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Managing waste for an efficient and clean circular economy: Indicators and tools

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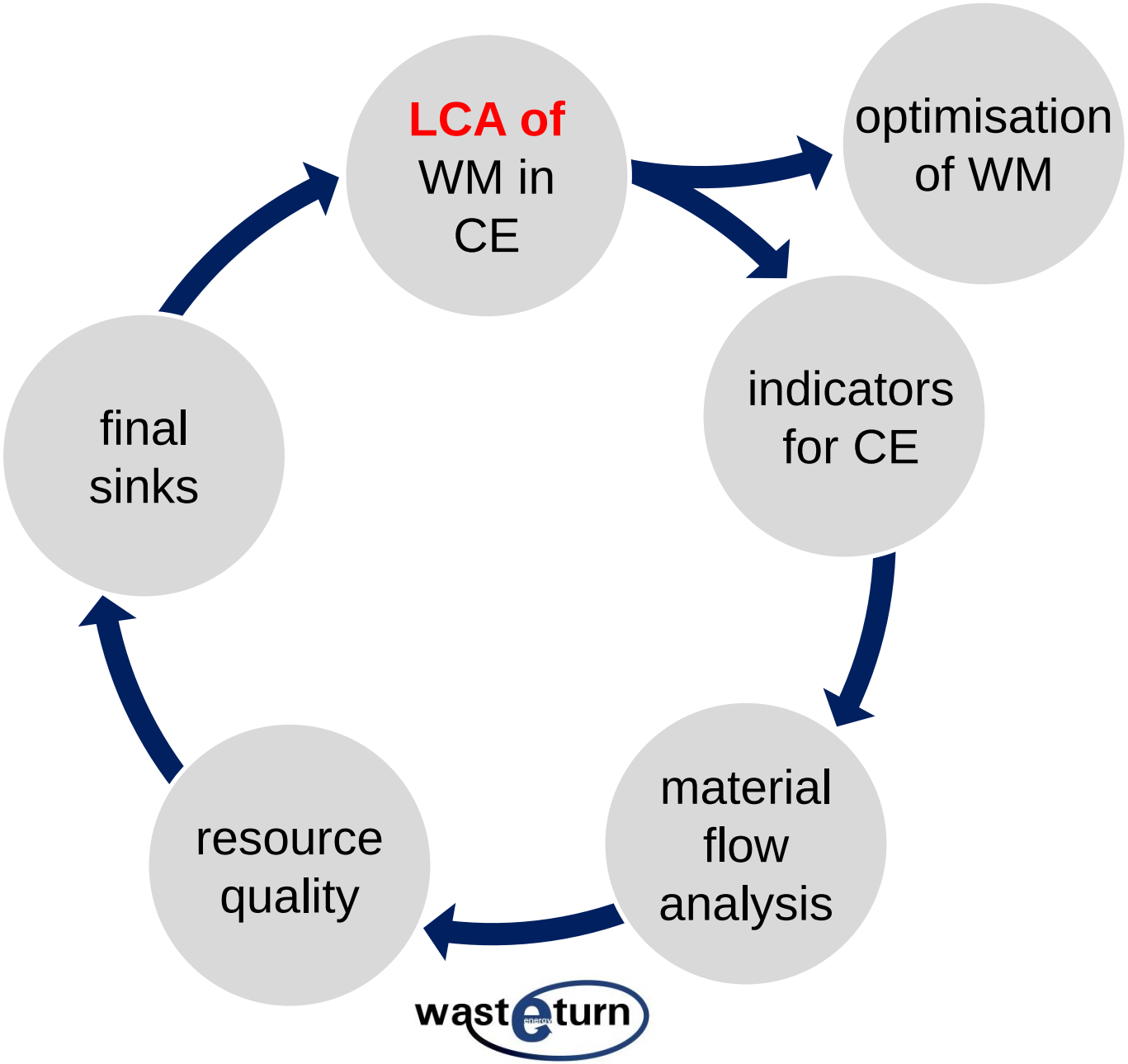
63rd Discussion Forum on LCA, Zurich

