Mapping metals and material cycles on a global scale - Insights for circular economy

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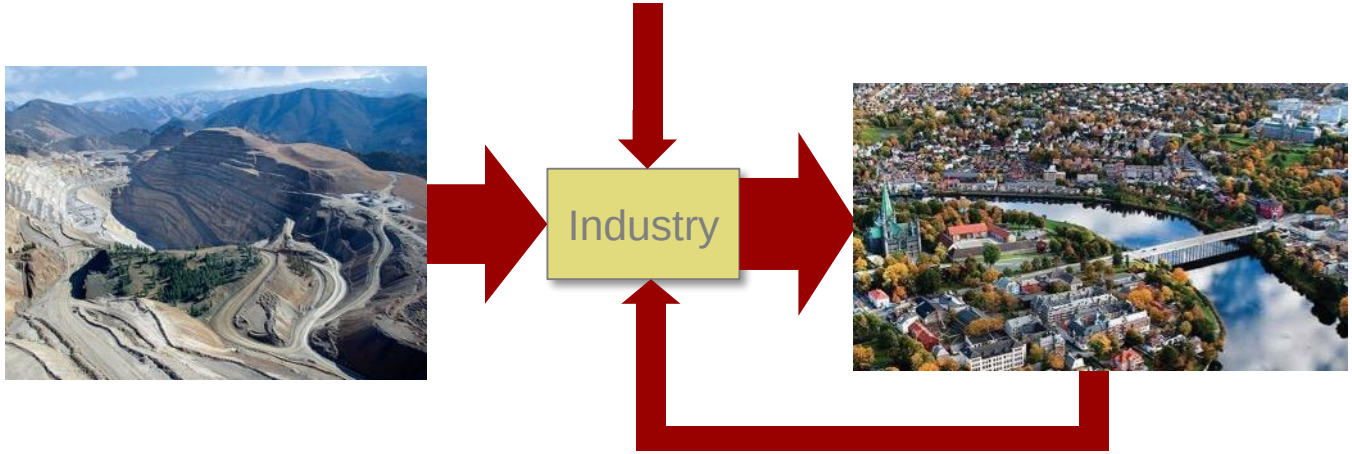
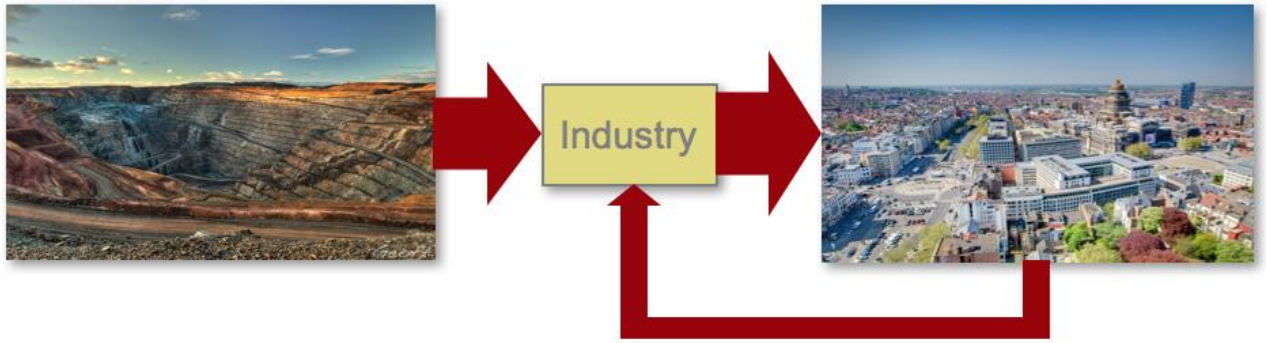
1. Motivation
2. Challenges for a circular economy
3. Examples for aluminium
4. Conclusions / hypotheses

