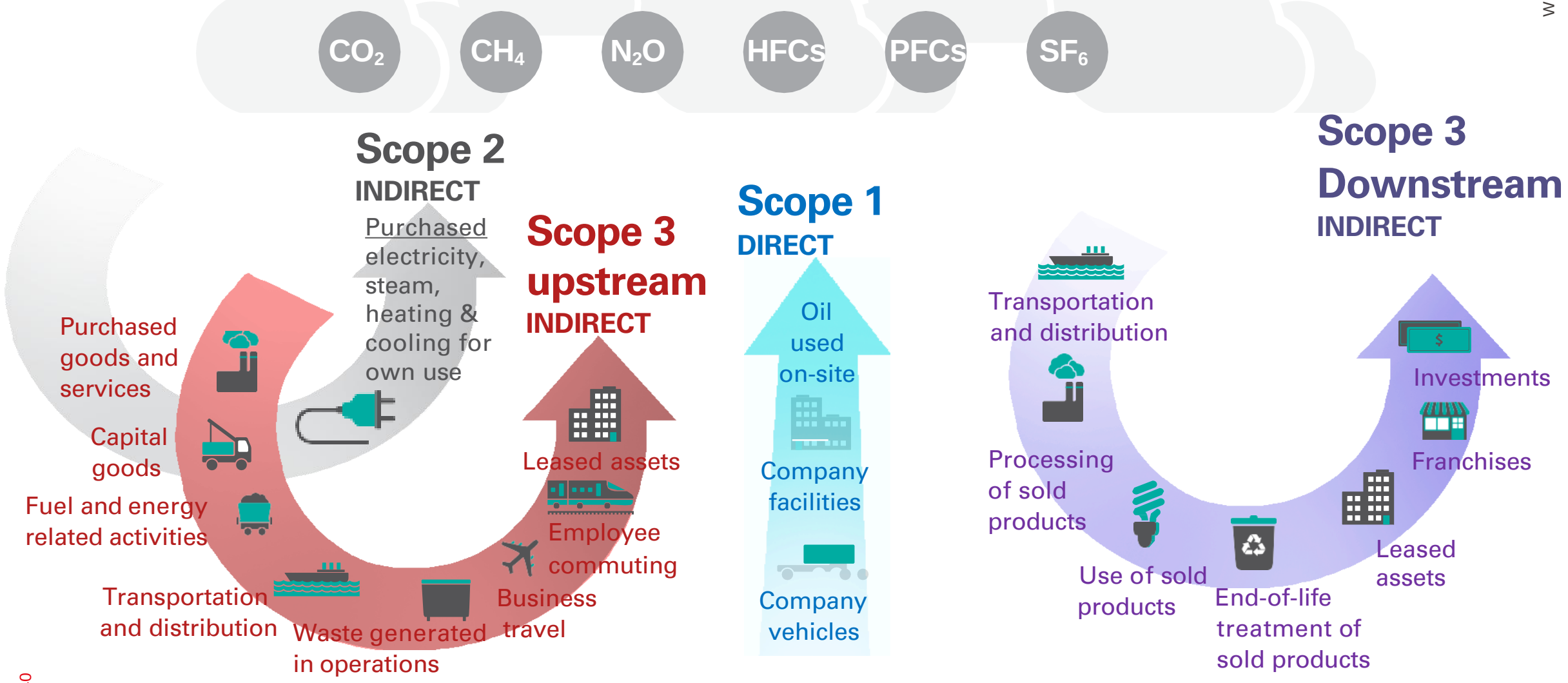


Circular economy - material flows - Statistics Explained (europa.eu)

Circular economy flow diagrams (europa.eu)

Scope 1, 2, 3 emissions

Wakeman



Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf

Decarbonization of global value chains

- Scope 3 upstream emissions can account for up to 70% of a company's total emissions
- Just 8 supply chains—food, construction, fashion, fast-moving consumer goods, electronics, automotive, professional services, and freight are responsible for >50% of global emissions (both energy and product-related impacts).

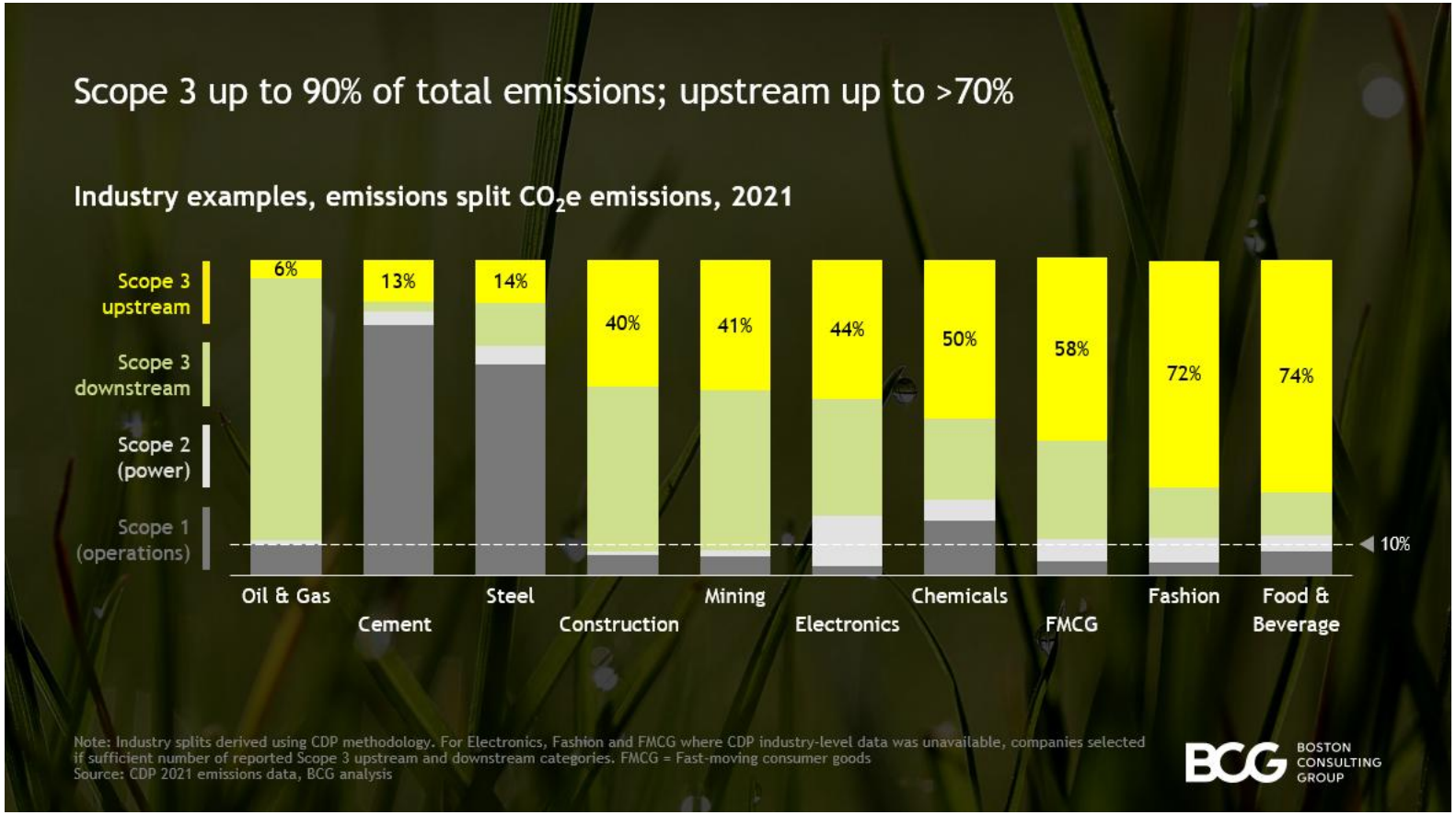
WORLD ECONOMIC FORUM

FORUM INSTITUTIONAL

Scope 3 emissions are key to decarbonization – but what are they and how do we tackle them?

Wakeman

The World Economic Forum emphasizes that addressing Scope 3 emissions is critical for achieving decarbonization.



How scope 3 emissions are key to decarbonization | World Economic Forum

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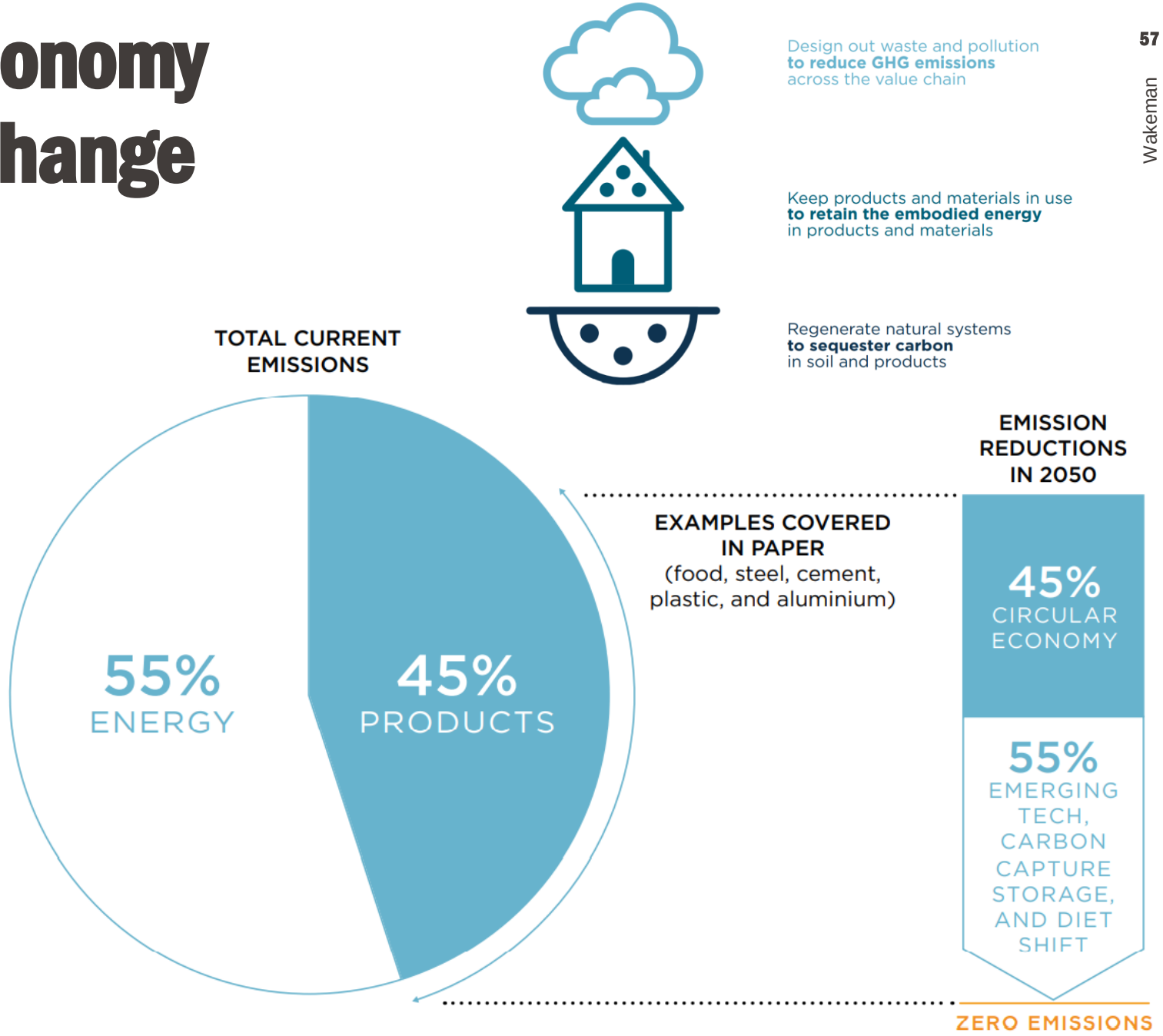
How a circular economy tackles climate change

- Emissions today
  - A) energy (55%)
  - B) Products (45%)

- Looking at products
  - Emissions reduction potential in 2050 enabled by circular economy



Wakeman

Completing The Picture - How The Circular Economy Tackles Climate Change | Shared by Comms (thirdlight.com)

Key elements of a circular economy

- Beyond a necessary energy transition

A FUNDAMENTAL CHANGE IN **THE WAY GOODS ARE MADE AND USED** IS REQUIRED TO MEET CLIMATE TARGETS

Design out waste and pollution

Keep products and materials in use

Regenerate natural systems

Completing The Picture - How The Circular Economy Tackles Climate Change | Shared by Comms (thirdlight.com)

What does a circular economy bring?

