Exploring prospective application of LCA to enhance Technological Development

A case study on bioleaching e-waste for metal recovery

65th LCA Discussion Forum. ETH, Zurich
May 24th 2017

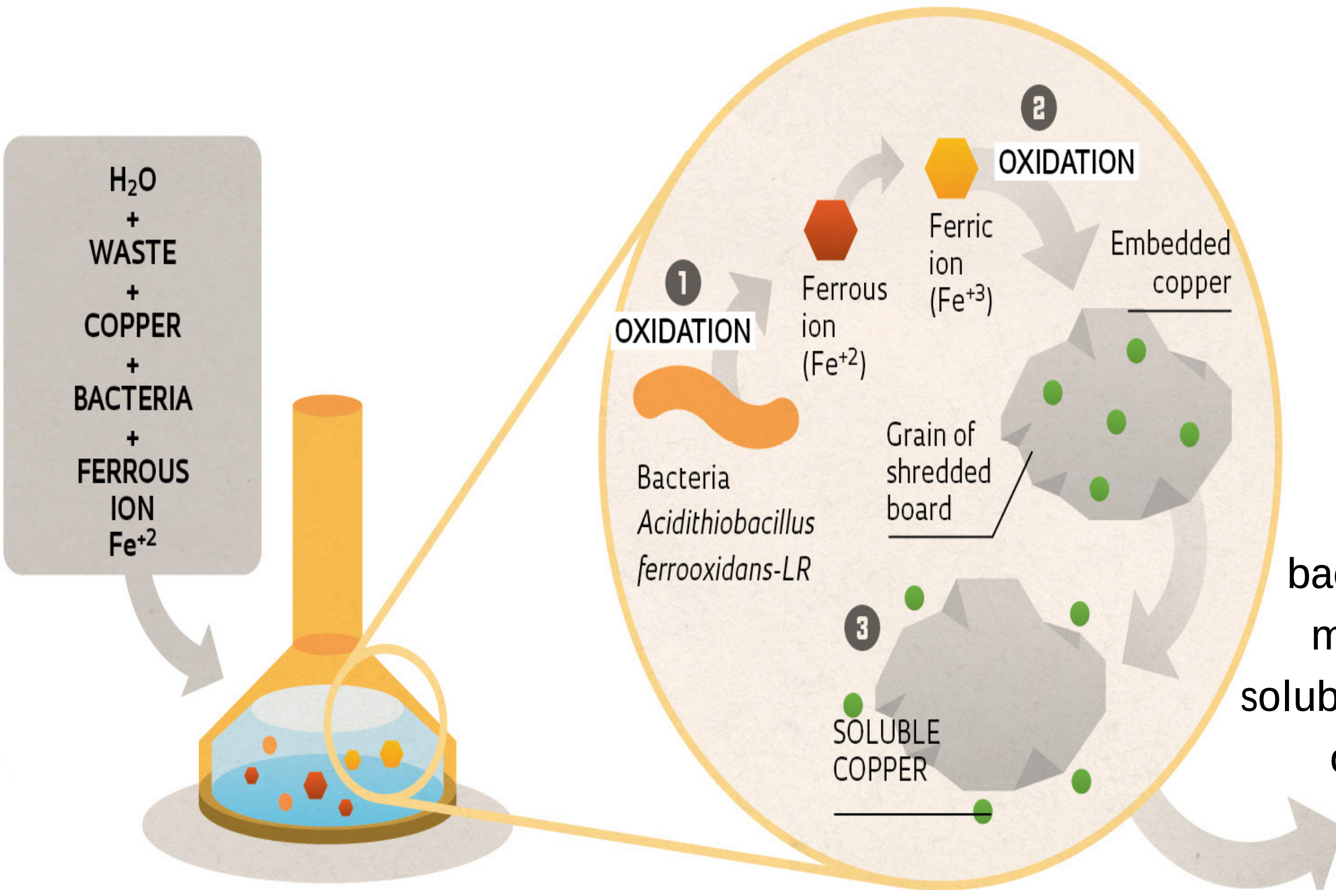
Marco Villares

Novel process for metal recovery from printed circuit boards (PCB)

collaboration
lab scale research
UNESCO – IHE, Delft

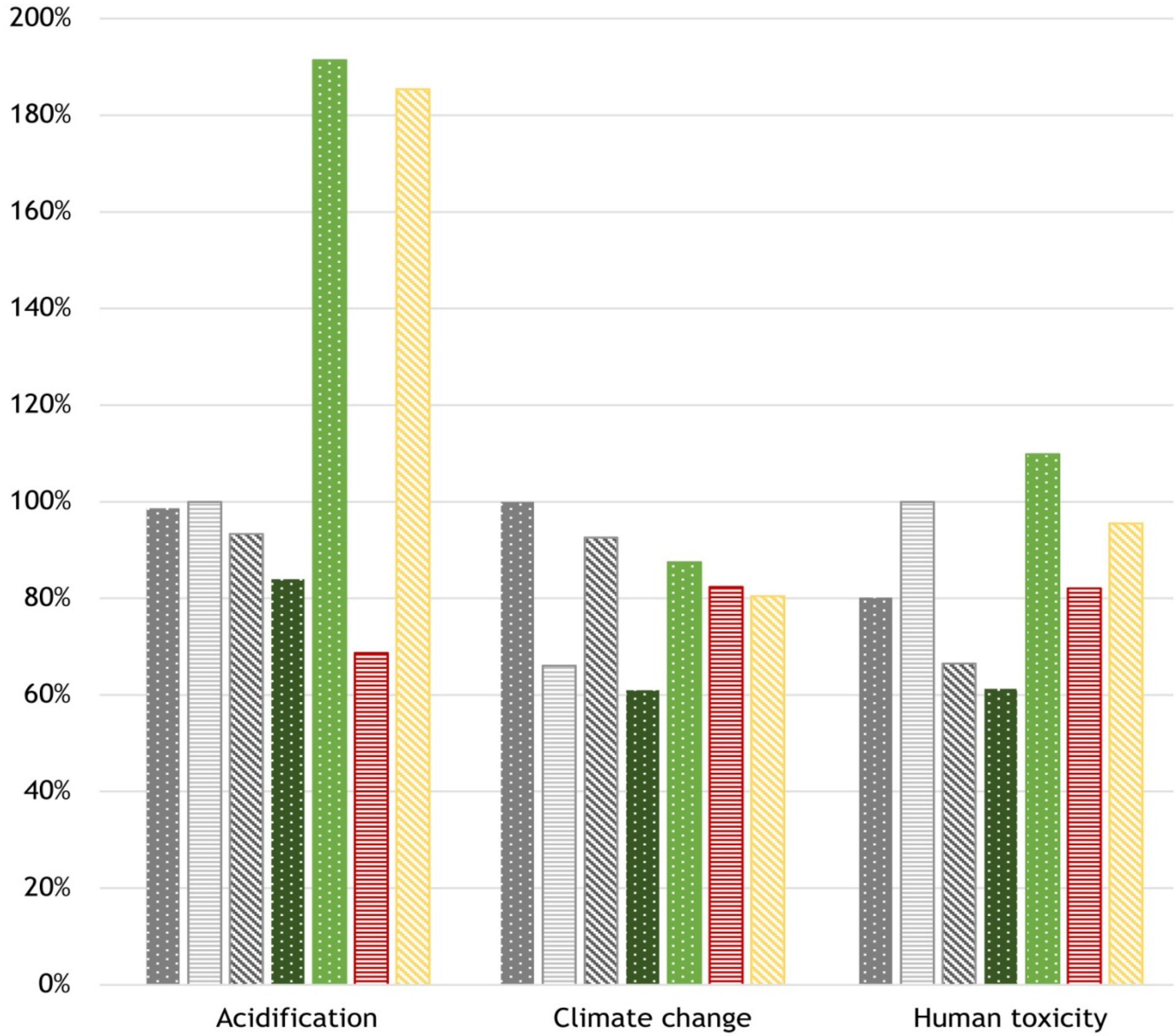
- **Introduction**
- Research plan
- Lab system
- Scaled up system
- Discussion
- Conclusions
- Recommendations

Novel process for metal recovery from printed circuit boards (PCB)



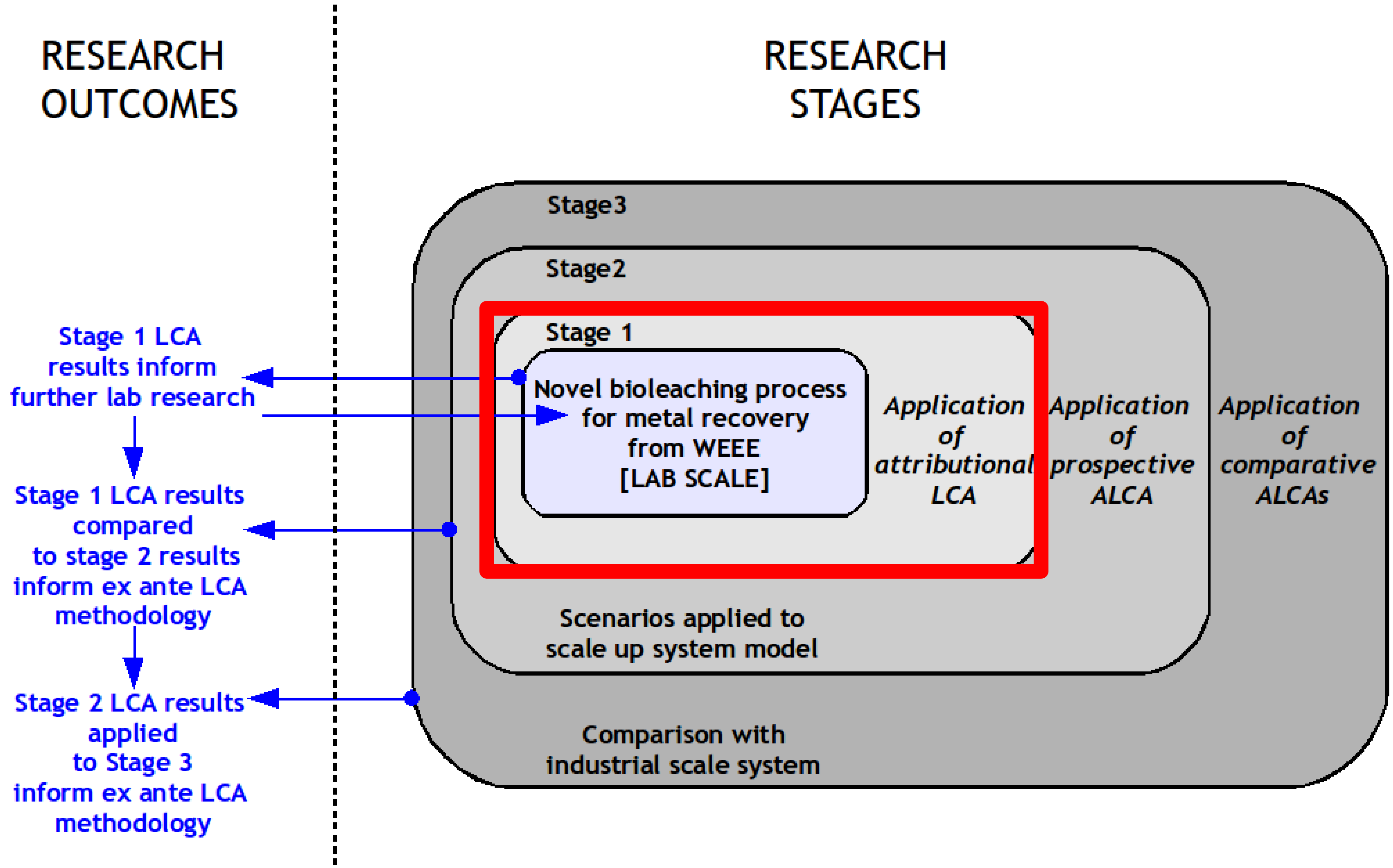
bacterially mediated solubilisation of metal

Novel process for metal recovery from printed circuit boards (PCB)



- Environmental impacts?
- Scale up?
- Compare?