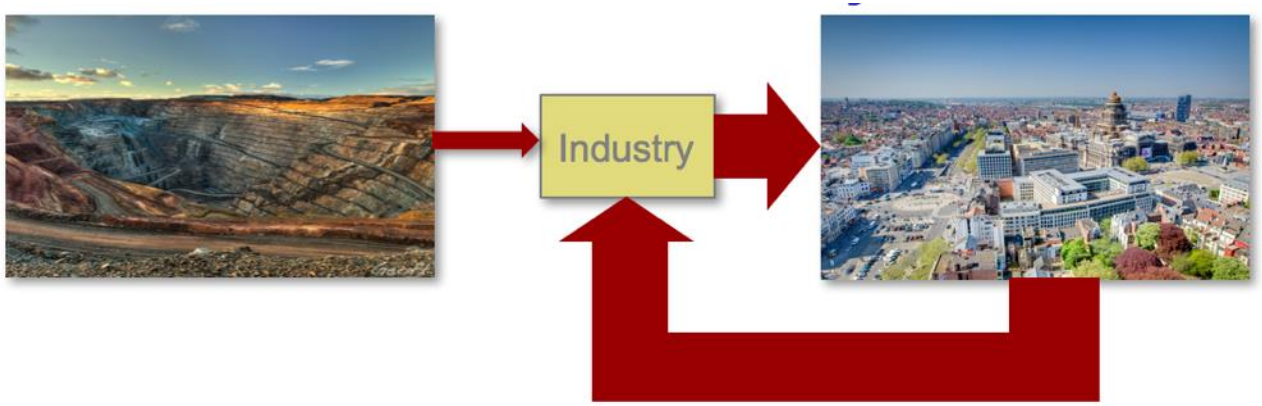


Motivation

Current economy

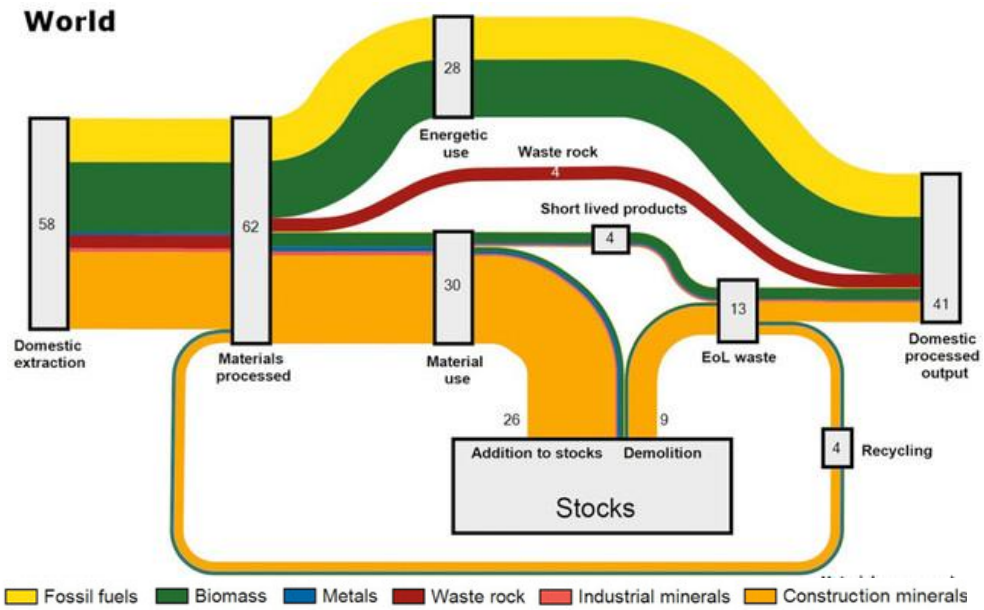


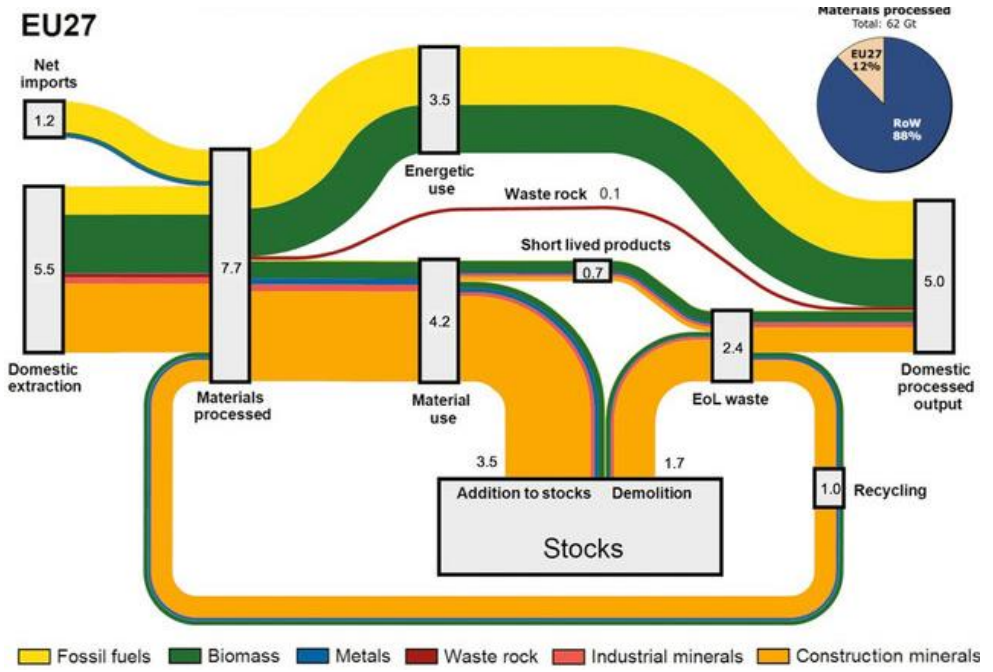
Circular economy



1. Is a circular economy better than the current economy? Why?
   - Comparison of apples and pears (growing vs. mature stock in use)
   - CE is about the form of an economy, not its purpose (including stocks…)
2. How can we move towards a circular economy?
   - Need to address quality challenges