- Combat climate change
- Crisis response
- Significant improvements in human health
- Increase supply chain resilience
- Improve long term financial performance

7 principles of the circular economy

1. **Design for longevity**; component replacement and update through modularity
2. **Reuse** through refurbishment, repair or remanufacturing
3. **Resource-efficient manufacturing** to minimize waste generation
4. **Recycling-friendly materials** and **design for ease of disassembly**
5. **Collaboration across the value chain** to optimize resource utilization and waste
6. **Local sourcing and production** to reduce transportation emissions
7. **Innovative business models** such as product-as-a-service, leasing, subscription, and take-back programs to incentivize circularity, to encourage sharing and access over ownership

From MGT-555 2024 course description

Circular economy business models

Close	Slow	Intensify	Dematerialize
• Material and energy recycled within the system • Via reuse, refurbishment and recycling	• Extends the use phase • Increased durability	• Asset is used more via sharing	• Virtual approaches to a physical asset

✓efficiency and productivity,
✓economic and financial viability,
✓design for dis-assembly
✓recovery, recycling,
✓sharing platforms,

✓extending the life of assets,
✓service vs. product
✓if the machine is turned off, the asset is not working for you

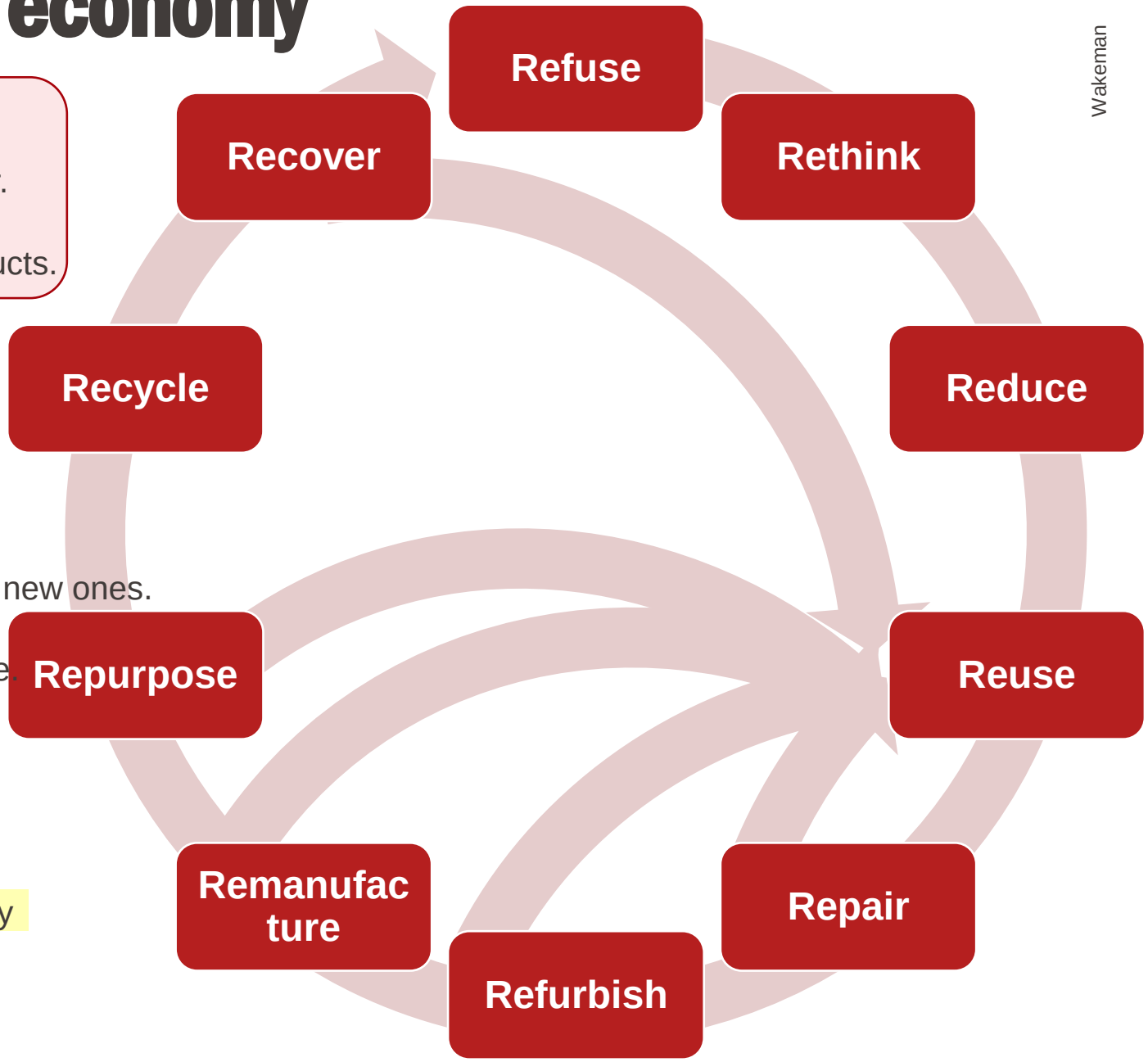
Wakeman

10 R's of the circular economy

1. **Refuse:** Say no to unnecessary products and services.
2. **Rethink:** Design products and systems to be more circular.
3. **Reduce:** Use fewer resources / materials to produce products.

Sufficiency

4. **Reuse:** Use products and materials multiple times.
5. **Repair:** Fix broken products versus throwing them away.
6. **Refurbish:** Restore old products to their original condition.
7. **Remanufacture:** Disassemble / rebuild products to create new ones.
8. **Repurpose:** Use old products /materials for a new purpose.
9. **Recycle:** Convert waste materials into new products.
10. **Recover:** Extract energy or materials from waste.
11. **Relocate:** Removal of waste to a different region or country



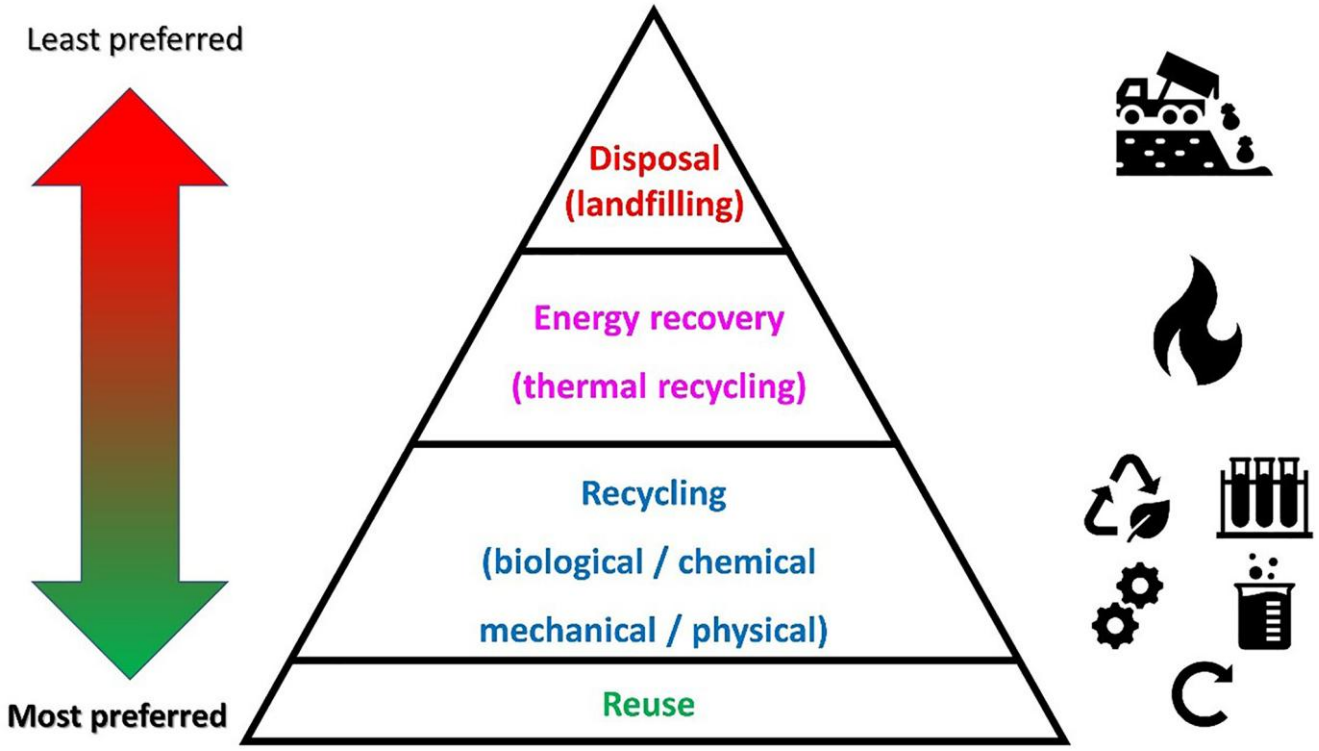
Which one of these is incorrect?

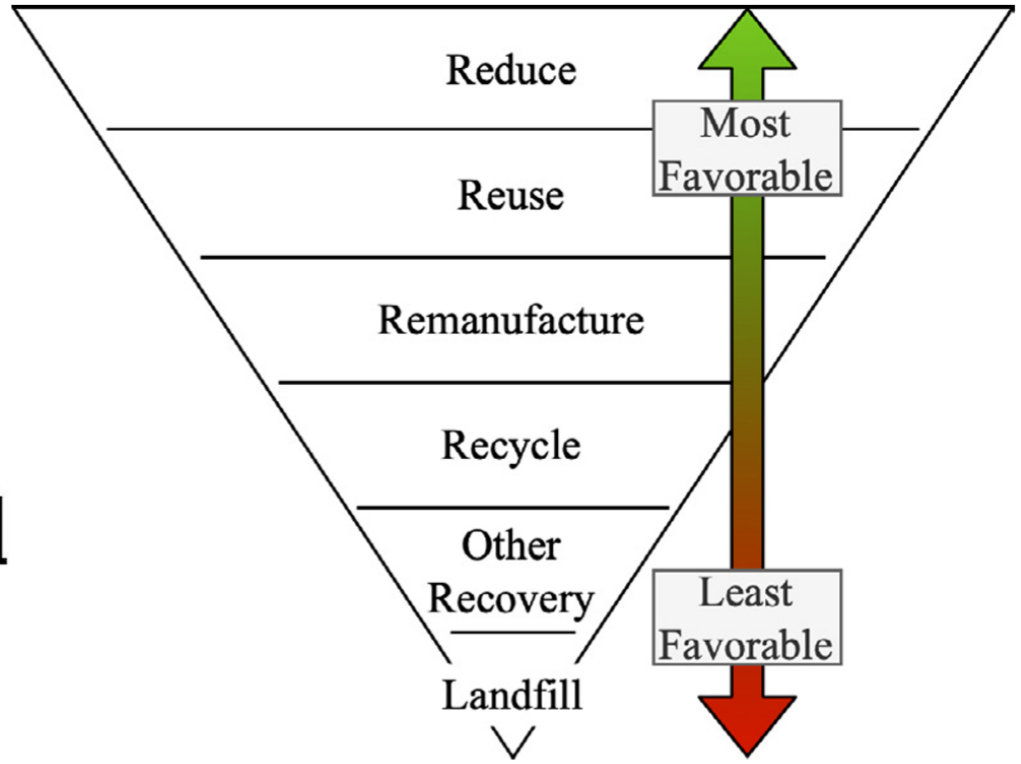
Platform for Accelerating the Circular Economy (pacecircular.org)

DEVENDEUR, POLO Refuse

Economy	Strategy	R-factor	Example	Innovations needed: Tech.	Design	Revenue	Societal
Circular	Smarter product use and manufacture (narrow)	Refuse	Make product redundant by abandoning its function or by offering the same function with radically more efficient product				
		Rethink	Make product use more intensive (sharing, multi-functional)				
		Reduce	Increase product manufacturing efficiency / consume fewer natural resources and materials				
	Extend life time of product and parts (slow)	Reuse	Another customer reuses products still in good condition fulling original function				
		Repair	Bring a defective product back to state where it fulfills original function				
		Refurbish	Restore an old product to bring it up to date				
		Remanufacture	Use of discarded products/parts in a new product with same function				
		Repurpose	Use of discarded products/parts in a new product with different function				
Linear	Useful re-application of materials (close)	Recycle	Process materials to obtain same (high grade) or lower grade quality				
		Recover	Incineration of materials with energy recovery				

Beyond recycling to bigger ‘R’ levers





Journal of Polymer Science, Volume: 61, Issue: 17, Pages: 1937-1958, First published: 19 May 2023, DOI: (10.1002/pol.20230154)

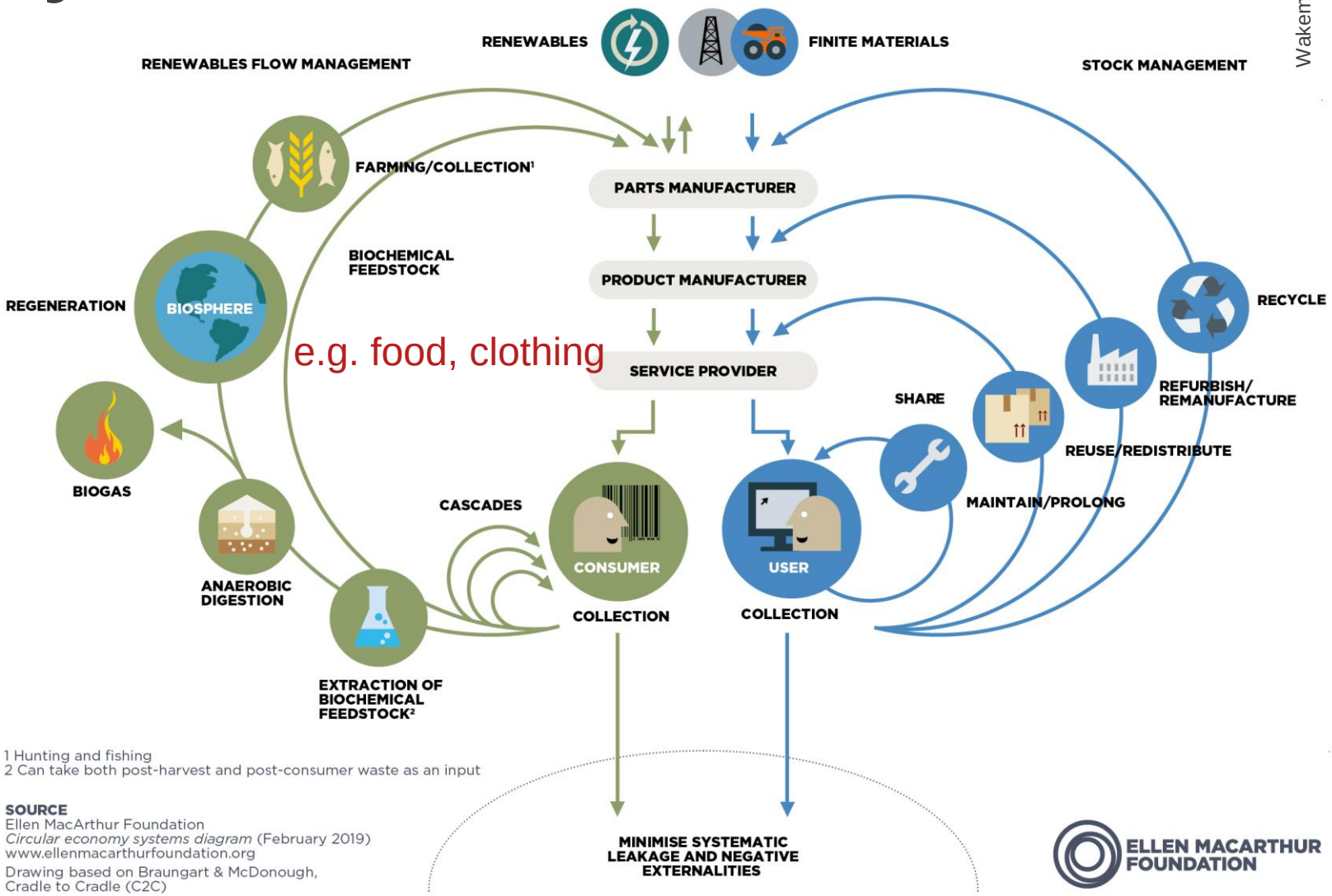
Fig. 3. The waste hierarchy (adapted from the EU Waste Framework Directive 2008/98/EC.