3 stage organisation of research



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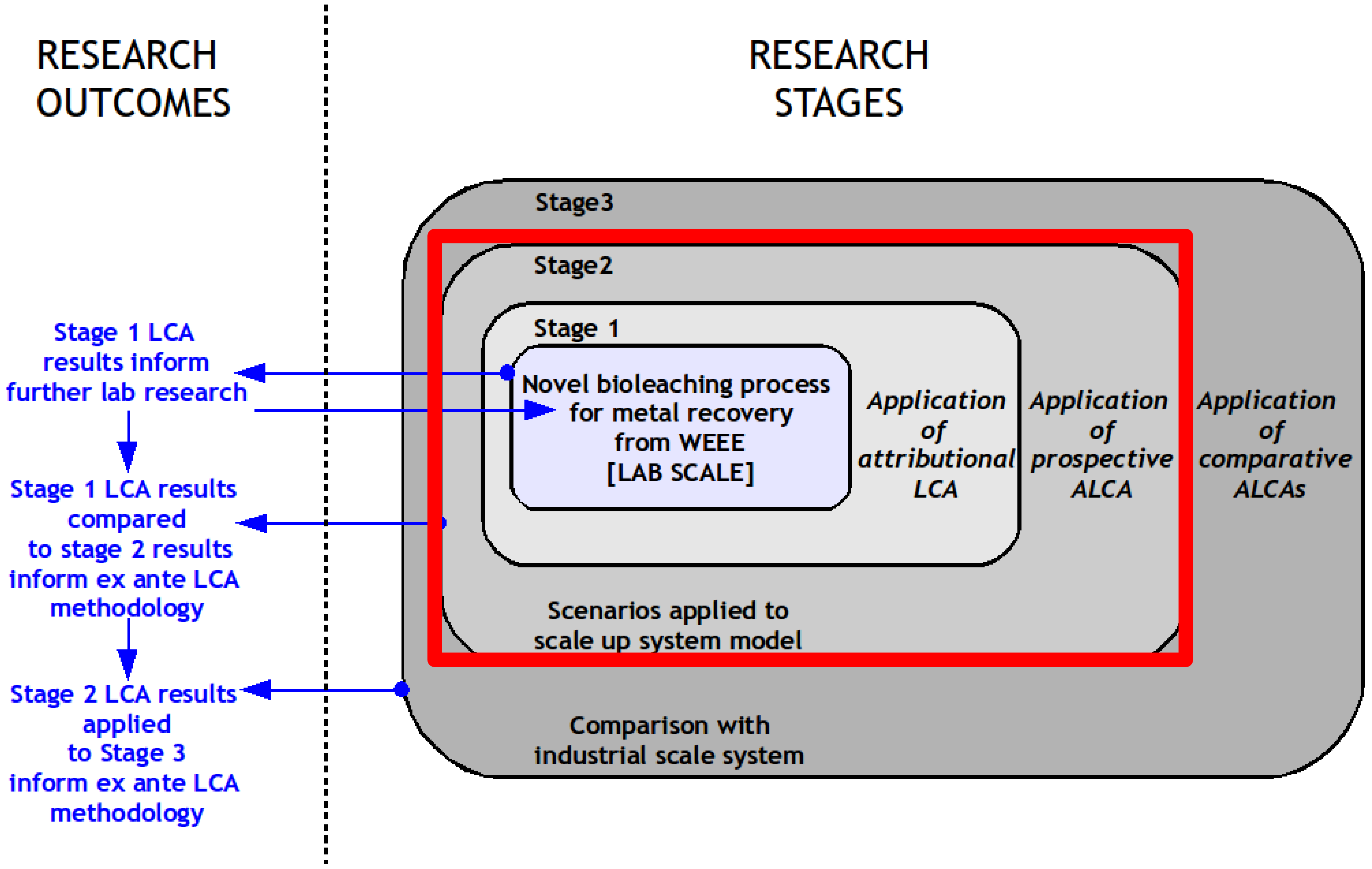
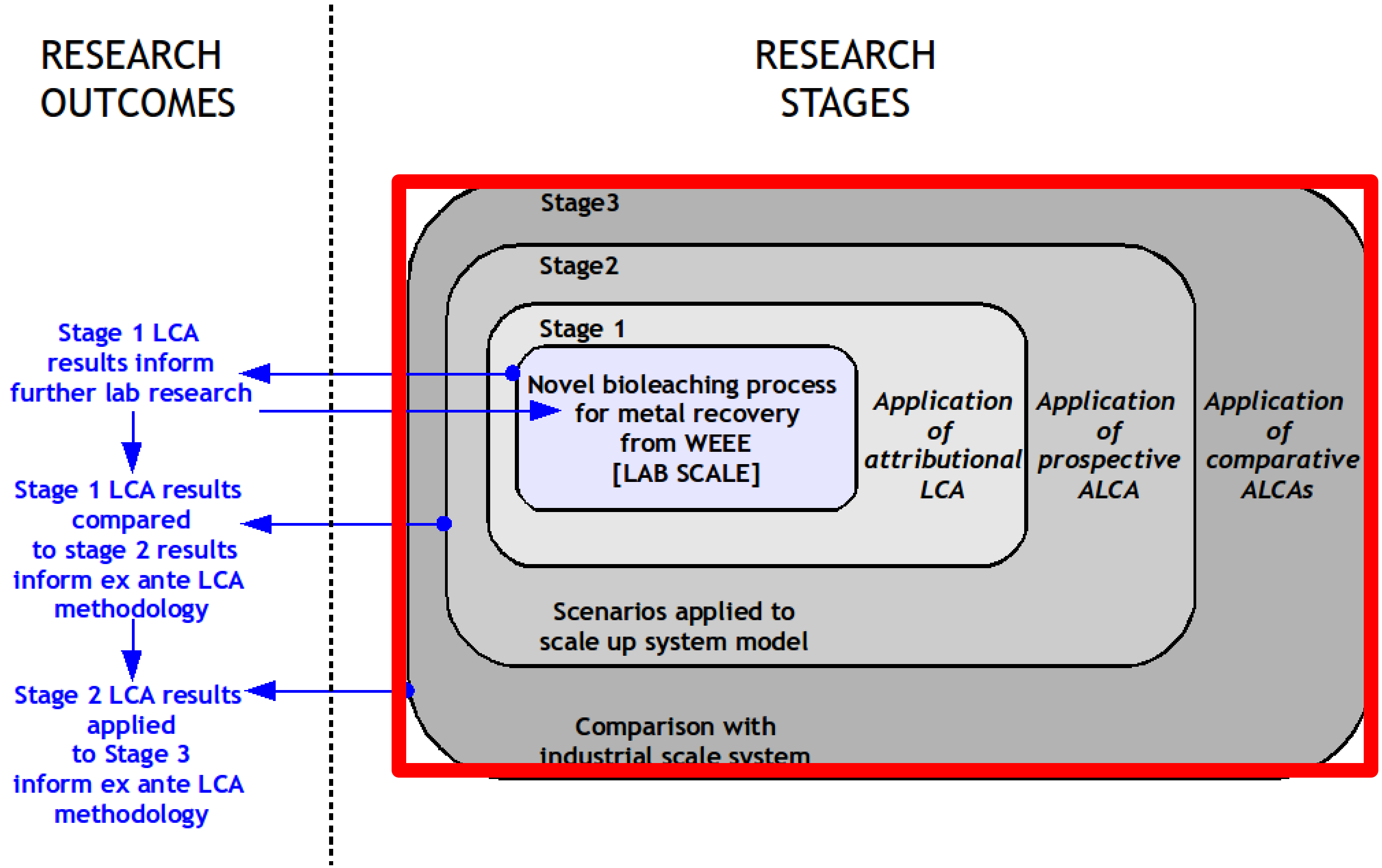


3 stage organisation of research



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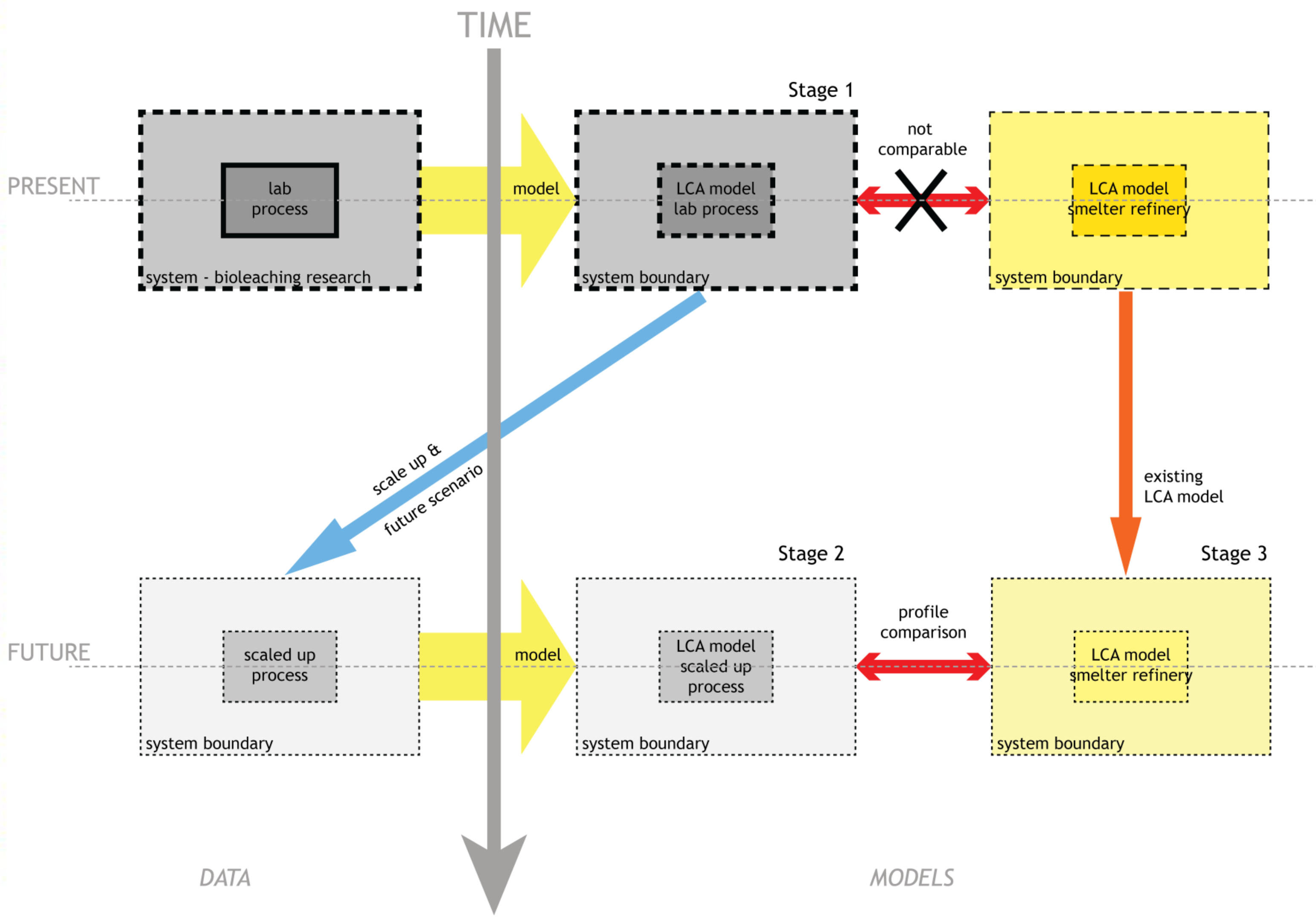
Execution of research



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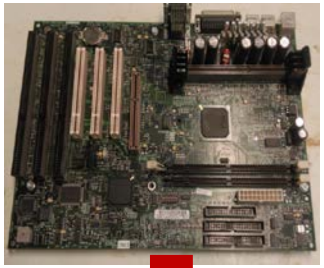
Laboratory bioleaching process



Printed Circuit Boards - PCB

Manual disassembly

Machine crusher

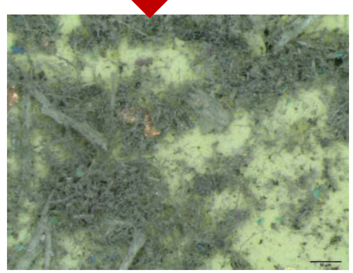
Crushed PCB (sterilized)