   - Affects entire system, including stocks, materials, energy

How circular is our economy?





Source: Haas et al 2015, Journal of Industrial Ecology

Three key drivers for global material cycles

1. Population growth and urbanization / industrialization

→ Moves materials from the ground into use

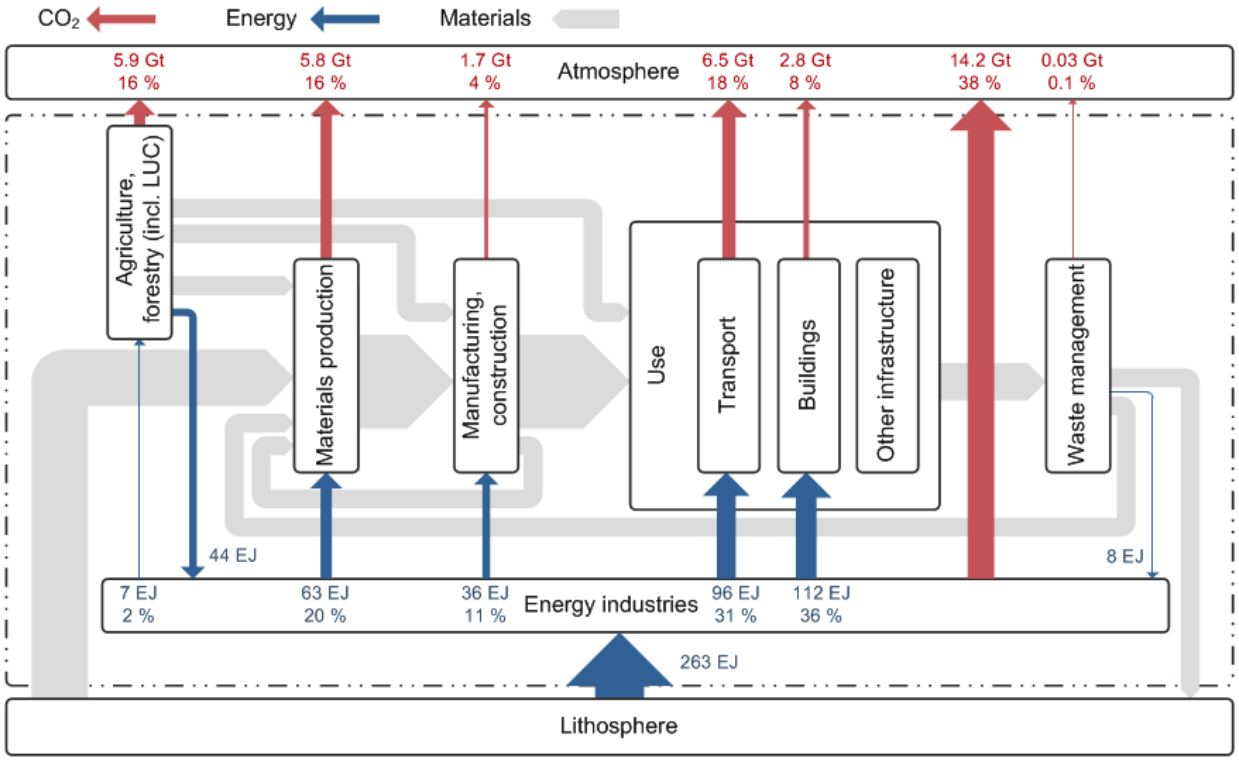
2. Globalization

→ Moves materials around the world

3. Climate change & sustainable development

→ Need for new infrastructures and changing global production and consumption patterns

