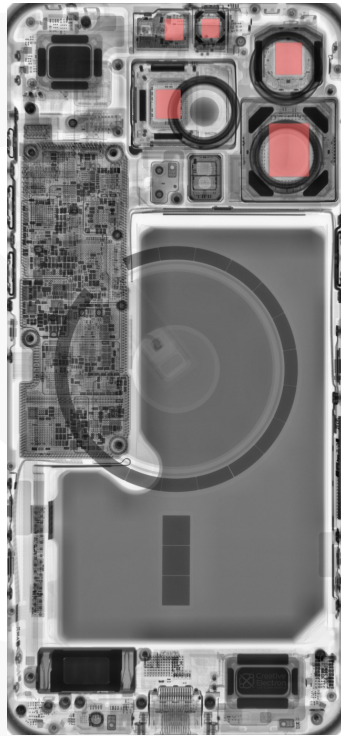


Sustainable Electronics for Eco-Responsible Digital Technology

ESOS - Electronique: Soutenable, Ouverte et Souveraine

Maxime Pelcat
2025

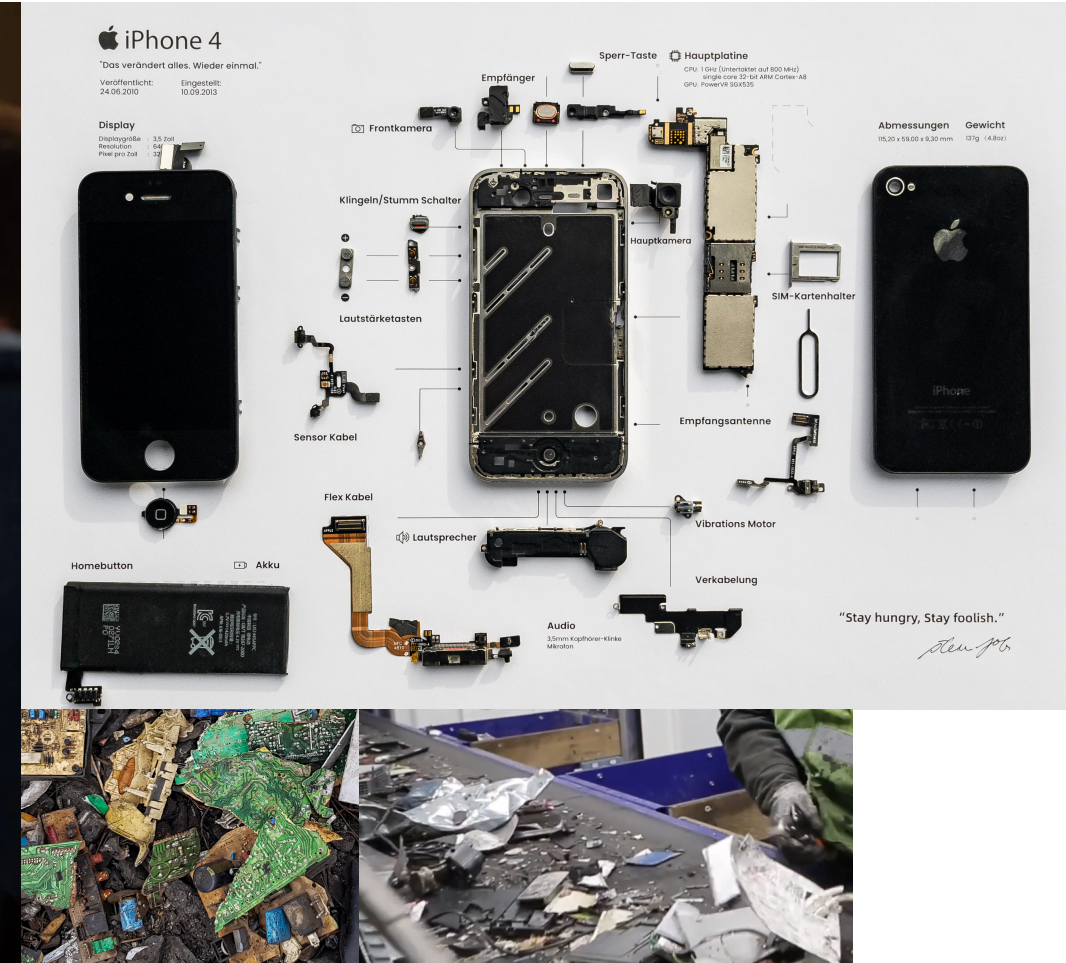


iPhone15 pro max
credit: Creative Electron for iFixit

Electronics and Obsolescence



Electronics and Obsolescence

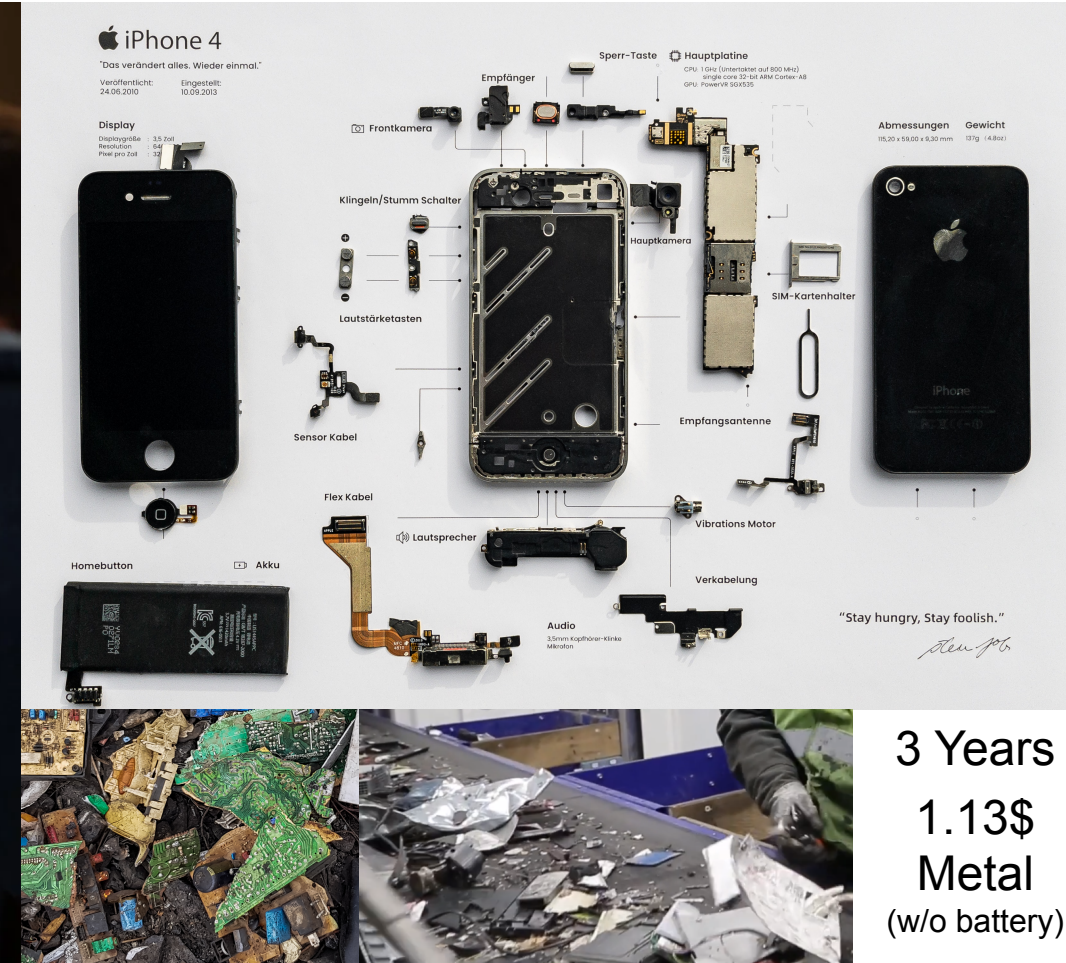


Electronics and Obsolescence



3 Years

Electronics and Obsolescence



3 Years
1.13\$
Metal
(w/o battery)

Electronics and Obsolescence

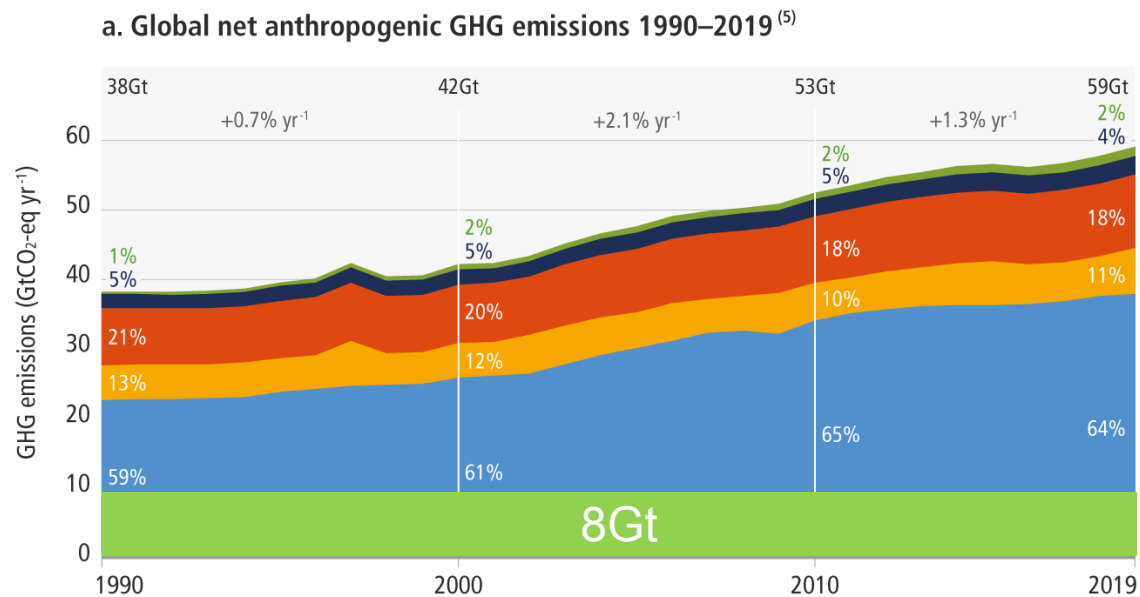


3 Years
1.13\$
Metal
(w/o battery)

Digital Electronics and Carbon Impact

- ▶ Carbon emissions must fall by 7% a year by 2050
- ▶ Digital technologies : 3 to 4% of impacts
- ▶ **Current trends are upward**, by several percentage points per year

