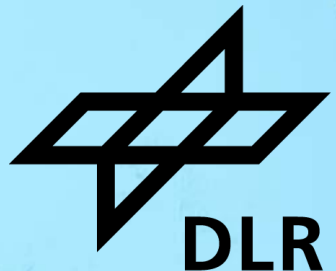


# QUANTIFYING CIRCULAR DESIGN: METRICS FOR SUSTAINABLE INNOVATION

Enric Prats-Salvado, Nicole Carina Neumann, Nipun Jagtap, Steffen Schlosser, Jens Bachmann, Nathalie Monnerie, Martin Roeb, Tobias Naegler, Tom Lorenz.



# Circularity @DLR: Project MaTiC-M



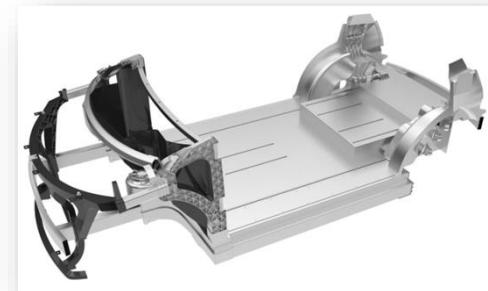
## 1. Development of a data-based Design for Circularity methodology:

- Consideration of recycling aspects in the product design
- Testing with DLR technologies

## 2. Sustainable designs for DLR technologies (use cases) in the fields of aviation, transportation and energy

## 3. Digital platform for product developers

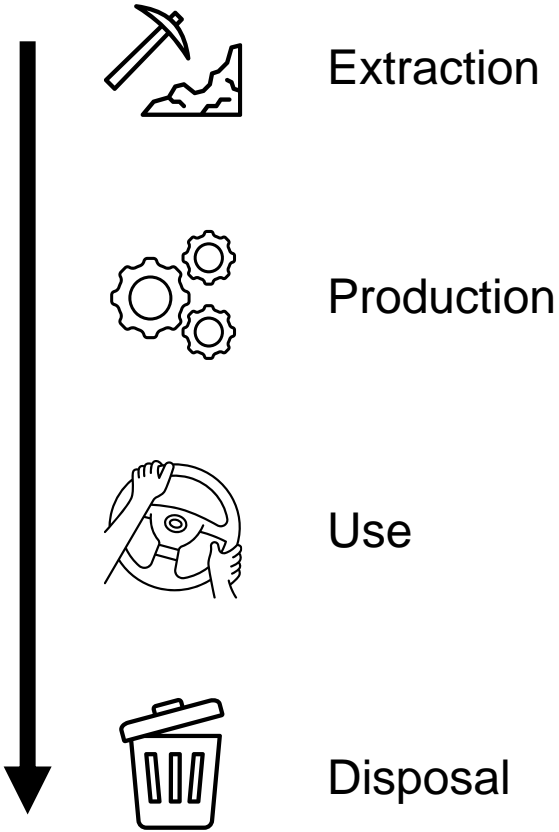
- Overview of design options and their effect on recycling potential
- Other aspects to be considered (economic, environmental...)



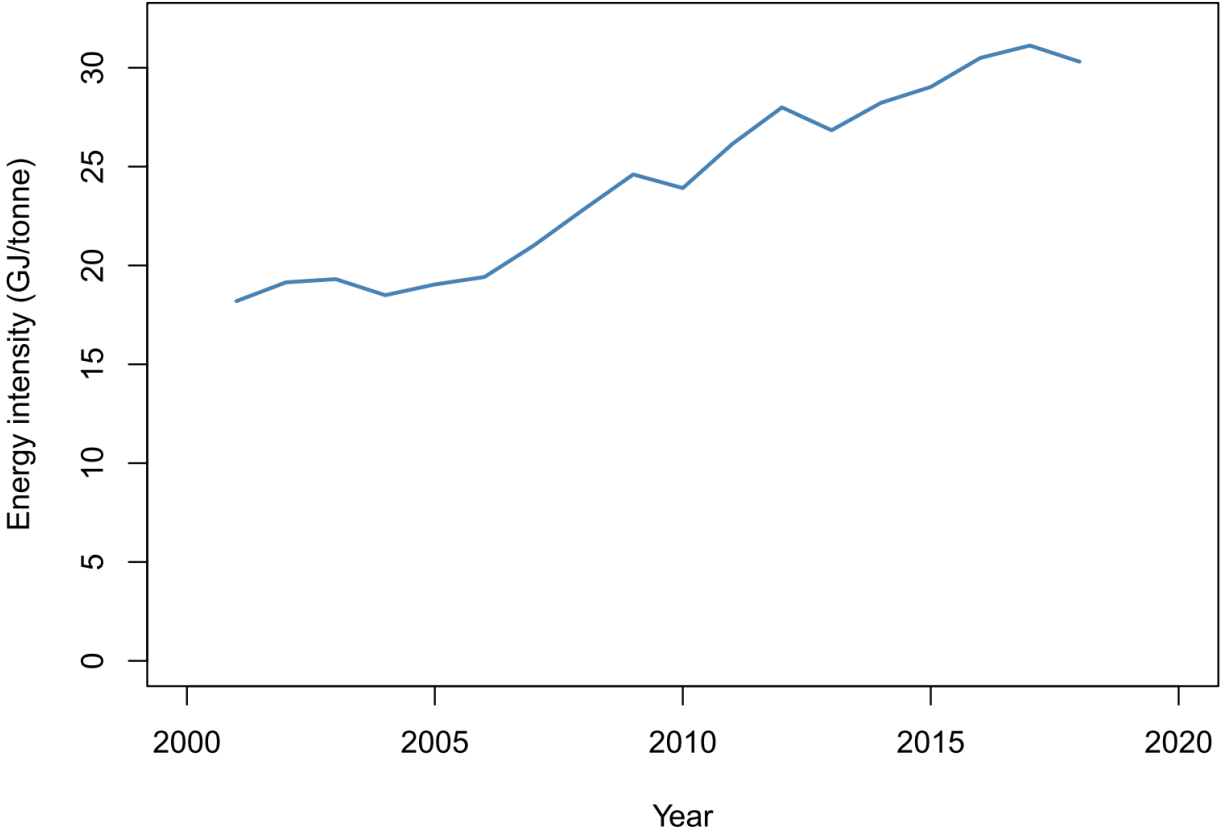
[2]