Linkages between materials, energy, and emissions: "socio-economic metabolism"

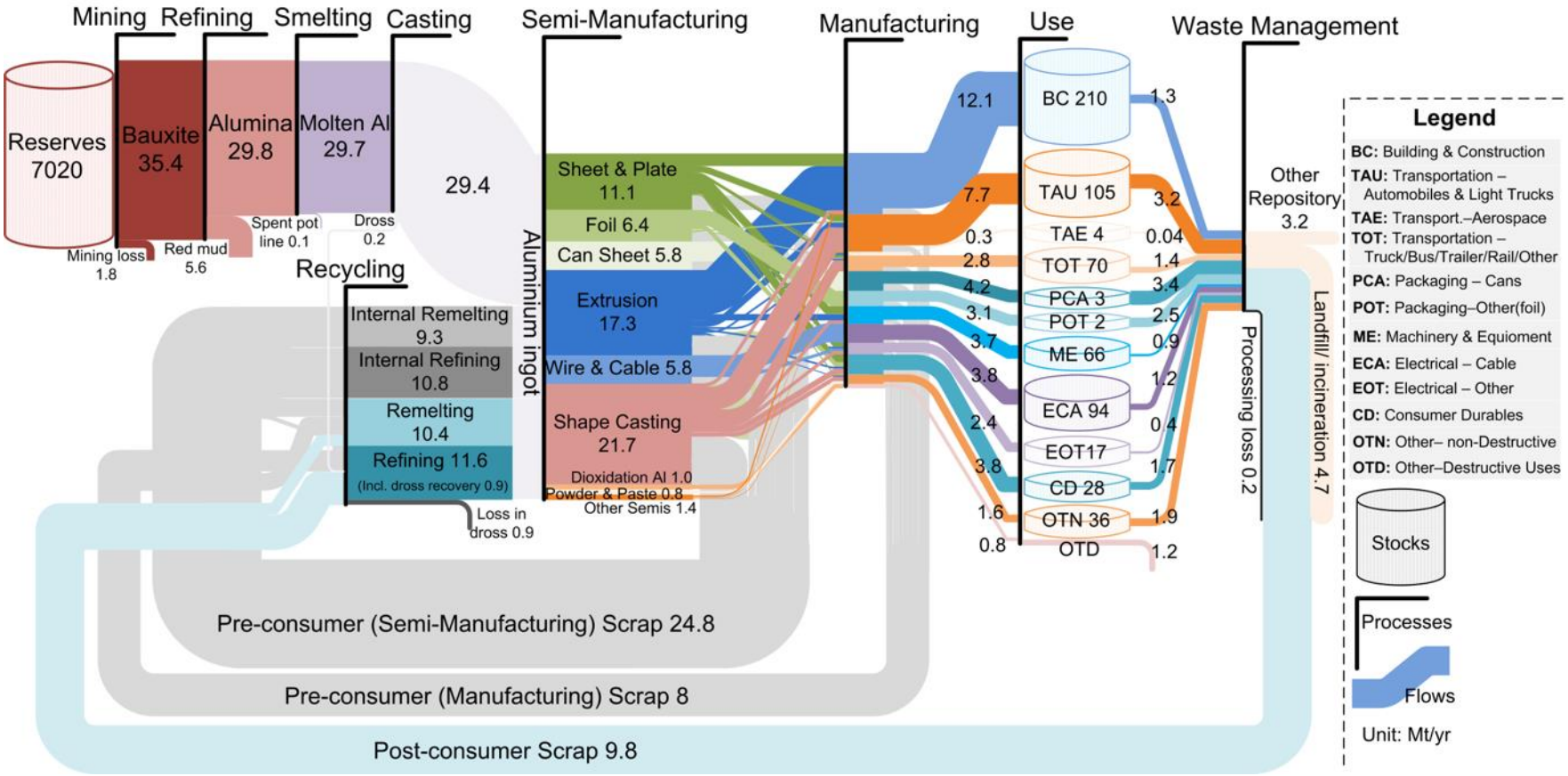


Data sources for 2008:
Emissions: EDGAR
Energy: IEA

Müller et al. 2013

1. The socio-economic metabolism shapes the quality of our life (services provided by stocks in use and environment)
2. Current socio-economic metabolism is not sustainable:
   - poverty / inequality (lack of access to essential services)
   - resource depletion, limited sinks for pollutants
3. Sustainable development requires transformation of socio-metabolic system