Laboratory bioleaching process

Open air shake flasks

leachate solution

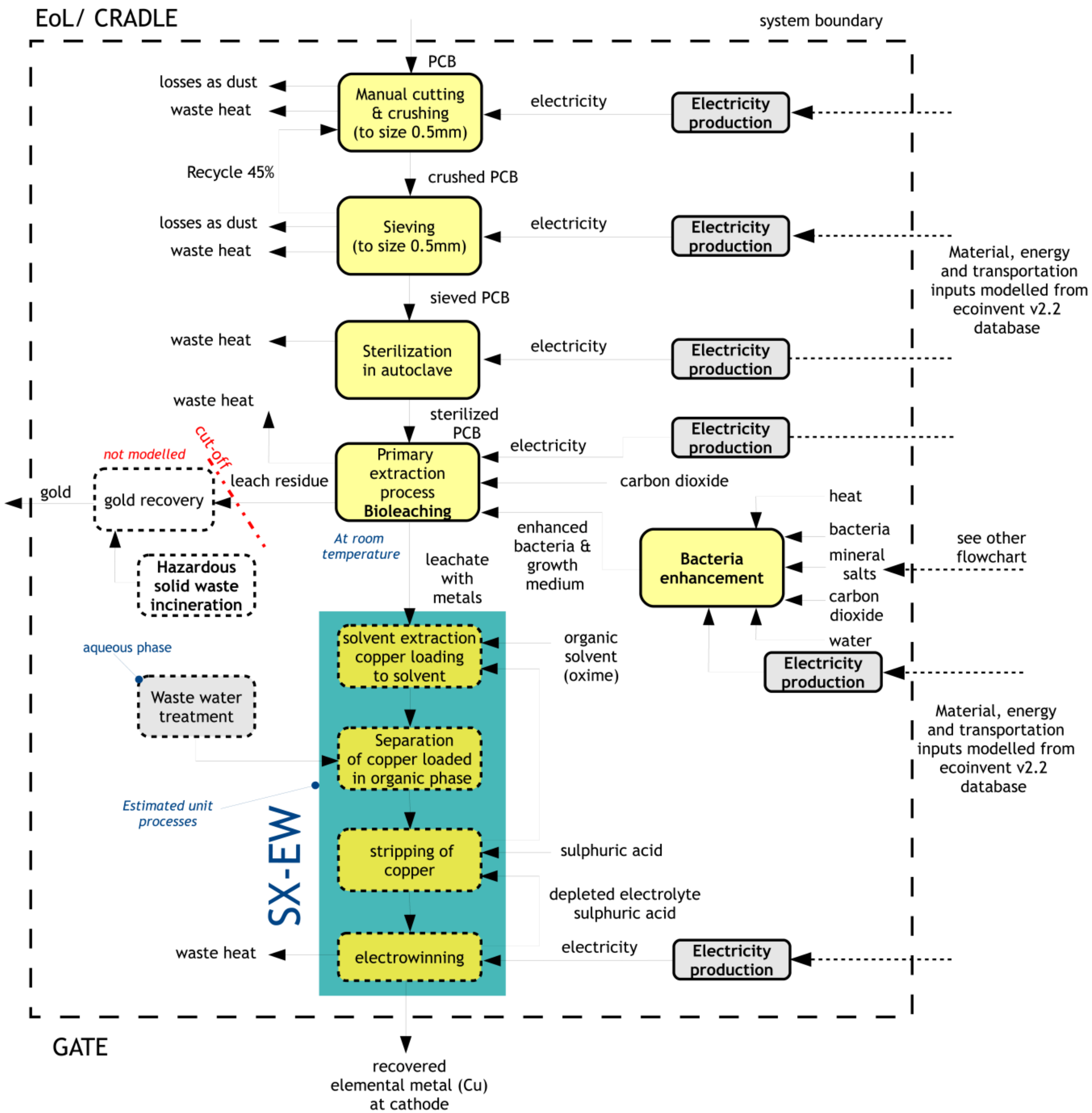
Yield: 96% Cu solubilised



solid residue (approx: 60% wt of PCB)

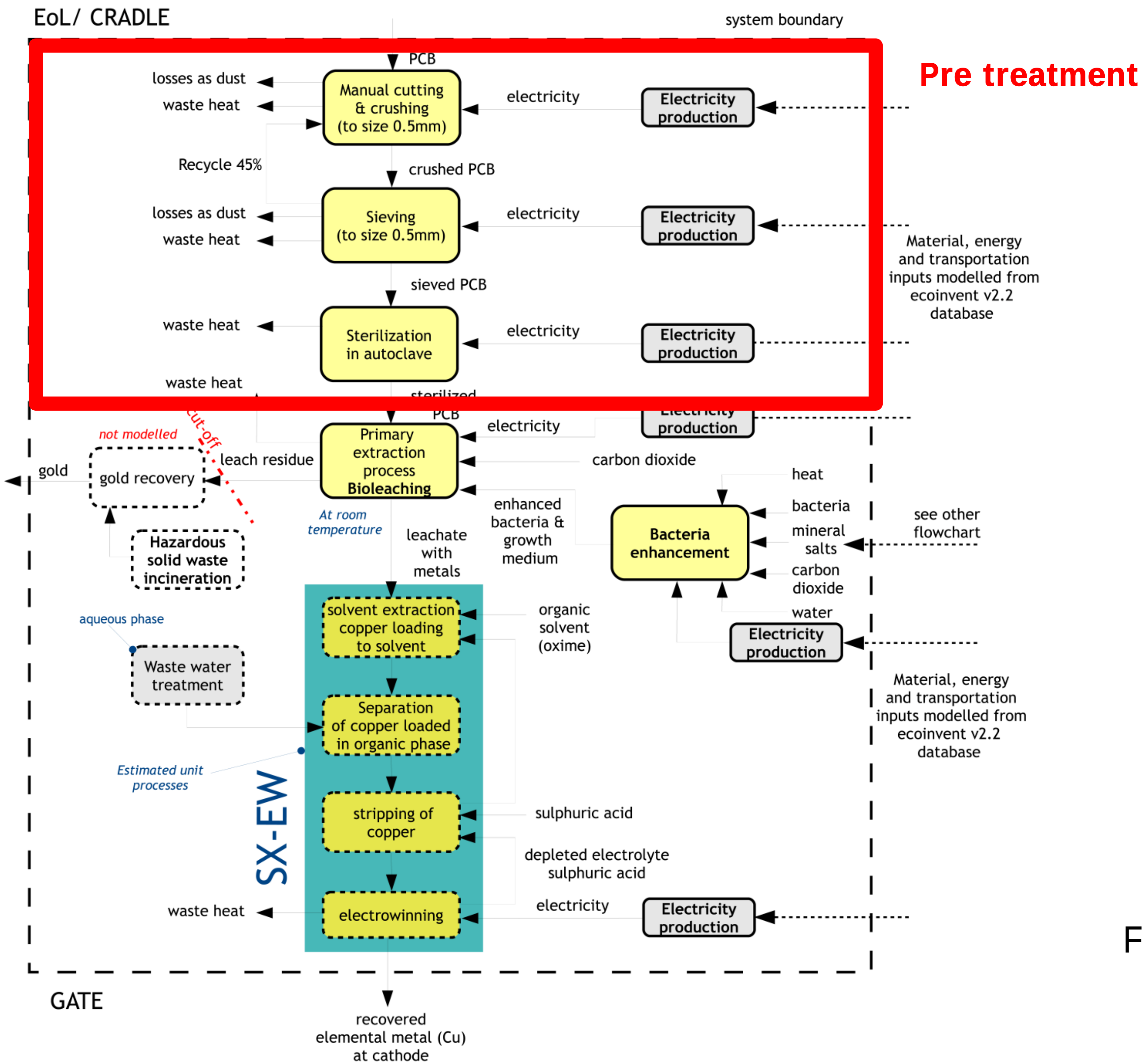
non metallic fraction & precious metals

Lab System - LCA



Flowchart

Lab System - LCA



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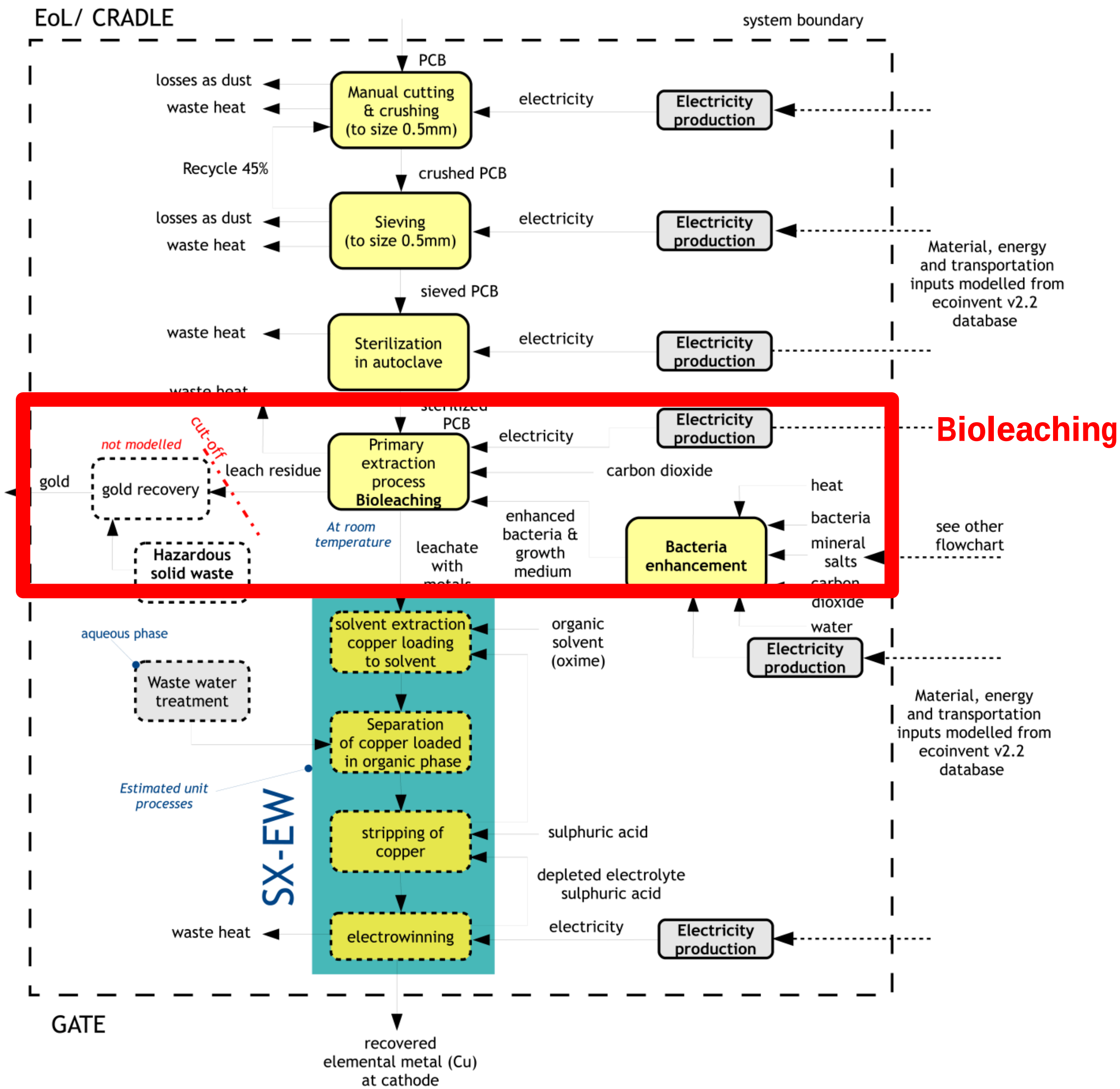

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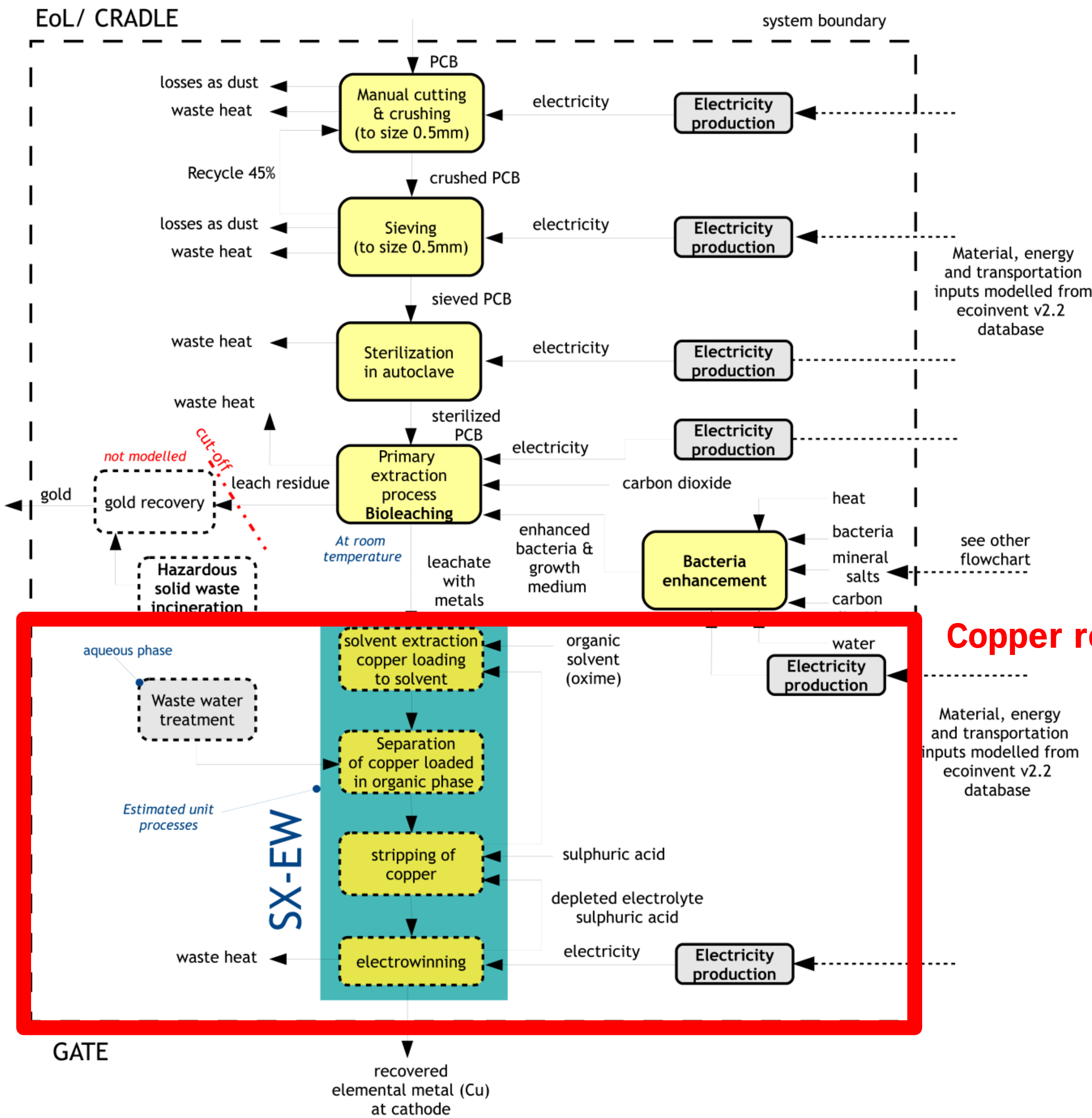