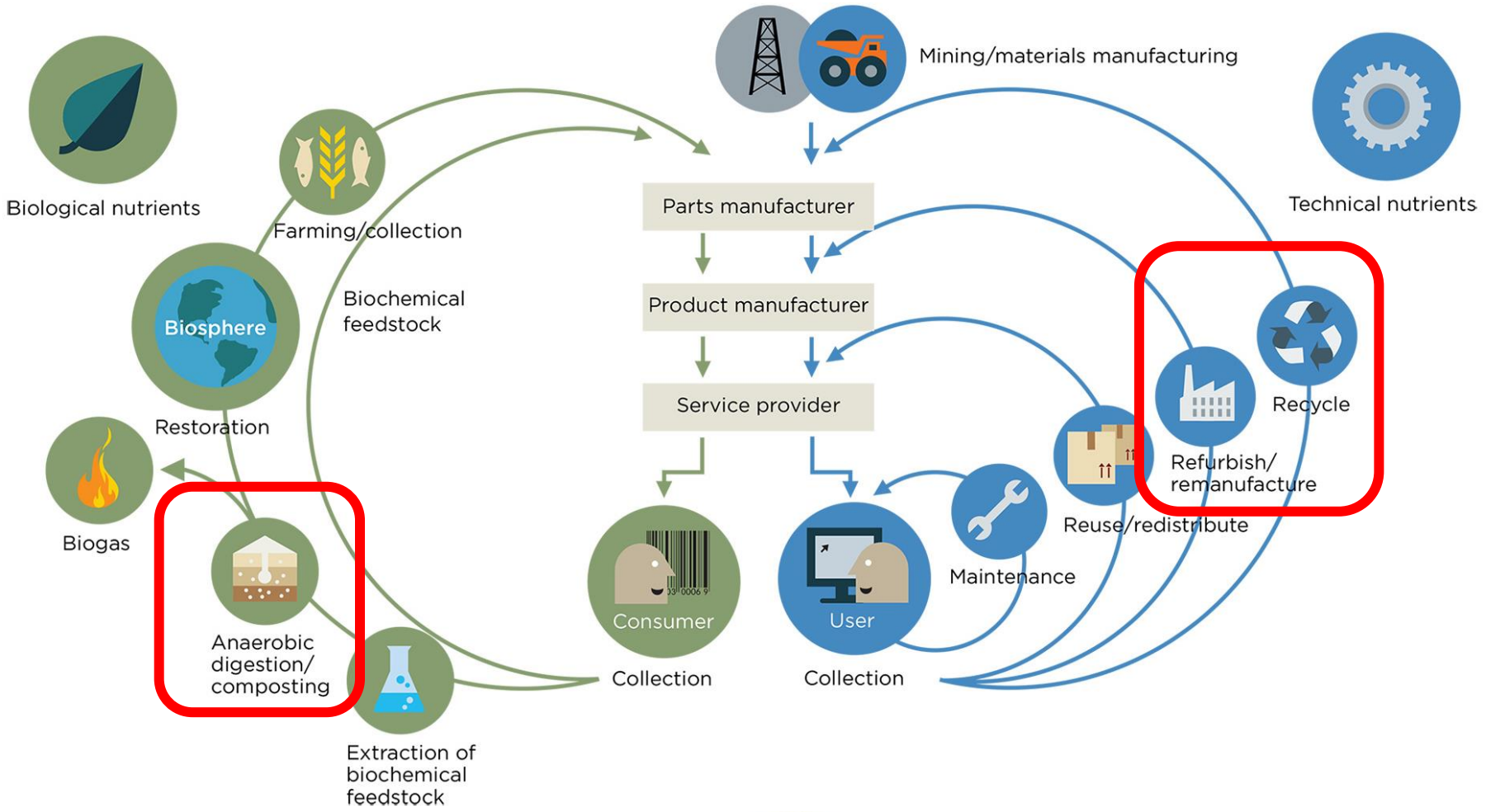
ESD ecological systems design

wasteturn energy

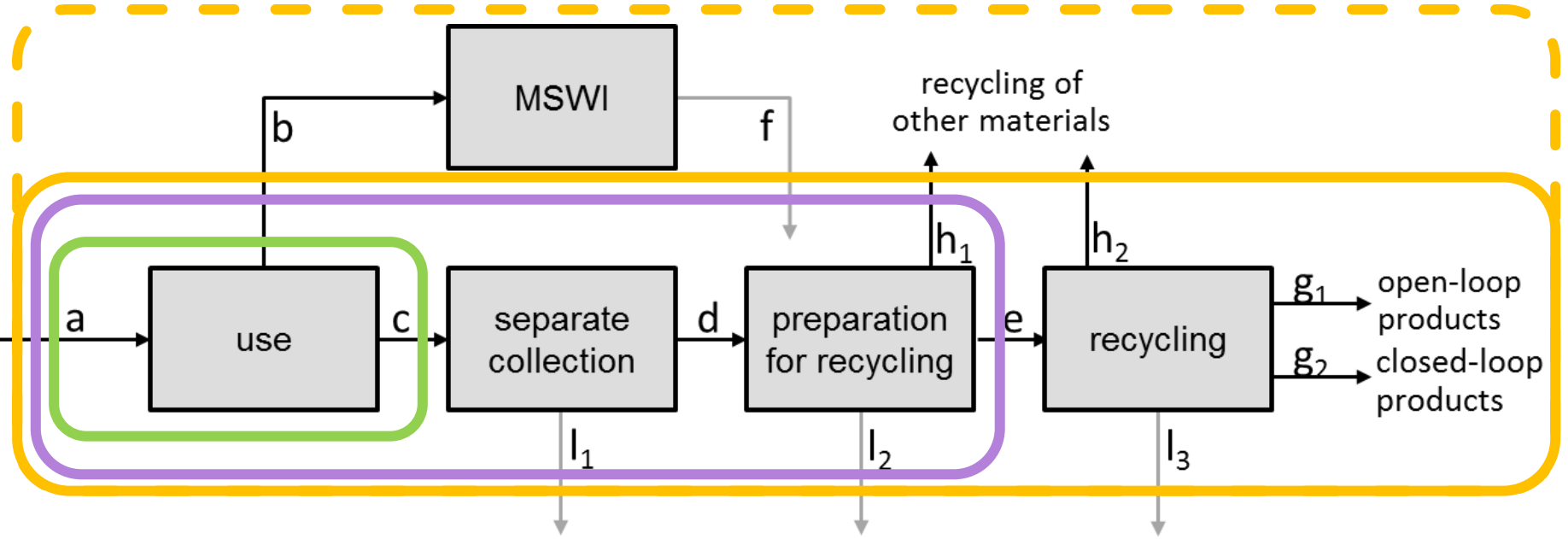
Overview


LCA of WM in CE
optimisation of WM
indicators for CE
material flow analysis
resource quality
final sinks

Waste management – contribution to Circular Economy



Indicators for Circular Economy

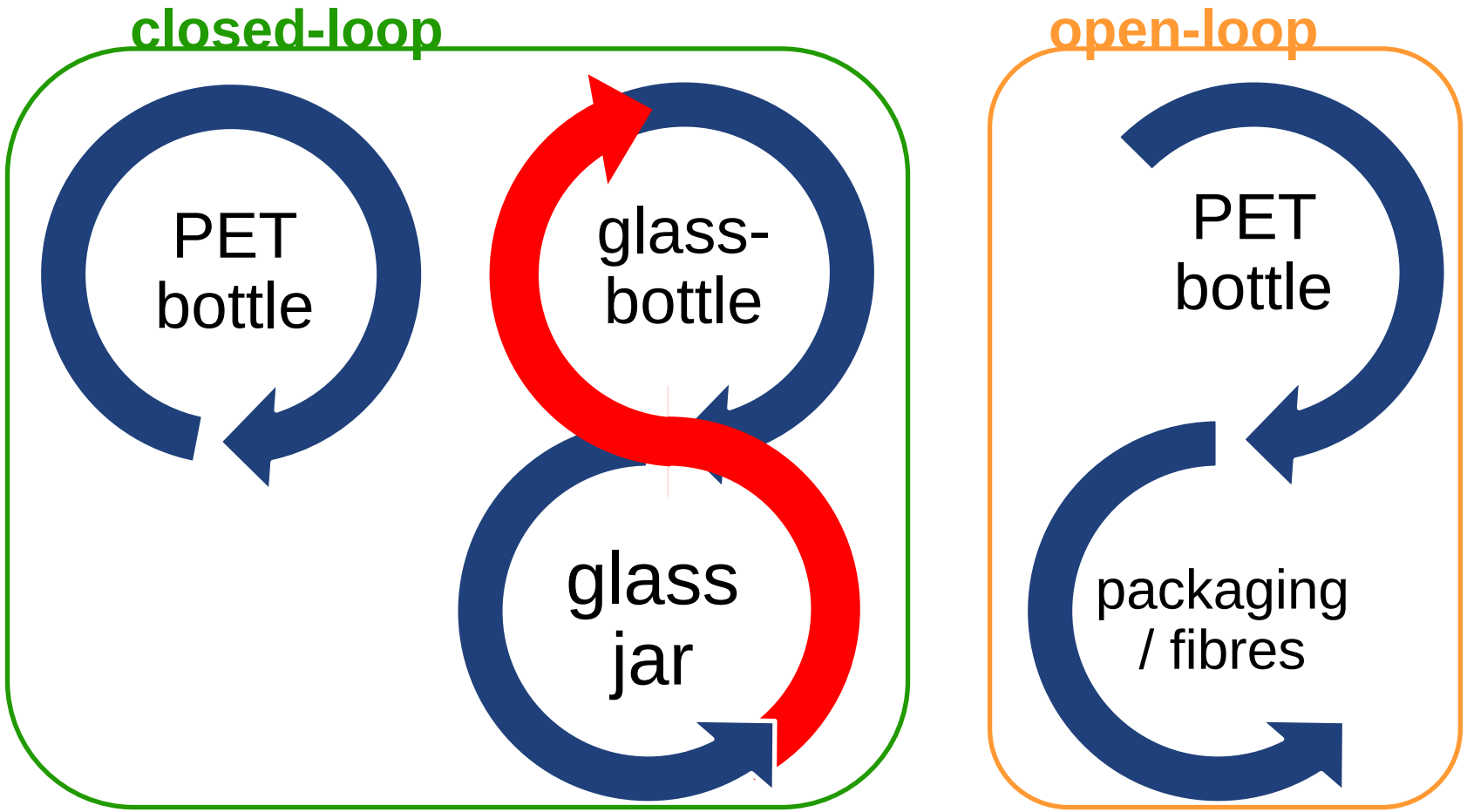


collection rate:
$CR = c/(b+c)$

intermediate recycling rate:
$iRR = (e+h_1)/(b+c)$

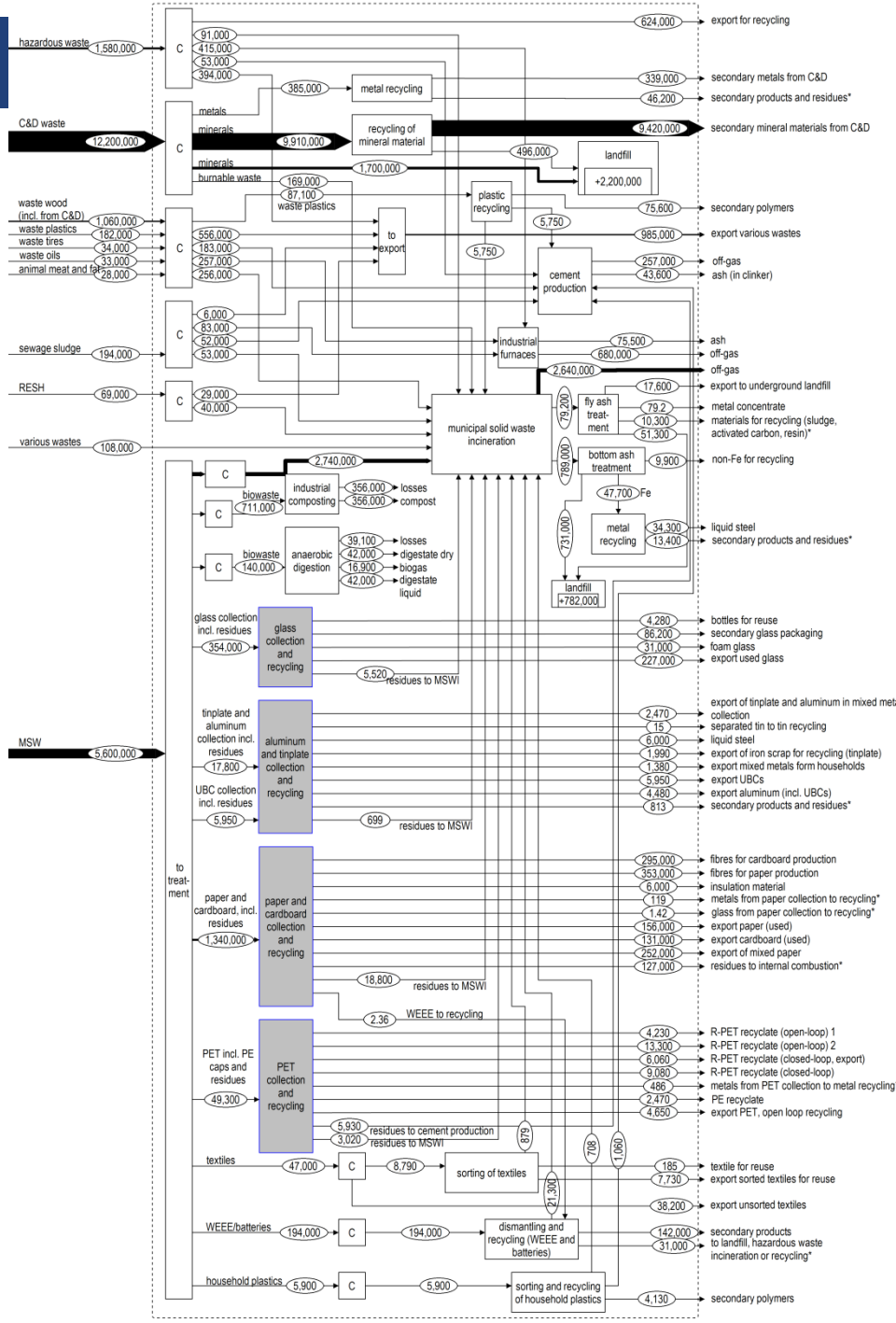
recycling rate:
$RR = (g_1+g_2+h_1+h_2)/(b+c)$

