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GLOBAL SUSTAINABILITY EFFECTS OF MICRO TECHNOLOGICAL ADVANCES – SOME CONCEPTUAL THOUGHTS

Kirsten S. Wiebe

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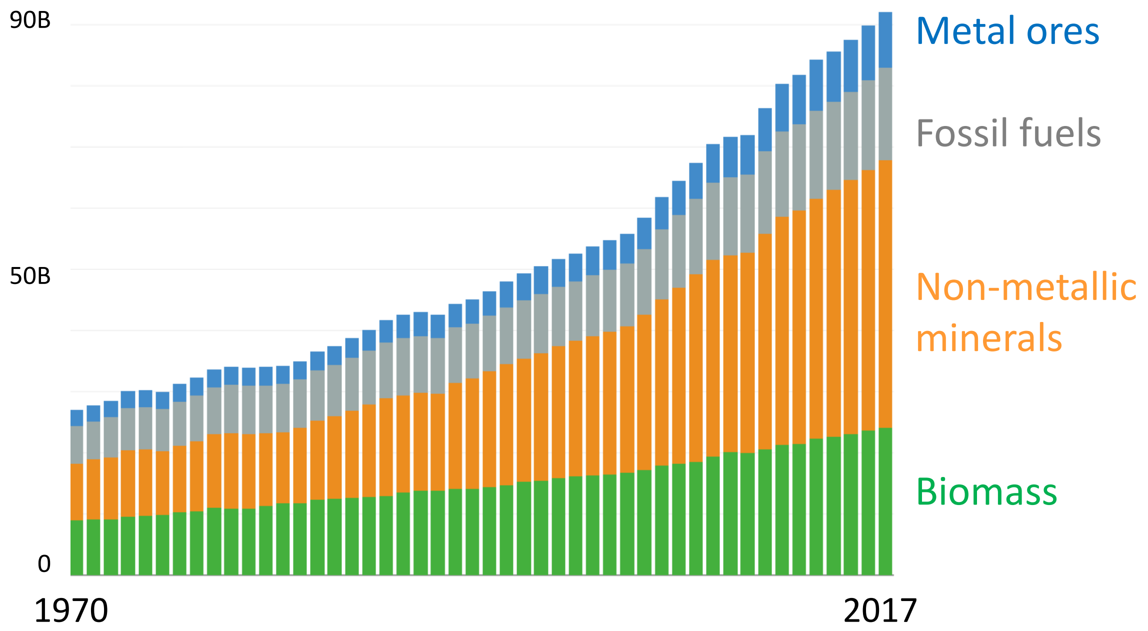
Technological advances are vital for the transformation to a more circular economy