Copper recovery

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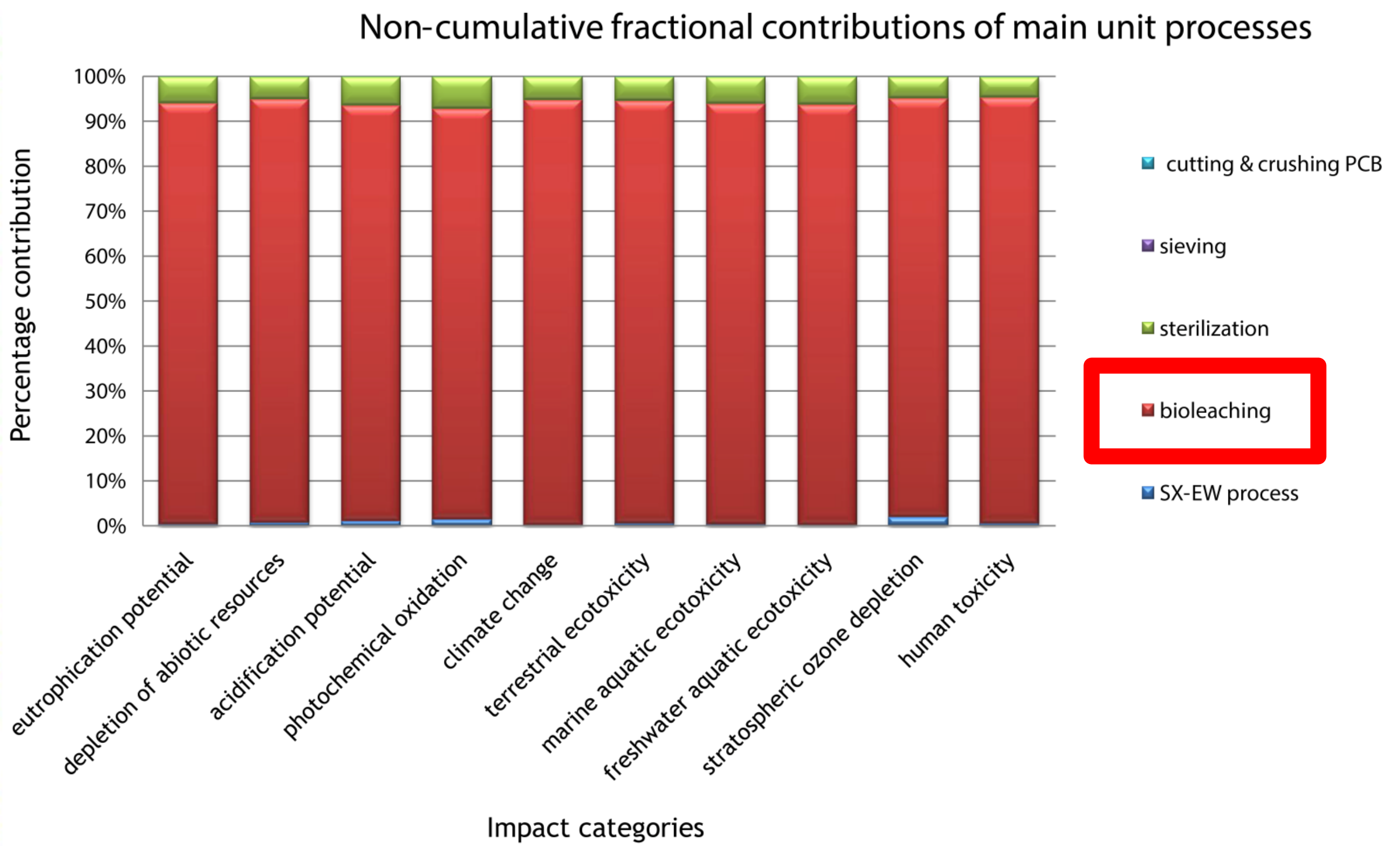
Lab System - LCA

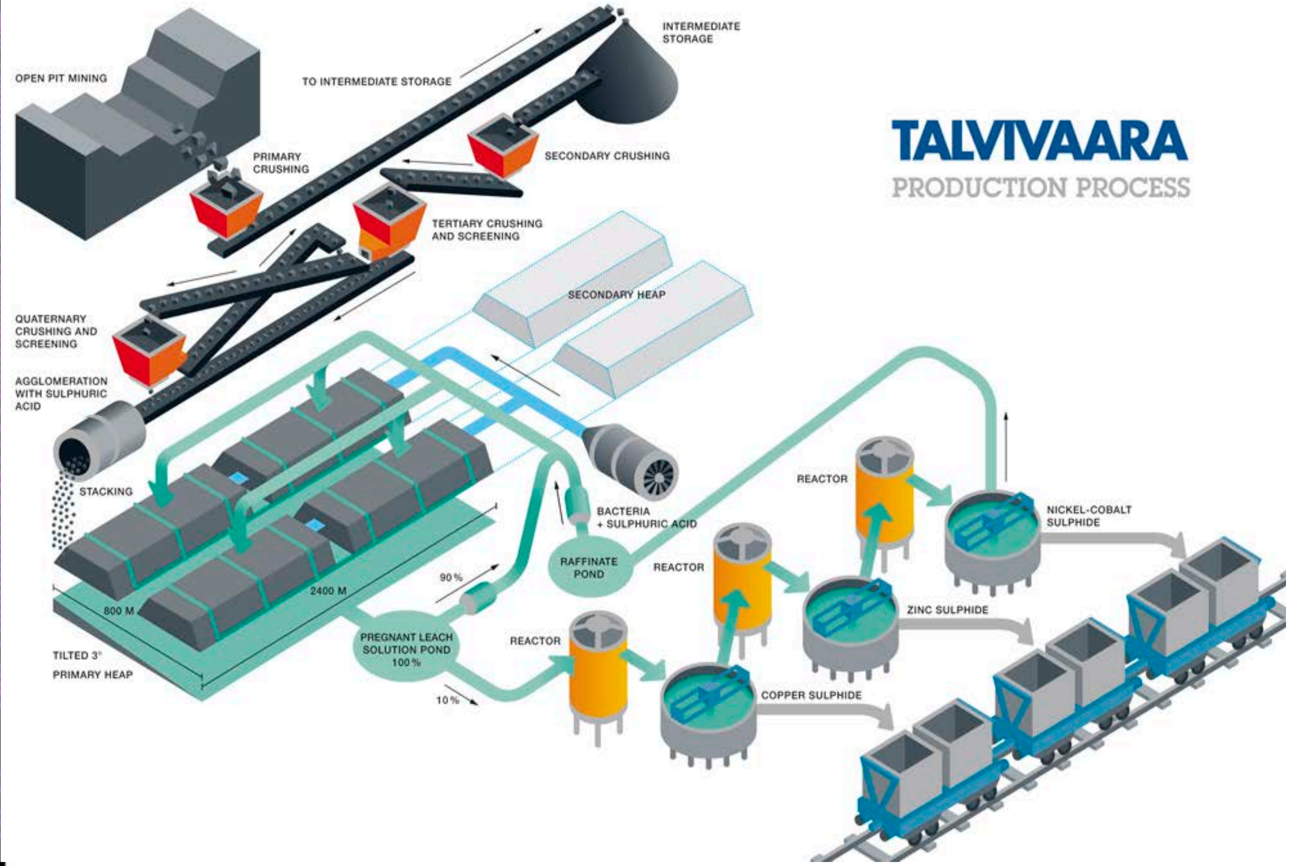


Contribution analysis

Scale up option - Open air heap bioleaching

Talvivaara
nickel mine
Sotkamo, Finland

Scale up option - Open air heap bioleaching



Crushing

Bioleaching

Precipitation

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Scale up option – continuous stirred tanks