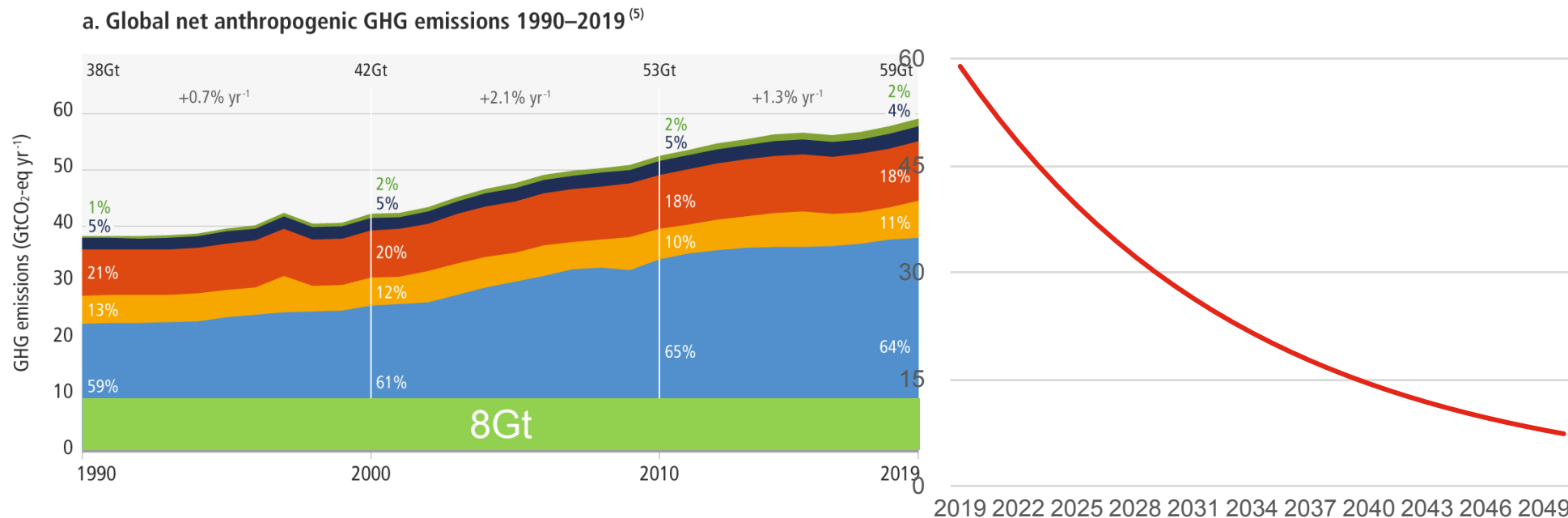
The Closing Window: Climate crisis calls for rapid transformation of societies, UN environment program 2022



Digital Electronics and Carbon Impact

- ▶ Carbon emissions must fall by 7% a year by 2050
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The Closing Window: Climate crisis calls for rapid transformation of societies, UN environment program 2022



Objective:
-7%/year

Electronics and Waste



- 62 Mt of electronic waste in 2022 *

(*Global E-waste Monitor 2020, UN, ITU)

- + 4% per year electronic waste
- only 22% of systems are recycled worldwide (~50% in France)



Electronics and Ecotoxicity

- A smartphone contains 53 metals.

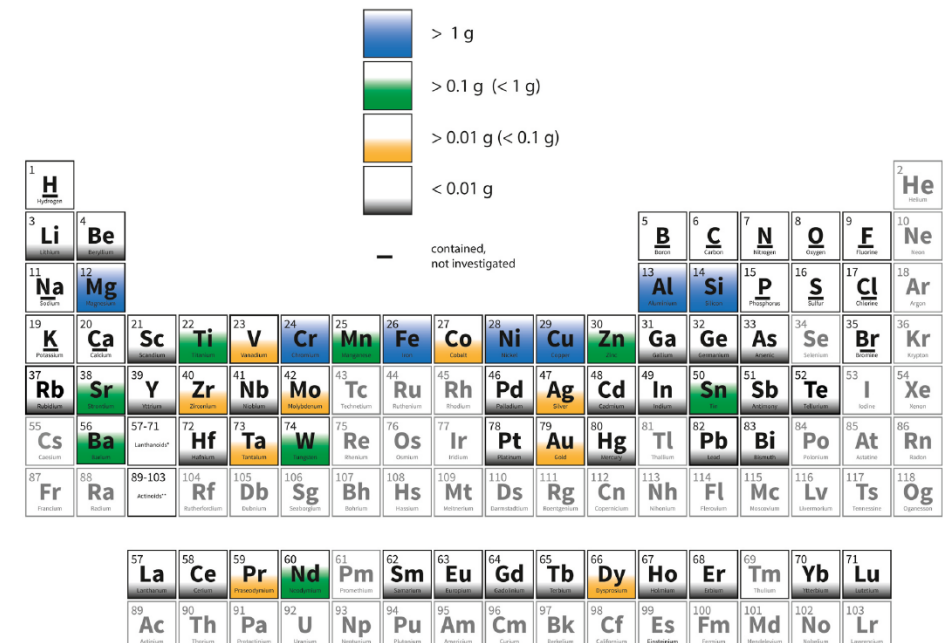
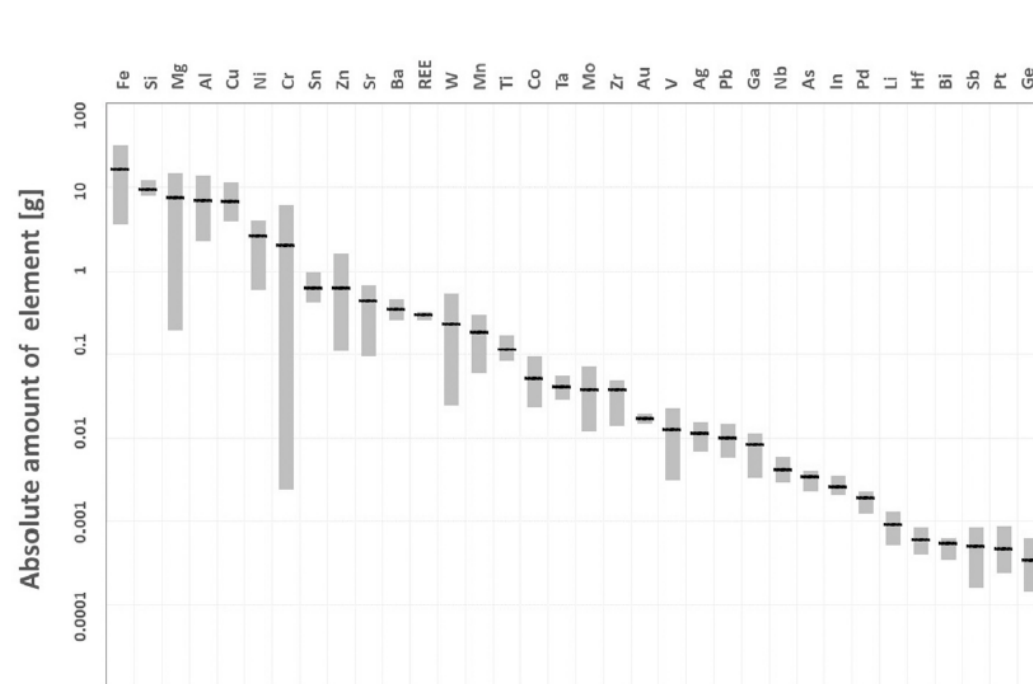