Circular economy

Biological cycle

Technical cycle

- Seeks to rebuild capital
  - Financial
  - Manufactured
  - Human
  - Social
  - Natural
- Ensures enhanced flows of goods and services.



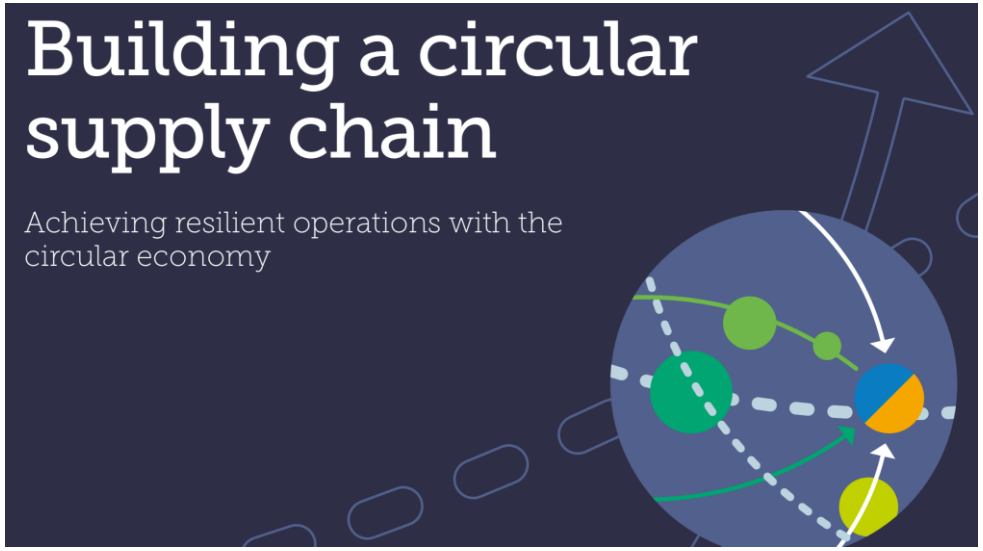
Circular Design Guide - Butterfly Diagram - YouTube

How to build a circular economy | Ellen MacArthur Foundation

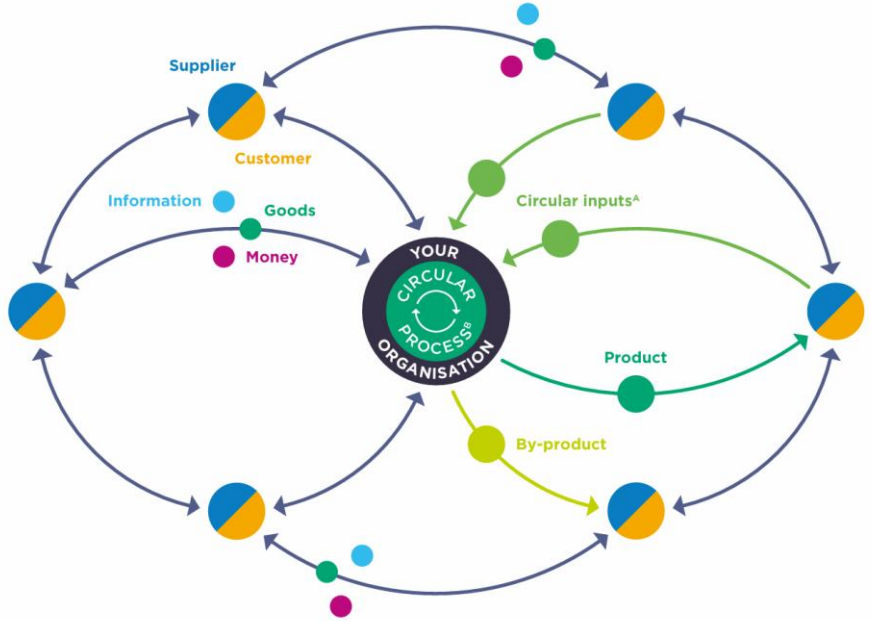
Circular economy diagram (ellenmacarthurfoundation.org)

What are circular supply chains?

- Distributed and interconnected networks to leverage local and global partnerships with suppliers, customers, and industry peers
- Multidirectional flows of information, goods, and money to enable data — such as the location, material composition, and disassembly options of an item — to flow between network partners
- The ability to capture and deliver value by keeping products and materials in use



Designing supply chains for the circular economy | Ellen MacArthur Foundation



CE for supply chain resilience

- Circular economy and supply chain resilience are interconnected
- Circular supply chains decouple operations from natural resource extraction, increasing material security and reducing exposure to price volatility
- Circular economy can ensure resilience in supply chains, especially in uncertain environments

Journal of Cleaner Production
Volume 434, 1 January 2024, 140140
ELSEVIER

Review

Circular economy as crisis response: A primer

Kris Hartley [a], Brian Baldassarre [b c], Julian Kirchherr [d e f]

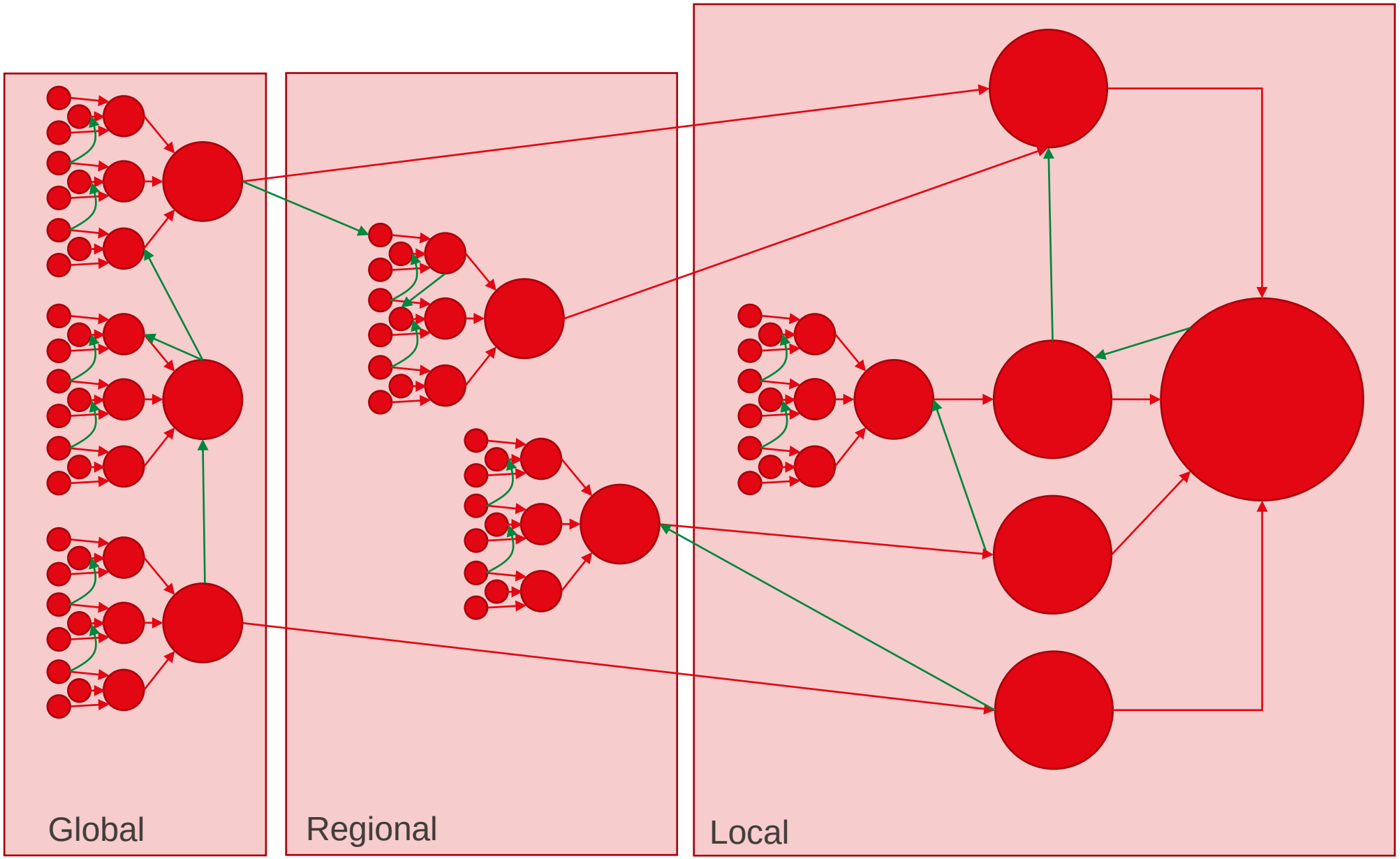
Circular economy as crisis response: A primer - ScienceDirect

Dealing with VUCA

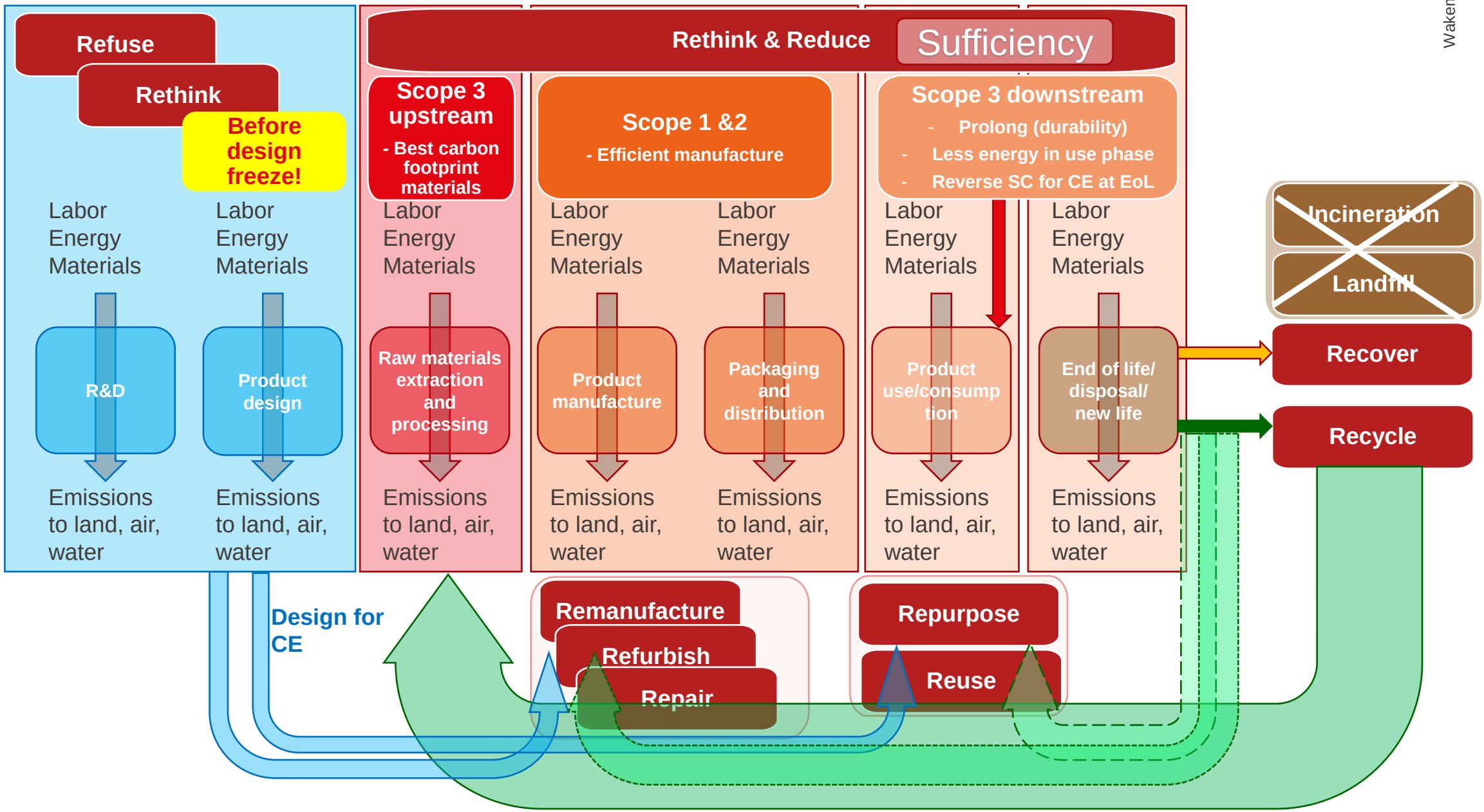
Designing supply chains for the circular economy (ellenmacarthurfoundation.org)