[2] <https://corporate.transavia.com/corporateit/-/media/Images/Public/Corporate/interior-fleet.jpg?h=683&la=it&w=1024&hash=4032734A9284E77C88127421FCEB0DED>

# Introduction: linear economy

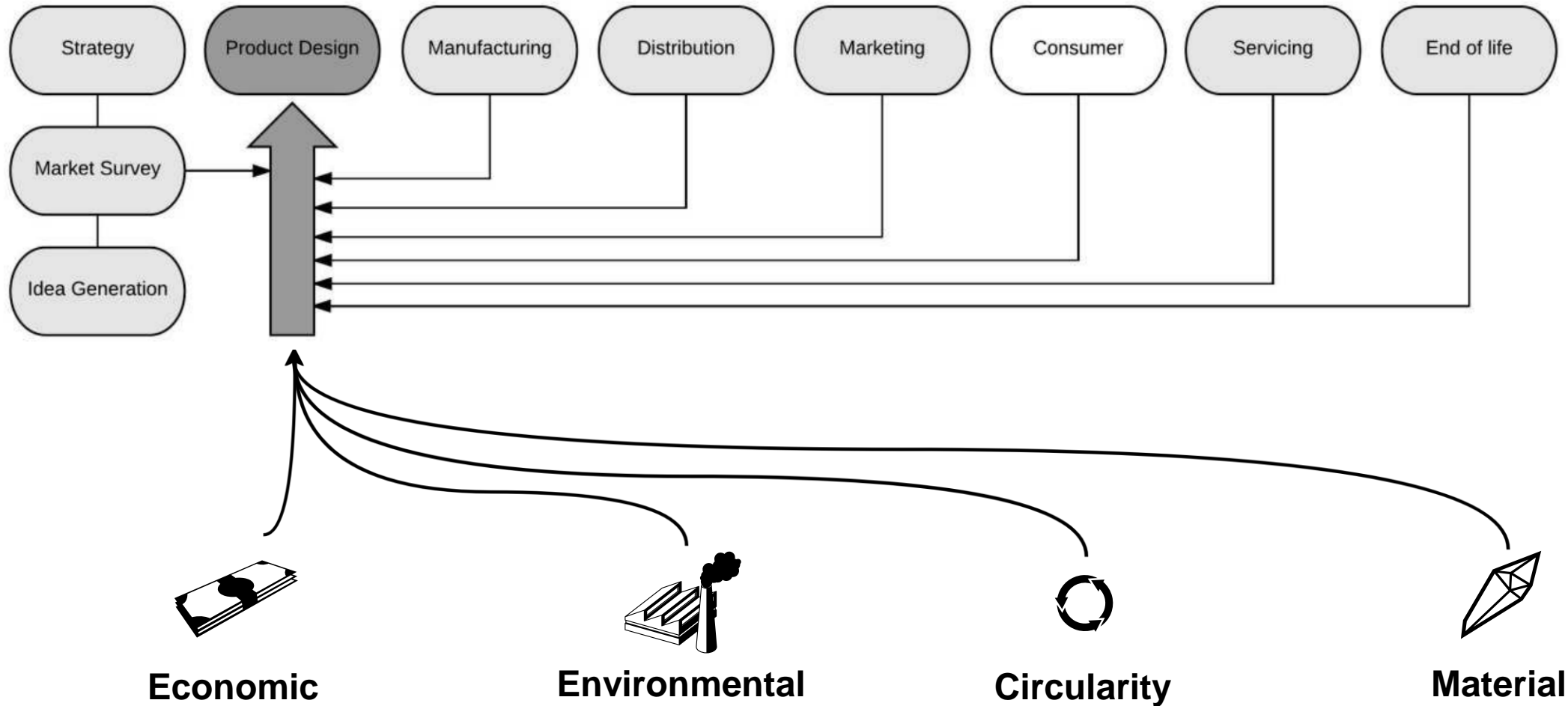


Energy intensity of copper mining in Chile:



Source: Aramendia 2023

# Design for Circularity



# Suggested Metrics



**Economic**



**Environmental**



**Circularity**



**Criticality**

**Units**

€/FU

kg CO<sub>2</sub>e/FU

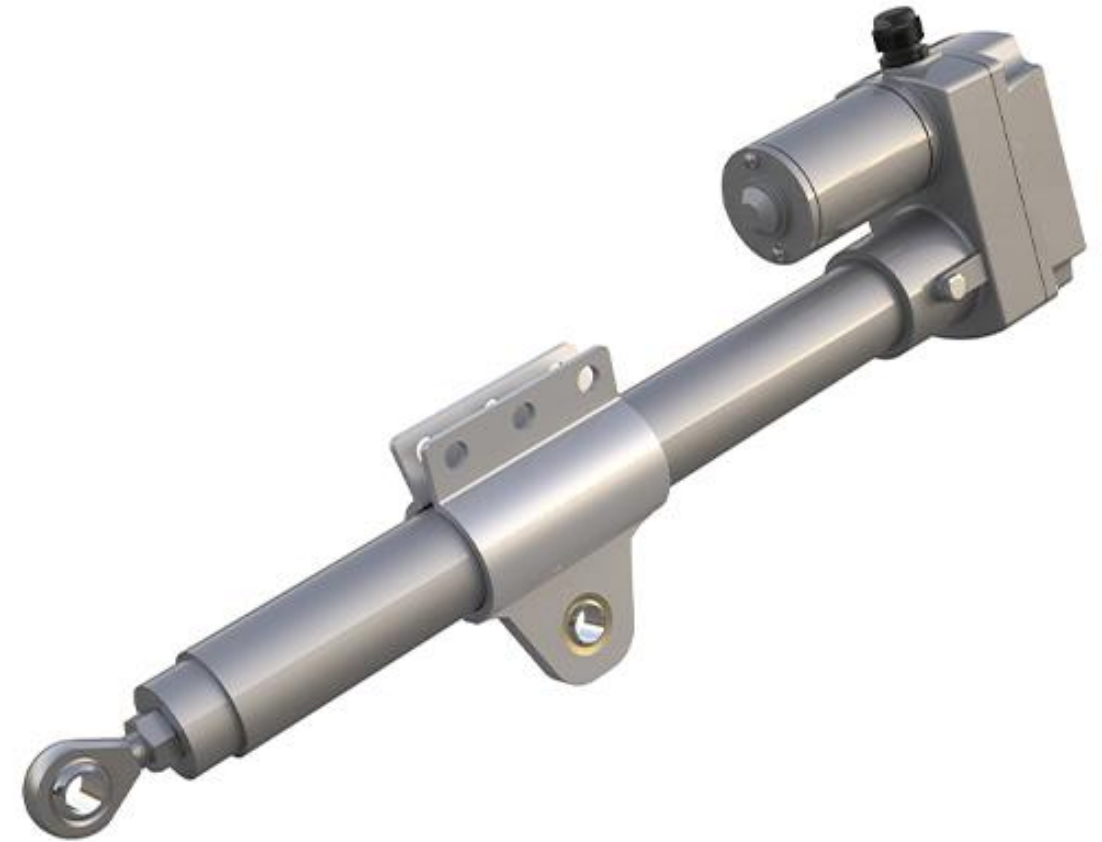
0-1 Factor  
(0 = fully linear  
1 = fully circular)

Criticality score  
(arbitrary units)

**FU:** Functional unit (e.g. 1 linear actuator)  
**CO<sub>2</sub>e:** CO<sub>2</sub> equivalent to account for all greenhouse gases