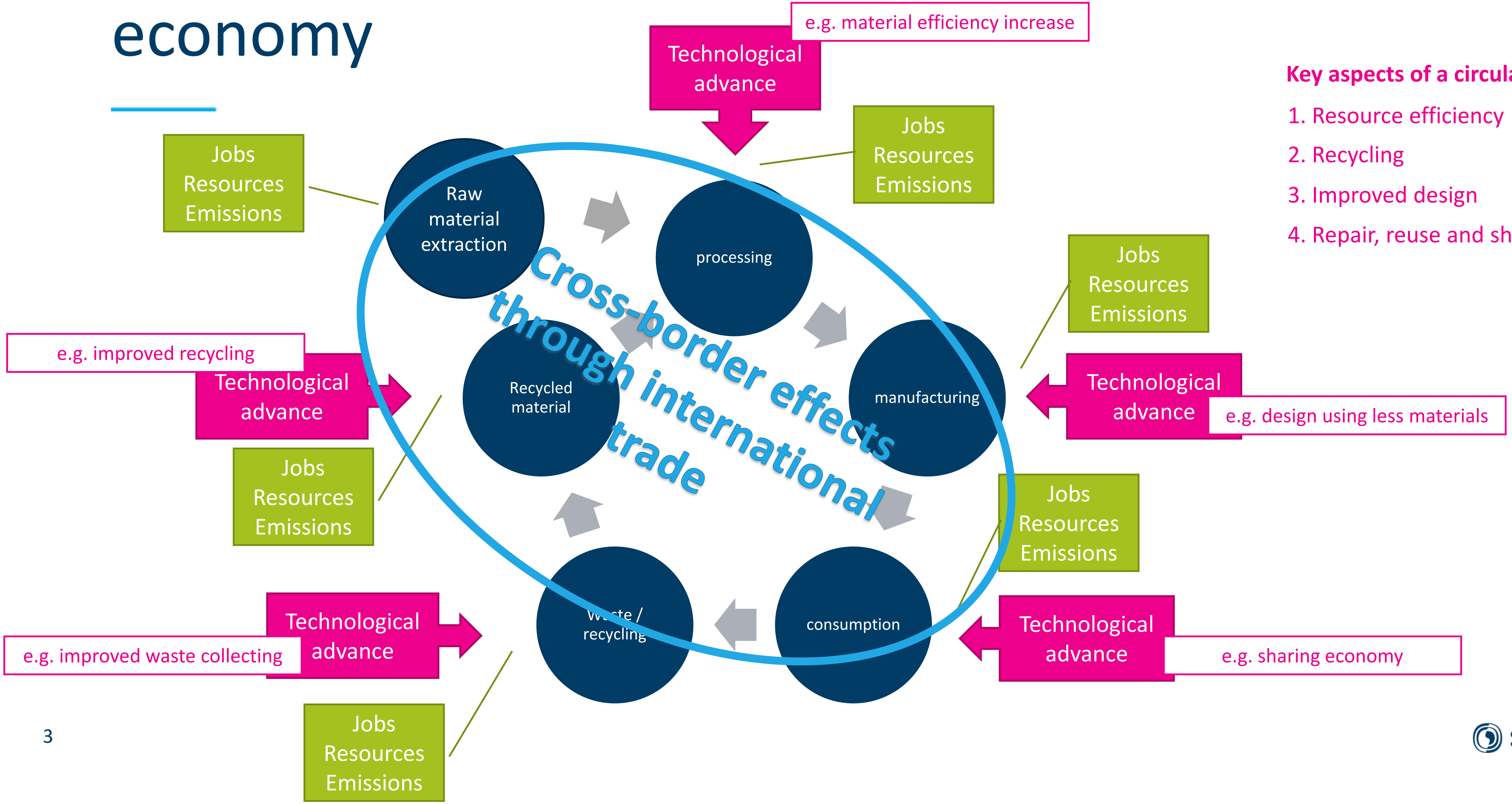
- Raw material extraction has tripled in the last 50 years
- "Decouple natural resource use and environmental impacts from economic growth" (UNEP *et al.*, 2011)
- Systemic transformation
  1. Reduce
  2. Recycle
  3. Repair & reuse
  4. (Re-)design

Global material extraction



Reference-Disclaimer: WU Vienna (2019): Material flows by material group, 1970-2017. Visualisation based upon the UN IRP Global Material Flows Database. Vienna University of Economics and Business. Online available at: materialflows.net/visualisation-centre

Technological advances for a more circular economy



Key aspects of a circular economy

1. Resource efficiency
2. Recycling
3. Improved design
4. Repair, reuse and share

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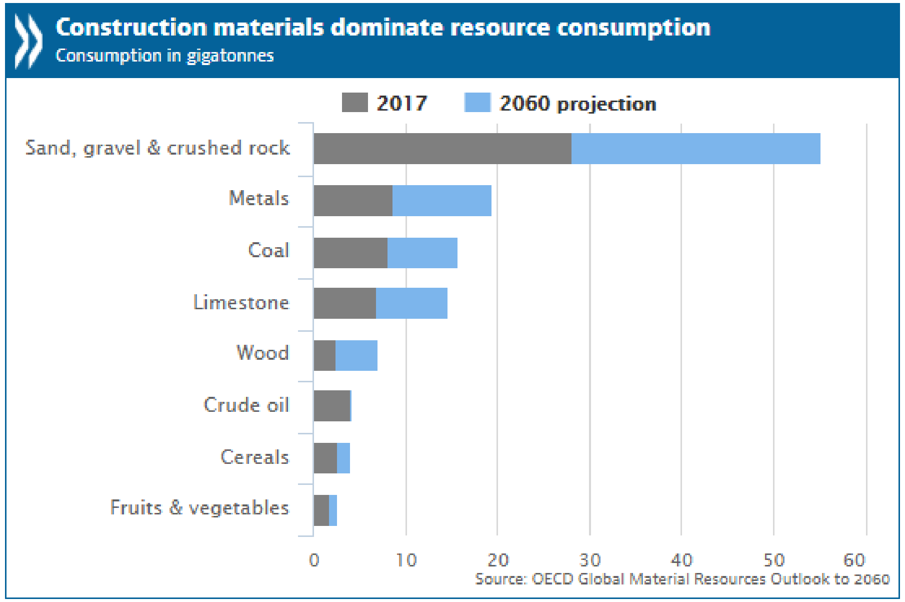
Importance of raw materials and raw material trade