Fig. 1. Investigated elements in selected smartphones and their average content.

Electronics and Ecotoxicity

- ▶ A smartphone contains 53 metals.
- ▶ with Au, Pd, Pt, and Cu, 82% of the metal **value** is recycled (6% of device weight), **if the device is collected**.
- ▶ Recycling from smartphones at EOL is not economically feasible for Co (disregarding batteries), Ga, Ge, In, Ta, and the rare earth elements.

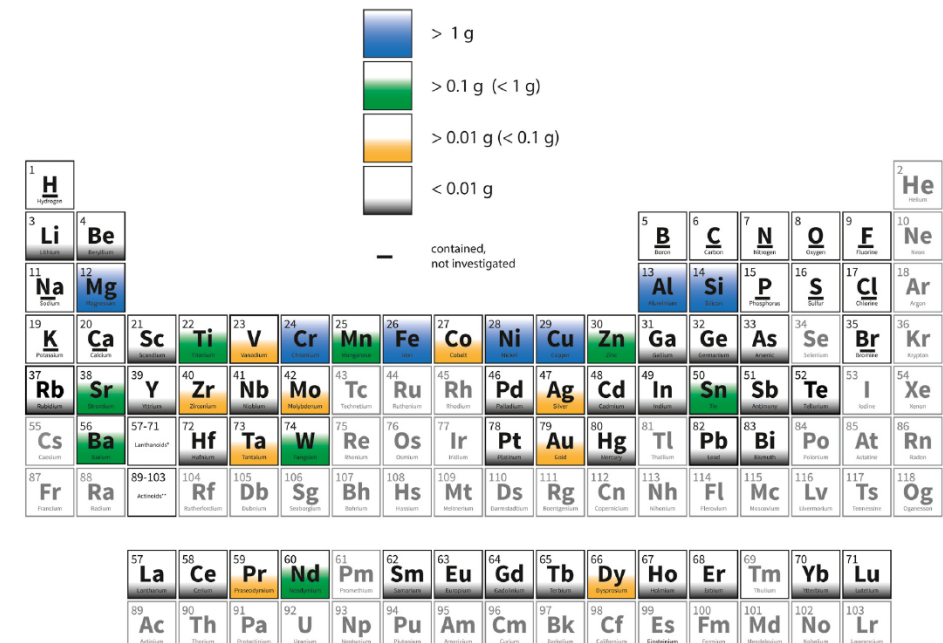
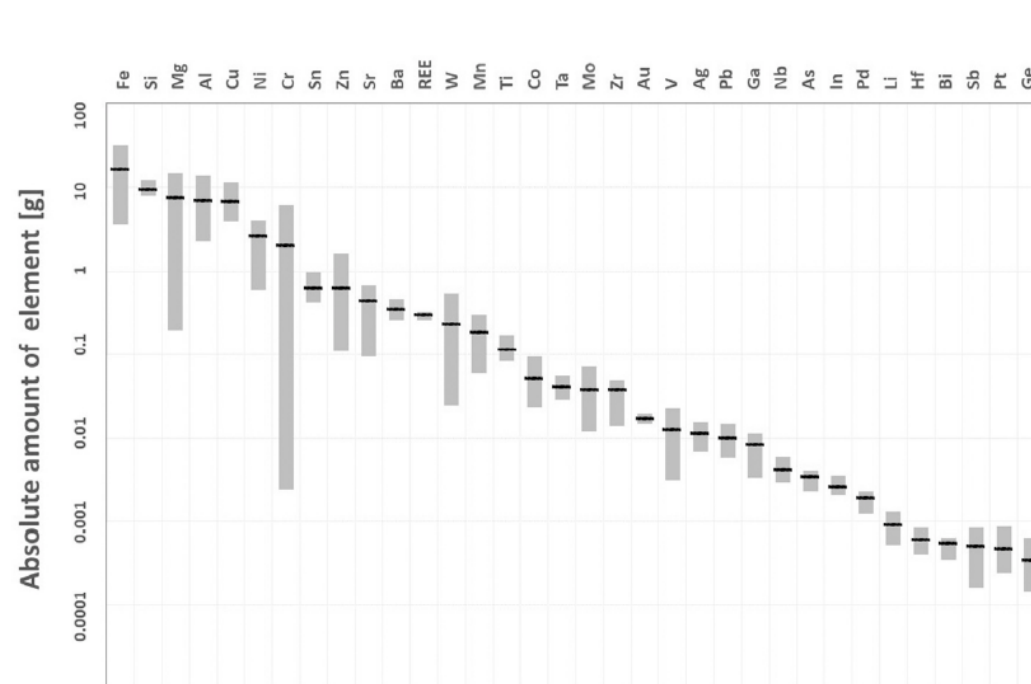


Fig. 1. Investigated elements in selected smartphones and their average content.

Environmental impact of electronics

UNDERSTAND

carbon impact life cycle analysis
inventory energy measurement
processes materials water usage
resource depletion electronic waste