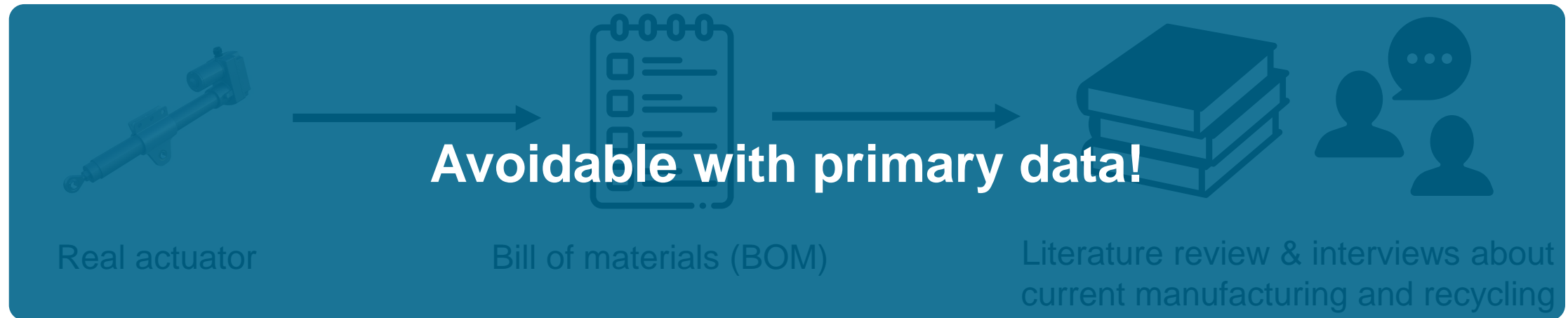


# Application of metrics: Linear actuator



**Electric linear actuator for heliostats**  
(GRA-3000 by G-ROCK Technology)

# Methodology: How do we calculate the metrics?

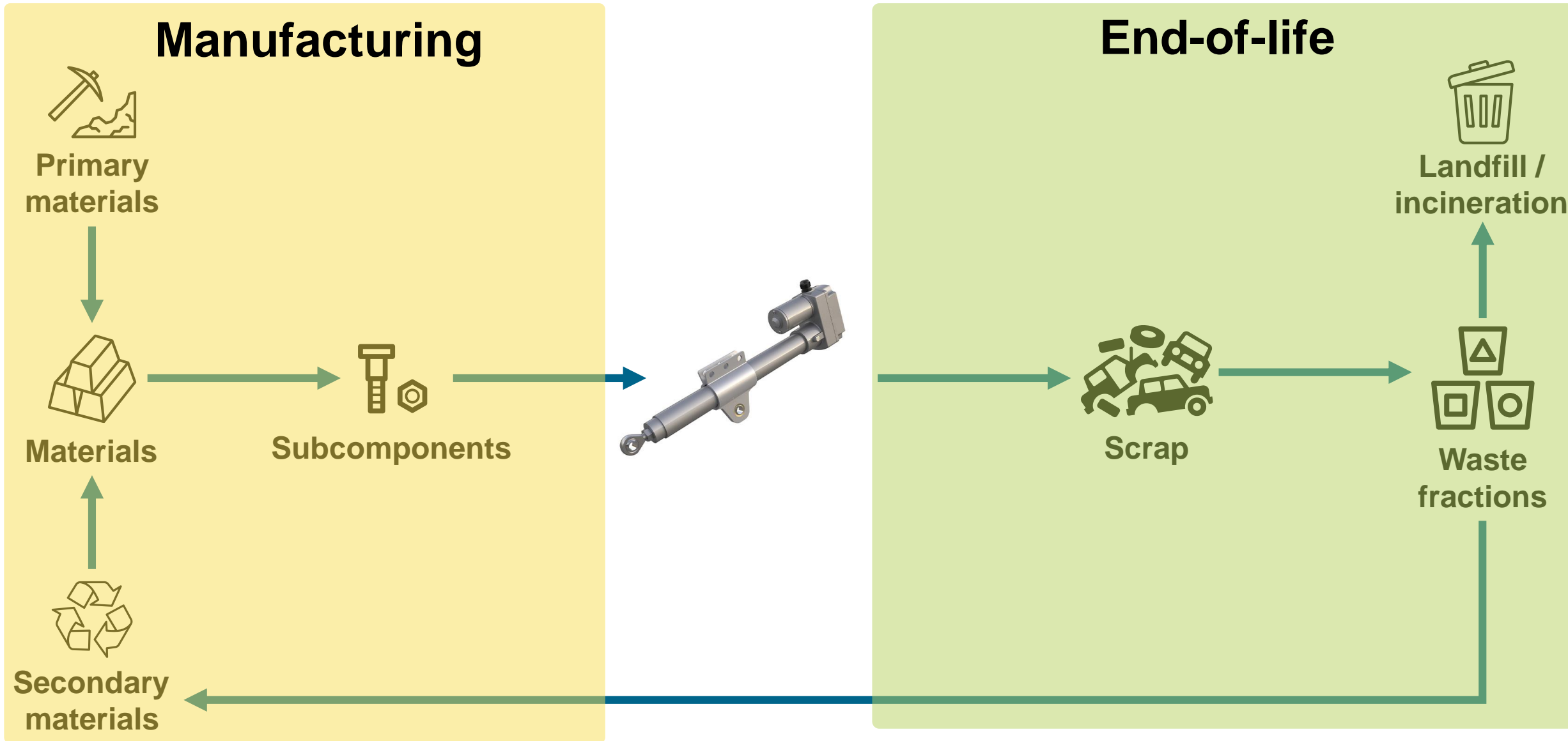