Closed-loop vs. open-loop recycling



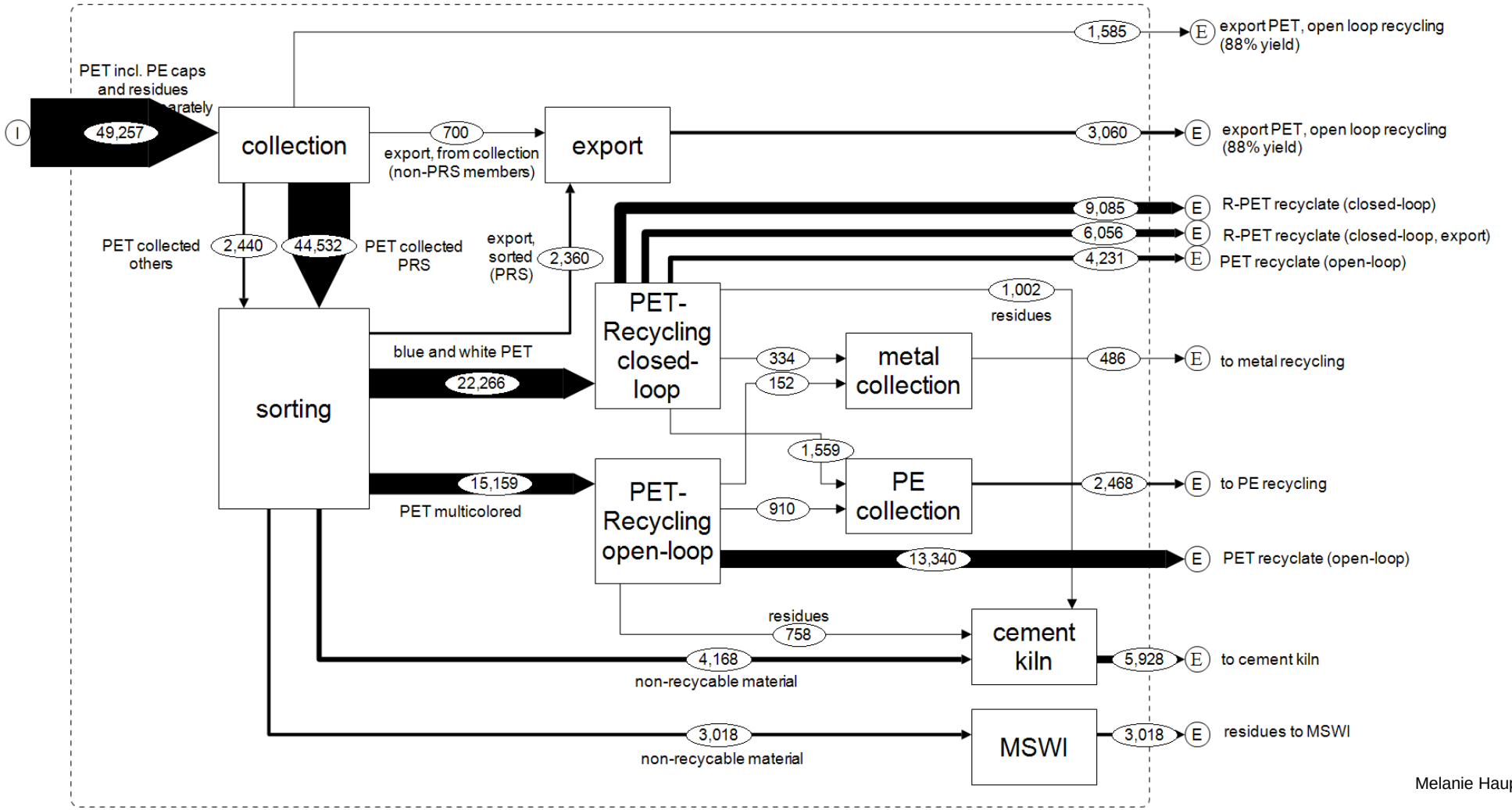
Material flow analysis

- Detailed MFA of Swiss waste management
- Case studies on
  - paper and cardboard
  - PET bottles
  - glass
  - aluminum and tinplate

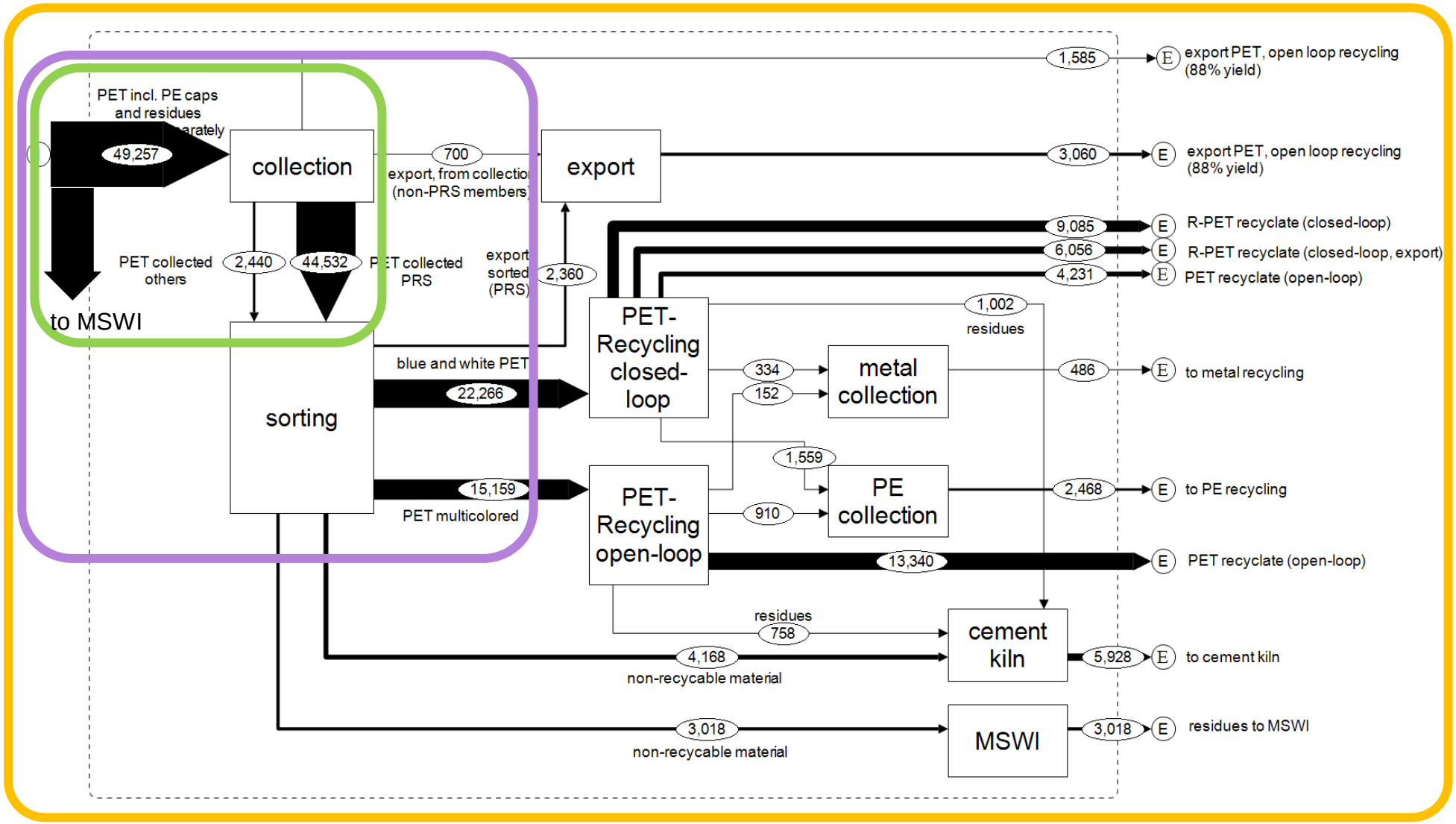


Haupt et al. 2016. Do we have the right performance indicators for the circular economy? – Insight into the Swiss waste management system. Journal of Industrial Ecology. doi.wiley.com/10.1111/jiec.12506