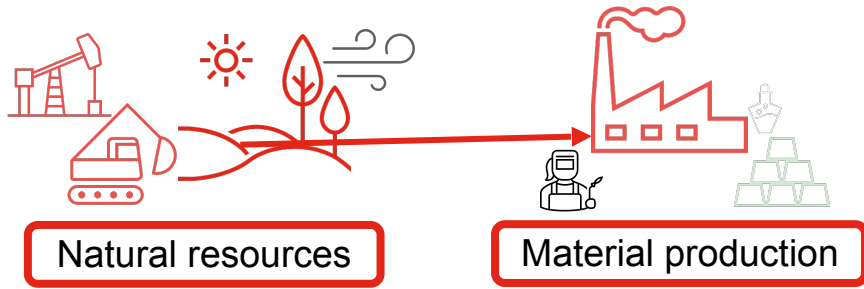


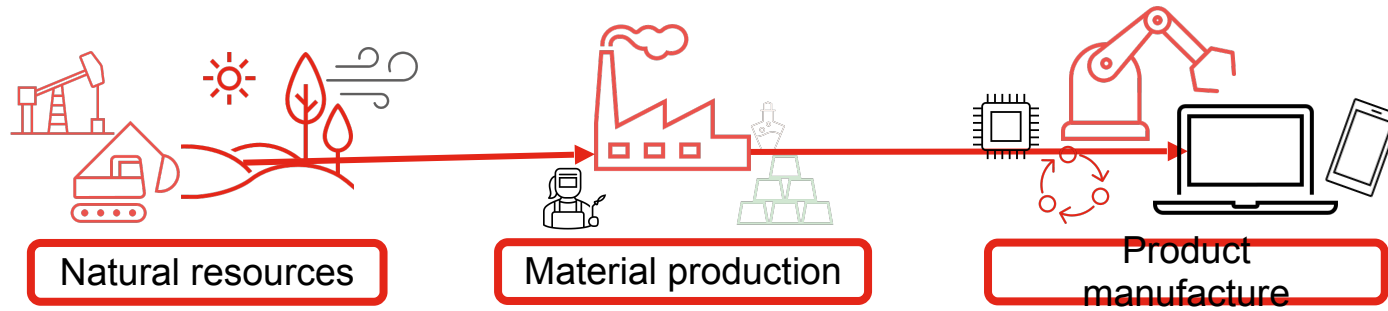
ACT

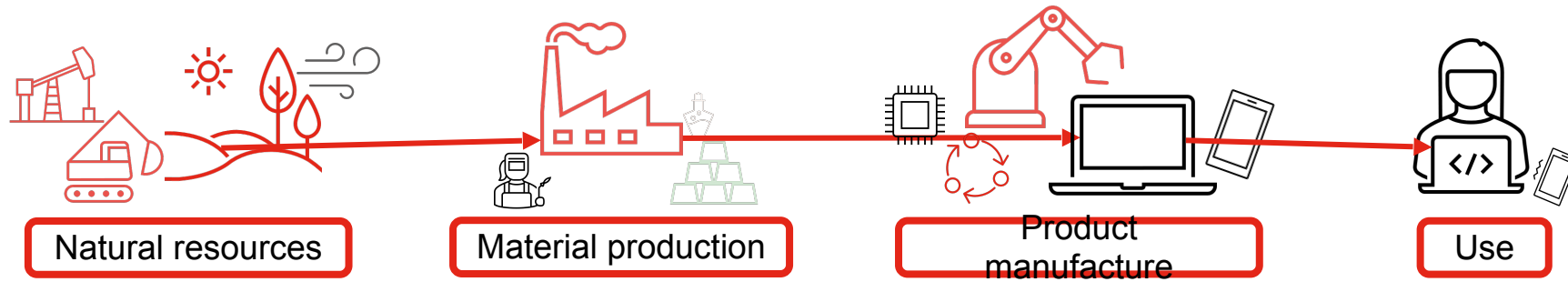
ecolabelling train repair reuse
collect recycle new technologies
inspect ecodesign revalidate
optimize ecoinnovation disassemble