Manufacturing & end-of-life models



Value for each indicator before implementing DfC improvements

# The life cycle of an actuator

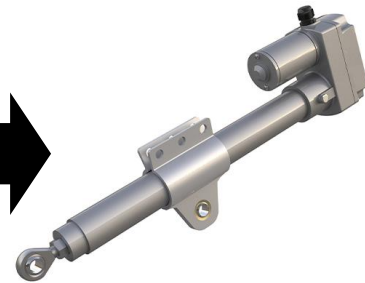
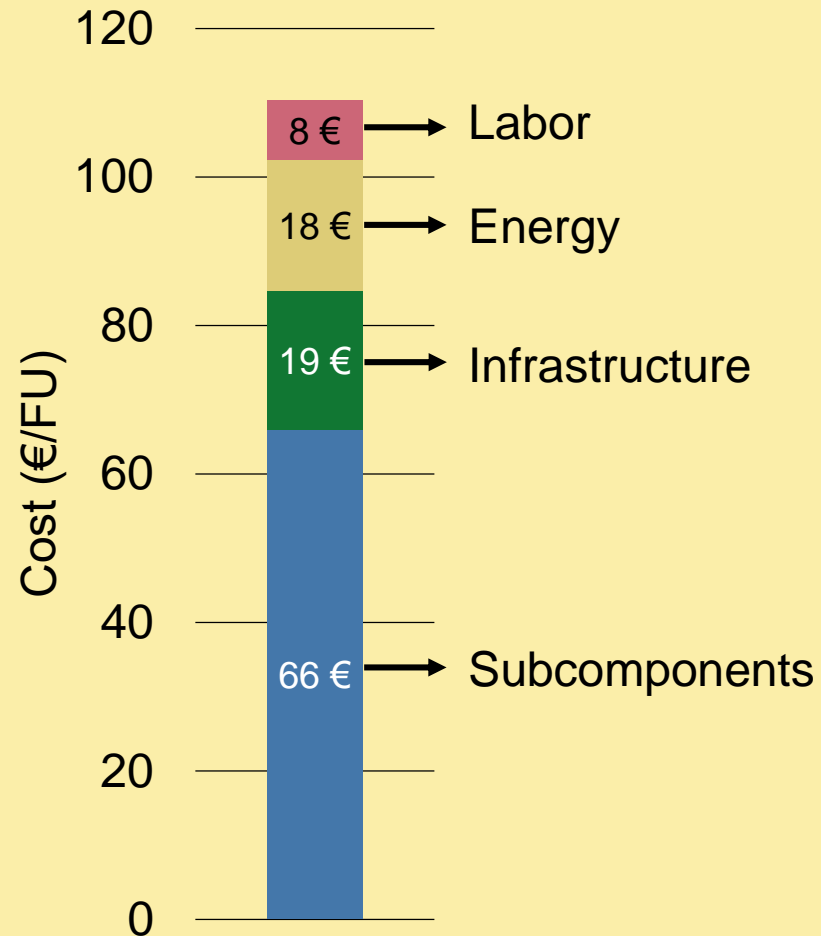