   → from design of processes/products to design of systems

Global anthropogenic aluminium cycle in 2009



Source: Liu, Bangs, and Müller 2012: Nature Climate Change

Is recycling better than primary production?

- Energy use is about 10 times lower
- But: scrap is scarce (in-use stocks are growing)

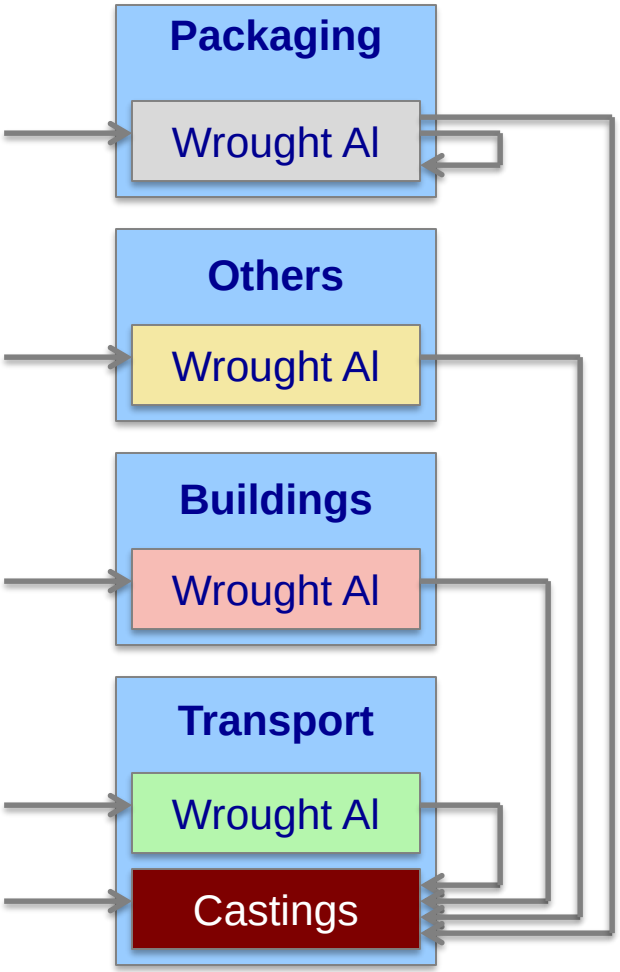
  the cycling of pre-consumer scrap leads to higher, not lower energy use

Historical development of the global trade-linked aluminium cycle

(ca. 70 million data records)

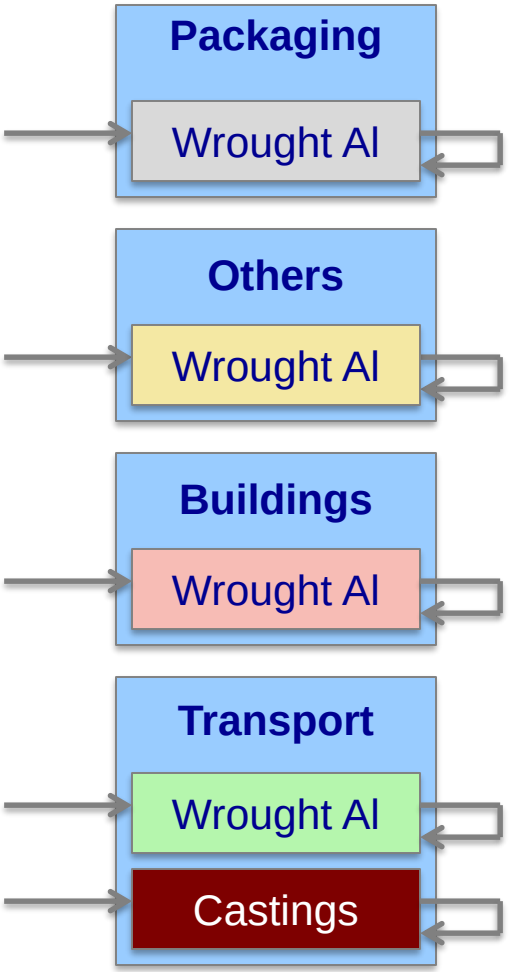
http://www.world-aluminium.org/statistics/massflow/