Example: PET bottles



Example: PET bottles

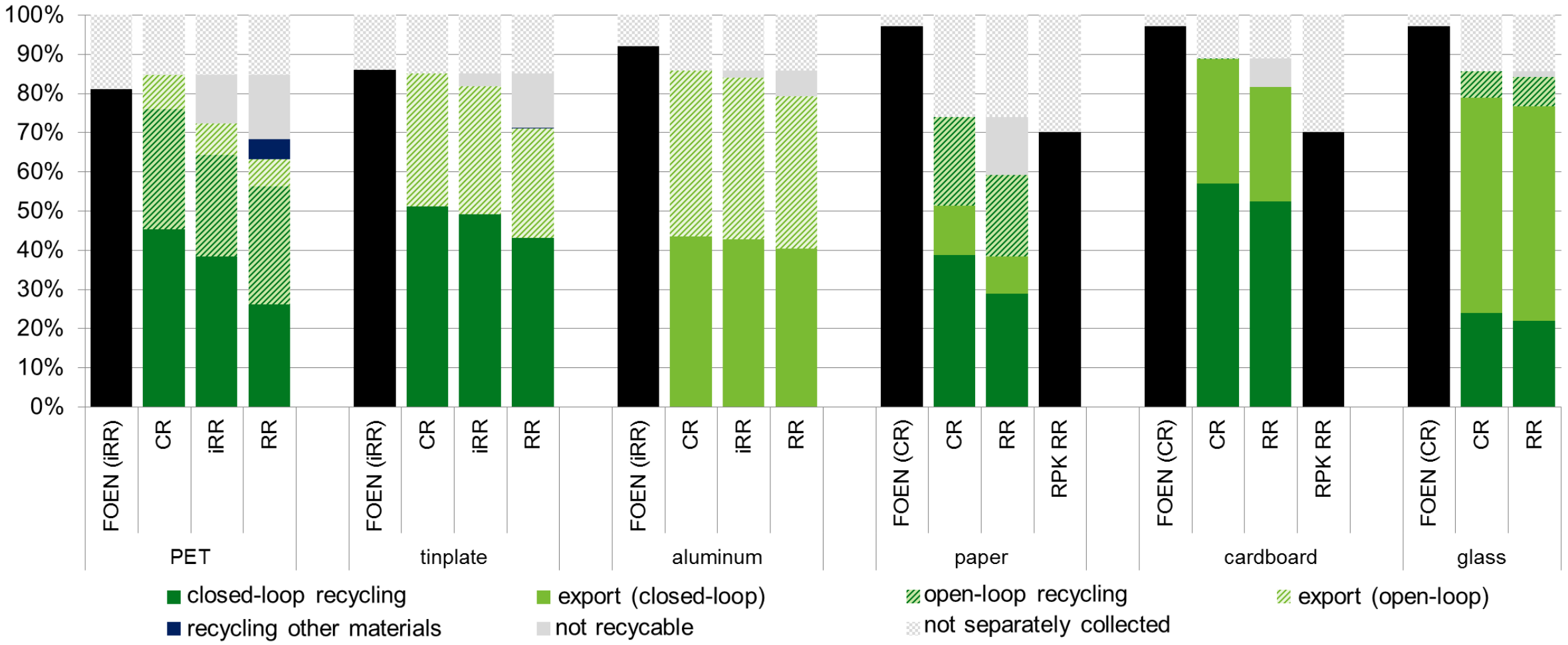


collection rate

intermediate recycling rate

recycling rate

Recycling vs. collection rates



*Haupt, M., C. Vadenbo, and S. Hellweg. Do we have the right performance indicators for the circular economy? – Insight into the Swiss waste management system. Journal of Industrial Ecology [*doi.wiley.com/10.1111/jiec.12506*].*

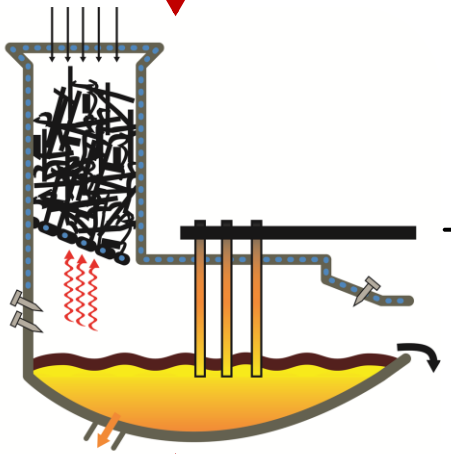
Conclusion: recycling vs. collection rates

- Collection rates or «Verwertungsquoten» communicated are optimistic and only a measure of separation in households
- Recycling rates should be used as indicator of circularity of a system
- Open- and closed-loop recycling should be considered separately