Linear supply chain

Re-wiring supply chains – circular lattice



Phases in the life cycle of a circular product



MFA of the incumbent vs. new product

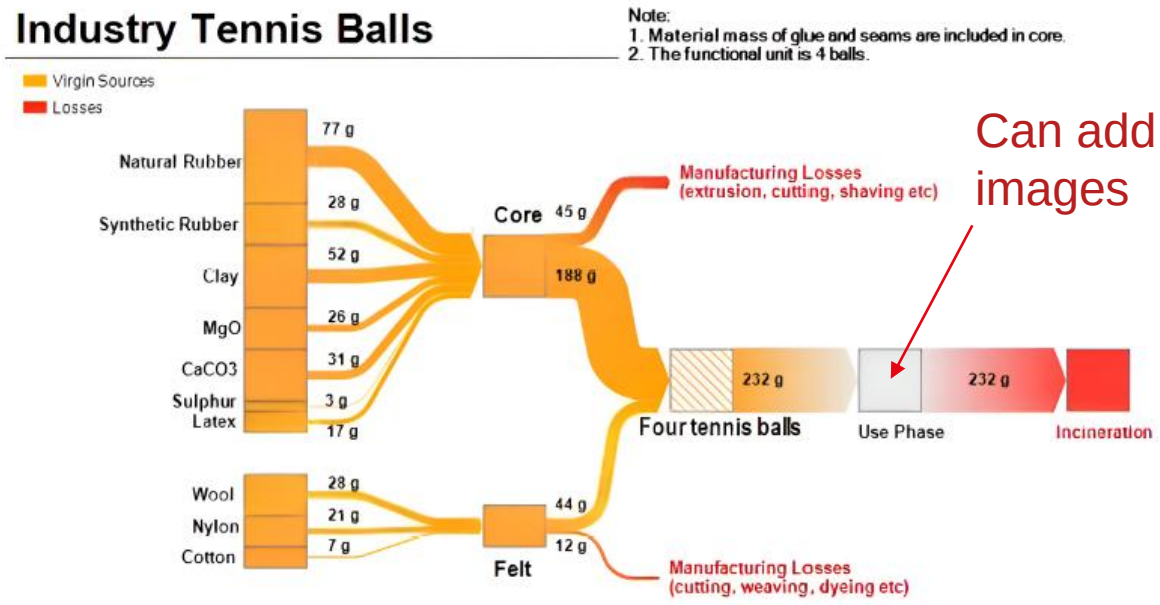


Figure C3: Material Flow Analysis of industry tennis balls

Can add images

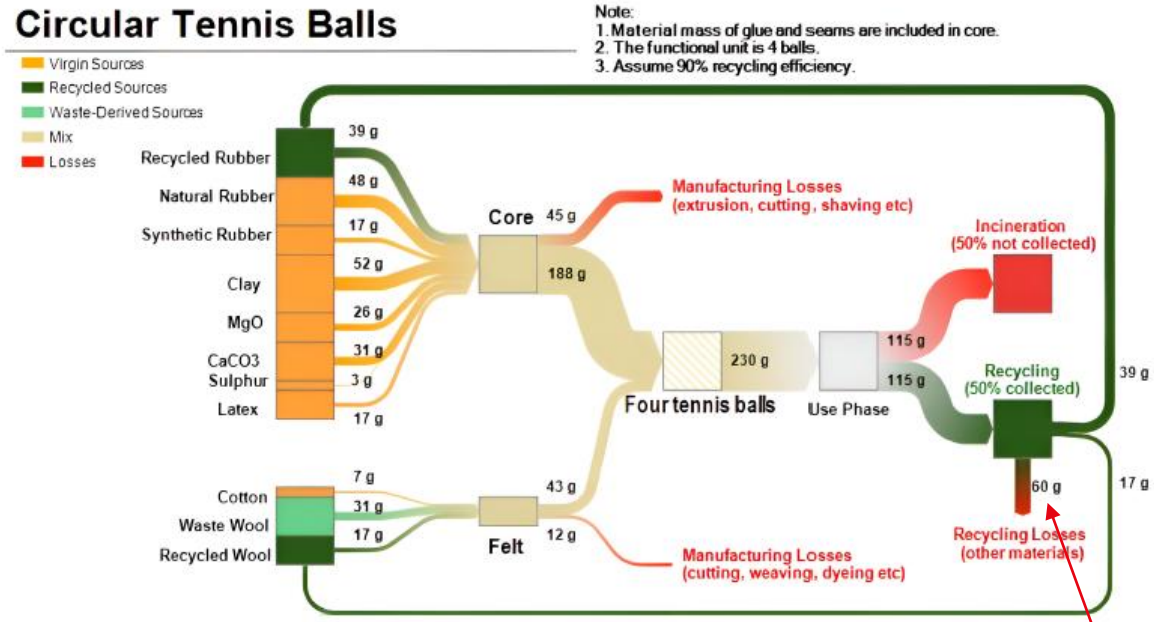


Figure C4: Material Flow Analysis of circular tennis balls

You can also automatically show how it changes versus time (incumbent, 2030, 2040, 2050)

Can add CO2e as a label

Download to full version https://moodle.epfl.ch/mod/resource/view.php?id=1347256

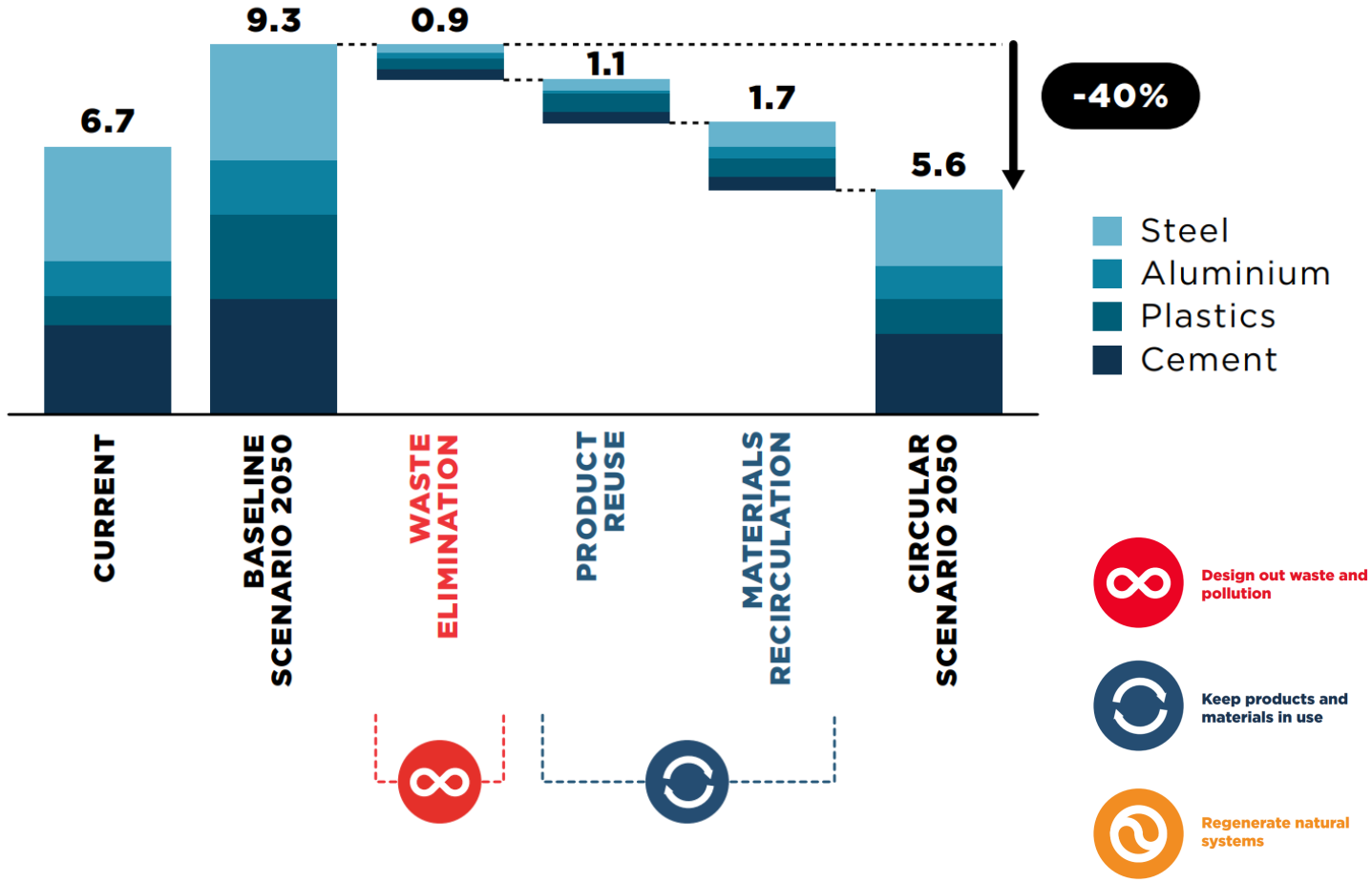
Overview

- Sustainability
- NetZero transition
- Linear vs. circular economy
- Circular economy frameworks
- Engineered product and materials examples
- Enablers to a CE
- Initiatives

Hard to abate materials

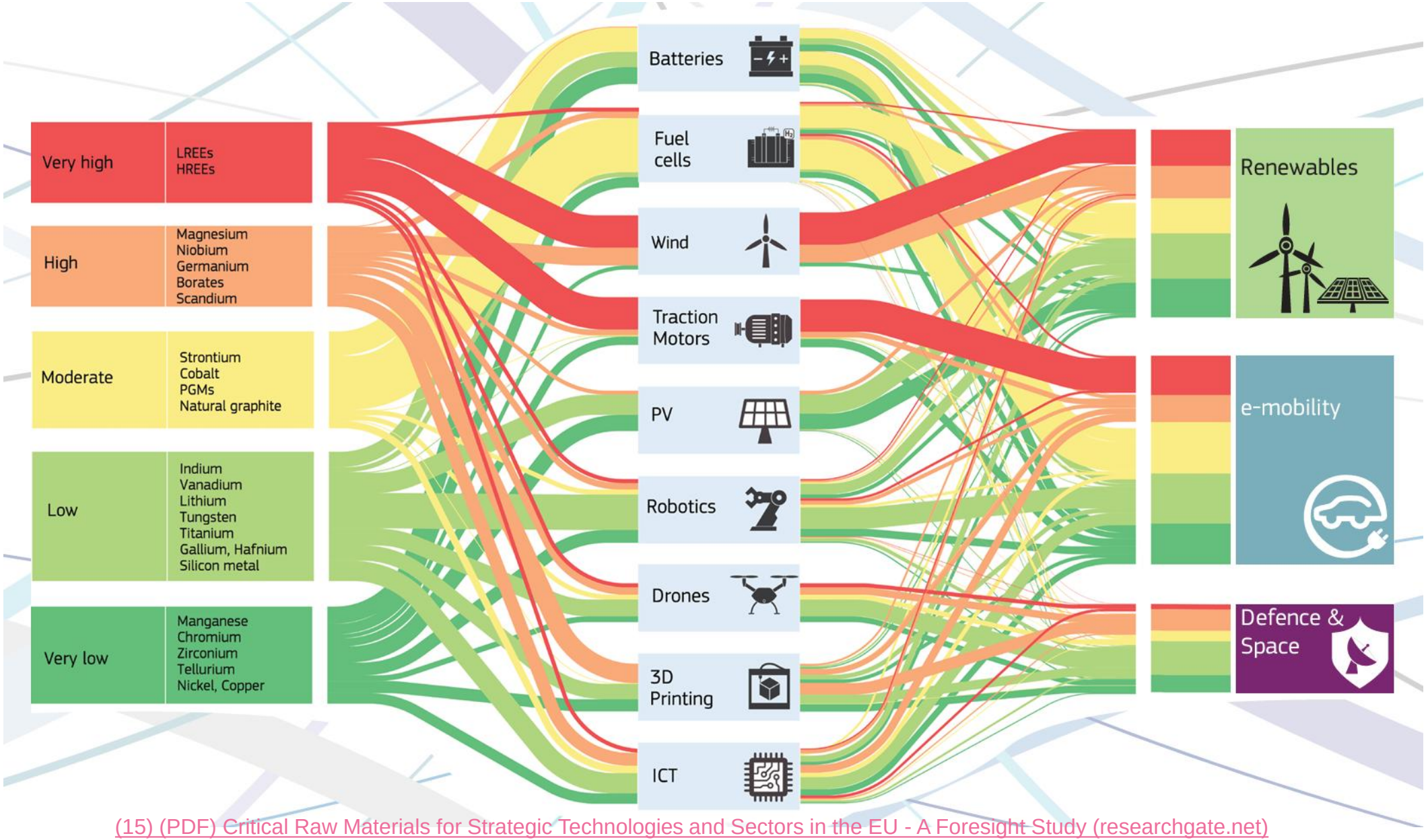
- Industry responsible for ~21% of global CO_2 emissions
- 60% of this is production of cement, steel, plastics & aluminum
- Use of these materials in passenger cars and buildings is 73% of the emissions from producing these four materials

FIGURE 4: A CIRCULAR ECONOMY COULD REDUCE ANNUAL GLOBAL CO_2 EMISSIONS FROM KEY INDUSTRY MATERIALS BY 40% OR 3.7 BILLION TONNES IN 2050



Completing The Picture - How The Circular Economy Tackles Climate Change | Shared by Comms (thirdlight.com)

Critical materials



(15) (PDF) Critical Raw Materials for Strategic Technologies and Sectors in the EU - A Foresight Study (researchgate.net)

Re-manufacturing example: Renault REfactory

Remanufacturing operation

- Reverse logistics ecosystem of partner companies
- Collects the old parts, dismantles and checks conformity,
- Reassembles, sells on as genuine and guaranteed parts
- Parts 40% less expensive vs. new, undergo same quality tests

volume of remanufactured engine parts is significant

- Gearboxes
- Engines
- Turbos
- Injectors)

Since 2012

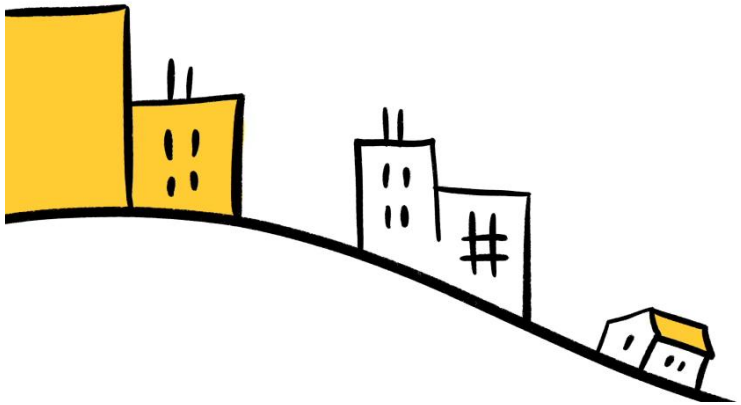
- Gearboxes > 112, 000, 60% of components renovated.
- Engines > 73, 000, 60 to 70% of components renovated.
- Turbos > 50, 000, 40% of components renovated.
- Injectors > 94, 000 (since 2010)

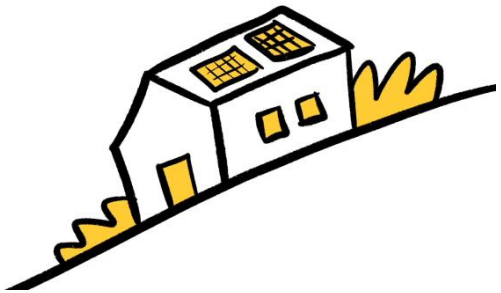
Groupe Renault creates the first european factory dedicated to the circular economy of mobility in Flins - Newsroom Renault Group

Examples

- The circular economy in action (ellenmacarthurfoundation.org)

GROUPE RENAULT





2min40s

Groupe Renault creates the first european factory dedicated to the circular economy of mobility in Flins - Newsroom Renault Group

Overview

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- Materials and engineered product examples
- Enablers to a CE
- Initiatives

Circular Supply Chains Are More Sustainable. Why Are They So Rare?

by Khaled Soufani and Christoph Loch

Harvard Business Review

June 15, 2021

[Circular Supply Chains Are More Sustainable. Why Are They So Rare? (hbr.org)]

slido

What is inhibiting wider adoption of a circular economy?