Raw materials use to double by 2060 with severe environmental consequences



OECD trade policy brief – Conclusions

- No country is self-sufficient in key raw materials.
- How revenue from the mining sector is spent is as important as how much is collected.
- Export restrictions are not the best way to support or create a downstream processing industry

https://www.oecd.org/environment/global-material-resources-outlook-to-2060-9789264307452-en.htm

Global sustainability effects of micro technological advances towards a more circular economy

Aim

- Identify effects on economy, society and environment that occur globally due to advances in a certain technology

Scope

- Analyse impacts on/effects along upstream and downstream value chains
  - within the country and abroad – cross-border effects
  - within the industry and, indirectly, in other industries
  - Economic (value creation), social (employment and related), environmental (emissions to and resource extraction from the natural environment)

Technological change & global value chain (GVC) effects – Questions to ask

- What is new compared to the incumbent technology? e.g.
  - Changed production structure of old technology
  - Entirely new technology replacing old technology
- What are the most important differences in the input structure of the technology production?
  - Which industries/countries produced the old intermediate inputs?
  - Which industries/countries produce the new intermediate inputs?
- How important is that new component (raw material/intermediate good)
  - For global trade in this component ?
  - For the affected industry in certain countries?
- What are the most important differences occurring through the use of the new technology? e.g.
  - Are there more or less people employed?
  - Is more or less capital and other resources required?

System wide analysis tools

- **Life-cycle Assessment (LCA)**
  Looking at the cradle-to-grave environmental pressures of individual products
- **Life-cycle Impact Assessment (LCIA)**
  Adds conversion to environmental impacts (e.g. GWP, biodiversity loss) to LCA

➔ Mostly not considering country-differences

- **Material-flow analysis (MFA)**
  "Captures the mass balances in an economy where inputs (extractions + imports) equal outputs (consumption + exports + accumulation + wastes)" *
- **Multi-regional input-output analysis (MRIO)**
  Representation of monetary flows through the economy at the meso-level, including **trade**, and country-specific impacts

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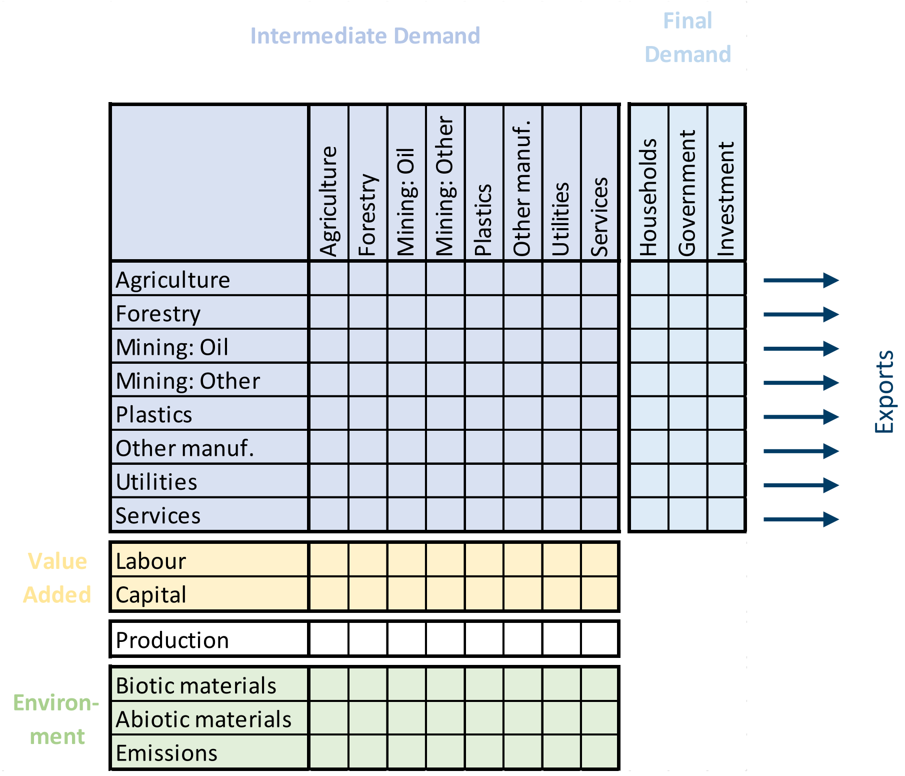
*https://www.sciencedirect.com/topics/engineering/material-flow-analysis