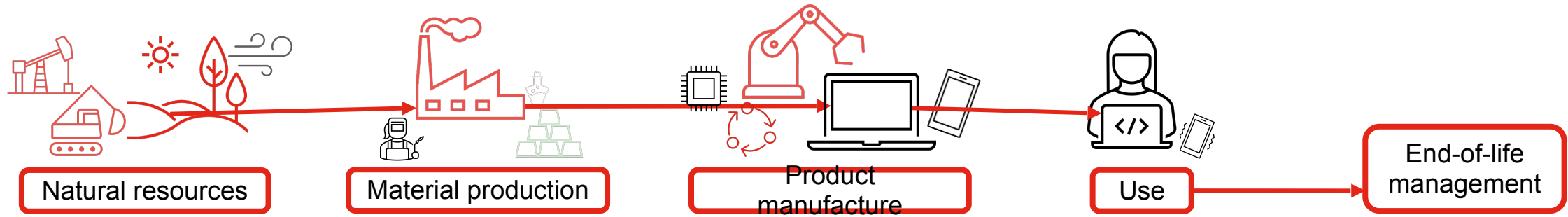


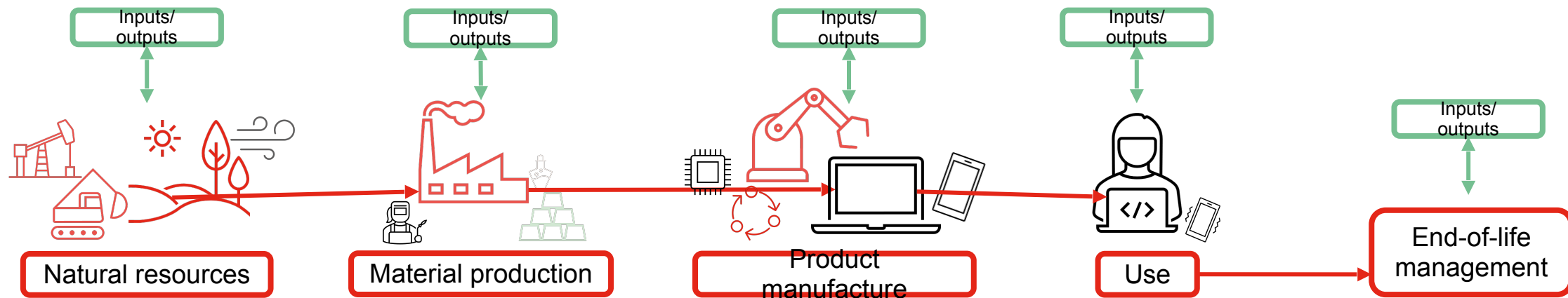
Natural resources

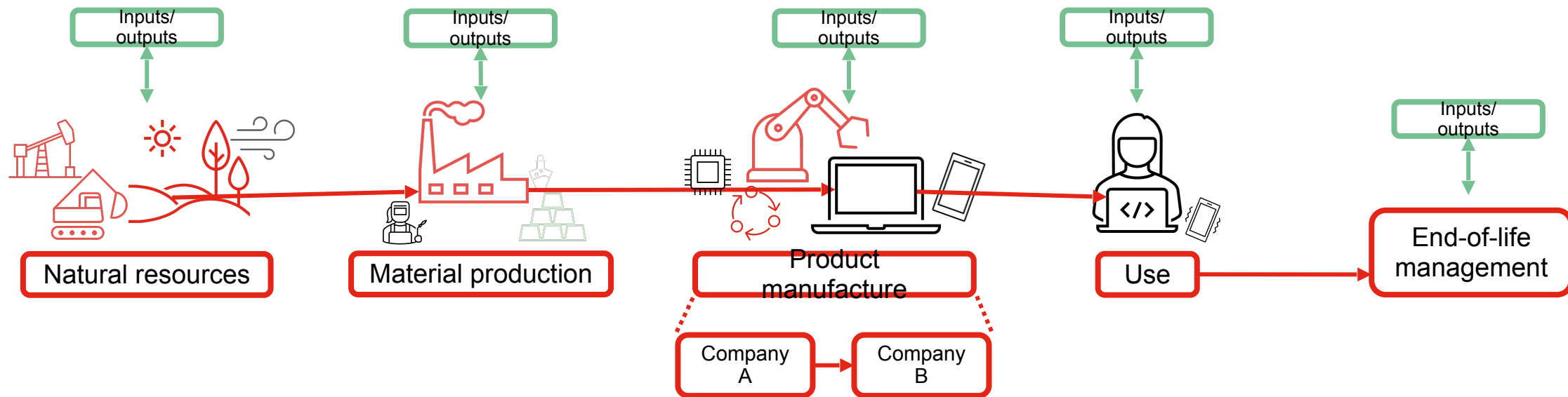


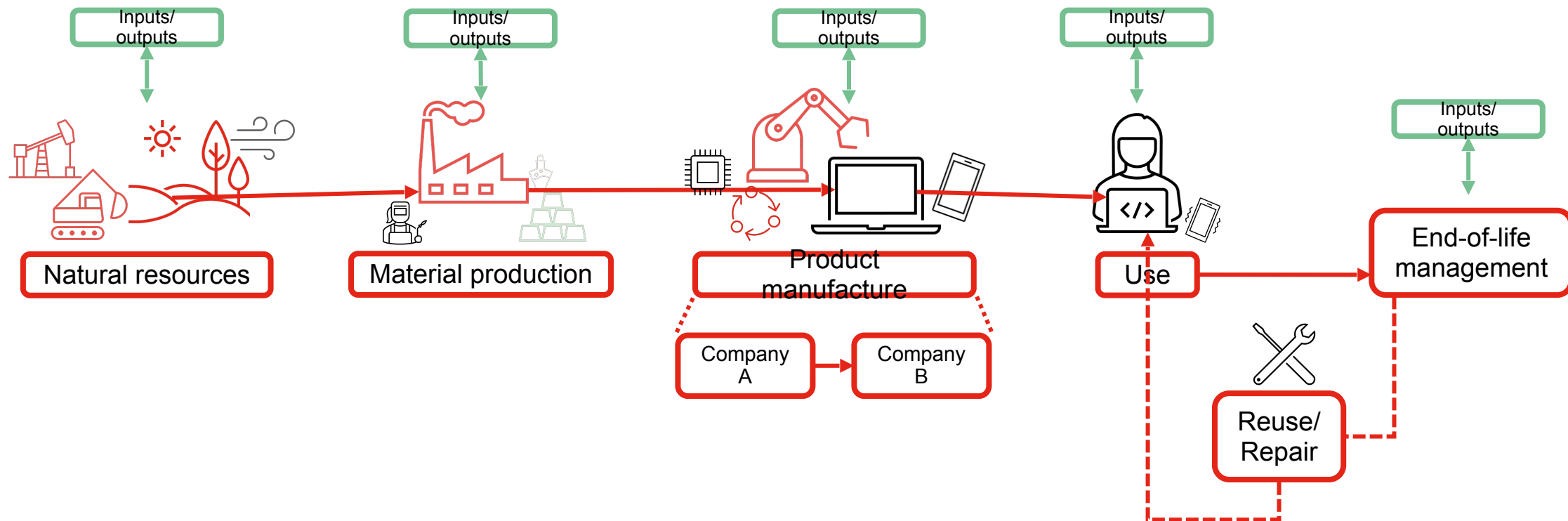


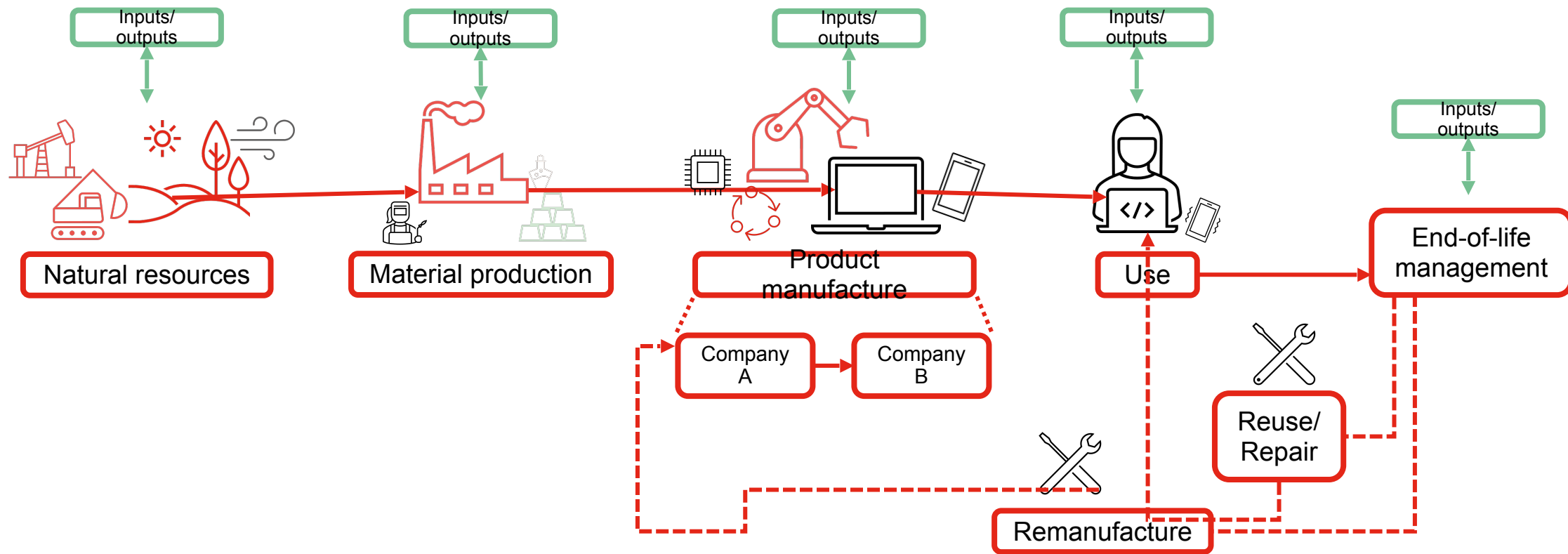