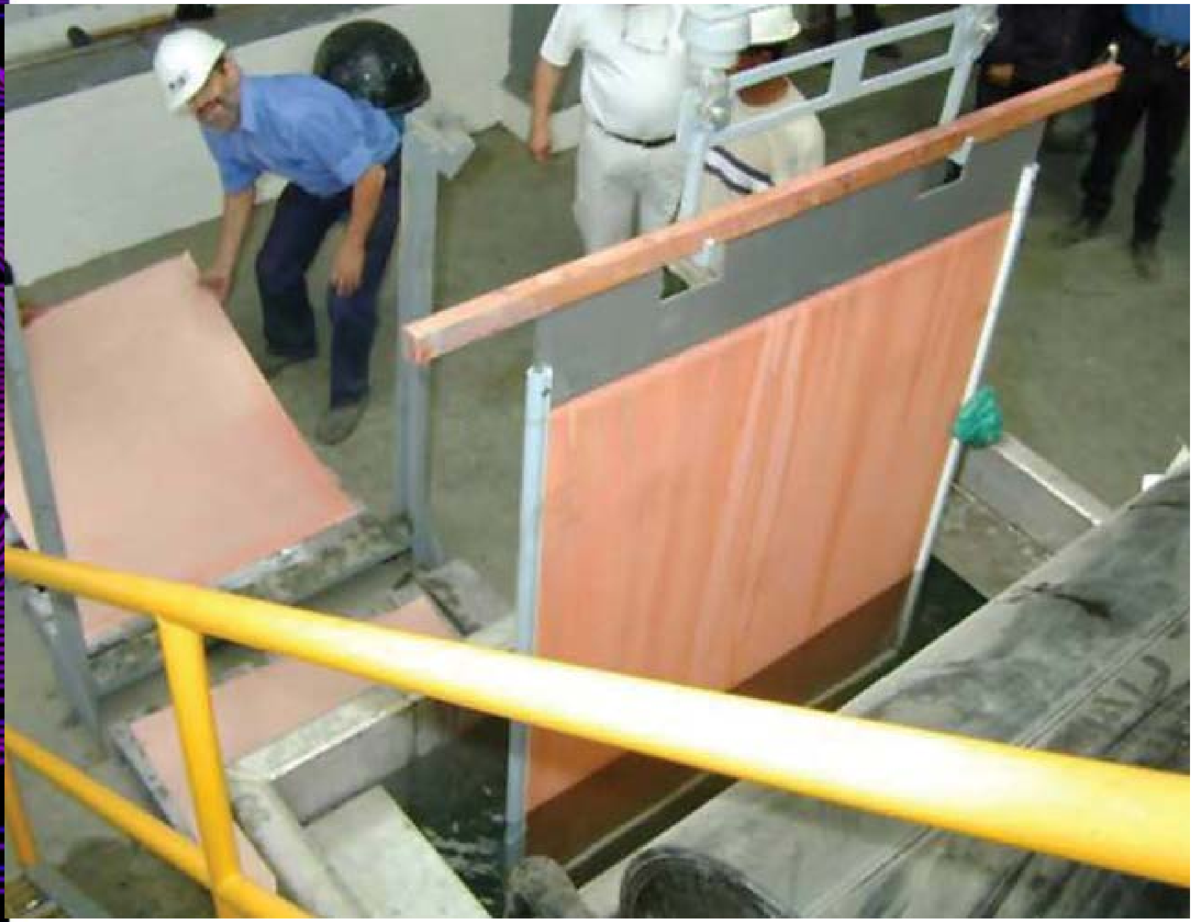
BioMinE
Pilot plant
Seville, Spain

Scale up option – continuous stirred tanks

tank impeller
air sparging
cooling baffles

high intensity aeration, agitation & heat exchange

Scale up option - continuous stirred tanks



pure
cathode
copper

Comparison with established technology

integrated
smelter
refinery

Scaled Up System - scenario

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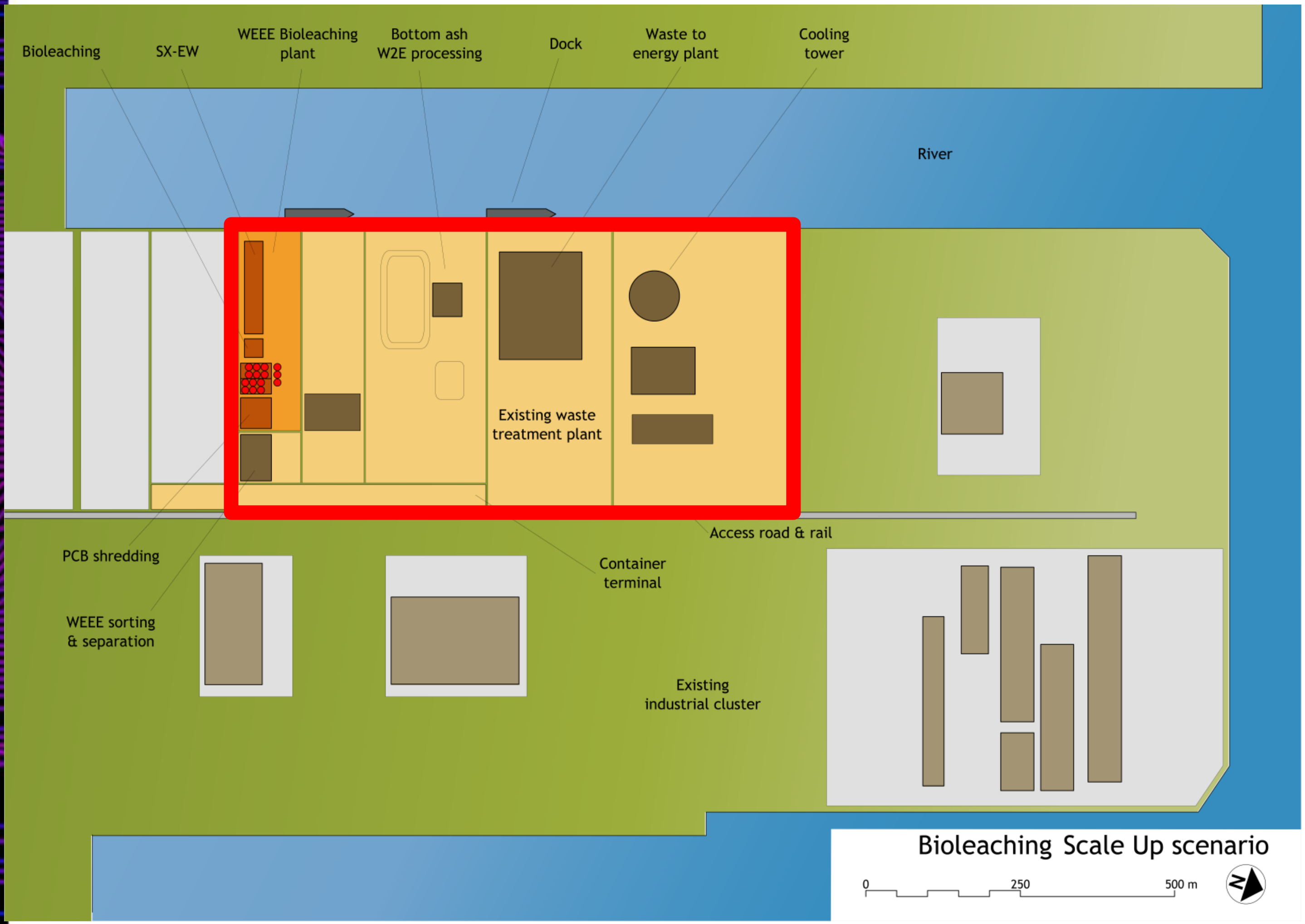

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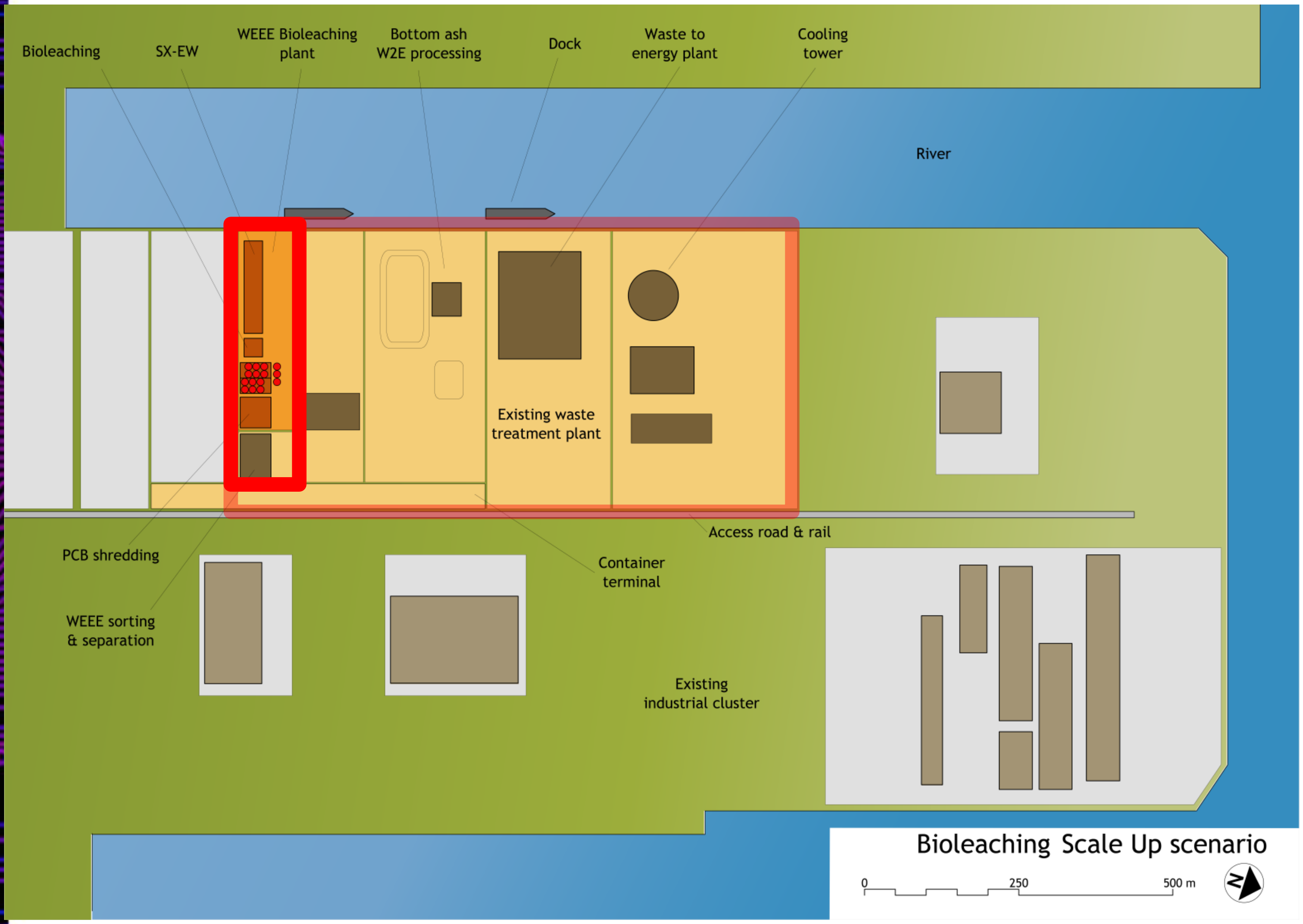
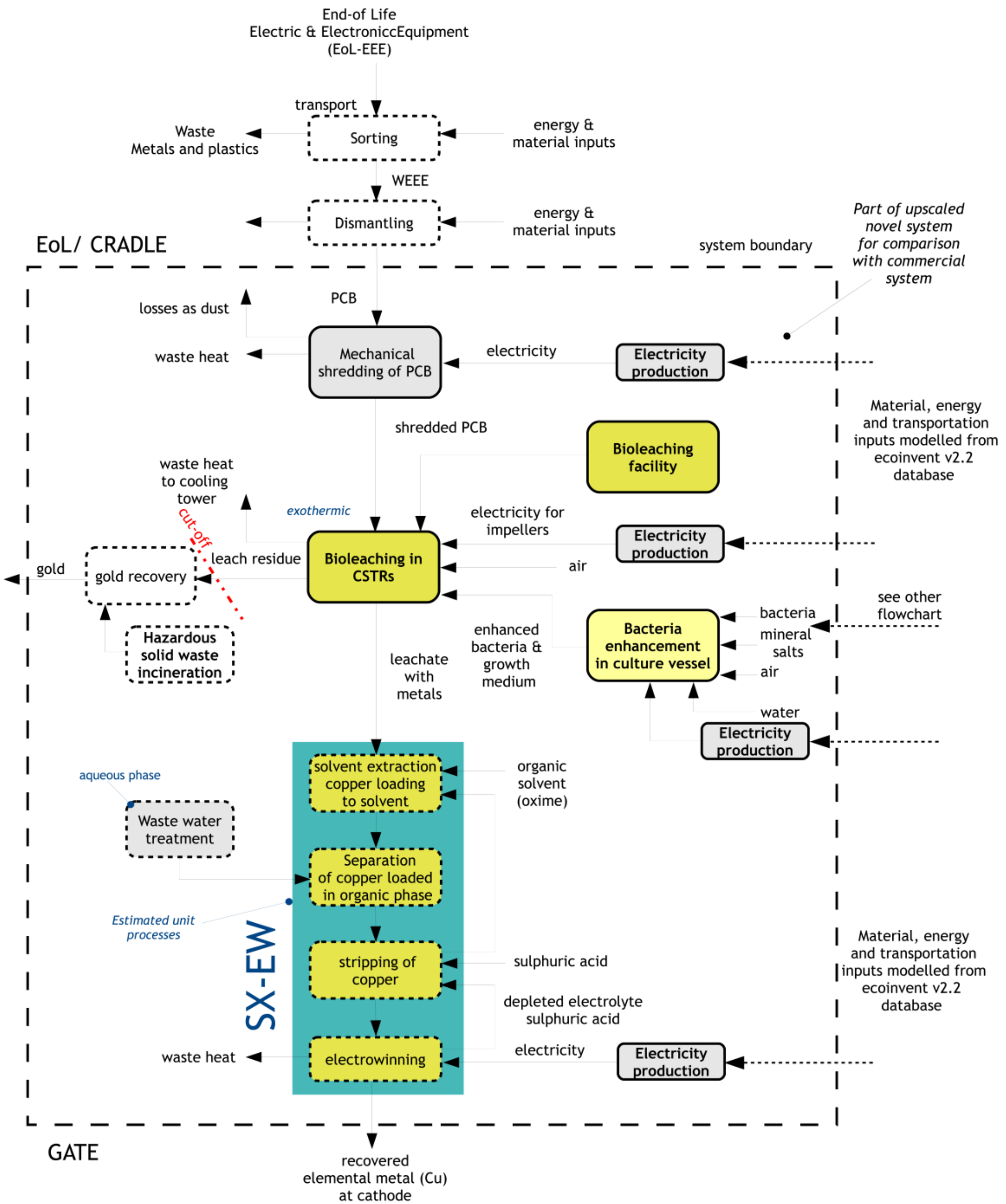