Impact of quality on recycling process

recovery from bottom ash

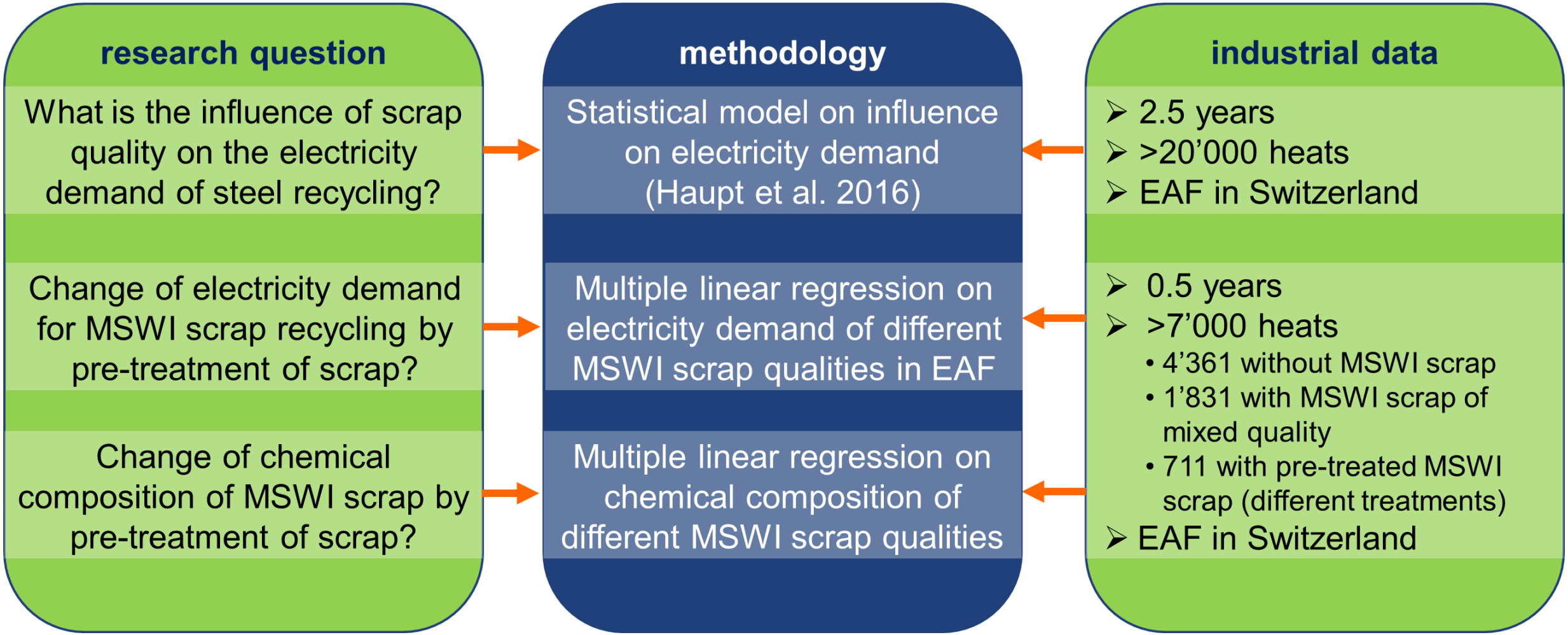
pre-treatment of MSWI scrap



liquid steel

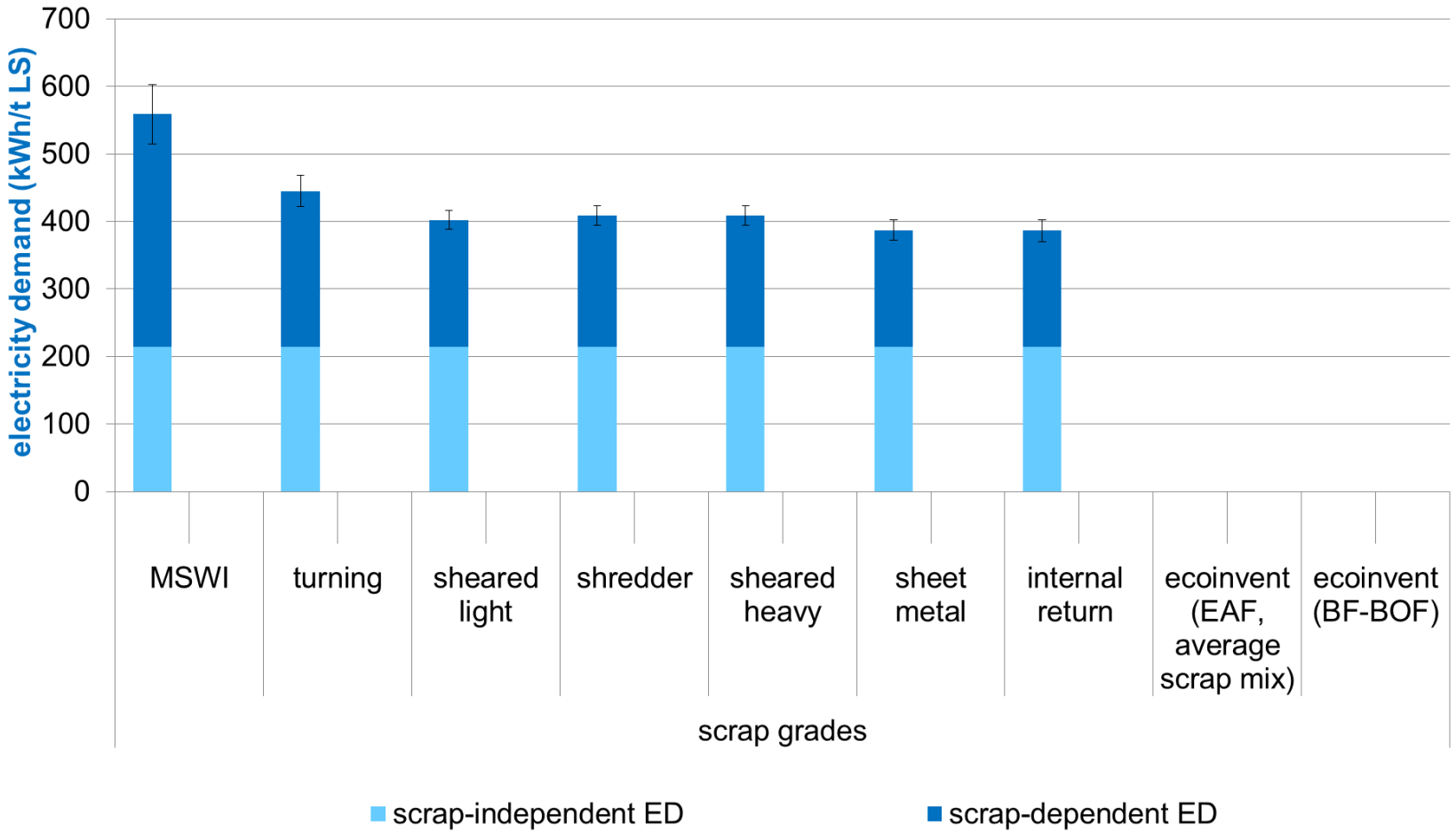
separation / pre-treatment

Research questions and models



Haupt, M., C. Vadenbo, C. Zeltner, and S. Hellweg. 2016. Influence of input-scrap quality on the environmental impact of secondary steel production. Journal of Industrial Ecology [doi.wiley.com/10.1111/jiec.12439].

Electricity demand in electric arc furnace



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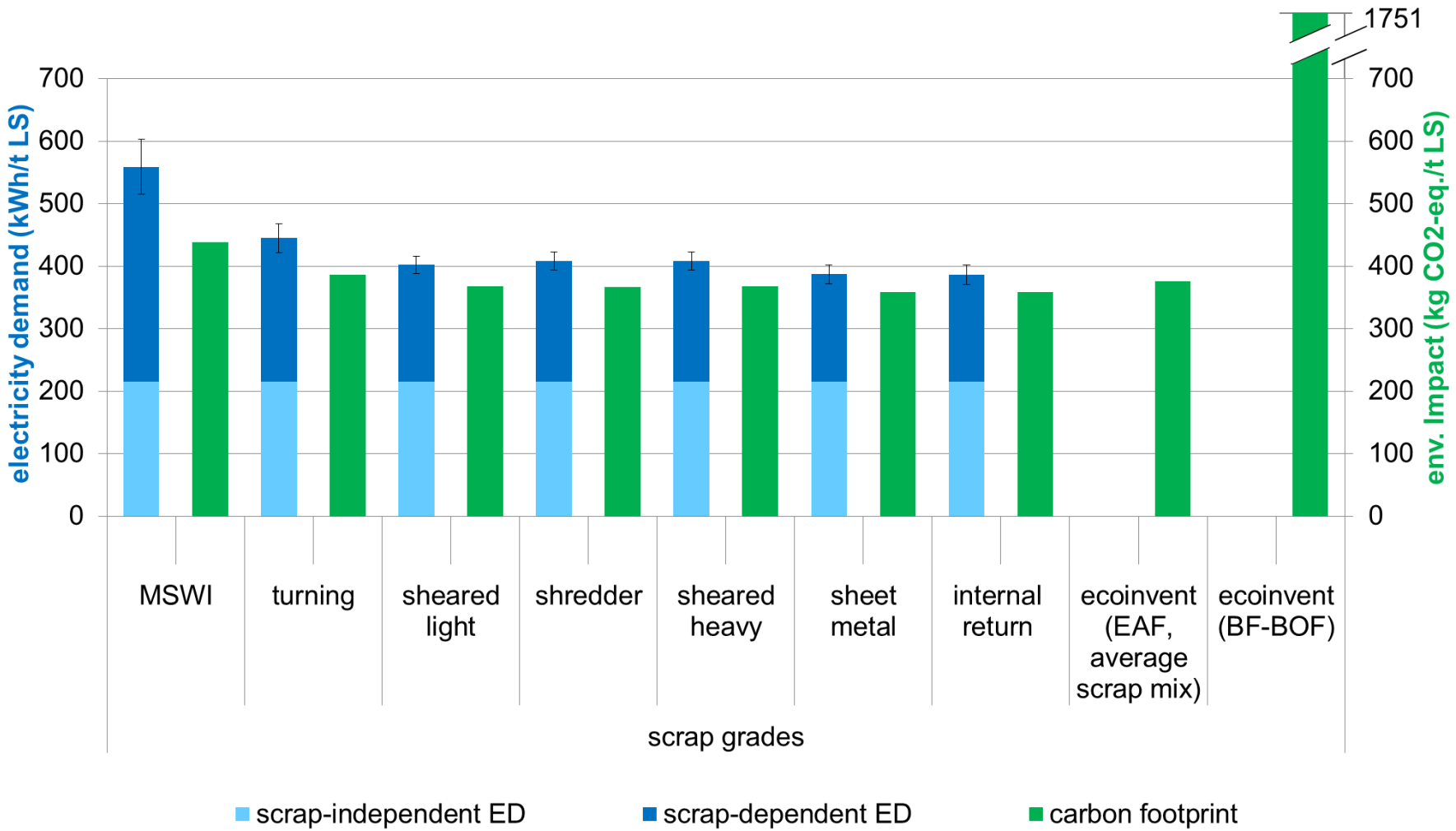
Environmental impact from electric steel production



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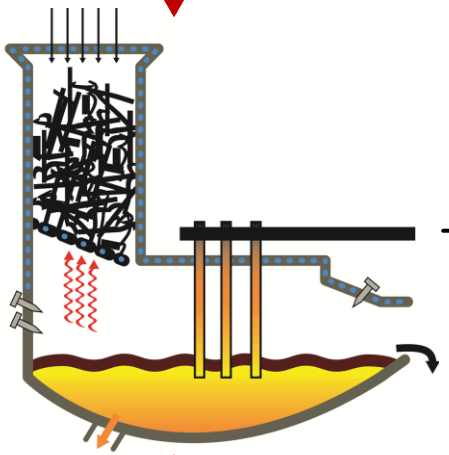
Separate collection vs. recovery after MSWI

recovery from bottom ash

pre-treatment of MSWI scrap



liquid steel

separation / pre-treatment

low quality scrap grades: 560 kWh/t
LS

+20 to 40% electricity

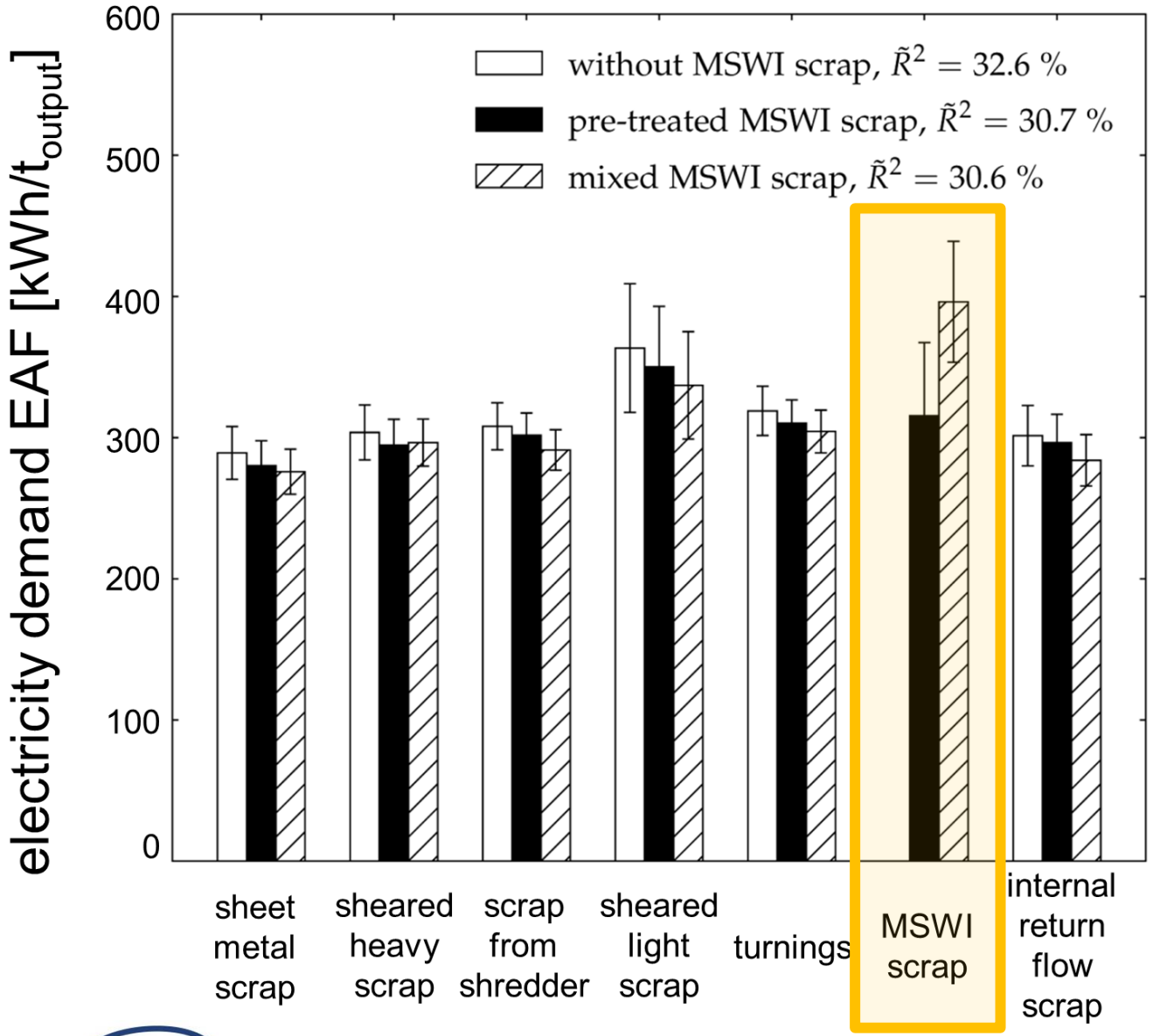
medium quality scrap grades: 410 kWh/t
LS + detinning