Global value chain (GVC) analysis using input-output (IO) data

Input-output (IO) analysis

- IO tables give a detailed snapshot of a country's economy
- IO tables are consistent with the System of National Accounts (SNA)
- Production and use of intermediate and final products by industry/economic actor
- Factor input use (e.g. labour, capital) by industry
- Direct / indirect / induced effects of technological change on the economy

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y}$$



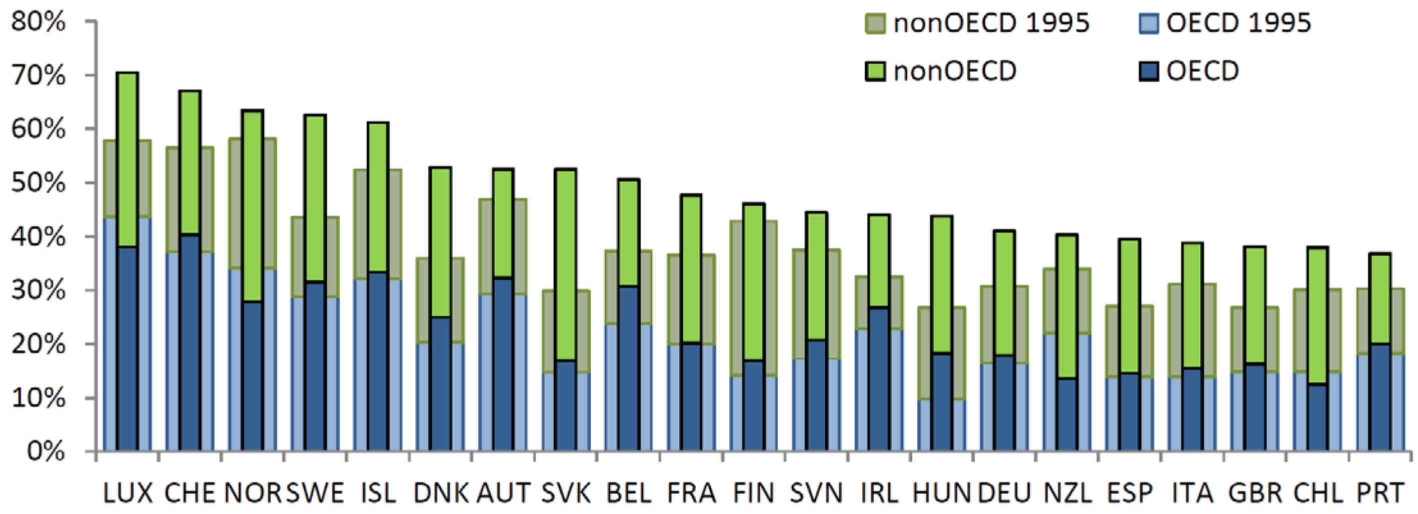
Global value chain (GVC) analysis using input-output data

Global IO analysis

- Linking national IO tables using bilateral trade data at the product group level

- Two major drivers
  - OECD/WTO Trade in Value Added (TiVA) initiative
  - Environmental footprints of countries

Figure 7: Share of CO_2 emitted abroad in total CO_2 embedded in domestic final demand



Wiebe, K. S. and N. Yamano (2016), "Estimating CO2 Emissions Embodied in Final Demand and Trade Using the OECD ICIO 2015: Methodology and Results", *OECD Science, Technology and Industry Working Papers*, 2016/05, OECD Publishing, Paris. http://dx.doi.org/10.1787/5jlrcm216xkl-en

Limitations and opportunities of GVC analysis of micro-technological advances based on global IO data

Limitations

- Aggregated industries/product groups
  - Impossible to correctly represent most micro technological advances
- Missing data for resource rich developing countries