Scenario

Scaled Up System - LCA



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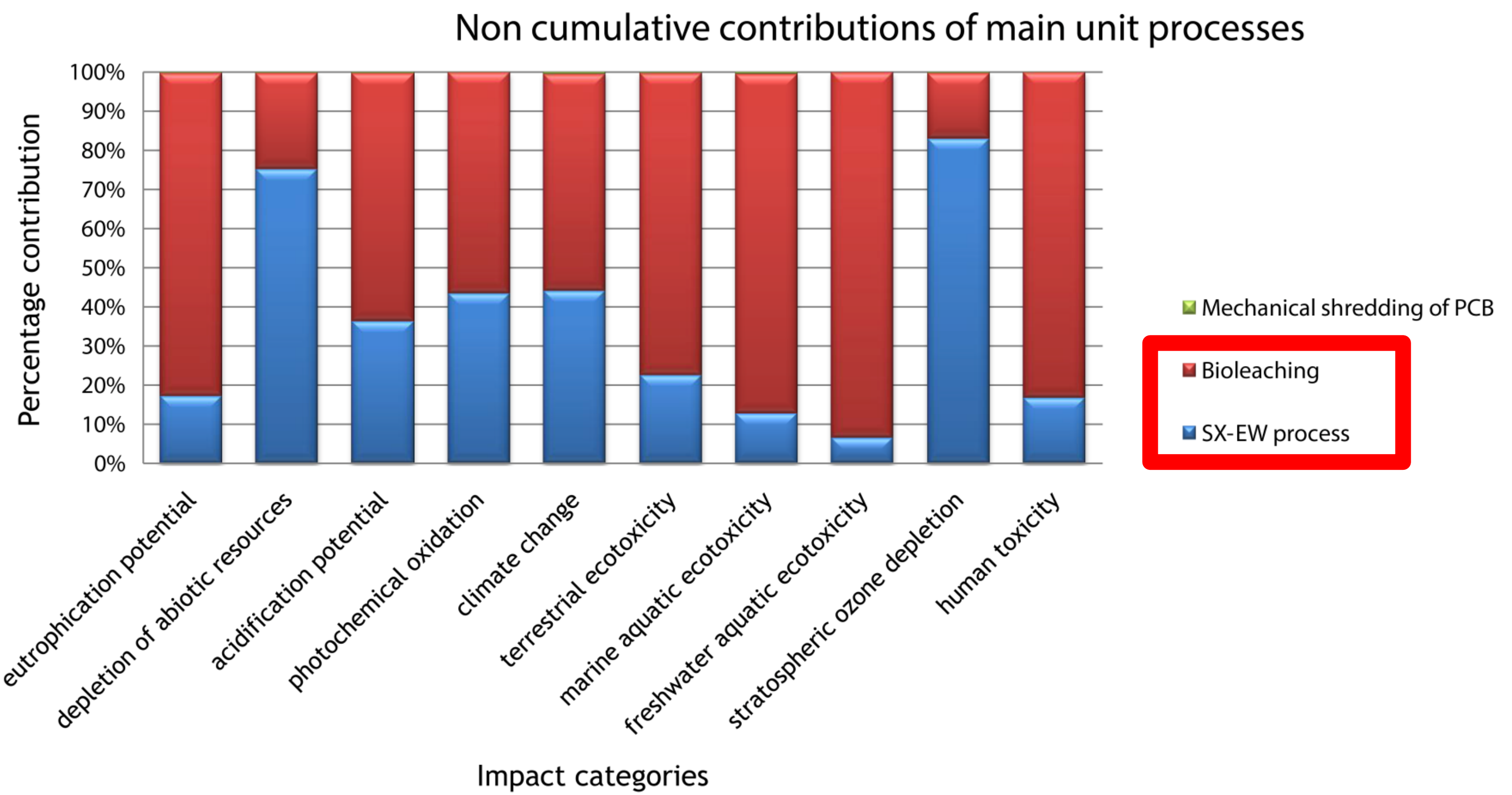
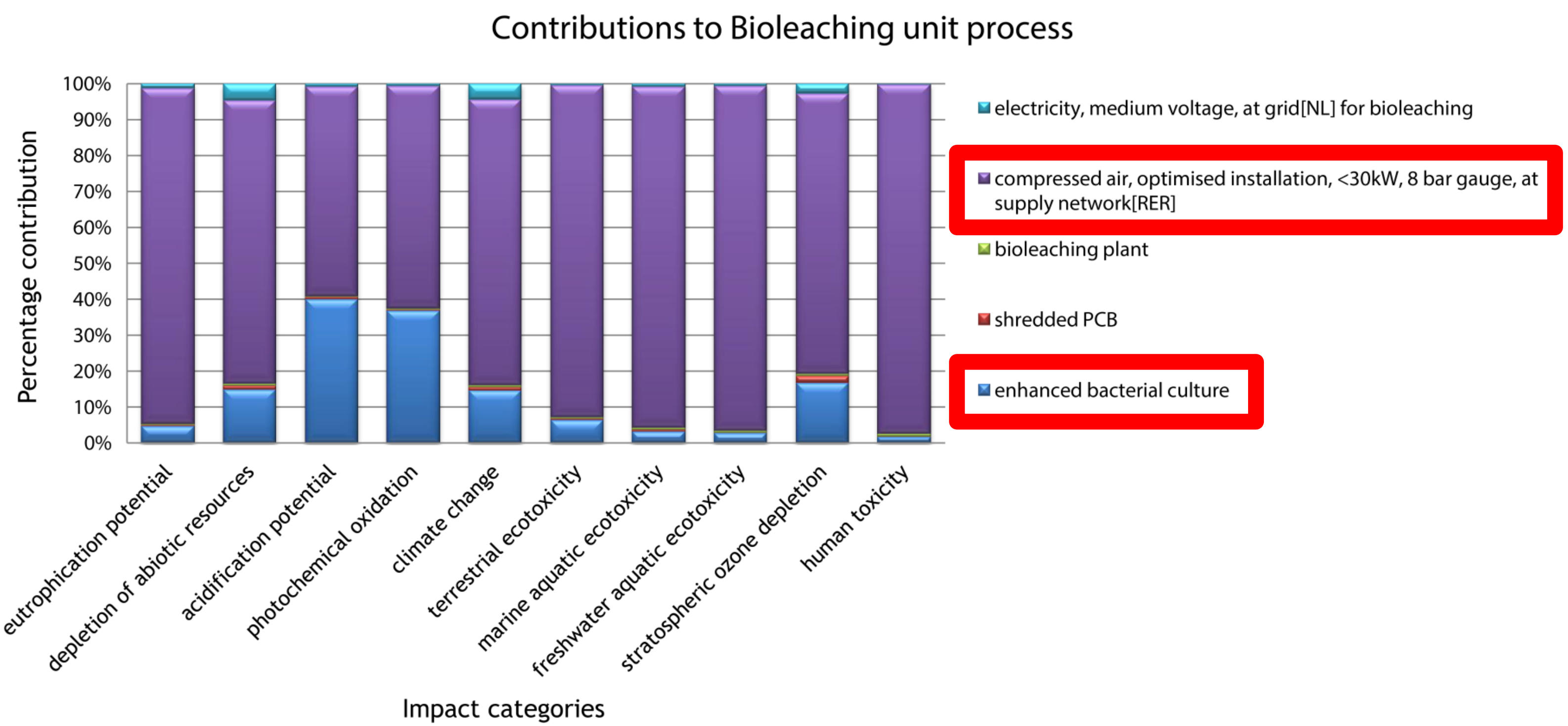


Contribution analysis

Scaled Up System - LCA



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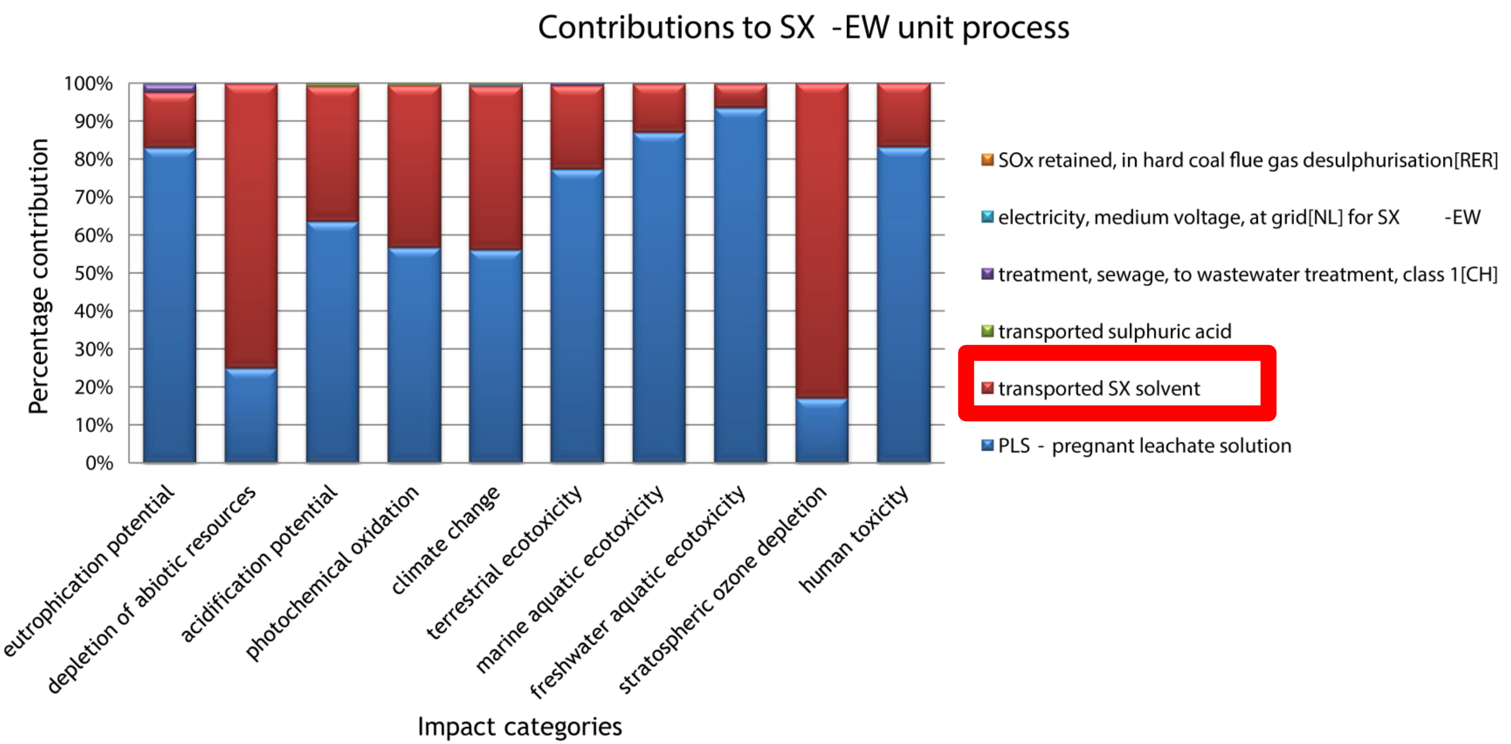

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Contribution analysis

Scaled Up System - LCA

Optimisation of pulp density (processed PCB)	PD 1%	PD 10%	PD 20%	
Category	Value	Value	Value	Unit
CML 2001, eutrophication potential, generic[GLO]	1.13	0.121	0.0633	kg PO4-Eq
CML 2001, resources, depletion of abiotic resources[GLO]	5.63	0.601	0.313	kg antimony-Eq
CML 2001, acidification potential, generic[GLO]	2.69	0.302	0.164	kg SO2-Eq
CML 2001, photochemical oxidation (summer smog), high NOx POCP[RER]	0.155	0.0169	0.00894	kg ethylene-Eq
CML 2001, climate change, GWP 100a[GLO]	345	39.8	22.3	kg CO2-Eq
CML 2001, terrestrial ecotoxicity, TAETP 20a[GLO]	0.0358	0.00379	0.00196	kg 1,4-DCB-Eq
CML 2001, marine aquatic ecotoxicity, MAETP 20a[GLO]	164	17.8	9.35	kg 1,4-DCB-Eq
CML 2001, freshwater aquatic ecotoxicity, FAETP 20a[GLO]	257	27	13.8	kg 1,4-DCB-Eq
CML 2001, stratospheric ozone depletion, ODP steady state[GLO]	7.10E-05	7.53E-06	3.89E-06	kg CFC-11-Eq
CML 2001, human toxicity, HTP infinite[GLO]	1,030	107	54.3	kg 1,4-DCB-Eq