Haupt, M., C. Vadenbo, C. Zeltner, and S. Hellweg. 2016. Influence of input-scrap quality on the environmental impact of secondary steel production. Journal of Industrial Ecology [doi.wiley.com/10.1111/jiec.12439].

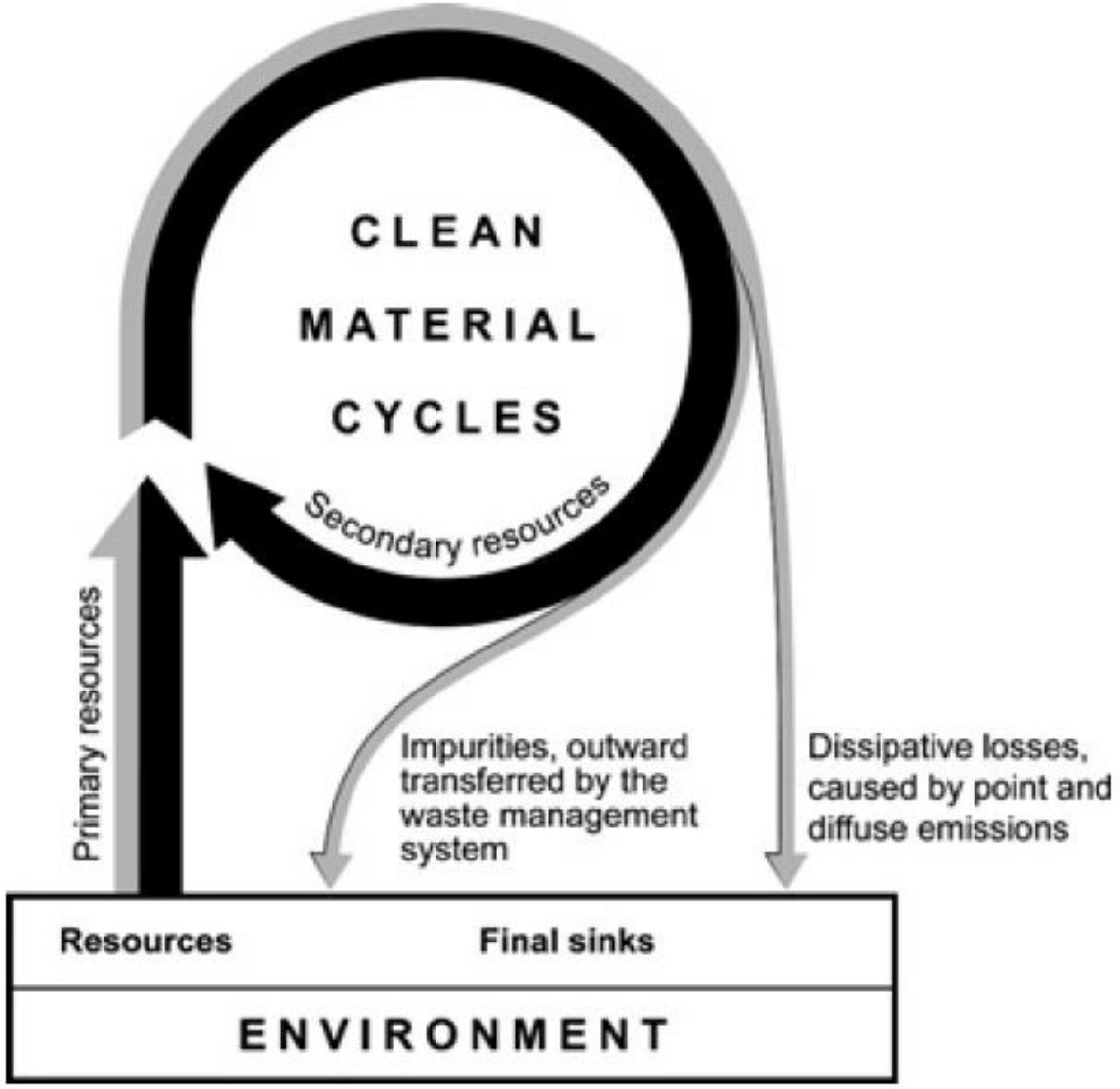
Improvements resulting from scrap pre-treatments

Analysis of heats…

- without MSWI scrap
- with mixed MSWI scrap
  (partly treated, various treatments)
- pre-treated MSWI scrap
  (treated at different locations)

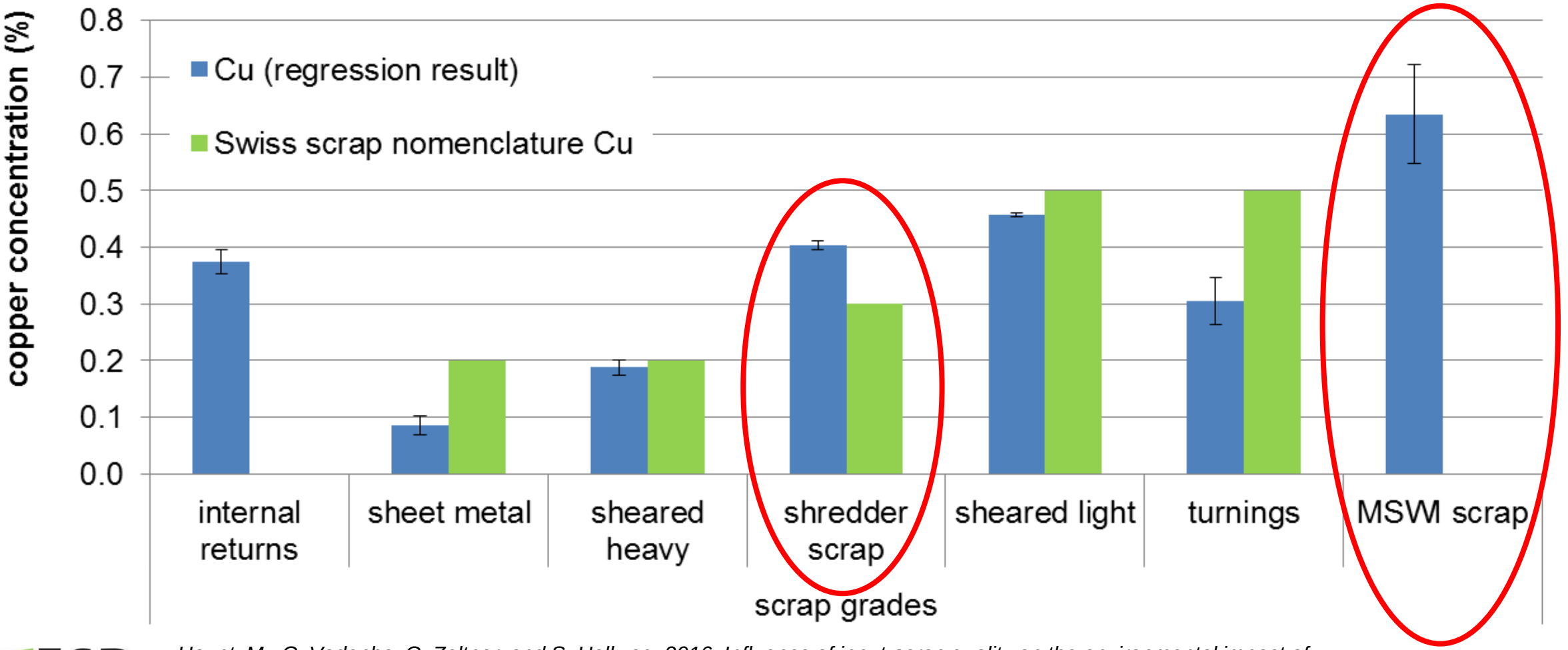


Material quality in a circular economy



Kral, U., K. Kellner, and P.H. Brunner. 2013. Sustainable resource use requires "clean cycles" and safe "final sinks". The Science of the Total Environment 461–462: 819–822.