ⓘ Start presenting to display the poll results on this slide.

Barriers to Circular supply chains?

- Successful examples tend to be local with products and services made of relatively limited number of components
- Human supply chains:
  - 1) performance via parts specialization AND
  - 2) economic efficiency via economies of scale

Consumers: give up performance for environmental sustainability

Business: give up some of the economies of scale and make less sophisticated products

More standardization designed in (for local recycling vs. aggregation)

Society needs to embrace this change

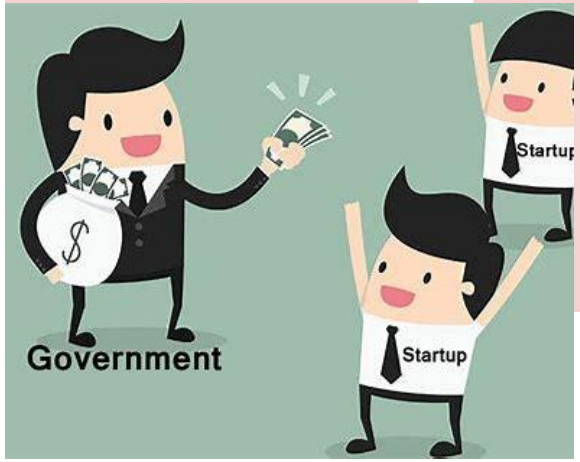
Value Retention Processes: Barriers to circularity

Regulatory and access barriers	Technological barriers	Financial barriers	Market barriers	Collection barriers
• Some used goods classified as “waste” • Macro level taxes and regulations • Special classification and/or import treatment of VRP products • Lack of industry standardization and defined standards	• Limited 3rd party access to OEM specifications • OEM design that inhibits VRP options for product	• CAPEX to VRP facility to existing manufacturing operations • Cost and overhead burden of collection infrastructure and logistics • New labor skills	• New low quality imported products vs. domestic VRP products • Marketing strategies inconsistent & customer confusion? • Lack of customer awareness or market pull (preference for new vs. sustainable products?) • Cannibalization of new products by VRPs (different gross margins?)	• Supply and quality of reuse inputs • Centralized vs. decentralized collection systems / reverse logistic costs • Regulated shared collection cost burden vs. firm-initiated (entire cost burden) • Convenience of diversion vs. disposal options

Re-defining Value – The Manufacturing Revolution | Resource Panel

Enablers: Role of Government Policy

Give vision	Guide	Incentives	Collaborations	Policy
• Not fix market failure	• Towards circular economy • Lubricate system with funding	• Financial support, creation of opportunities, control depreciation • Needs to be direct, traceable, and measurable	• Public and private partnerships • Public sector assumes risk • Private sector provides the technology focused on circularity.	• Achieve growth • Create jobs • Stabilize economies • Utilize a countries own resources (reducing imports)



This has started yet the funding levels do not represent the challenge ahead.

Sustainable finance

Investors	Companies	Investing	Growth	Objectives
• Moving to favor sustainable enterprises • Seen as more attractive long term investment opportunities	• Naturally remain profitable and attractive • Stakeholder driven, NetPositive	• Sustainability is an attractive and rapidly growing opportunity • Suffering recent headwinds	• Double digit growth to 2030 (≈ 12-20%) • Major mega trend • Trillion-dollar business opportunity for such products and services	• Companies establish • social and environmental objectives • Monitor and review them

There is already around T$1.6 invested in impact investments

GIINsight: Sizing the Impact Investing Market 2022 - The GIIN

J.P. Morgan Investment Outlook 2021 | J.P. Morgan Asset Management (jpmorgan.com)

gross world product ~ T US$115

EV ESG (Environmental Social Governance) ratings?

- EVs today do not give lower ESG ratings vs. conventional OEMs
- Need to move from linear to circular model
- Beyond the use phase

You	1	2	3
Volvo Car AB	**Tesla, Inc.**	**Geely Automobile Holdings Ltd.**	**Bayerische Motoren Werke AG**
ESG RISK RATING **19.0 Low** Negl **Low** Med High Severe	ESG RISK RATING **24.7 Medium** Negl Low **Med** High Severe	ESG RISK RATING **15.9 Low** Negl **Low** Med High Severe	ESG RISK RATING **22.9 Medium** Negl Low **Med** High Severe
EXPOSURE **Medium** Low **Med** High	EXPOSURE **Medium** Low **Med** High	EXPOSURE **Medium** Low **Med** High	EXPOSURE **Medium** Low **Med** High
MANAGEMENT **Strong** Weak Avg. **Strong**	MANAGEMENT **Average** Weak **Avg.** Strong	MANAGEMENT **Strong** Weak Avg. **Strong**	MANAGEMENT **Strong** Weak Avg. **Strong**
TOP MATERIAL ESG ISSUES Product Governance Corporate Governance Human Capital Business Ethics	TOP MATERIAL ESG ISSUES Product Governance Human Capital Corporate Governance Business Ethics	TOP MATERIAL ESG ISSUES Carbon - Products and Services Corporate Governance Human Capital Human Rights - Supply Chain	TOP MATERIAL ESG ISSUES Product Governance Business Ethics Carbon - Products and Services Human Capital
CONTROVERSY RATING 2 **Moderate**	CONTROVERSY RATING 3 **Significant**	CONTROVERSY RATING No Controversy	CONTROVERSY RATING 3 **Significant**

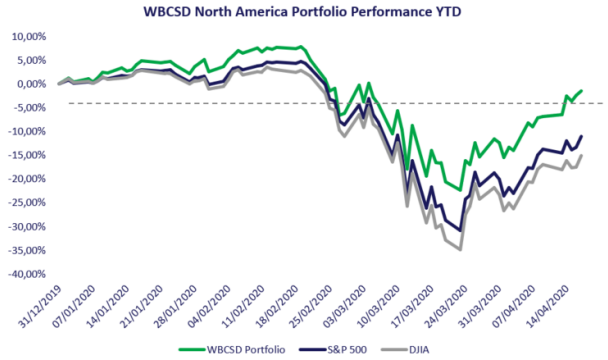
Companies with sustainability focus out-perform

ESG outperformance amid COVID-19 crisis

31 North American member stocks weathered downturn better than the market

Consistently outperforming: WBCSD portfolio* beat the market by about 10% year to date

Rapid recovery from the crisis lows: almost returned to business-as-usual price level

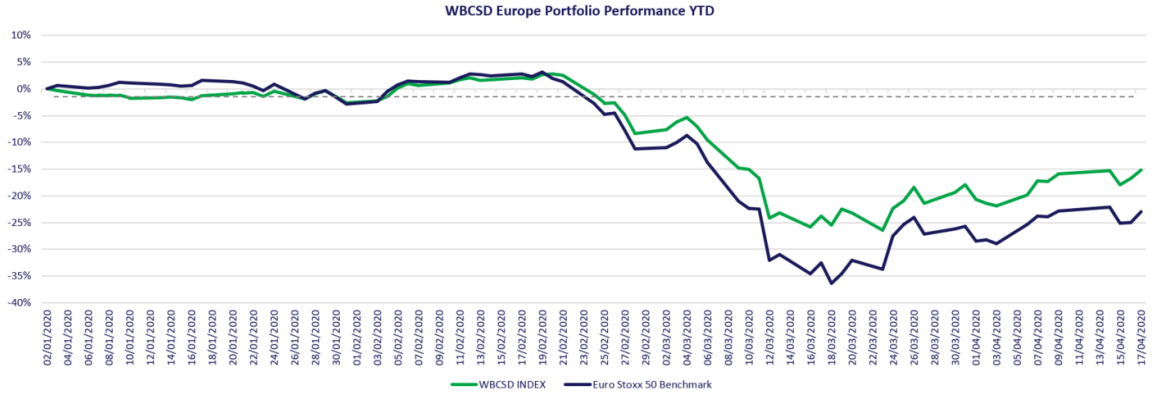


* 3M, Abbott, ABInbev, ADM, Apple, Bunge, Cemex, Chevron, Cooper Tire, Corteva, Dow, DuPont, Eaton, Exxon Mobil, Goodyear, Google (Alphabet), Greif, IFF, International Paper, Kellogg, Maple Leaf Foods, Microsoft, Nutrien, PepsiCo, Procter & Gamble, S&P, Tiffany, UPS, Verizon, Walmart, Whirlpool. (Market cap-weighted)

ESG outperformance amid COVID-19 crisis

67 stocks of European members are more resilient in the view of investors

Significant better performance in the bearish market: reflecting investor confidence in European members



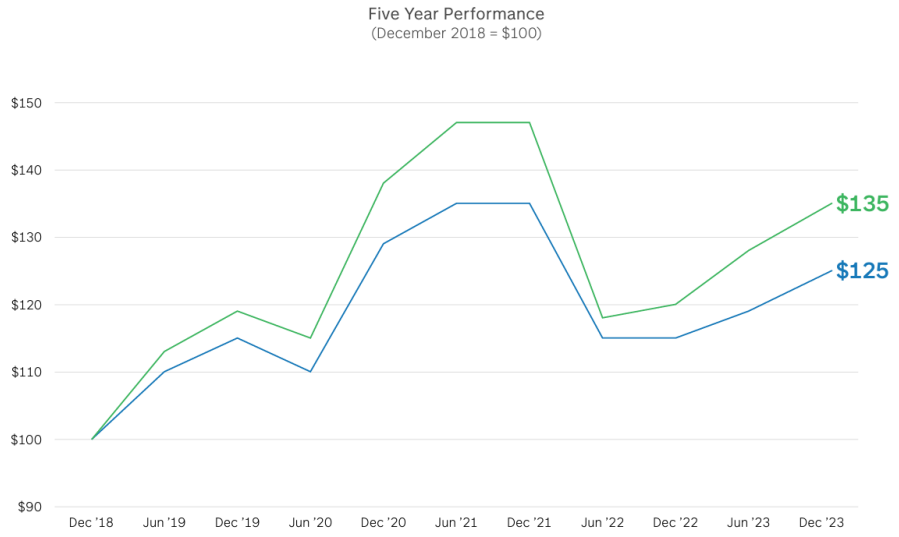
- Focus on sustainability helped relative performance during Covid-19 market turbulence.

2020: a different kind of “super year” - World Business Council for Sustainable Development (WBCSD)

- Sustainable funds outperformed over last 5 years (MorganStanely)

MSInstituteforSustainableInvesting-SustainableRealityFY2023-Final.pdf (morganstanley.com)

Five Year Performance of Sustainable and Traditional Funds



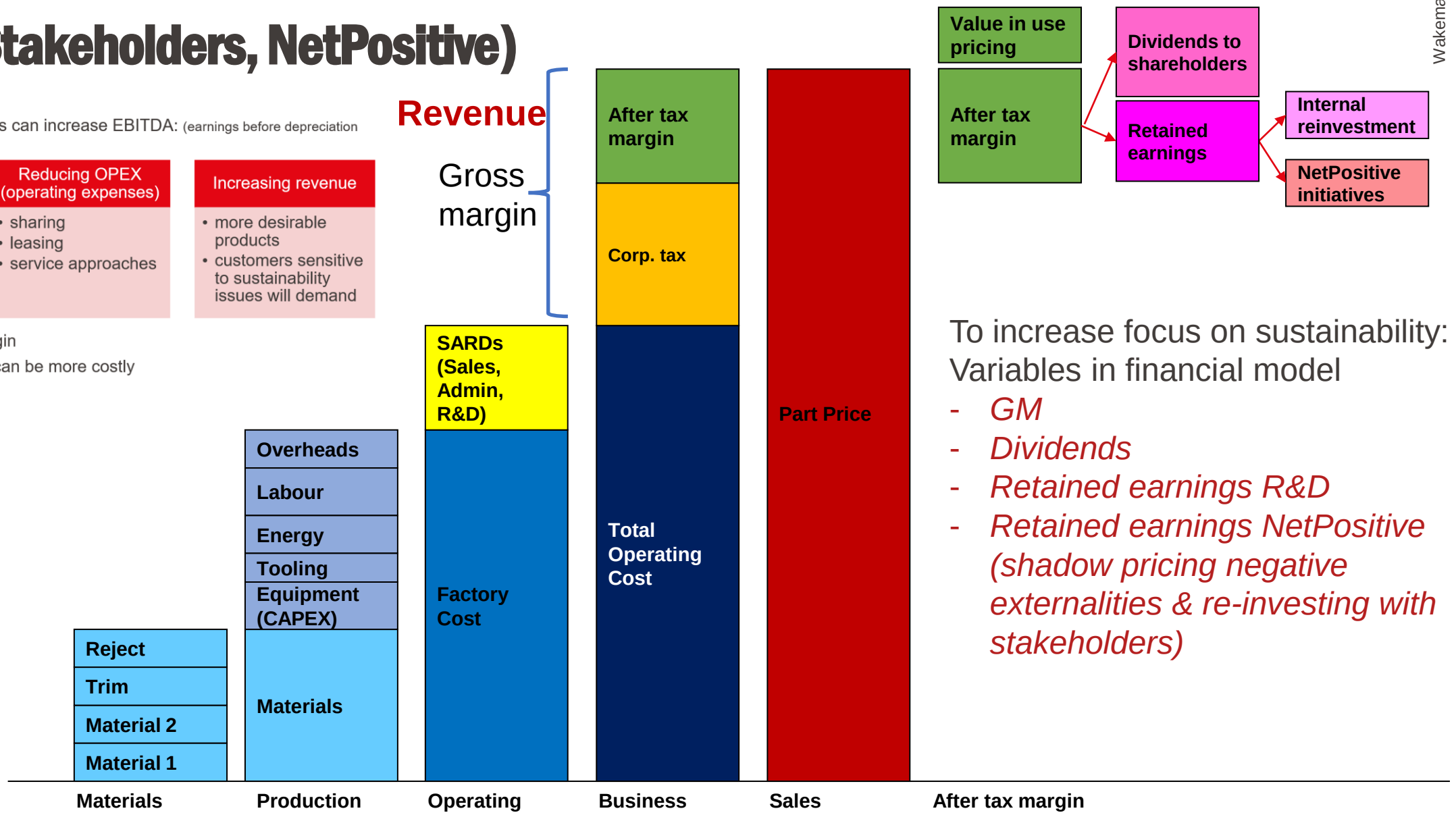
The chart shows how a $100 investment in December 2018 would have performed if the sustainable/traditional fund achieved the median return in each period.