Opportunities

- Use the GVC thinking for individual technologies, by including bilateral trade data
- Complement other value chain analysis tools, e.g.
  - LCA by considering the effect of the product on the value chain and impacts across borders
  - Environmental impact assessment by providing socio-economic and environmental analysis in a consistent framework

Micro to global

Micro technological advances

- Replacing one input by another
- Reducing material inputs

Detailed global bilateral trade databases

- UN COMTRADE https://comtrade.un.org/
- OECD Balanced International Merchandise Trade Statistics (121 countries, 57 products) https://stats.oecd.org/Index.aspx?DataSetCode=BIMTS_CPA
- OECD Bilateral Trade in Goods by Industry and End-use (BTDIxE), ISIC Rev.4 https://stats.oecd.org/Index.aspx?DataSetCode=BTDIXE_I4 (171/208 countries, 99/109 Industries)

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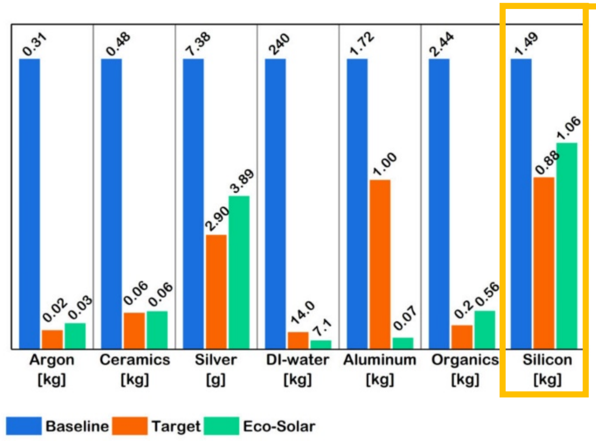
Example: solar panel

Upstream: Reduce
Downstream: Recycle & reuse
Upstream: even more reduction

EU project ECO Solar with SINTEF participation

Ressursforbruk for produksjon av et multikrystallinsk panel med 60 solceller



Number of solar panels Eco-Solar 40% more than Baseline

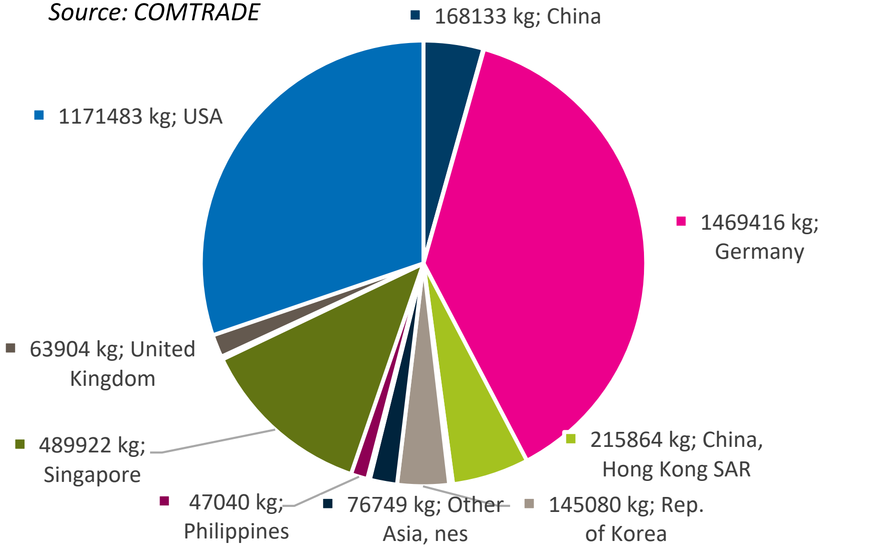
30% less environmental pressures

Grafen viser besparelsene innenfor en rekke viktige materialer som brukes i dagens solcelleproduksjon. Den blå søylen viser dagens normalforbruk, den oransje søylen viser forskernes mål i prosjektet. Den grønne søylen viser faktisk forbruk med bruk av ECO-Solar konseptet. Illustrasjon fra prosjektet.

https://gemini.no/2019/04/dette-er-verdens-gjerrigste-solcellepanel/

Trade in relevant raw materials: Silicon containing by weight not less than 99.99% of silicon (HS 280461)