Environmental impact from electric steel production



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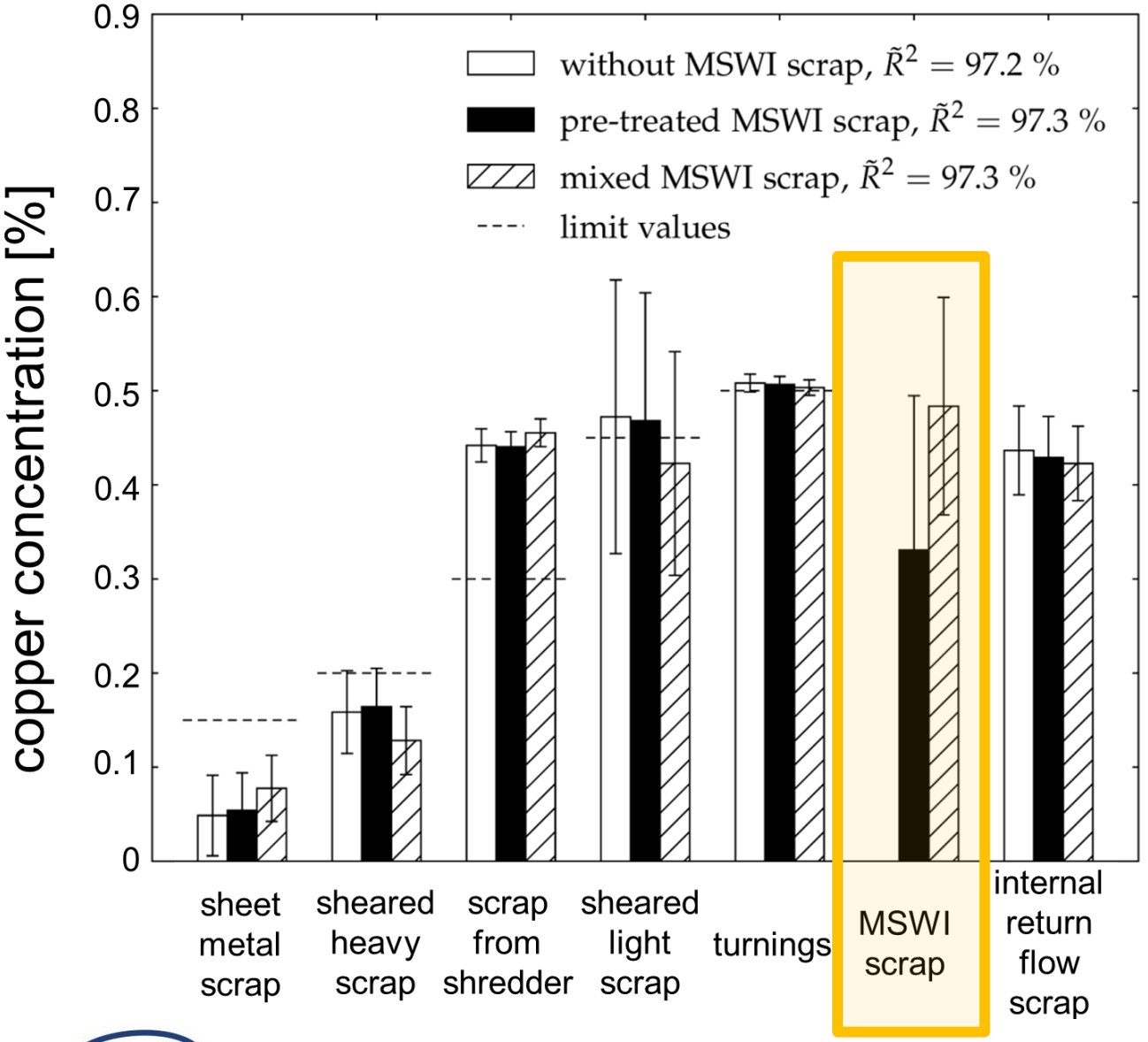
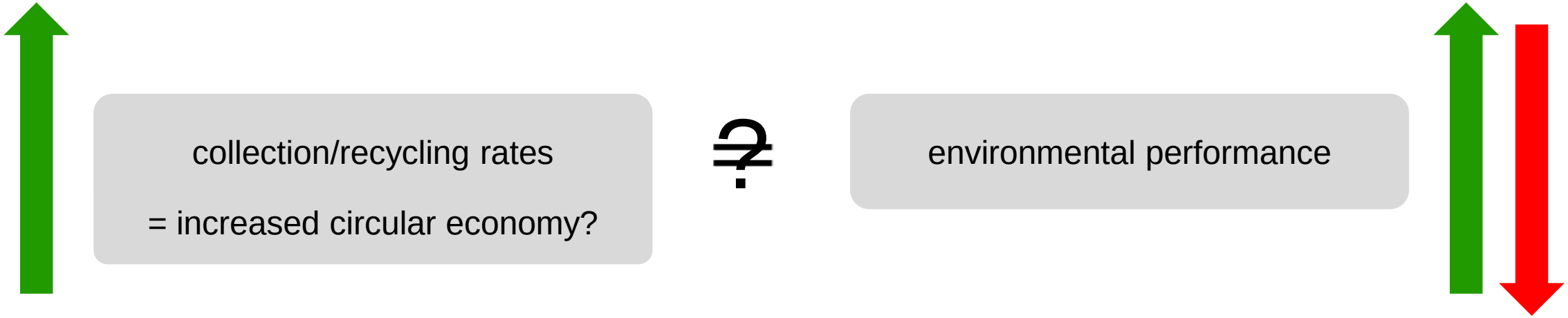


Discussion

- quality of scrap determines electricity demand in EAF
  - quality scrap ↘ → electricity demand ↗ → env. impacts ↗
  - environmental impacts still only a third of primary production
- secondary steel is sink for tin and copper
  - tin and copper not removed from liquid steel – dilution losses
  - tramp elements mostly enter recycling from low-quality scrap
- Preliminary result: pre-treatments seem to enhance scrap quality – sampling coming up 2017

… but – how about environmental impacts?



Recommended literature: Geyer, R., B. Kuczenski, T. Zink, and A. Henderson. 2015. Common Misconceptions about Recycling. Journal of Industrial Ecology 20(5).

Life cycle assessment and optimisation

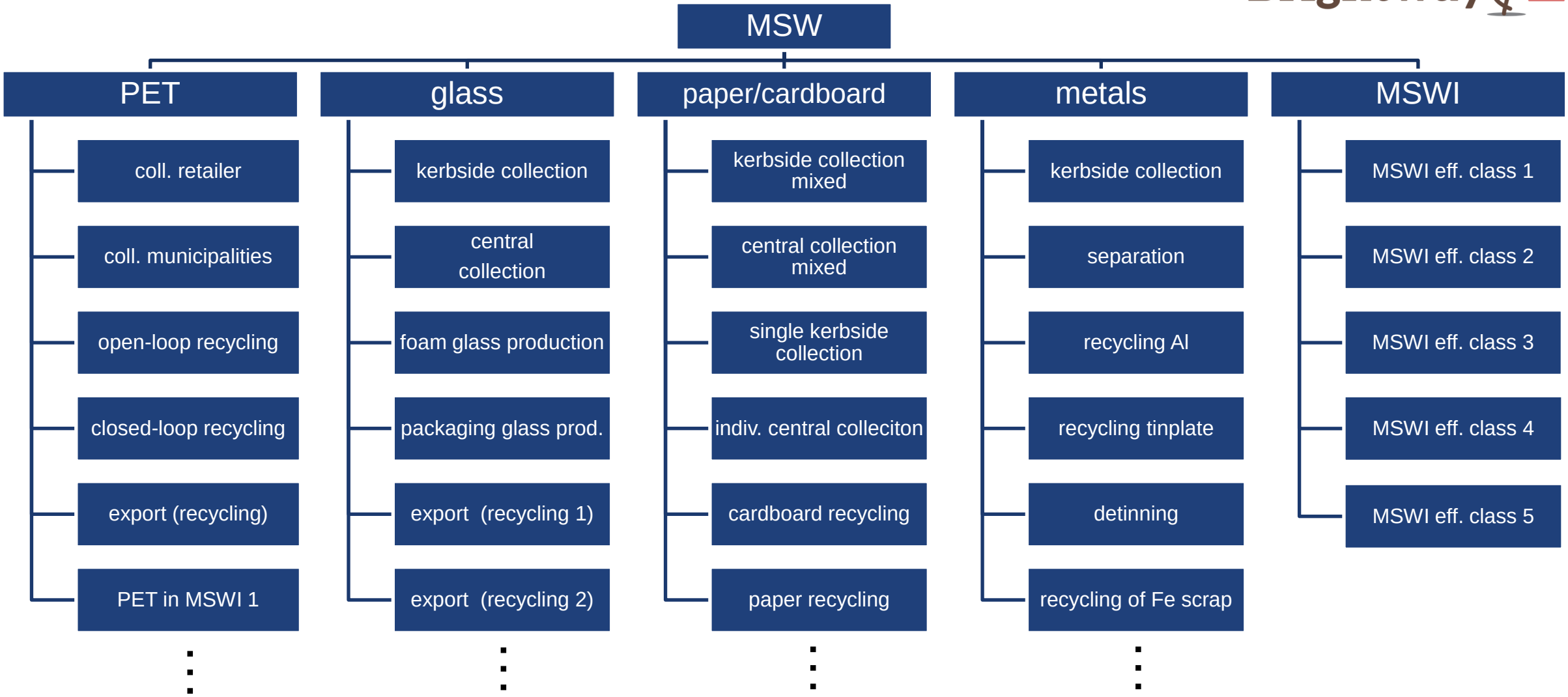
MFA → **LCA** → **optimization**

- identification of possible treatment and recycling pathways
- processes in place today
- transfer coefficients of processes