Externalities available for reinvestment (Stakeholders, NetPositive)

- Sustainability approaches can increase EBITDA: (earnings before depreciation and amortization)

Reducing COGs (cost of goods sold)	Reducing OPEX (operating expenses)	Increasing revenue
• efficiency gains • waste management	• sharing • leasing • service approaches	• more desirable products • customers sensitive to sustainability issues will demand

- Can increase gross margin
- Sustainable feedstocks can be more costly

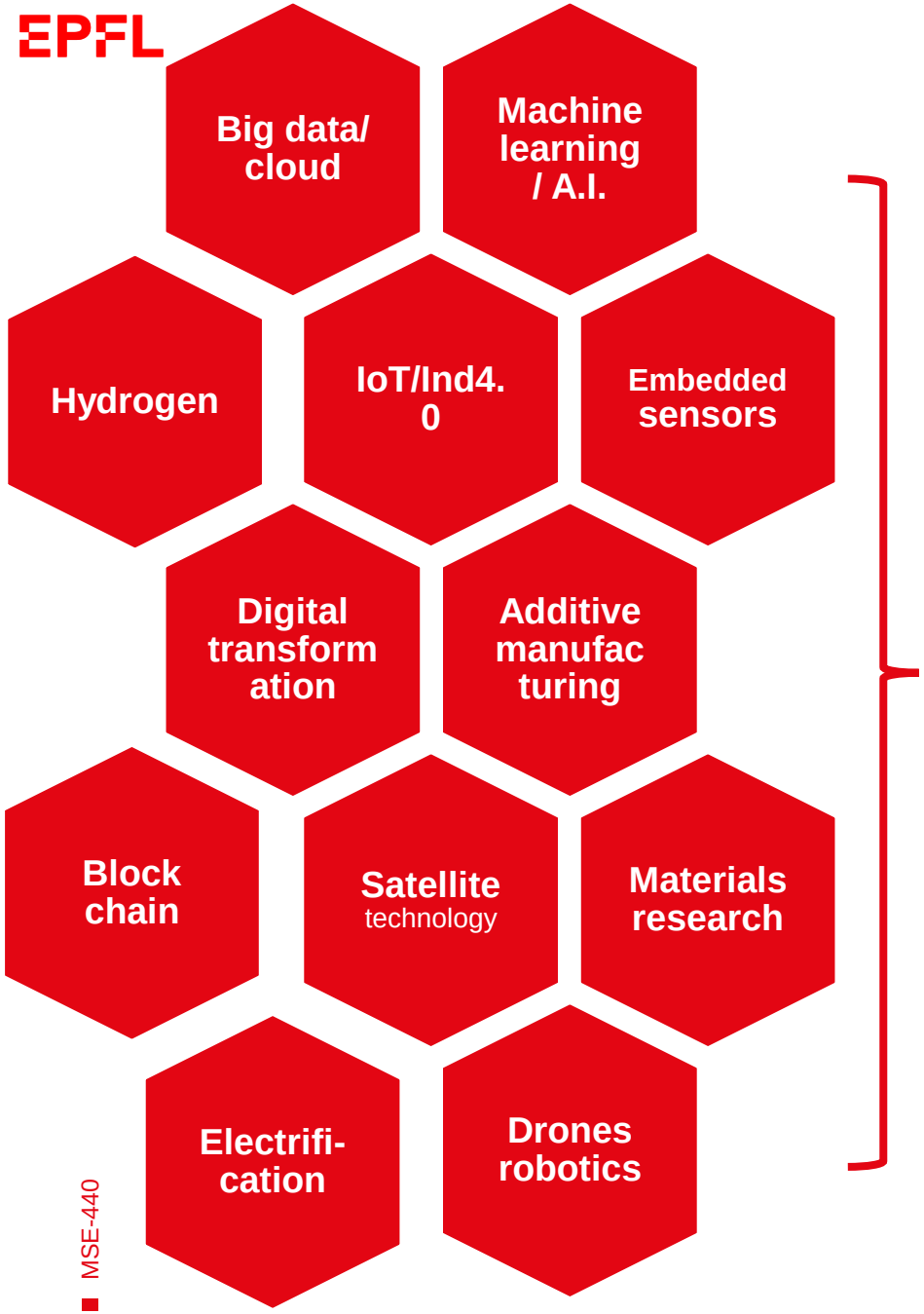


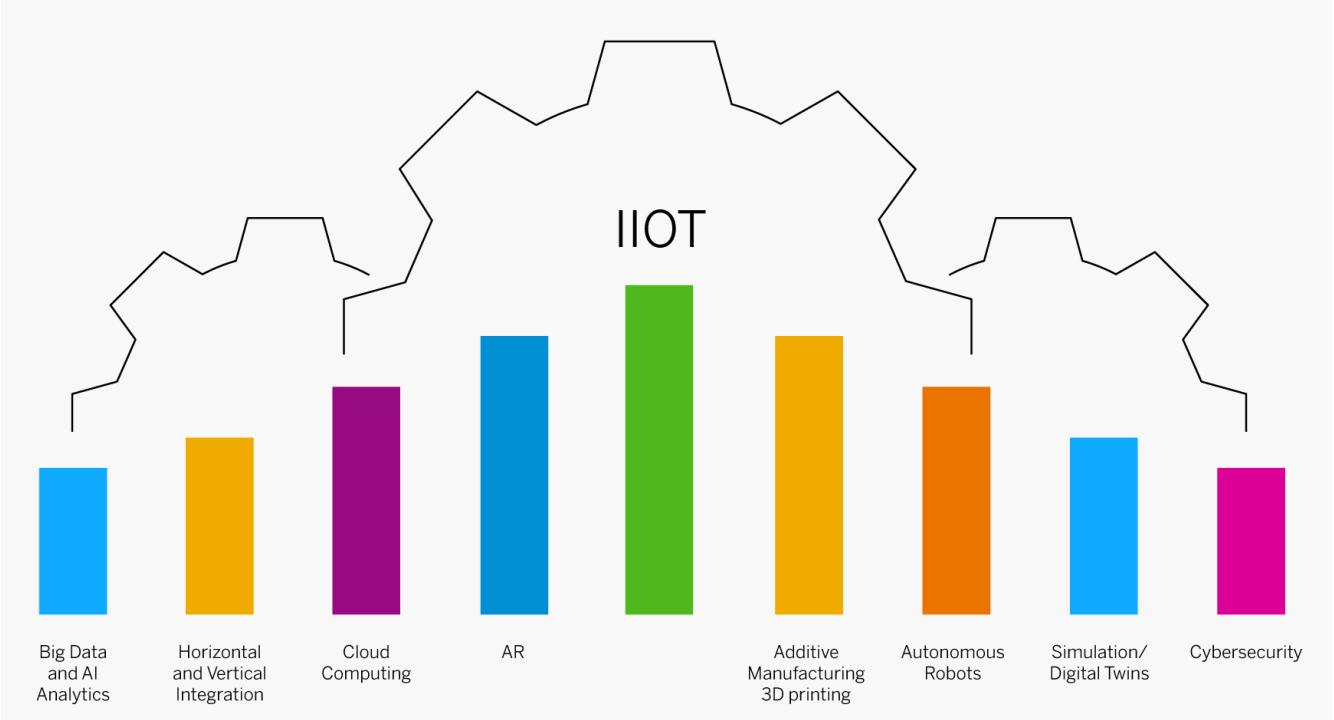
To increase focus on sustainability:
Variables in financial model

- *GM*
- *Dividends*
- *Retained earnings R&D*
- *Retained earnings NetPositive (shadow pricing negative externalities & re-investing with stakeholders)*

Technological enablers to circularity / NetZero

The advanced materials industry has a huge opportunity to create a circular economy, create clean energy, to mitigate climate change …





What Is Industry 4.0? | Definition, Technologies, Benefits | SAP Insights

How to achieve the benefits of a circular economy?

Wakeman

Stakeholders	Production systems	Decouple	Retain value	Overcome waste
• Engage value chain stakeholders in behavioral and social system transformation.	• Designing industrial economic and production systems • to enable, accept, and support system circularity.	• Adoption of practices that decouple the rate economic growth from the rate of environmental impact.	• Retain value within the economic system (value-retention processes), including: arranging direct reuse, repair, refurbishment, remanufacturing	• Need emphasis on overcoming waste and retaining value within production- and product-systems

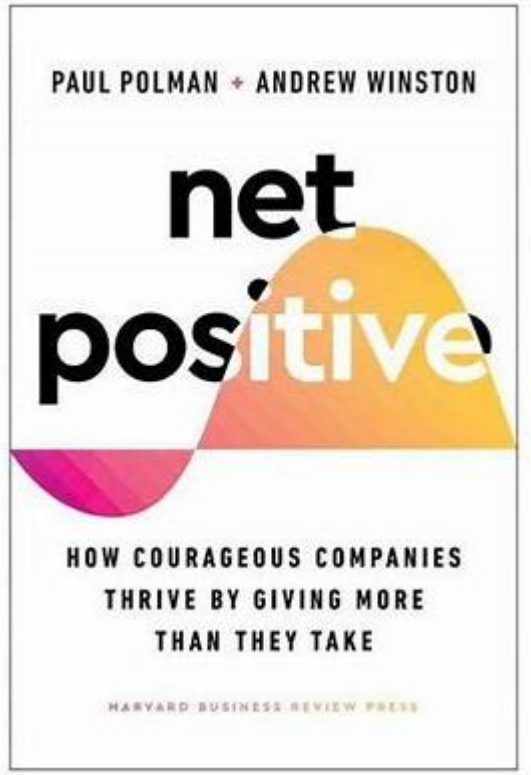
- **Otherwise the pursuit of circular economy can only be incremental, at-best.**

Re-defining Value – The Manufacturing Revolution | Resource Panel

NetPositive

A "NetPositive" company is one that grows by helping the world flourish. They:

1. Operate 1st in service of multiple stakeholders—which *then* benefits investors (as opposed to putting shareholders above all others)
2. Take full ownership of all company impacts (scope 1, 2, 3), intended or not
3. Embrace deep partnerships, even with critics;
4. Tackle systemic challenges by rethinking advocacy and the relationship with governments.

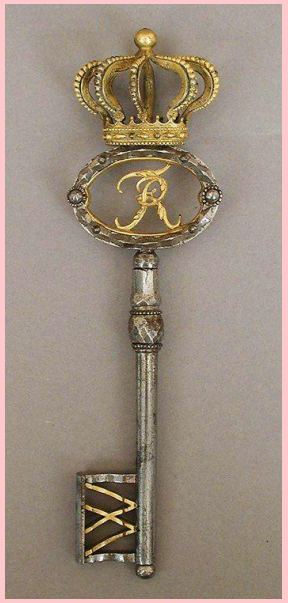


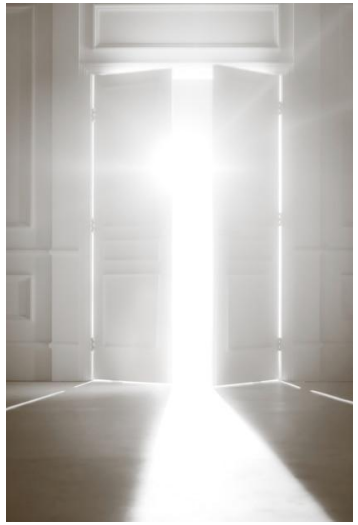
No company has yet reached the ambitious goal of becoming net positive. But a growing number have begun the journey—unlocking greater value for their businesses while helping solve larger problems for the benefit of all.