Source: COMTRADE



Norway's imports in 2017: 3875 t → low importance for global market

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Example: batteries & other electronics

Just imagine

Less environmental pressures

Social pressures: less employment, but also less dangerous employment

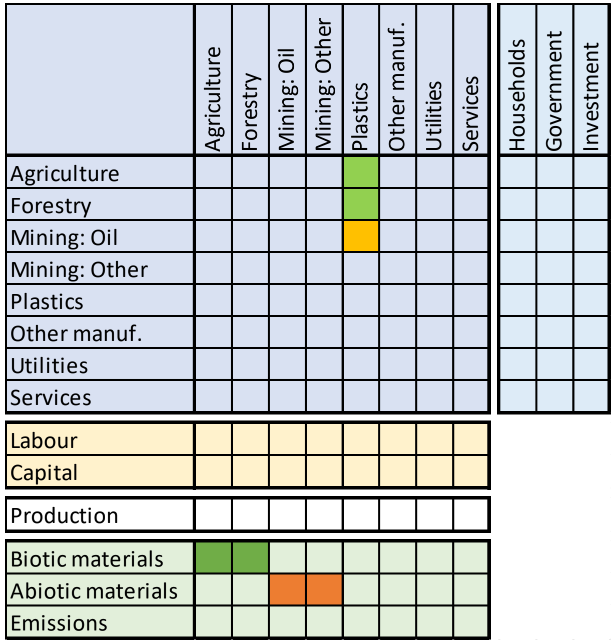
Lithium in Chile

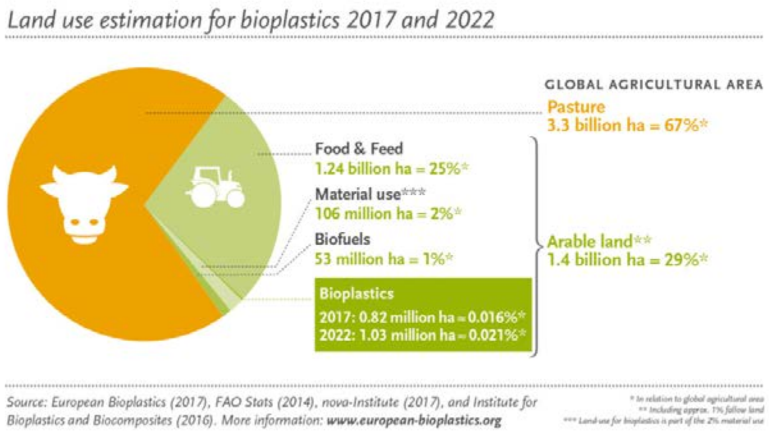
Cobalt in DR Congo

Example: Bioplastics

Differences in production

- Raw materials
  Oil vs starch, cellulose, wood, sugar
- 8% of global oil is used for plastics
- Increasing use of biomass
  - Pollution from fertilizers
  - Food-feed-fuel discussion will not necessarily
    be food-feed-fuel-plastics





https://www.european-bioplastics.org/bioplastics/materials/

Example: Bioplastics

Upstream: GVC changes
Downstream: less environmental impacts

Differences in production

- Raw materials
  Oil vs starch, cellulose, wood, sugar
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    be food-feed-fuel-plastics

Trade related impacts

- Oil production is concentrated in few world regions
- Bio-based materials can be produced globally

Use of results

Industries / companies

- Be aware of non-cost related impacts outside the direct supply chain/network
- Link of companies' actions to global environmental pressures, e.g. raw material scarcity
- Reduce dependencies
  - Reduction in material inputs
  - 'In-house' recycling

Policy

- Consider environmental impacts outside national borders
- Distribute employment effects around the world
- Decrease import dependencies

Take away

We need to combine economic, environmental, and social impact analysis, and explicitely consider international trade to assess global sustainability!

- Indirect effects on society and environment should always be estimated to avoid potential negative implications of a technology that's originally designed to be "good" = "green"
- Micro-technological advances need to be deployed at a large scale in order to foster a global shift towards a more circular economy
- If this is done, international raw material markets might be affected to a large degree in two ways
  - Shortages of materials needed for new technologies might arise
  - Raw material extraction countries might suffer if the raw materials are increasingly replaced by recycled materials (or lower demand through reuse and sharing)

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Teknologi for et bedre samfunn