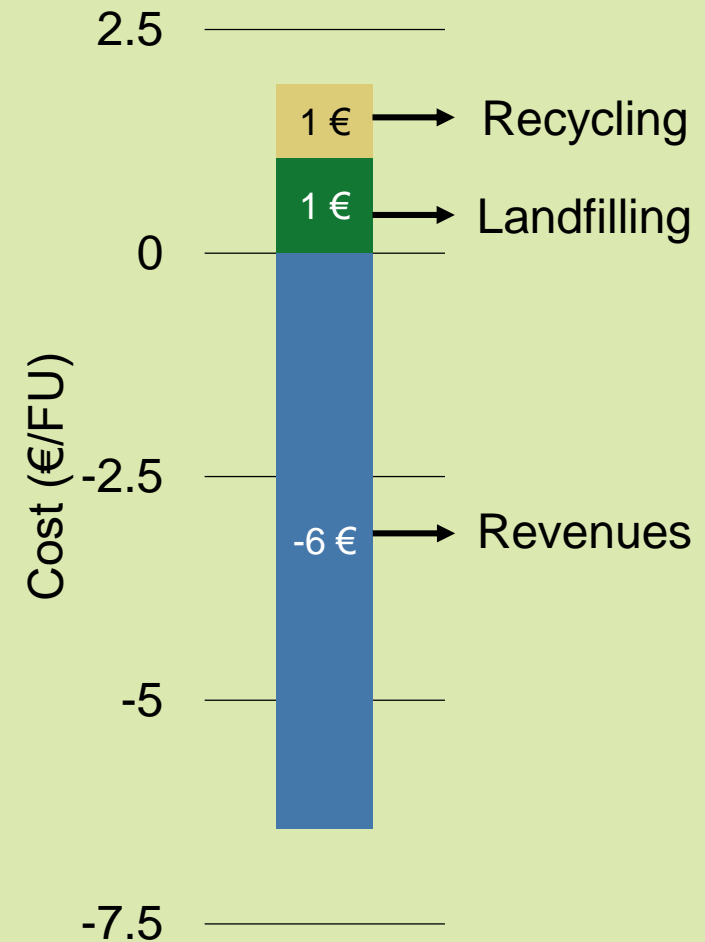
# Economic Indicator



## Manufacturing (110 €/FU)



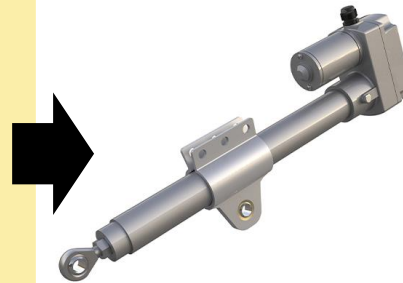
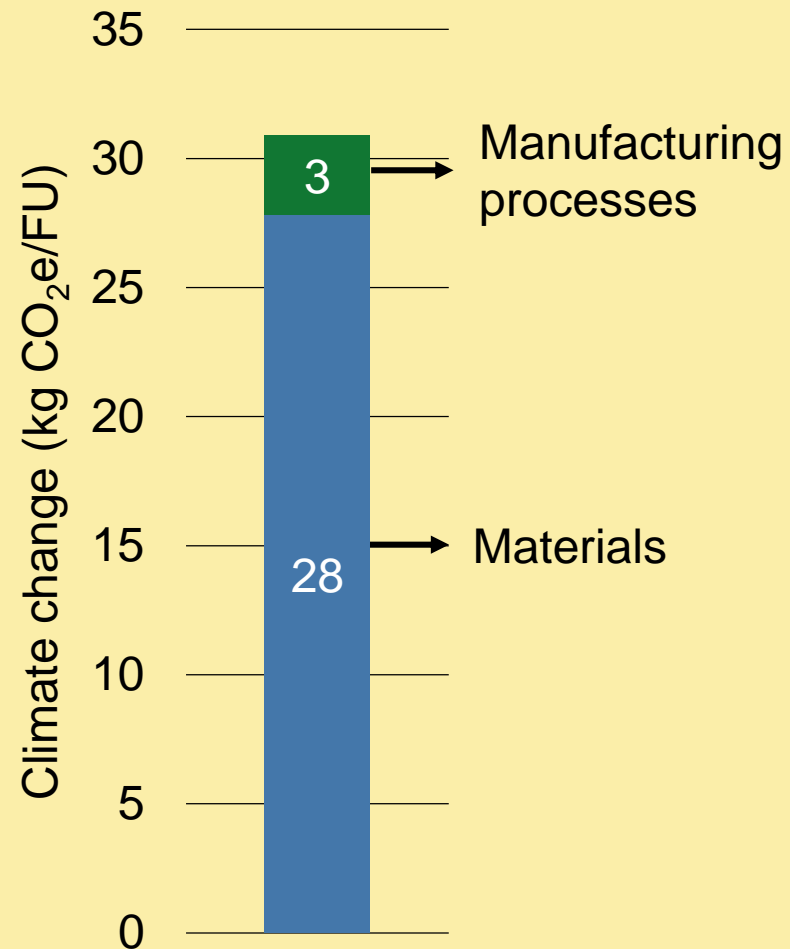
## End-of-life (-4 €/FU)



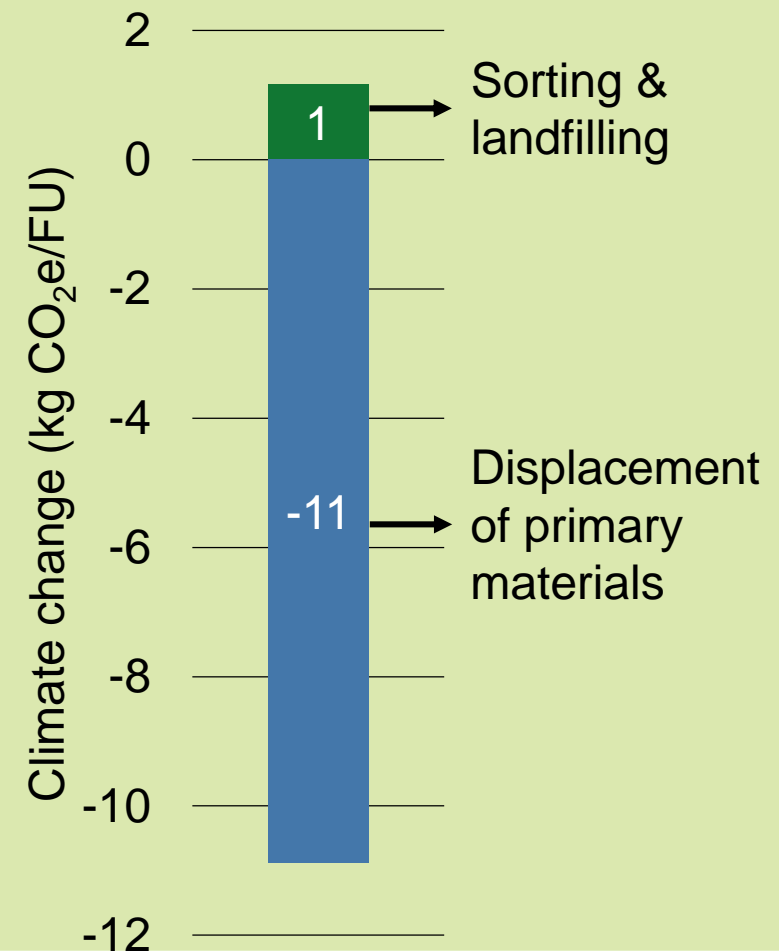
FU: Functional unit

# Environmental Indicator

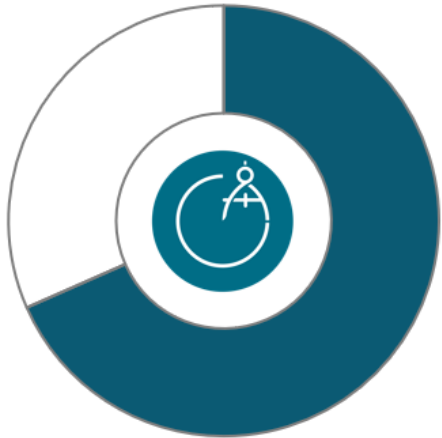
## Manufacturing (31 kg CO<sub>2</sub>e/FU)