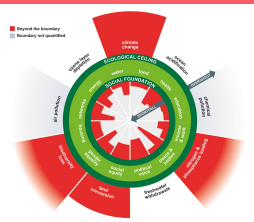
Net Positive: How Courageous Companies Thrive by Giving More Than They Take

PESTLE level thinking for systemic change

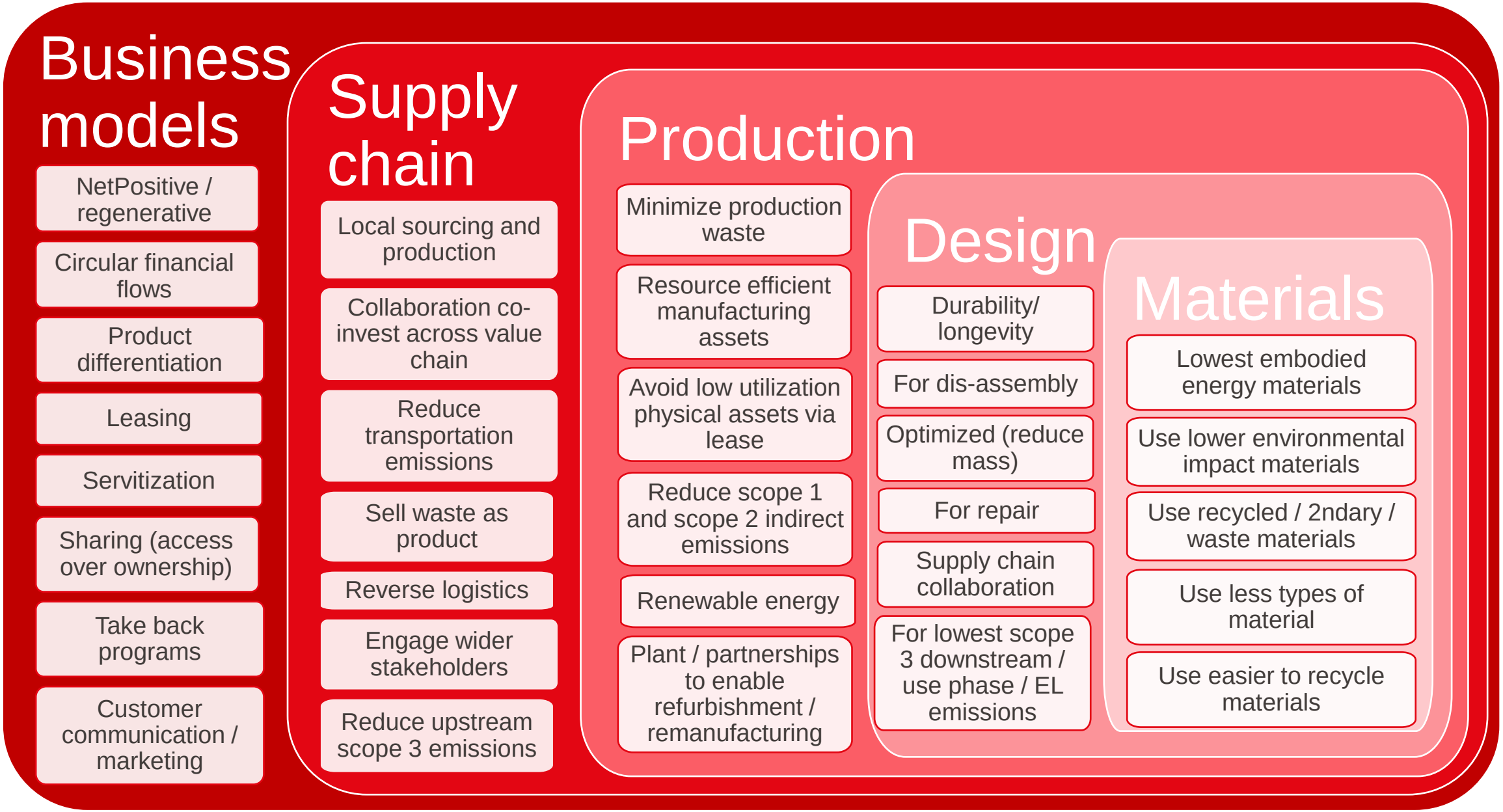
Political	Environmental	Social	Technological	Legal	Economic







Engineered products and a circular economy



Overview

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Human needs and some psychology

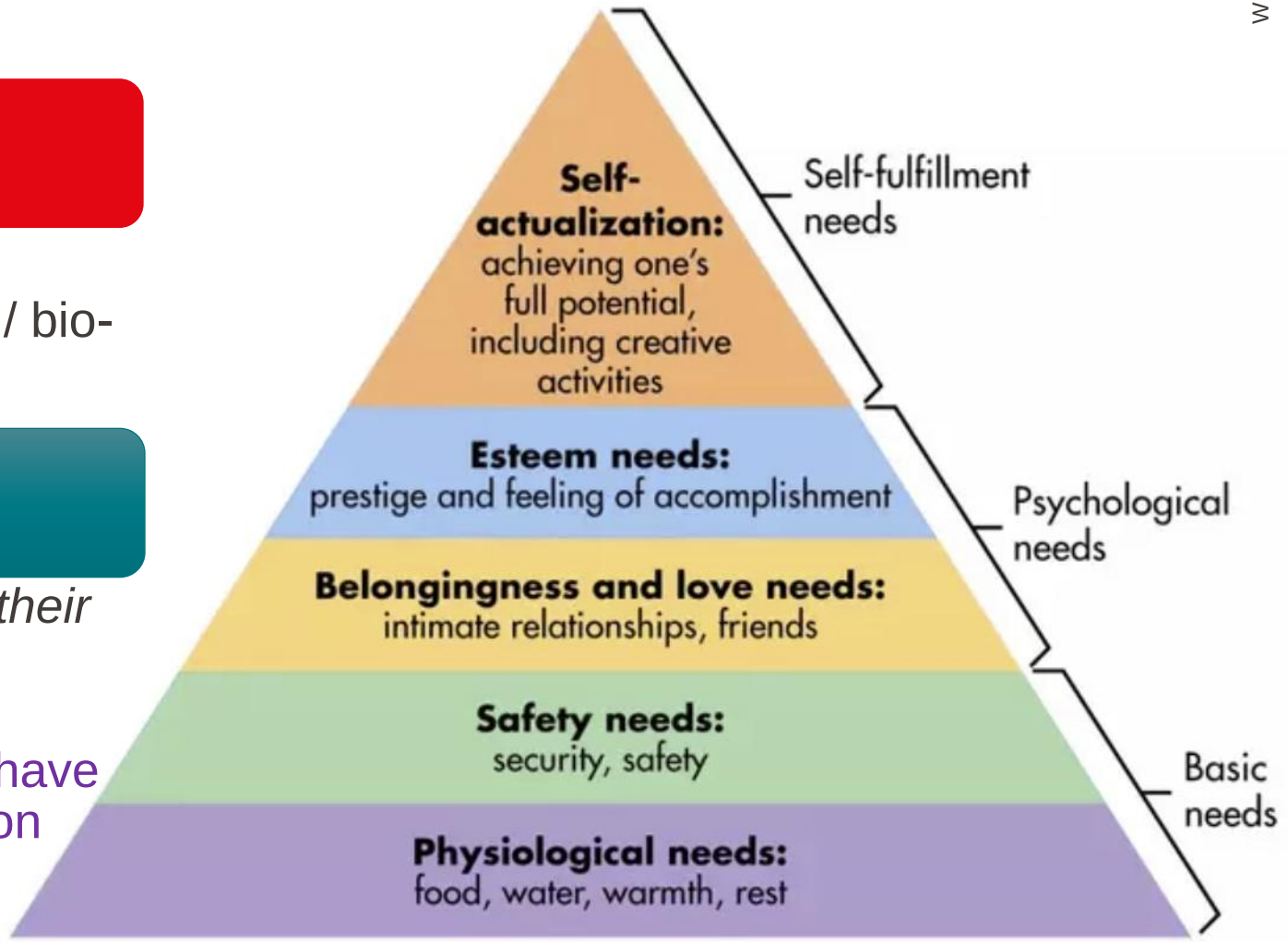
In the west

- We look to self-actualize
- Prepared to pay more for an ecological / bio-based / premium product …

While … many others

- *across the world are still trying to meet their basic human needs of food, water, and shelter*
- needs are so pressing that they do not have the head space to consider the impact on future generations as they are trying to survive and feed their children.

- We look to fulfil our needs



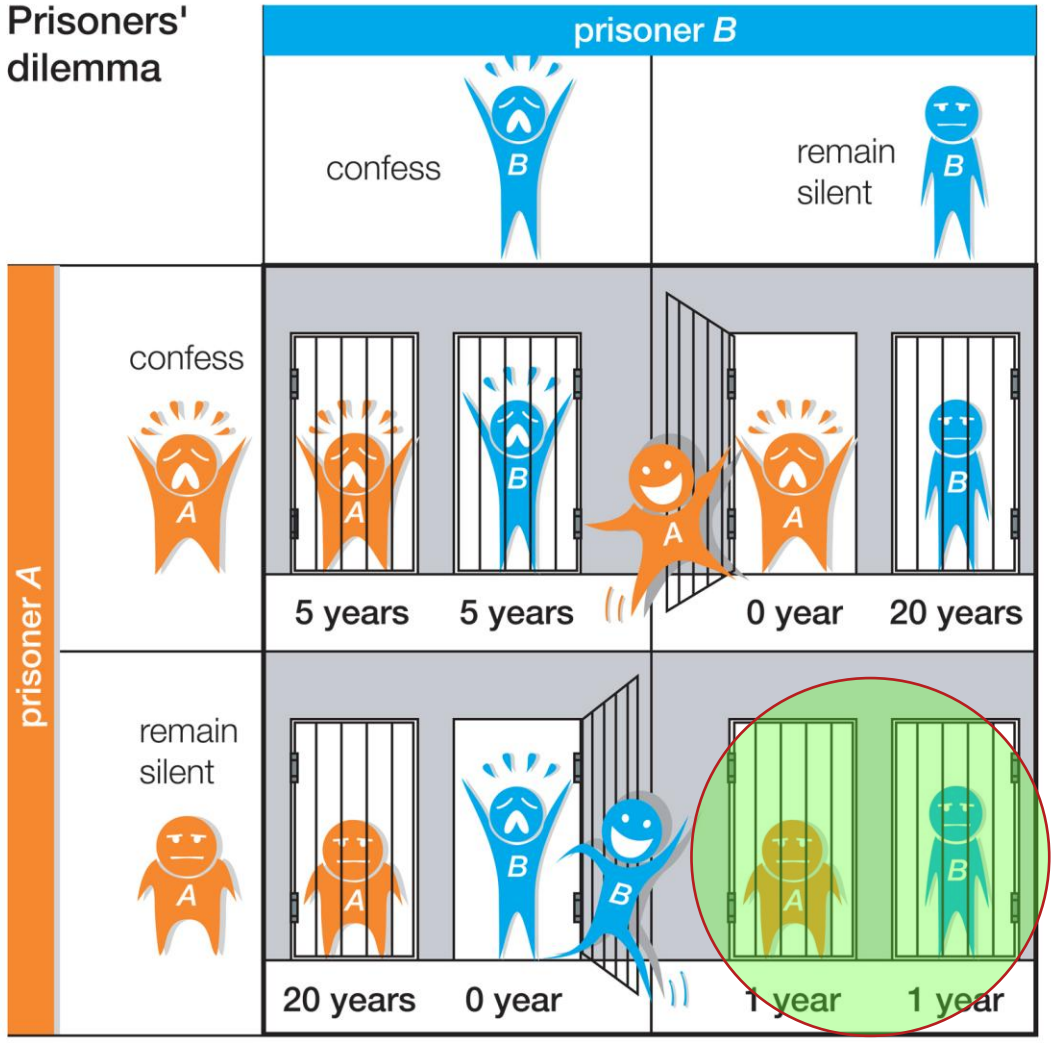
Wakeman

Maslow's Hierarchy of Needs | Simply Psychology

Climate change & game theory

- People or nations might not cooperate even though it would be in their combined best interests to do so
- By prioritizing their personal or national interests, individuals acting rationally can create a worse overall result.
- We need to embrace change, take the strain, and address the issue together.

The dilemma, then, is that **mutual cooperation yields a better outcome** than mutual defection but is not the rational outcome because the choice to cooperate, *from a self-interested perspective, is irrational*.



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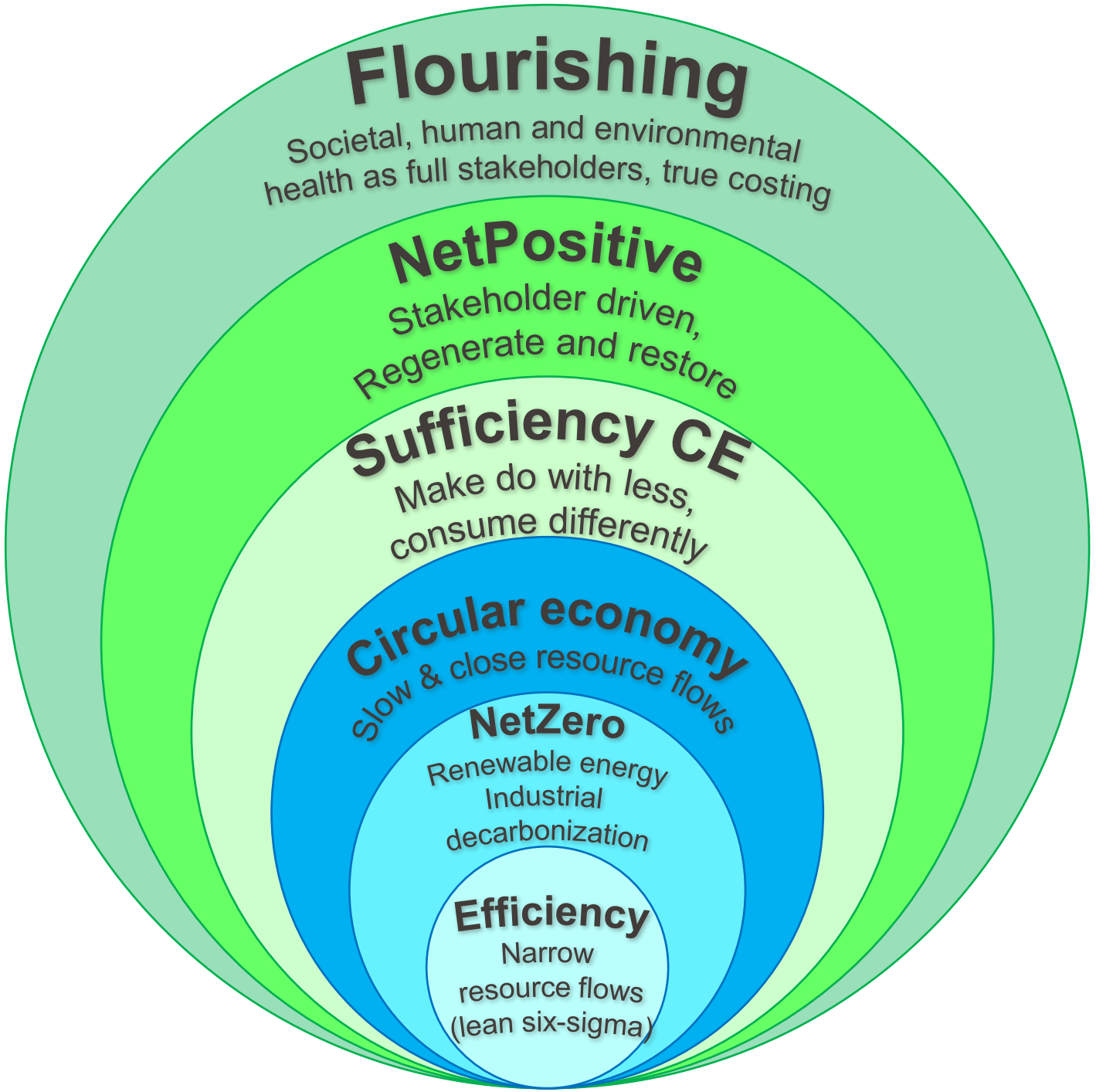
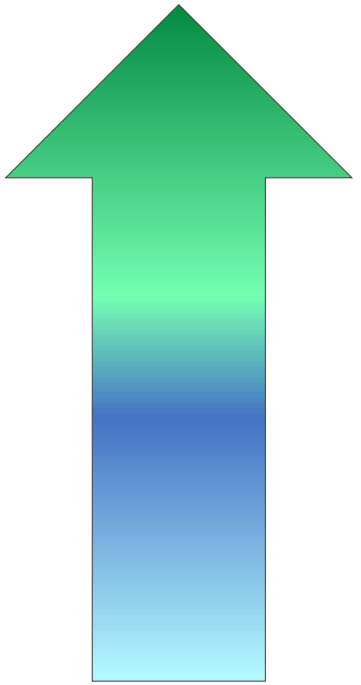
Climate change and the prisoner's dilemma | Financial Times (ft.com) Game theory - The prisoner's dilemma | Britannica Prisoner's dilemma - Wikipedia