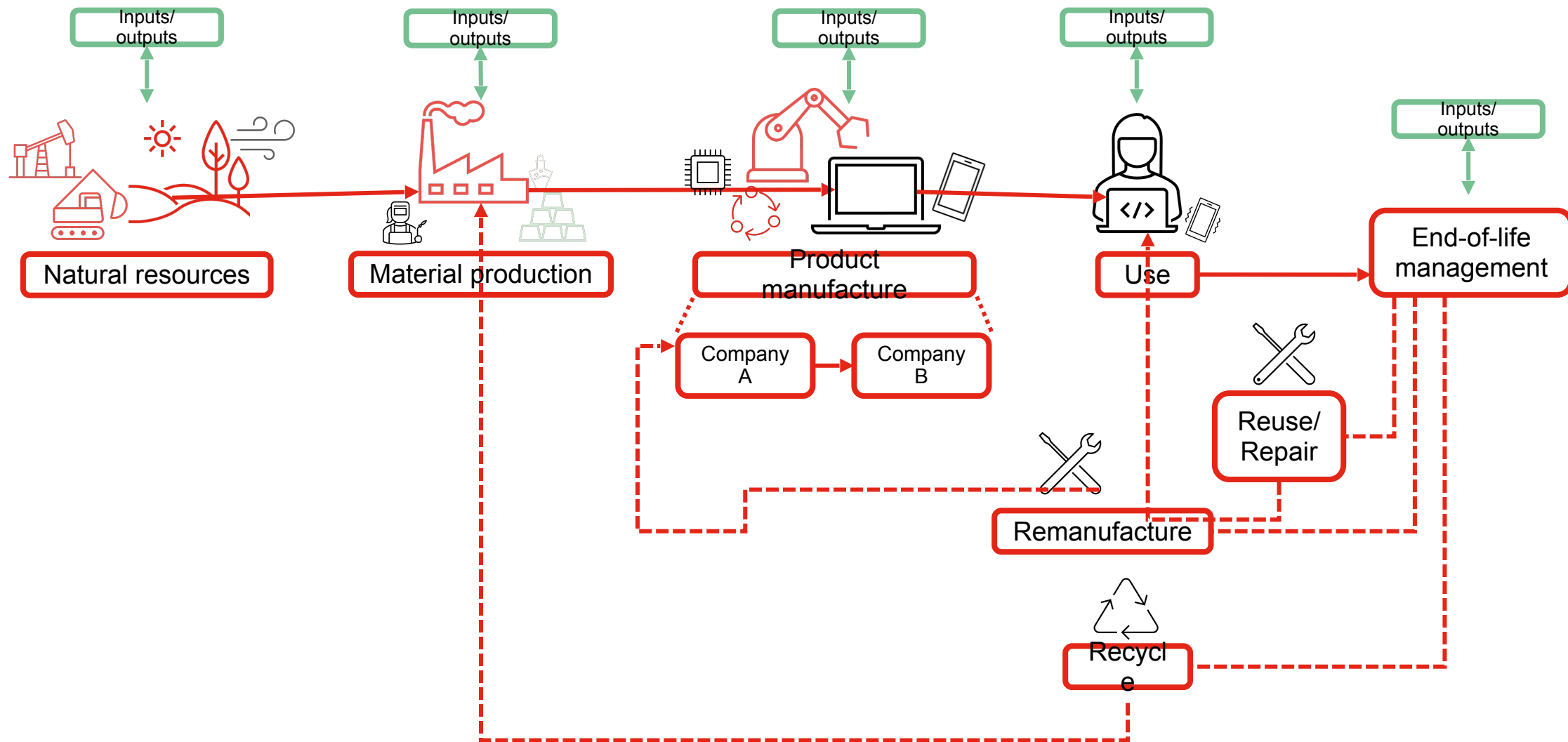


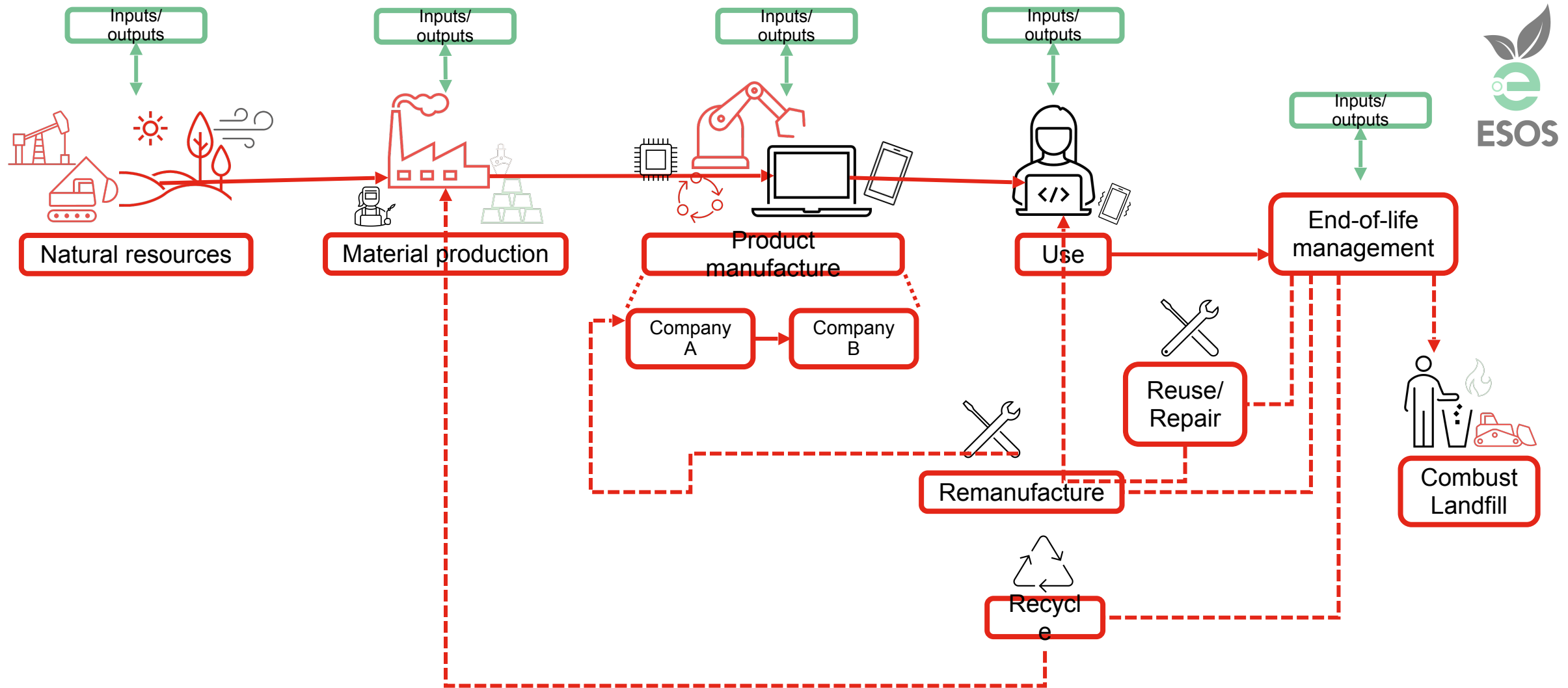


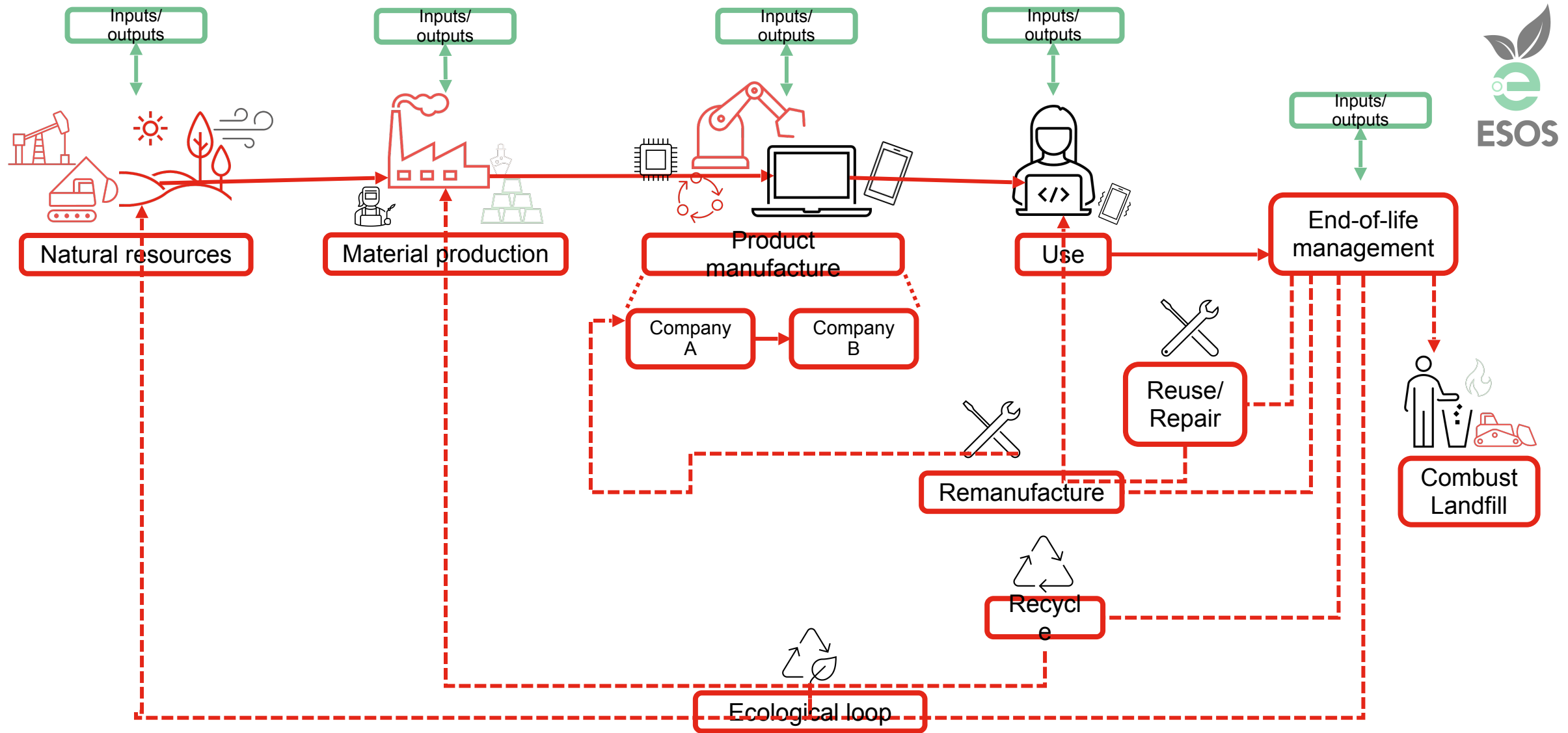






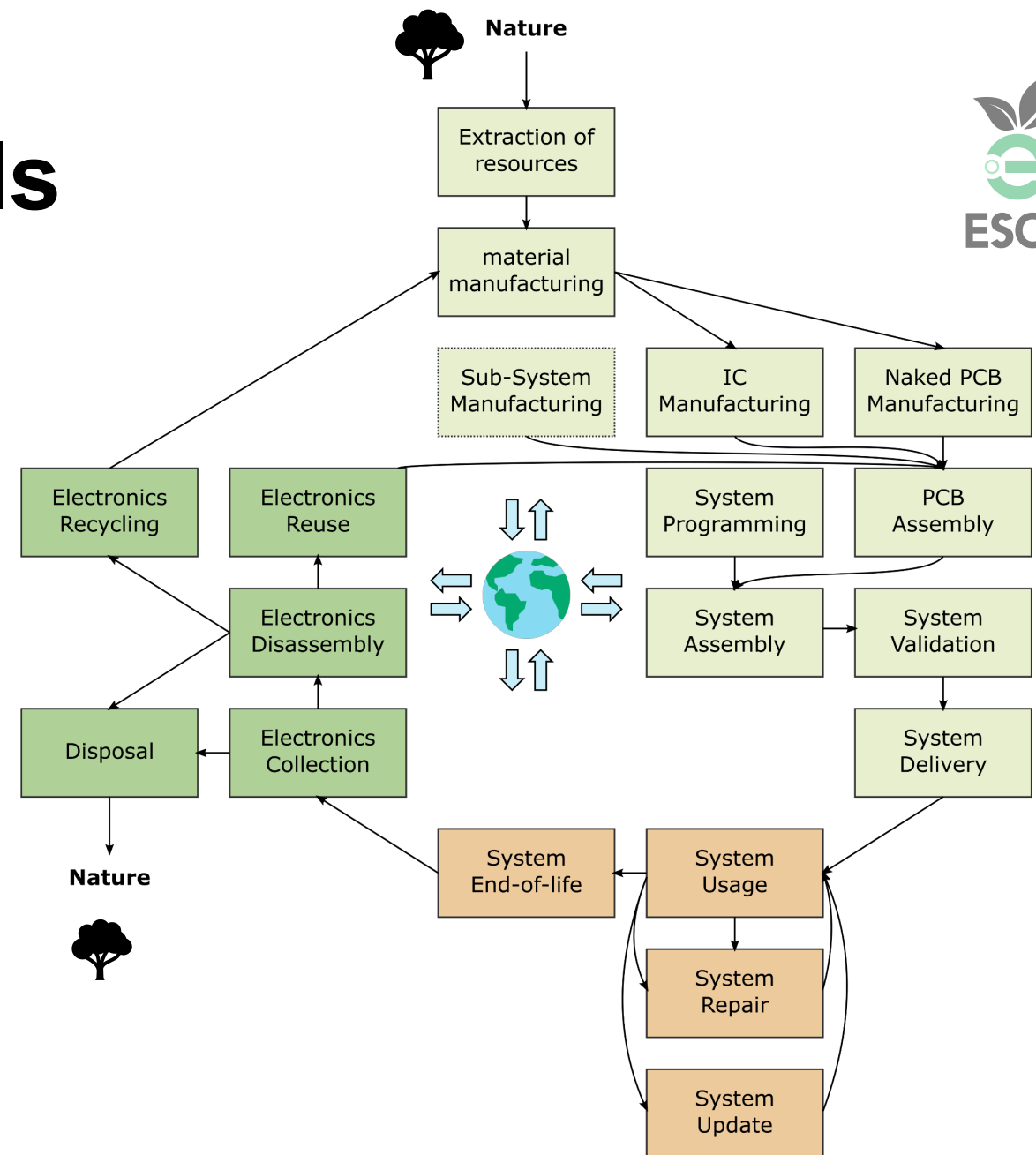






Some ecodesign tools