Optimisation

Scaled Up System - LCA

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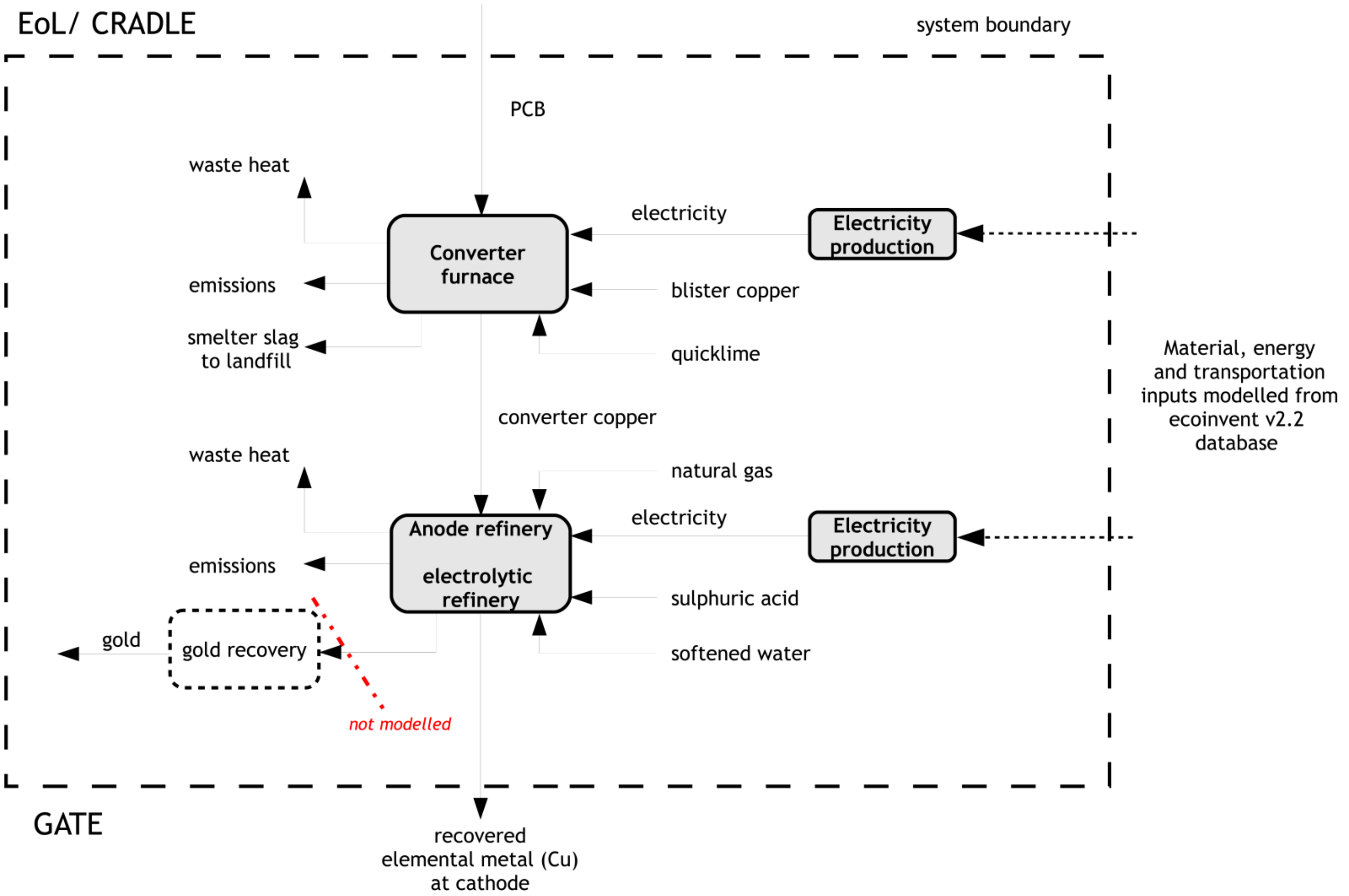
Optimisation

Scaled Up System - comparison



Flowchart

Pyrometallurgical system

Scaled Up System - comparison

Multiple of difference between impacts of bioleaching and pyrometallurgical product systems

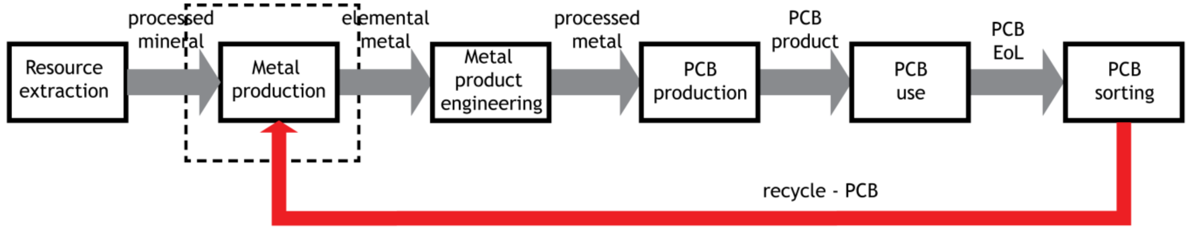
Impact category, characterisation factor (Guinée et al., 2002)	Pyrometallurgical system: Integrated smelter-refinery	Scaled up bioleaching system: Pulp density 1%	Scaled up optimised bioleaching system: Pulp density 10%	Scaled up optimised bioleaching system: Pulp density 20%	Unit
eutrophication, generic[GLO]	6.4×10^{-5}	17,629	1,888	988	kg PO_4-Eq
depletion of abiotic resources[GLO]	3.3×10^{-4}	16,907	1,805	940	kg antimony-Eq
acidification, generic[GLO]	2.2×10^{-4}	12,227	1,373	745	kg SO_2-Eq
photochemical oxidation, high NOx POCP[RER]	2.1×10^{-5}	7,452	813	430	kg ethylene-Eq
climate change, GWP 100a[GLO]	1.0×10^{-1}	3,317	383	214	kg CO_2-Eq
terrestrial ecotoxicity, TAETP 20a[GLO]	1.7×10^{-6}	21,437	2,269	1,174	kg 1,4-DCB-Eq
freshwater aquatic ecotoxicity, FAETP 20a[GLO]	4.1×10^{-1}	630	66	34	kg 1,4-DCB-Eq
stratospheric ozone depletion, ODP steady state[GLO]	7.3×10^{-9}	9,686	1,027	531	kg CFC-11-Eq
human toxicity, HTP infinite[GLO]	7.3×10^{-2}	14,168	1,472	747	kg 1,4-DCB-Eq

x 10,000 - x10

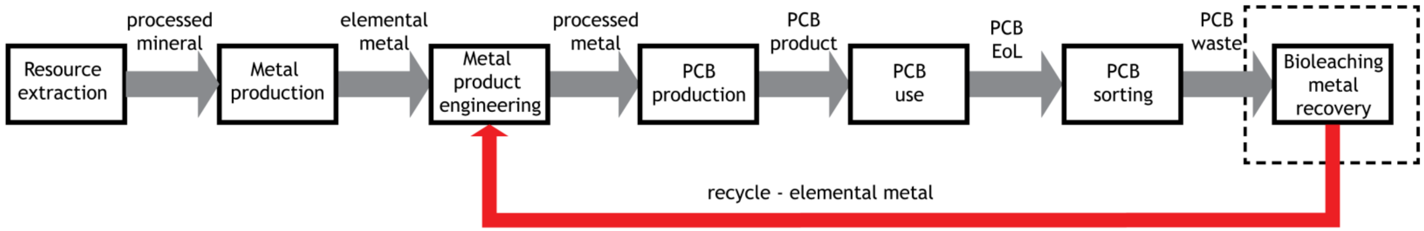
Order of magnitude between potential impacts

Discussion

Comparability?



Pyrometallurgical product system



Bioleaching product system

Re-examining the system boundary

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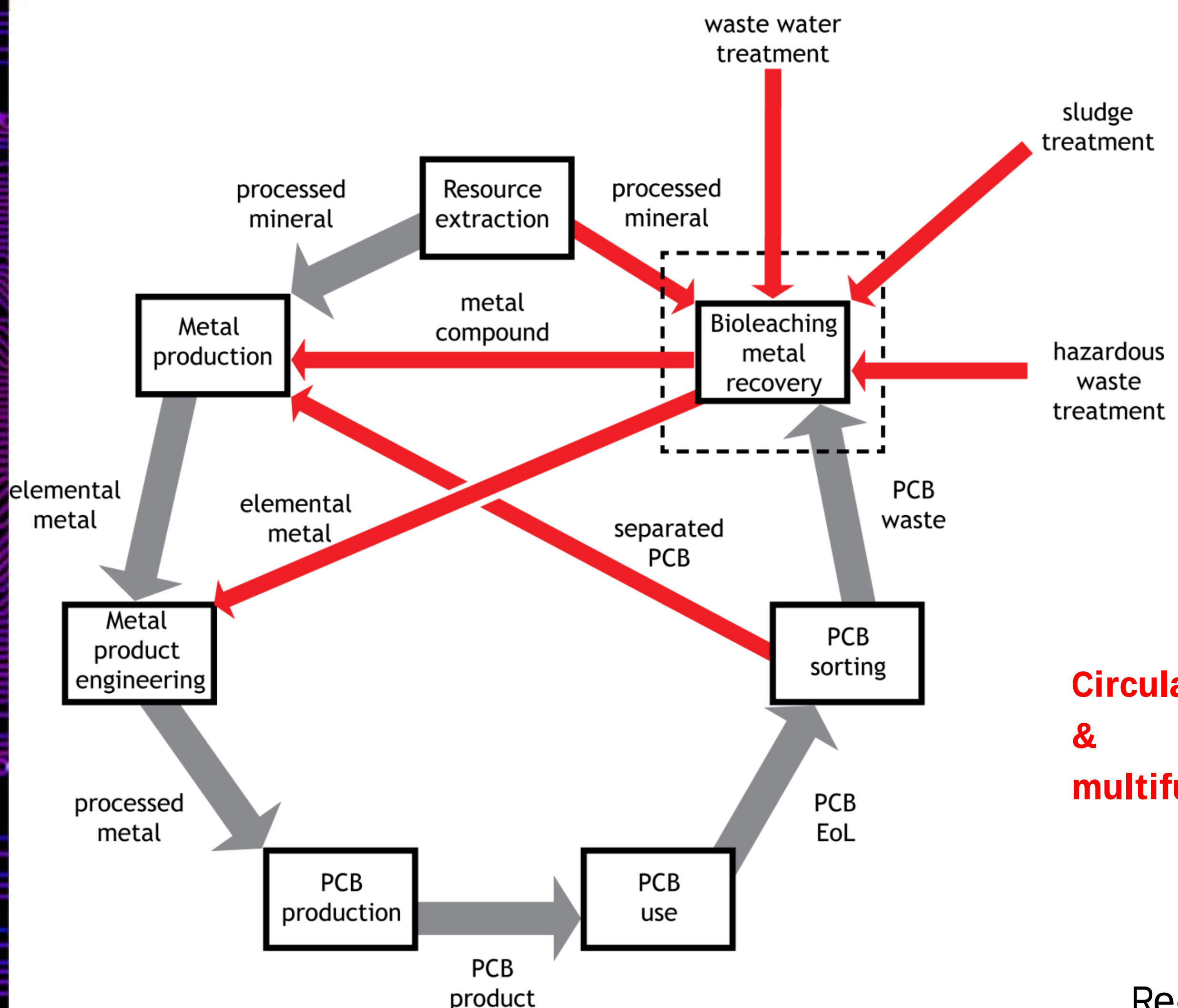
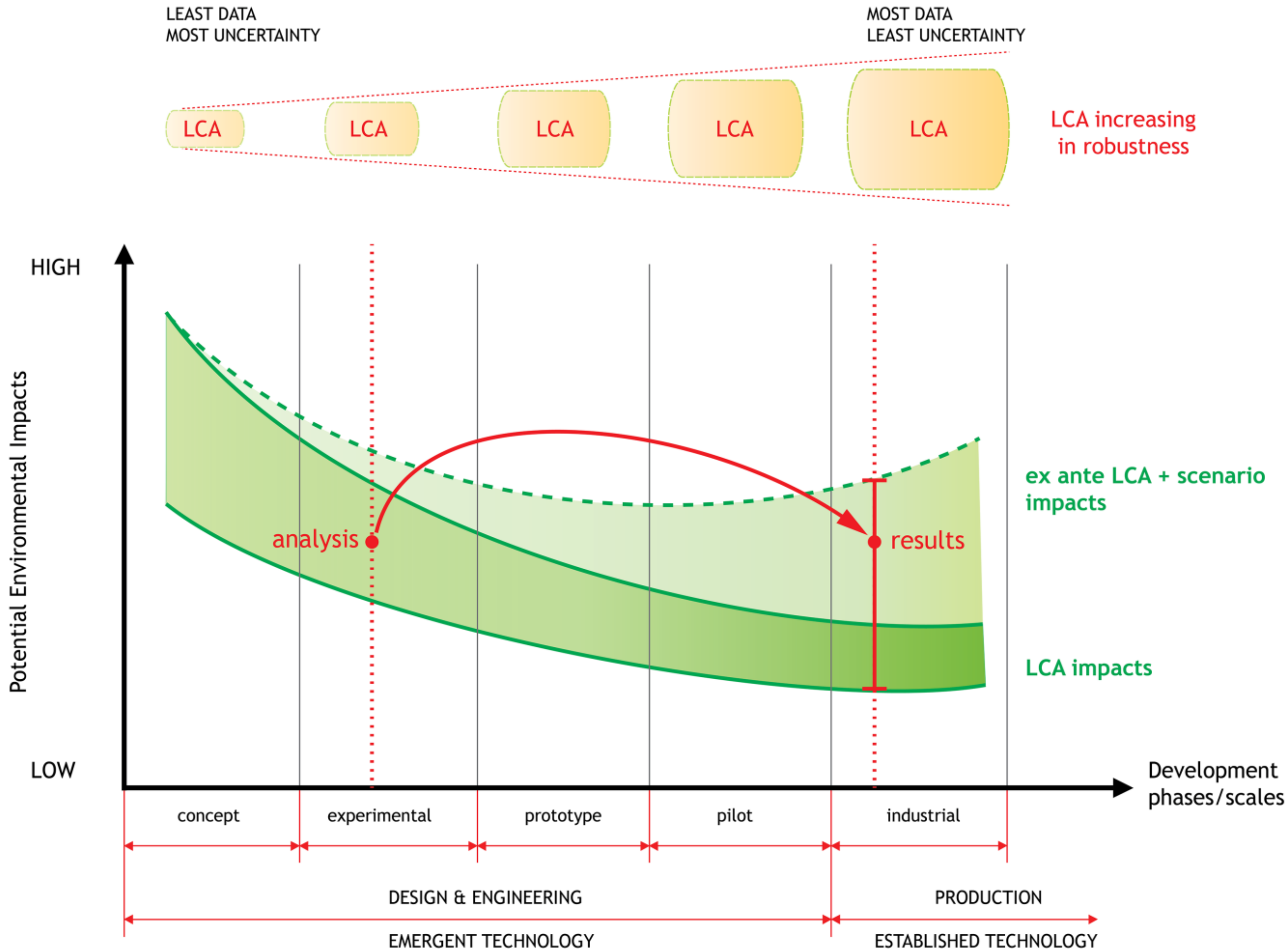
Discussion