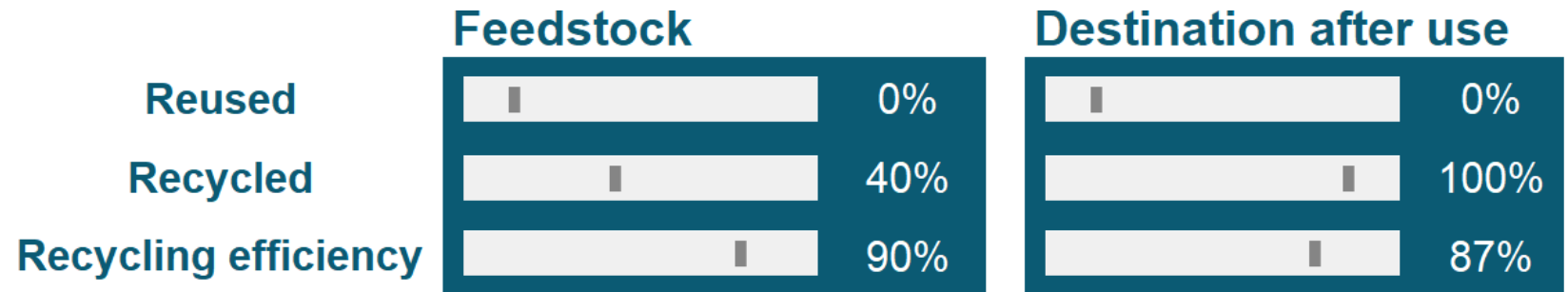
## End-of-life (-10 kg CO<sub>2</sub>e/FU)