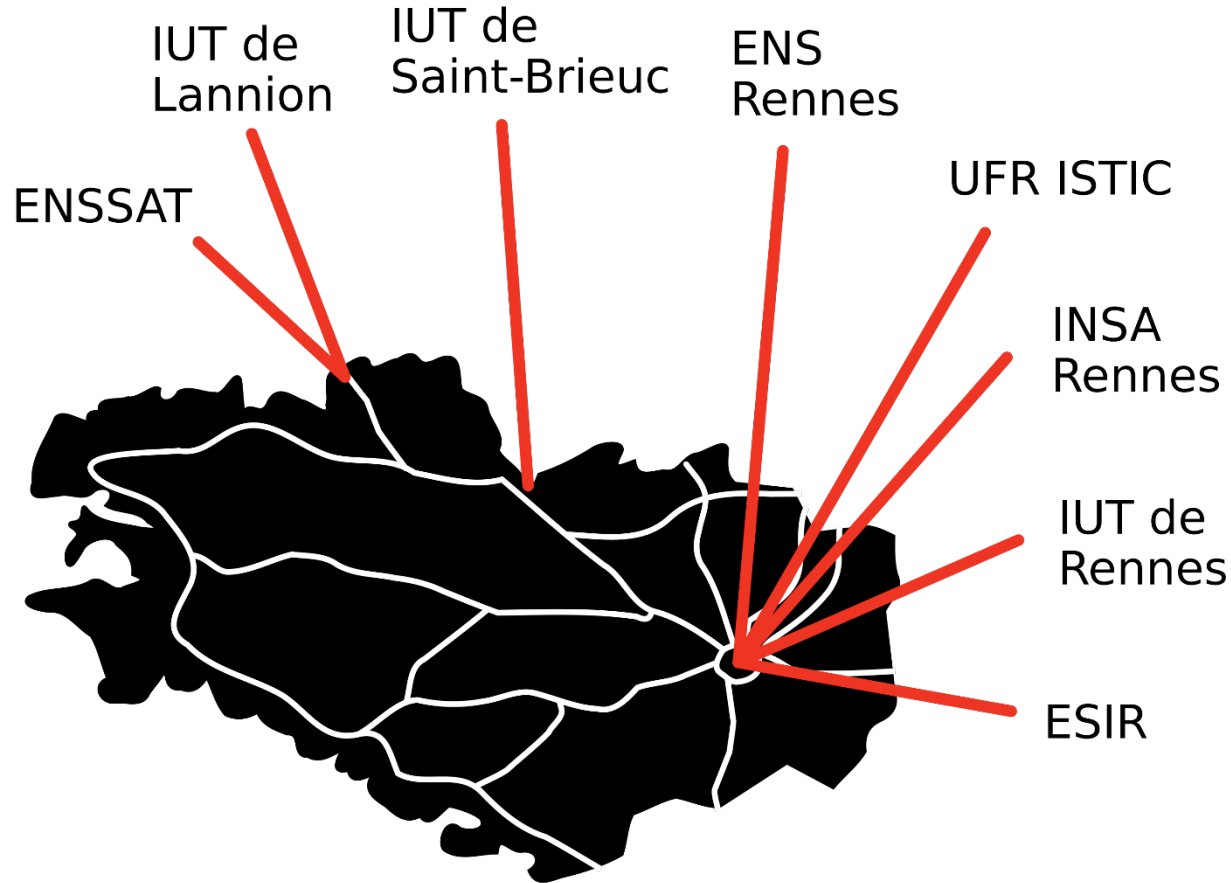
- **Life Cycle Analysis**
- **Circular economy**
 - 3R: Repair, Reuse, Recycle
- **New processes and materials**
 - PCB, IC, other components
- **Better manufacturing**
- **Novel Business Models**
- ...