Today's aluminium recycling system: cascading use



- The bottom reservoir is formed by automotive secondary castings (mainly engine parts).
- **Today, the cascading system is economically and ecologically meaningful.**
  → It makes use of all the metals (aluminium, alloying elements, other elements)
  → This saves alloying elements for secondary casting
- **In the future, the same system with the same resources may become unsustainable.**
  → Increasing amounts of scrap
  → Limited capacity of engine parts to absorb this scrap
  → Scrap surplus in about a decade if cascading structure is maintained

Tomorrow's aluminium recycling system: Closed alloy cycles?



- A closing of alloy cycles would reduce the amount of scrap to be absorbed by automotive secondary castings.
  → Use scrap for a wider range of applications (sinks)

Conclusions (1)

1. **Materials, energy, and emissions form complex metabolic systems.**
   Dynamic MFA models allow users to anticipate potential challenges
   and to evaluate alternative strategies.

2. **The global economy is far from circular.**
   → Currenty limiting: growing stocks in use
   - urbanization & industrialization
   - less abundant metals: energy and cleaning technologies
   - light metals: fuel saving
   incomplete recovery of end-of-life products
   → Future limiting: more old scrap → quality challenges for closing cycles
   access to critical raw materials (?)

3. **Recycling targets: more is not always better**
   - Pre-consumer scrap recycling: inefficiency causing more resource use
   - Post-consumer scrap recycling: effectively saves resources (ore & energy)
   but even better if products are still used
   → The most resource saving economy is one without (need for) recycling

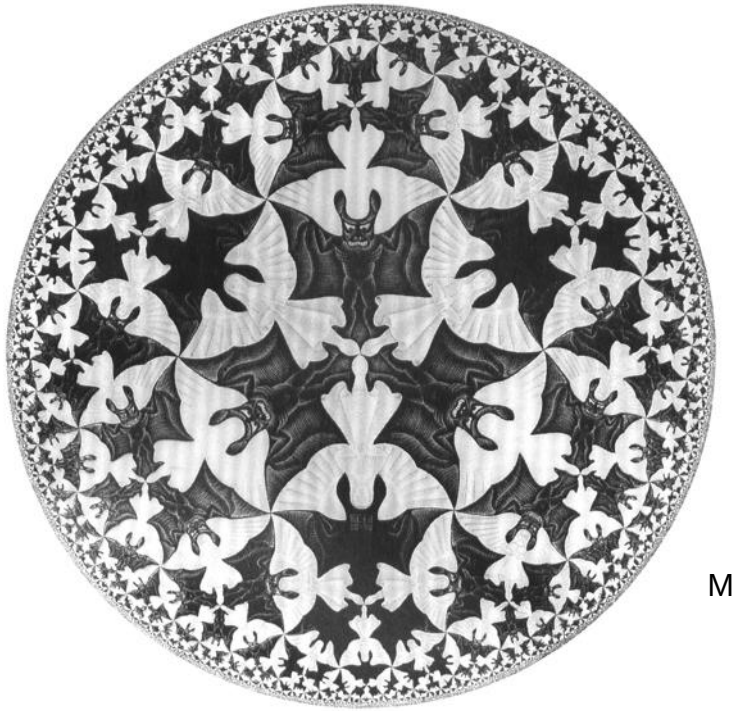
Conclusions (2)

4. **A circular economy should be regarded as a mean, NOT as an end**
   → It can support the reaching of several SDGs
      - 12: Responsible consumption and production
      - 13: Climate action

   → It may be in conflict with the reaching of other SDGs
      - 1: Poverty alleviation
      - 7: Affordable and clean energy
      - 8: Decent work and economic growth
      - 9: Industry, innovation, and infrastructure

   → Need for systems approaches to support priority setting

Angels or devils?
It depends on the system definition



M.C. Escher (1960): Circle Limit IV

Thank you!

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