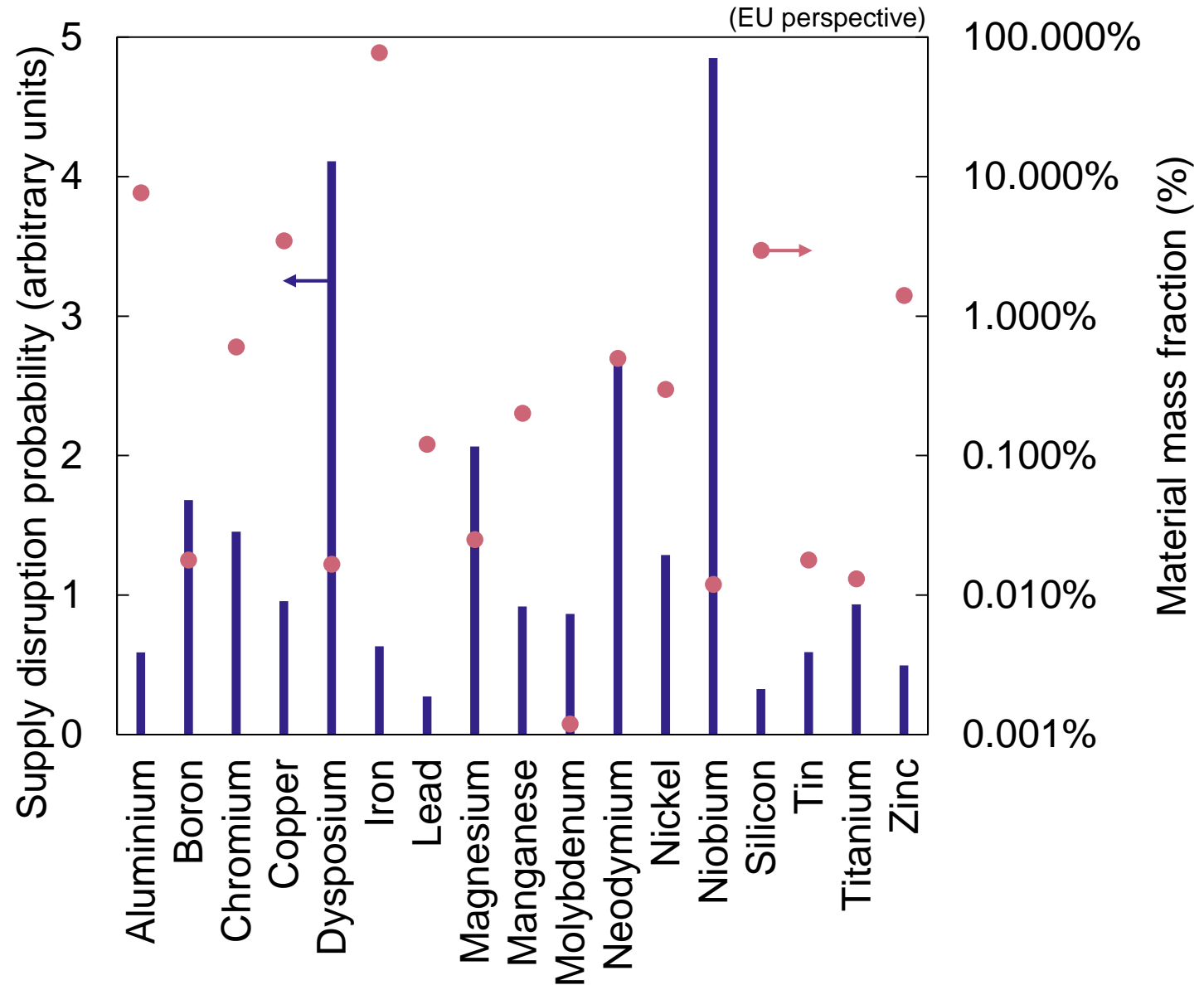
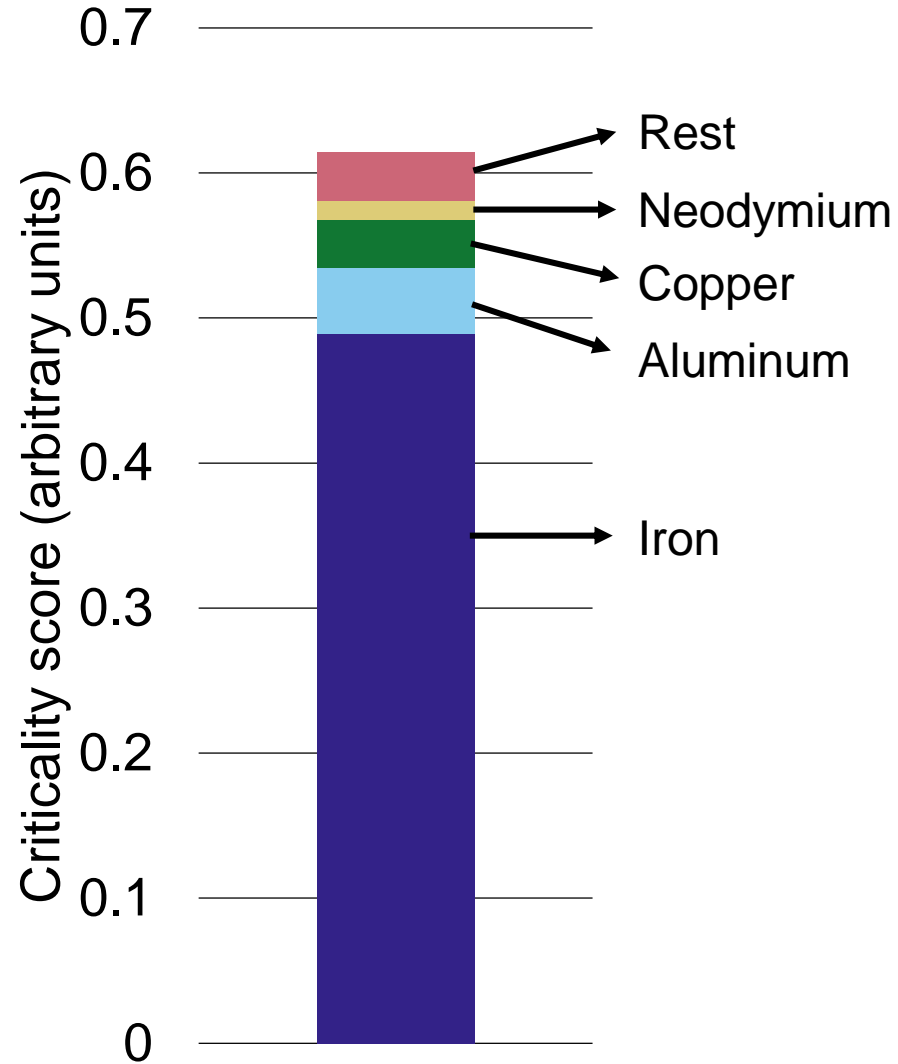
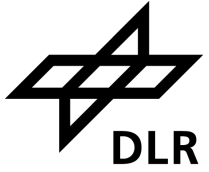
# Circularity Indicator



**MCI = 0.68**



# Criticality Indicator



# Overview of indicators and hotspots



**Economic**



**Environmental**



**Circularity**



**Criticality**

<b>Value</b>	106 €/FU	21 kg CO <sub>2</sub> e/FU	0.68	0.61 arbitrary units
<b>To be improved</b>	<ul style="list-style-type: none"> <li>• Electric motor</li> <li>• Gears</li> </ul>	<ul style="list-style-type: none"> <li>• Circuit board</li> <li>• Stator magnets</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of reused parts</li> <li>• Increase % of recycled metal</li> </ul>	<ul style="list-style-type: none"> <li>• Magnets with rare-earth elements</li> </ul>



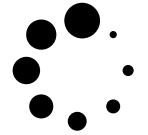
# Conclusions



4 indicators: better assessment vs. information overload



Primary data is critical, but available for target audience



Testing of new designs pending!

# Thanks for your attention!



**Eric Prats-Salvado**  
Institute of Future  
Fuels (DLR)



LinkedIn

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