ESOS project

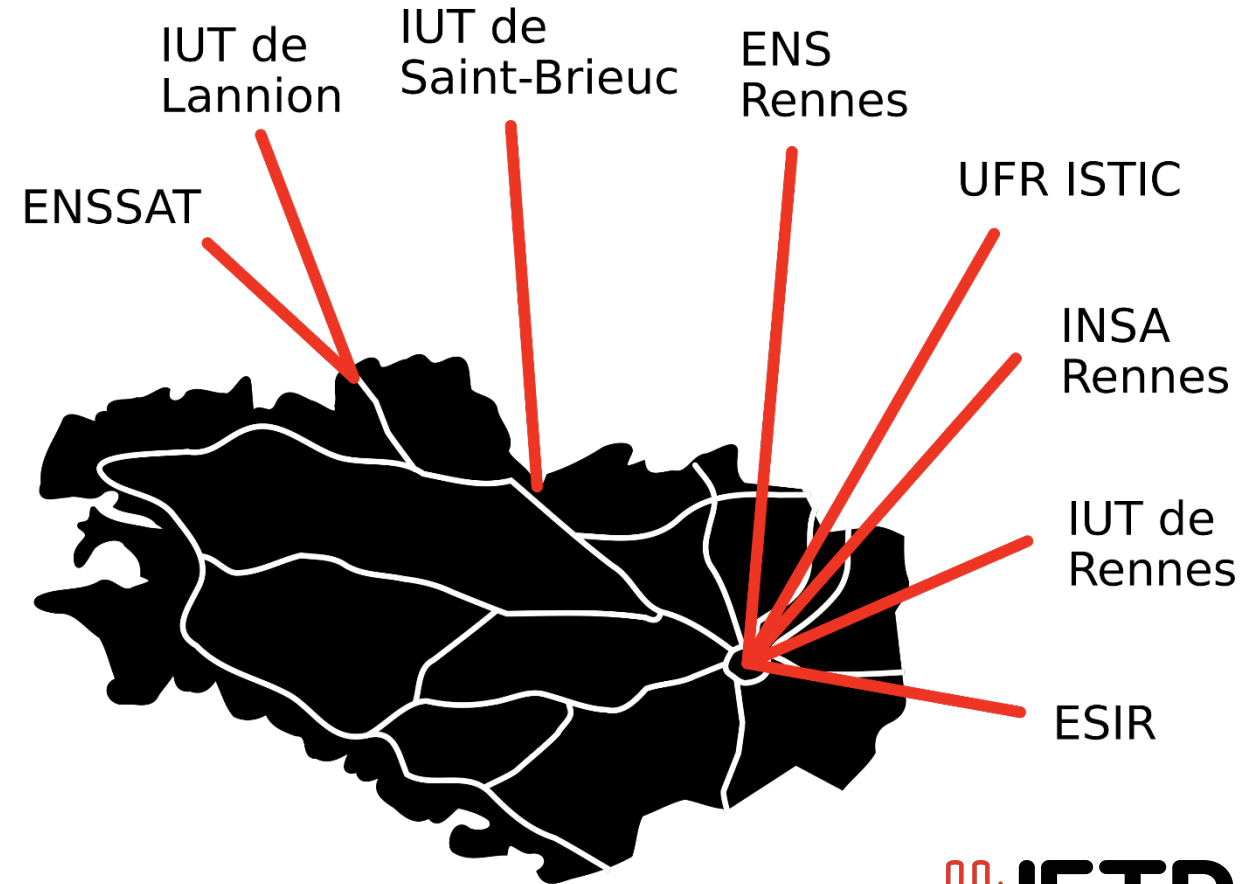
- A PIA4 *Compétences et Métiers d'Avenir* Project
 - France2030 – operated by ANR
 - 6.4M€
 - 2023 –2028
- Consortium
 - **INSA Rennes, Université de Rennes, CMQe Lannion, ENS Rennes**
 - **40+ involved teachers and researchers**
 - **40+ industrial partners**

ESOS – 8 teaching institutions, 2 labs

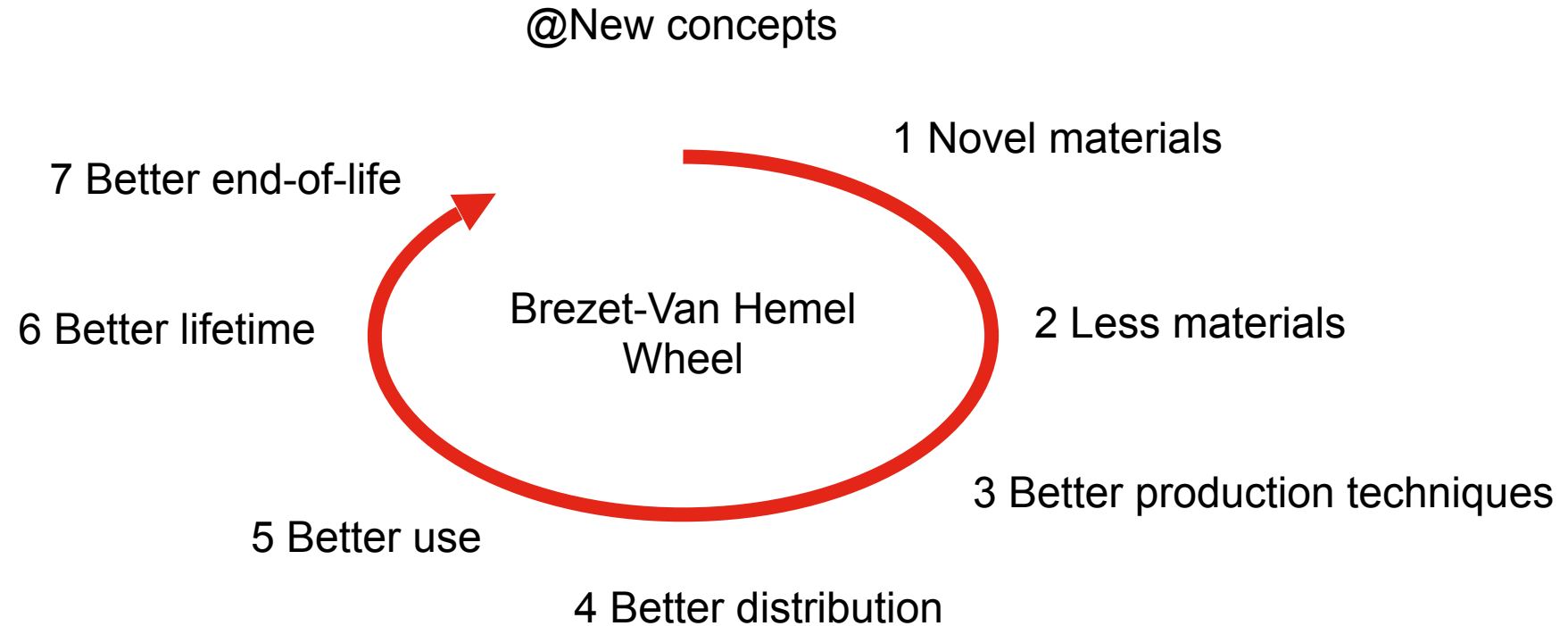


ESOS – 7 actions

- ▶ **Attract pupils** to electronics
- ▶ **Train students** to ESOS
 - Licence, master
 - INSA E-SET parcours Systèmes Soutenables et Ecoconception (SSE)
- ▶ **Train teachers** to ESOS
- ▶ **Train professionals** to ESOS
- ▶ Create **open teaching material**
- ▶ **Research and Innovation**
- ▶ <https://esos.insa-rennes.fr>



ESOS – 14 PhDs



ESOS – 14 PhDs



@New concepts

Brezet-Van Hemel
Wheel

Longer lifetime
digital systems

7 Better end-of-life

6 Better lifetime

Energy
harvesting

5 Better use

Low energy
electronics

4 Better distribution

1 Novel materials

2 Less materials

3 Better production techniques

Low impact
sensors and
antennas

Biosourced
electronics

Digital systems
ecodesign

ESOS – to benefit from the actions

- ▶ **Research Seminars**
 - <https://esos.insa-rennes.fr/recherche>
- ▶ **Industrial Brunches**
 - <https://esos.insa-rennes.fr/actualites/esos-au-brunch-de-leco-conception>
- ▶ **GreenIT Summer School**
 - <https://ecolegreenit25.sciencesconf.org>
- ▶ **Professional trainings to Electronics LCA and Ecodesign**
 - LCA : 2 days, Brightway or Ecodesign Studio, EcoInvent database
 - <https://esos.insa-rennes.fr/formations>
- ▶ **Sustainable Computing Workshop @ ACM Computing Frontiers**
- ▶ **And more to come !**



Thank you



Electronics and Ecotoxicity

- ▶ RoHS laws (2002/95/CE and 2011/65/UE) have much reduced the most toxic elements
 1. Lead (Pb)
 2. Mercury (Hg)
 3. Cadmium (Cd)
 4. Hexavalent chromium (Cr⁶⁺)
 5. Polybrominated biphenyls (PBB)
 6. Polybrominated diphenyl ether (PBDE)
 7. Bis(2-ethylhexyl) phthalate (DEHP)
 8. Butyl benzyl phthalate (BBP)
 9. Dibutyl phthalate (DBP)
 10. Diisobutyl phthalate (DIBP)

- ▶ However, all non-extracted materials end-up incinerated and/or in landfill.

- ▶ The Basel Convention regulates the transboundary movements of hazardous wastes, including WEEE, but many wastes still cross borders.