Towards a flourishing society (regenerative & restorative)





Adapted from:
Frontiers | The Sufficiency-Based Circular Economy—An Analysis of 150 Companies (frontiersin.org)

Now time for action

TCS winter

cone-icy-road-turn-car-tire (dreamstime.com)

Exercise

- Think of 3 SMART sustainability initiatives

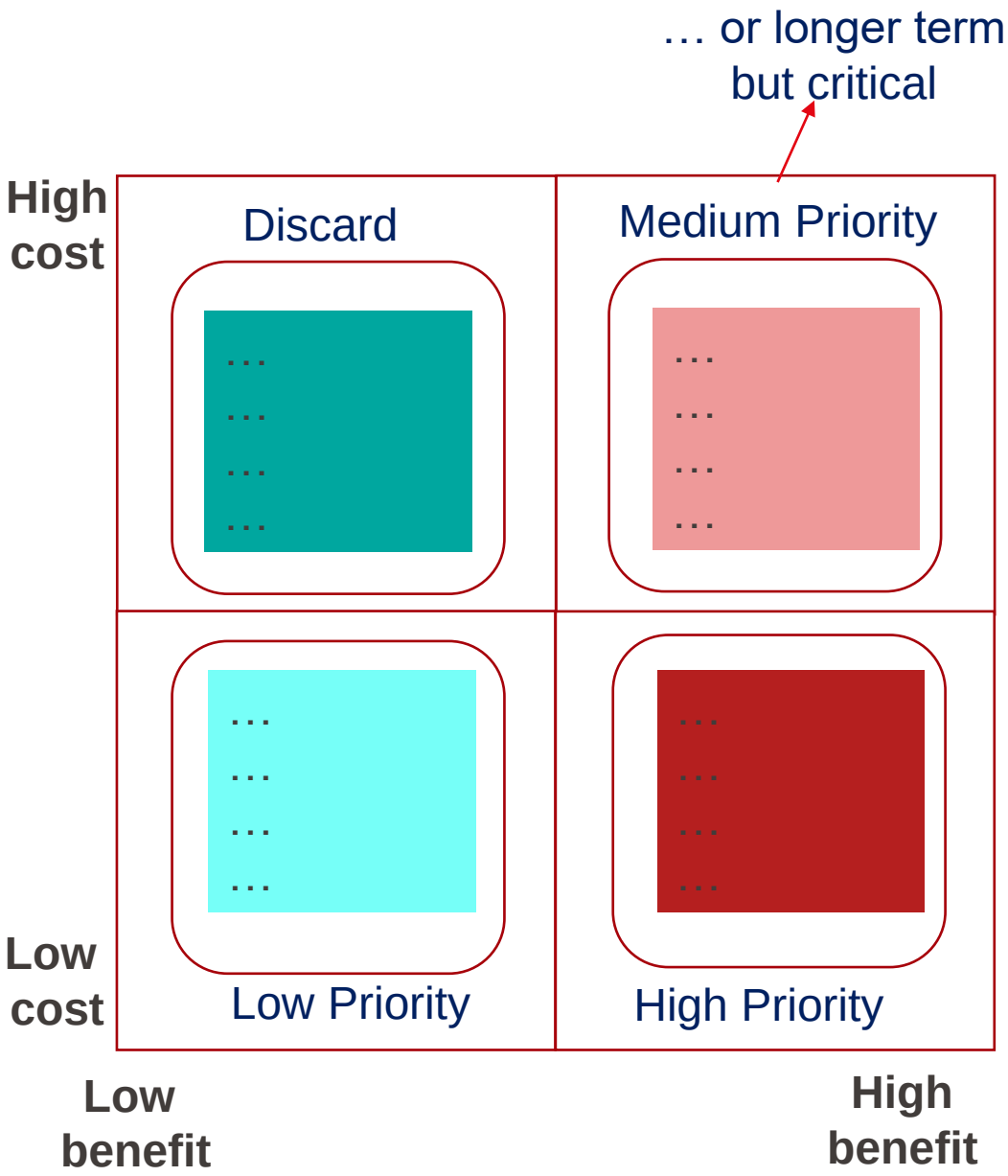
SMART objectives - Bing images

What are Strategic Initiatives? How to Develop & Execute + Examples (cascade.app)

Sustainability initiatives

- Operations focused
- Product focused
- Supply chain
- Industry wide

- Develop strategic mix of
  - Short
    (fast to implement, low cost/high benefit)
  - Medium
    (transition to the future)
  - Longer term
    (high risk, high benefit, maybe high cost)



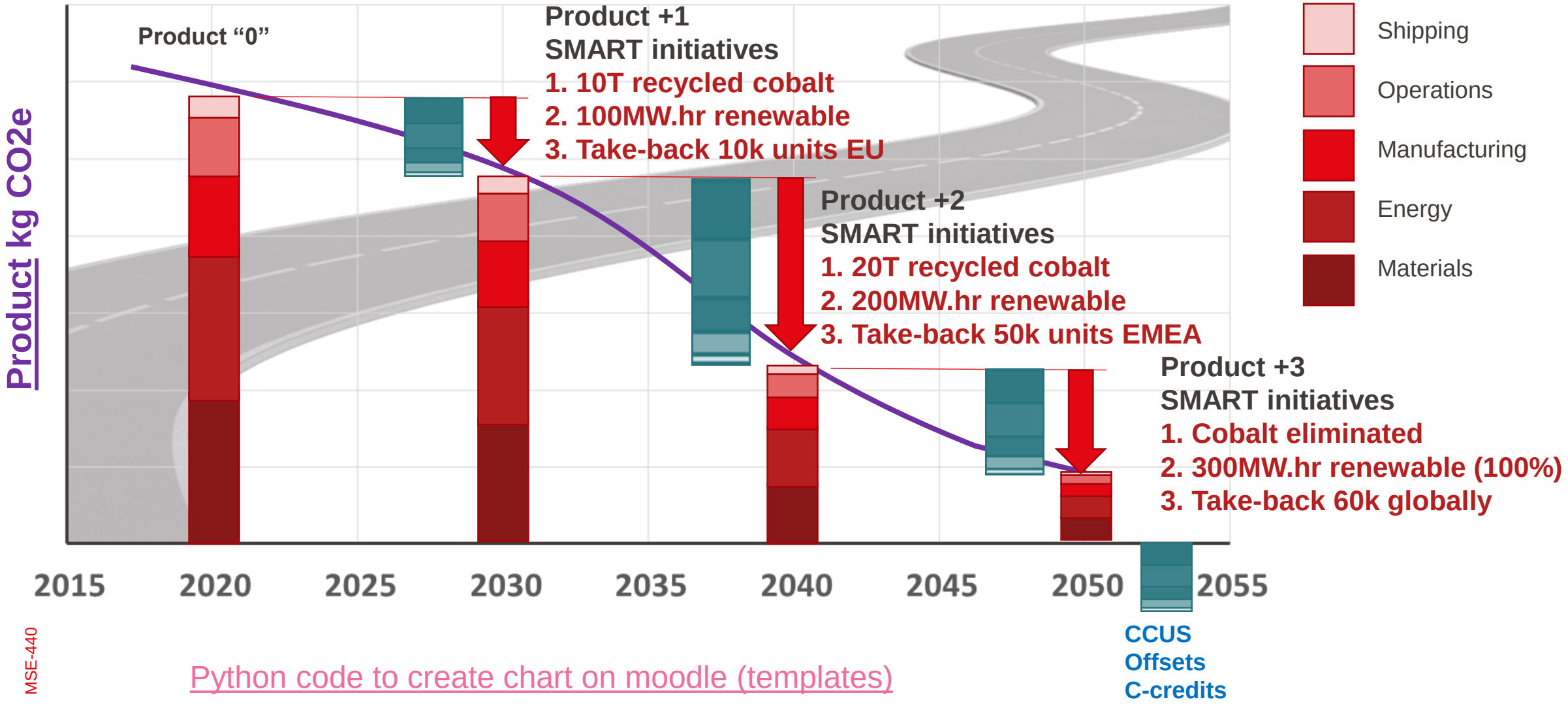
Example: SMART initiatives

Wakeman

Initiative description	Next steps	Impact	Challenges	Resource needs	Key dates	Stakeholders
• Install PV panels on 1000m^2 of factory roof • Generate 540 kWh/day to reduce scope 2 emissions by	• Research benefits on product LCA • Choose 3 suppliers • Quotation by end of August • Presentation to board September 20th	• Reduce CO2e from oil heating (25.2 g CO2e vs. 1kg CO2e / kWh fossil fuels) • PV production impact recovered in 1 year • Abate 30 tonnes CO2e/yr	• 7-8 year payback period • Site assessment	• 25% of project engineer for 9 month • 200k CHF CAPEX	• Quotation end August • Decision end Oct. • Planning permission to end December • Operational target April 2025	• Building services manager • Chief sustainability officer • Customers (demanding lower CO2e in our commodities) • CFO • LCA group

Product decarbonization roadmap

- NetPositive vs. time and table of initiatives



Python code to create chart on moodle (templates)

Summary: Eliminate. Circulate. Regenerate.

to reduce emissions and meet the targets set out in the Paris Agreement

Half of the story

- The transition to renewable energy is vital in order to tackle climate change

2nd Half of the Story

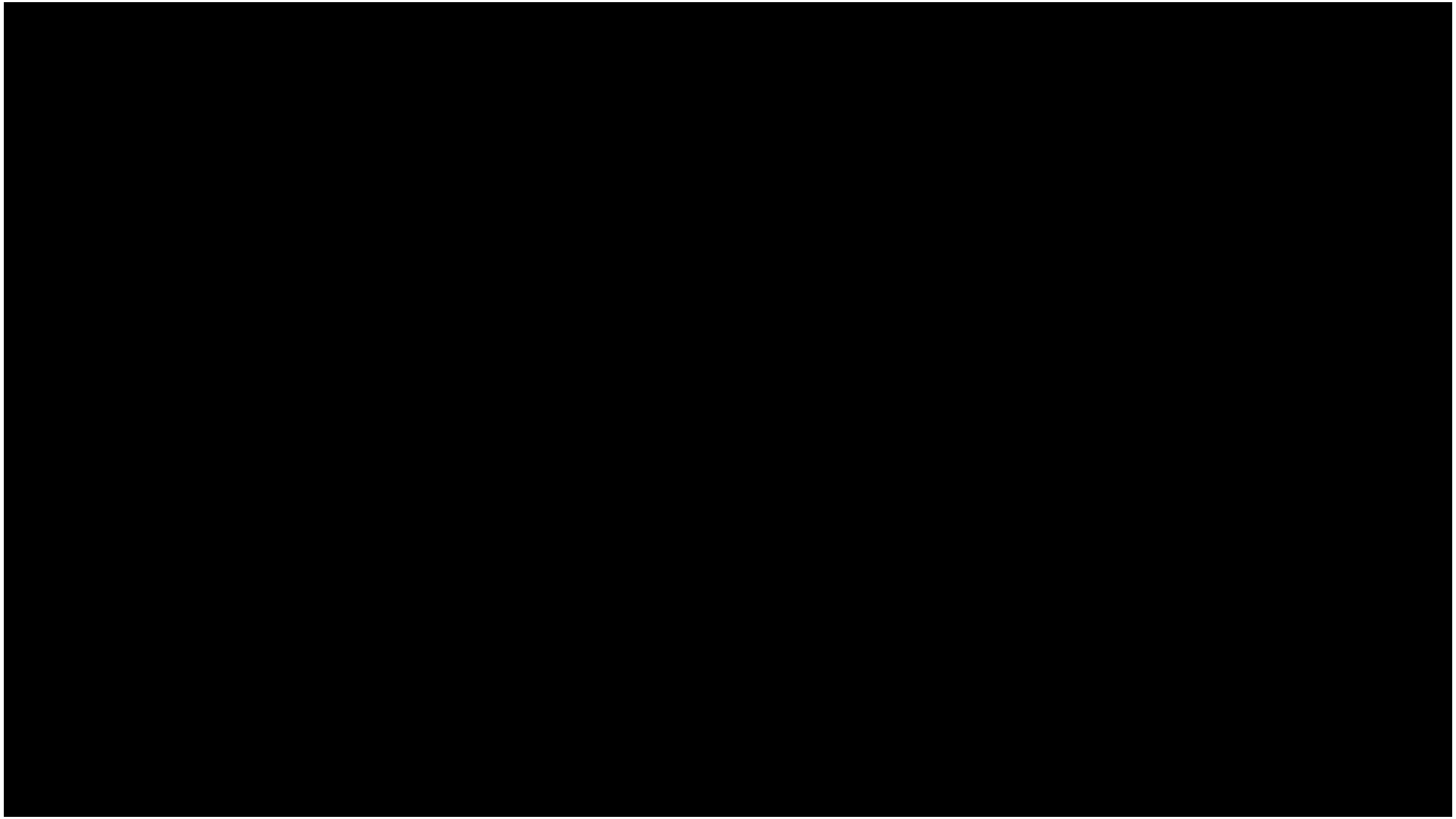
- 45% of global greenhouse gas emissions come from the way we make and use products and food.

That means we need to redesign our economy

- Eliminate waste and pollution
- Recirculate products and materials
- Regenerate nature

- We need a circular economy to help us reach NetZero

Completing the picture - How the circular economy tackles climate change - YouTube



2min15s