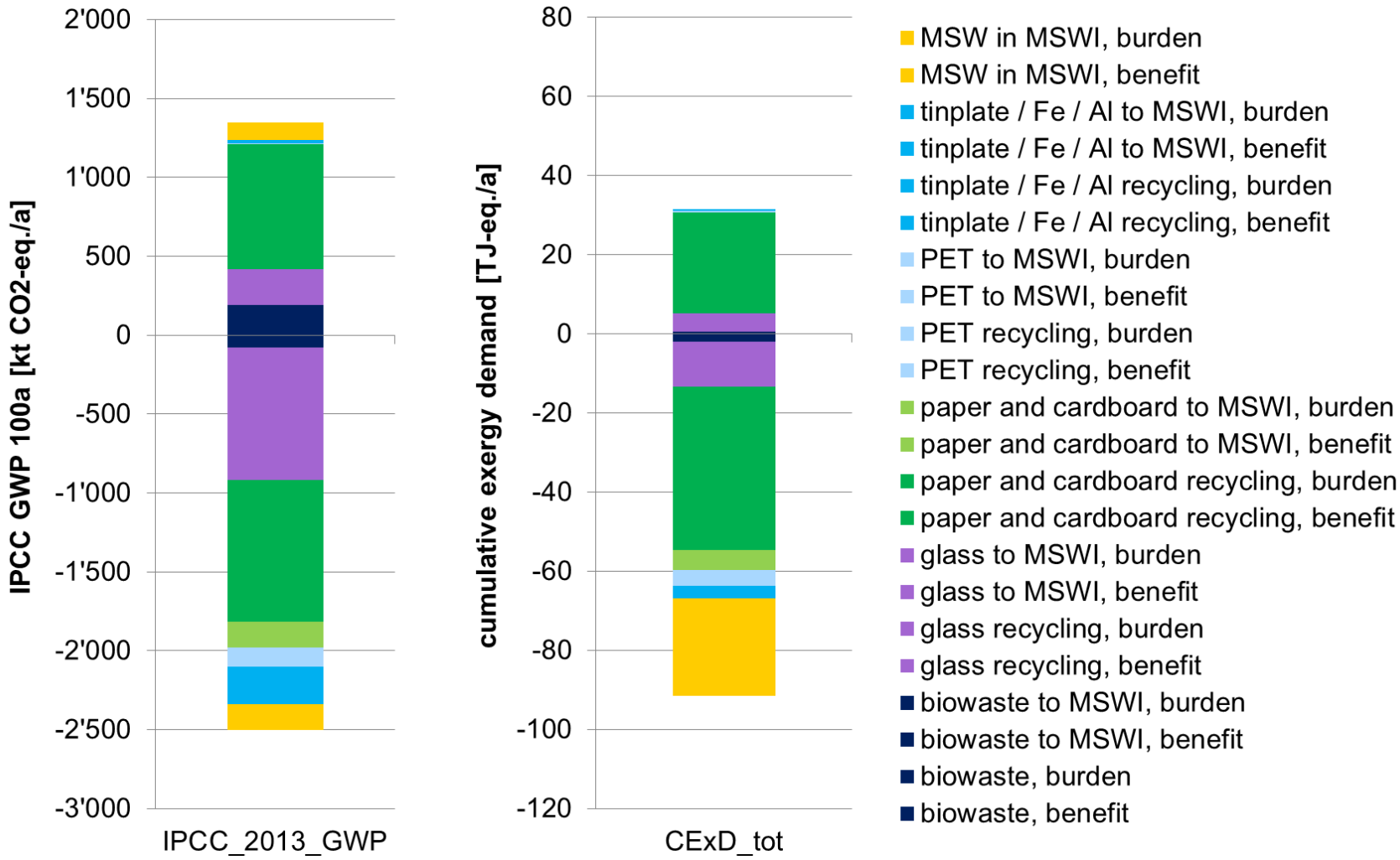
- LCA for all treatments and recycling processes: open- and closed-loop, in Switzer-land or export; current and future
- several impact categories are used, e.g. IPCC 2013, CExD, ReCiPe and Usetox

- environmentally optimal Swiss waste management in 2012, 2020, 2035 and 2050
- pareto front for multi-objective optimisation (if relevant)

Methodology: Modular LCA



Preliminary LCA results



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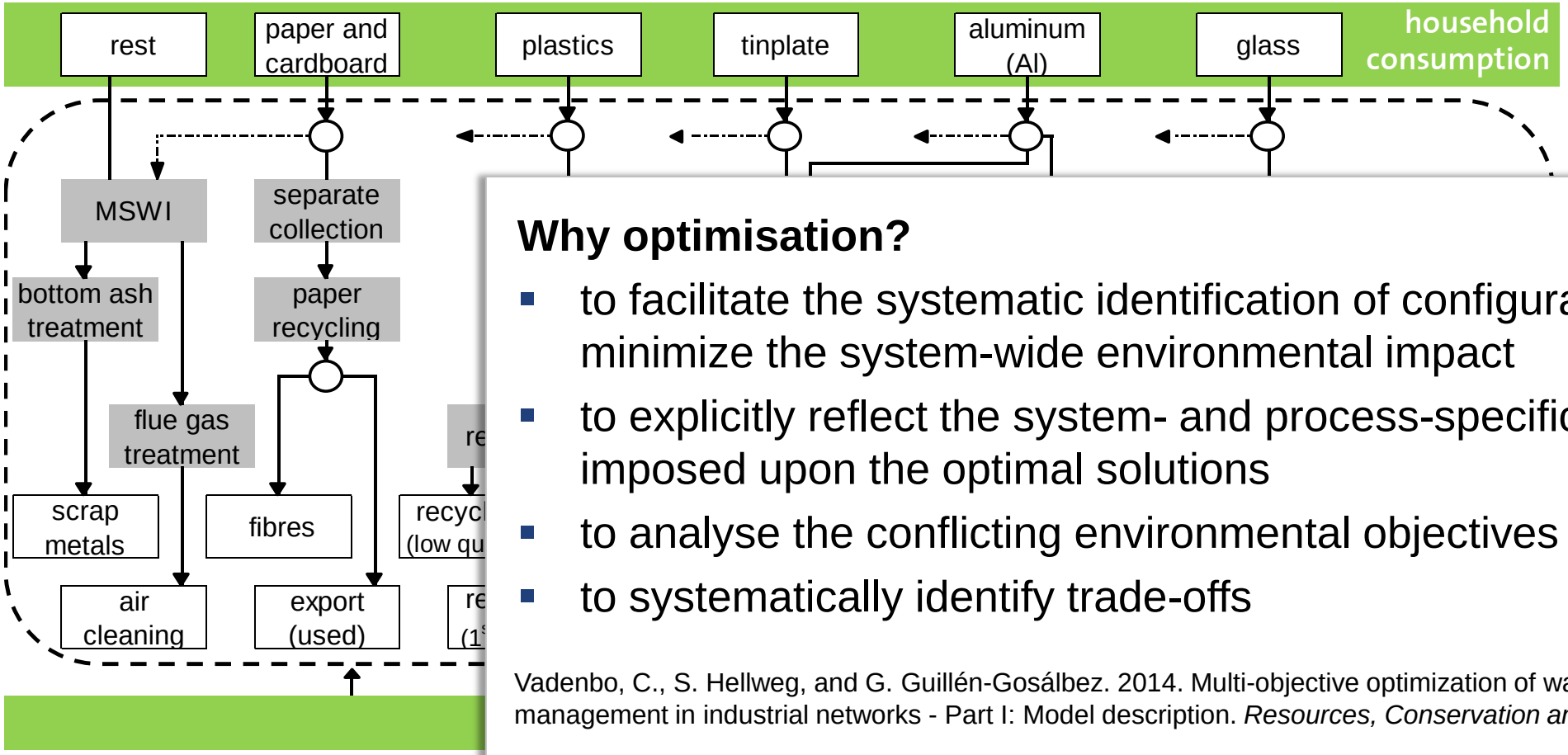
System perspective optimisation (outlook)



Why optimisation?

- to facilitate the systematic identification of configurations that minimize the system-wide environmental impact
- to explicitly reflect the system- and process-specific constraints imposed upon the optimal solutions
- to analyse the conflicting environmental objectives
- to systematically identify trade-offs

Vadenbo, C., S. Hellweg, and G. Guillén-Gosálbez. 2014. Multi-objective optimization of waste and resource management in industrial networks - Part I: Model description. *Resources, Conservation and Recycling* 89: 52–63.

Take home messages

- Recycling rates should be net of all losses (as far as possible)
- Most circular ≠ environmentally best option

  → Environmental impacts of various recycling processes vary and should be considered when defining recycling targets
- Waste management has a key role in circular economy, but choice of treatment should be LCA based

We gratefully acknowledge the financial support from the Swiss National Science Foundation (NRP 70), the cantonal office of waste, water, energy and air (Zurich) and the development centre for sustainable management of recyclable waste and resources (ZAR).

Thank you very much for your attention!

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www.ifu.ethz.ch/ESD