Circular potential
&
multifunctionality

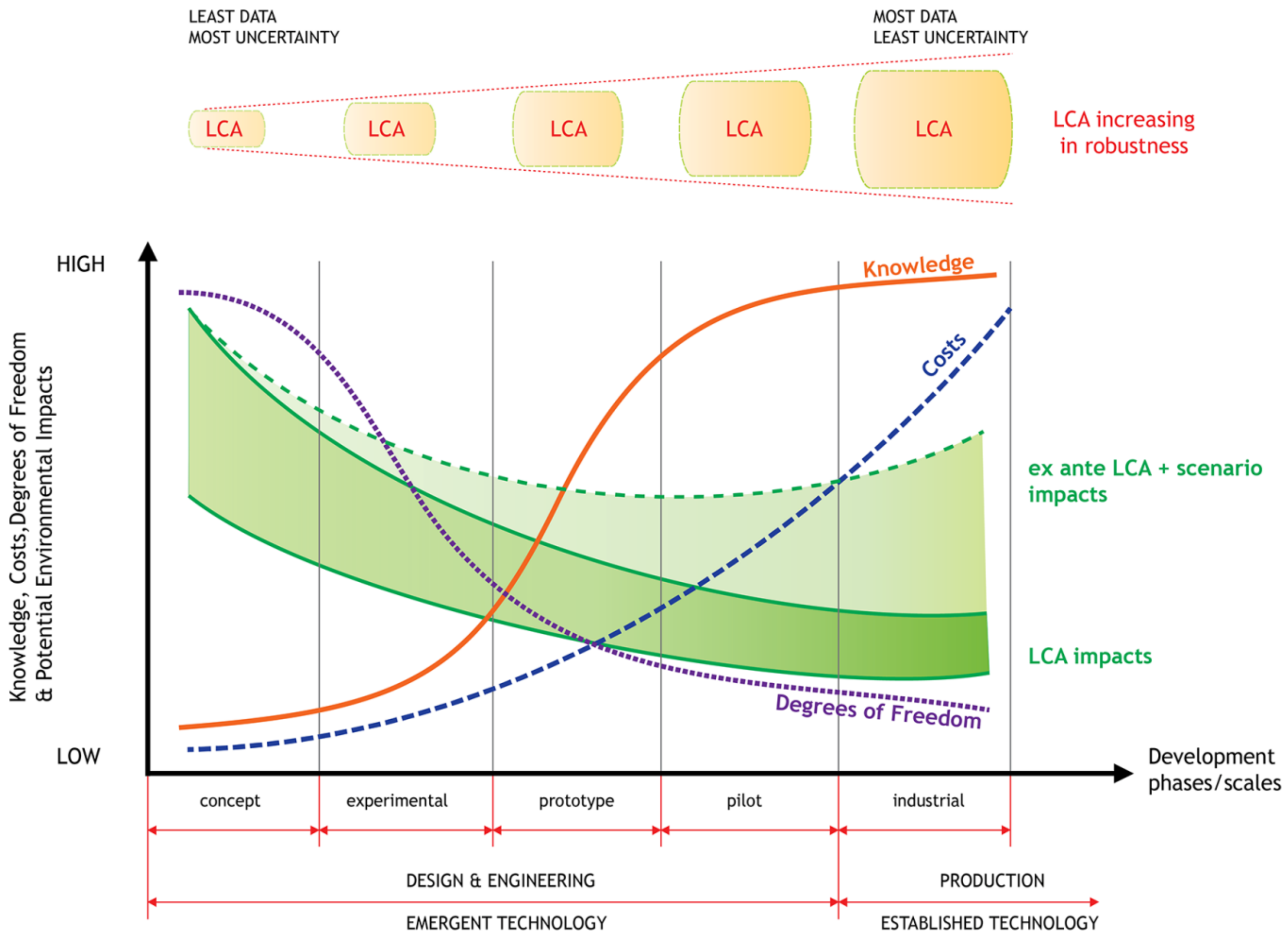
Re-examining the system boundary

Discussion



Technology development & LCA

Discussion



Technology development & LCA

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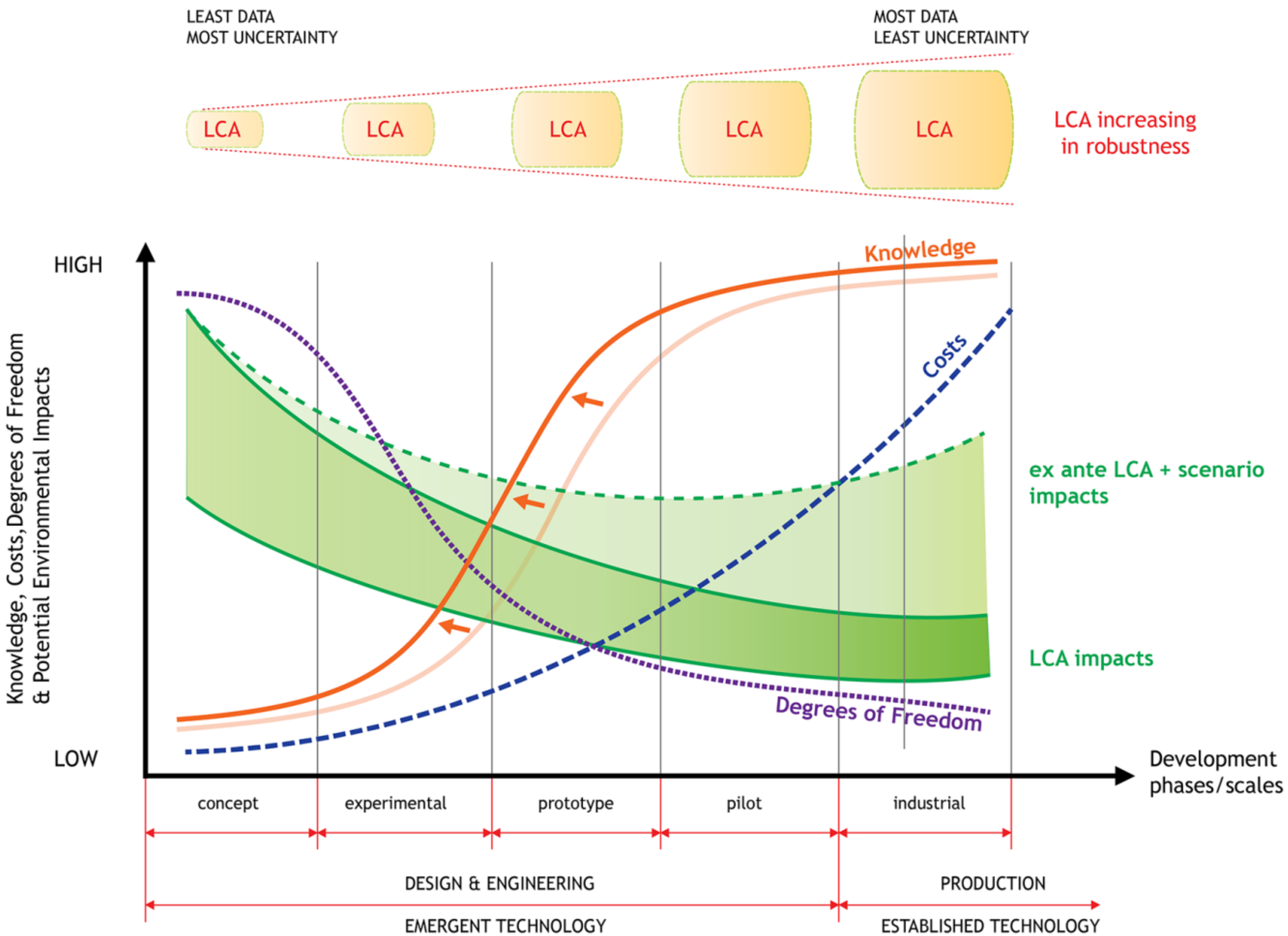

Technology development & LCA

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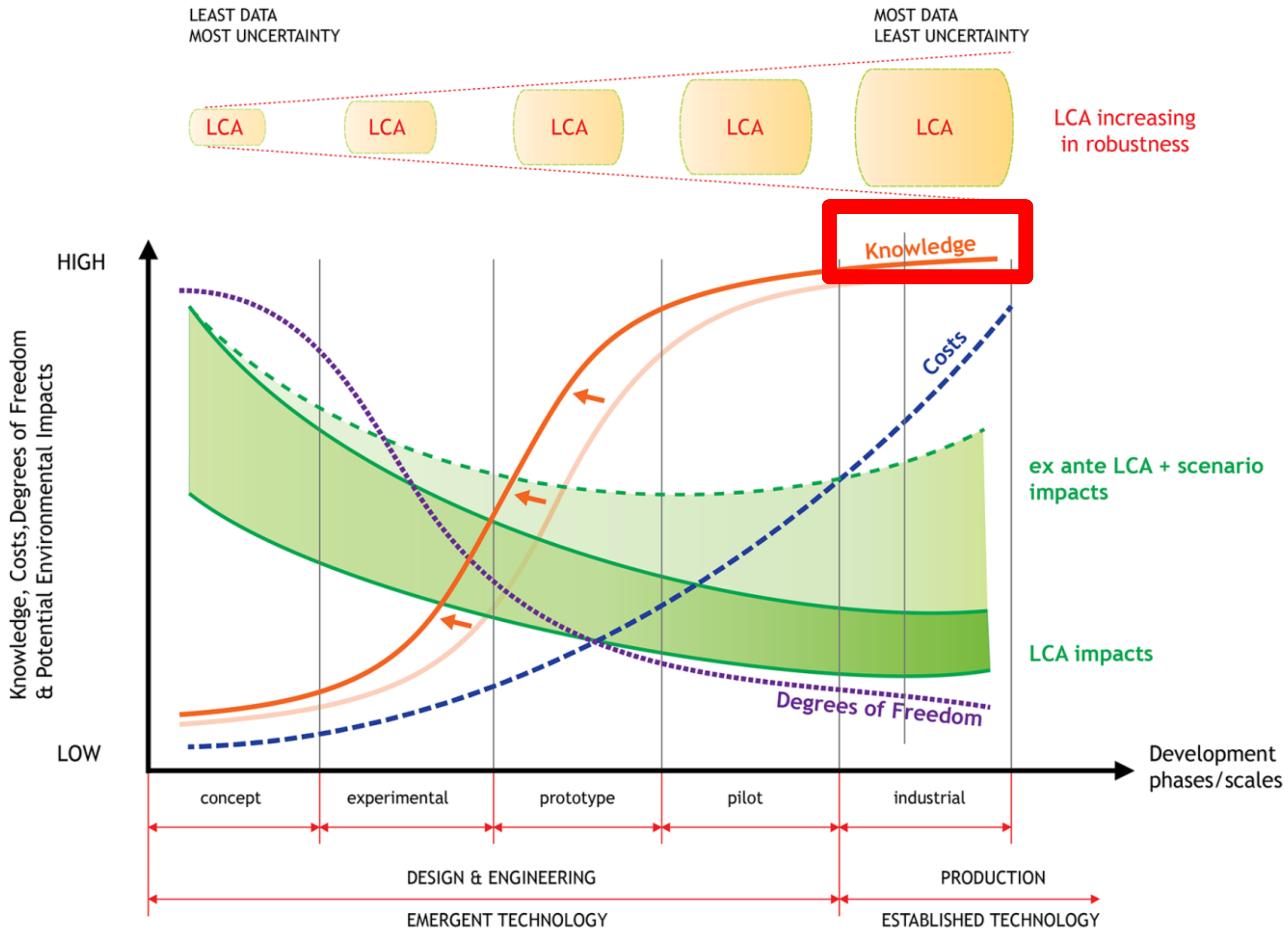
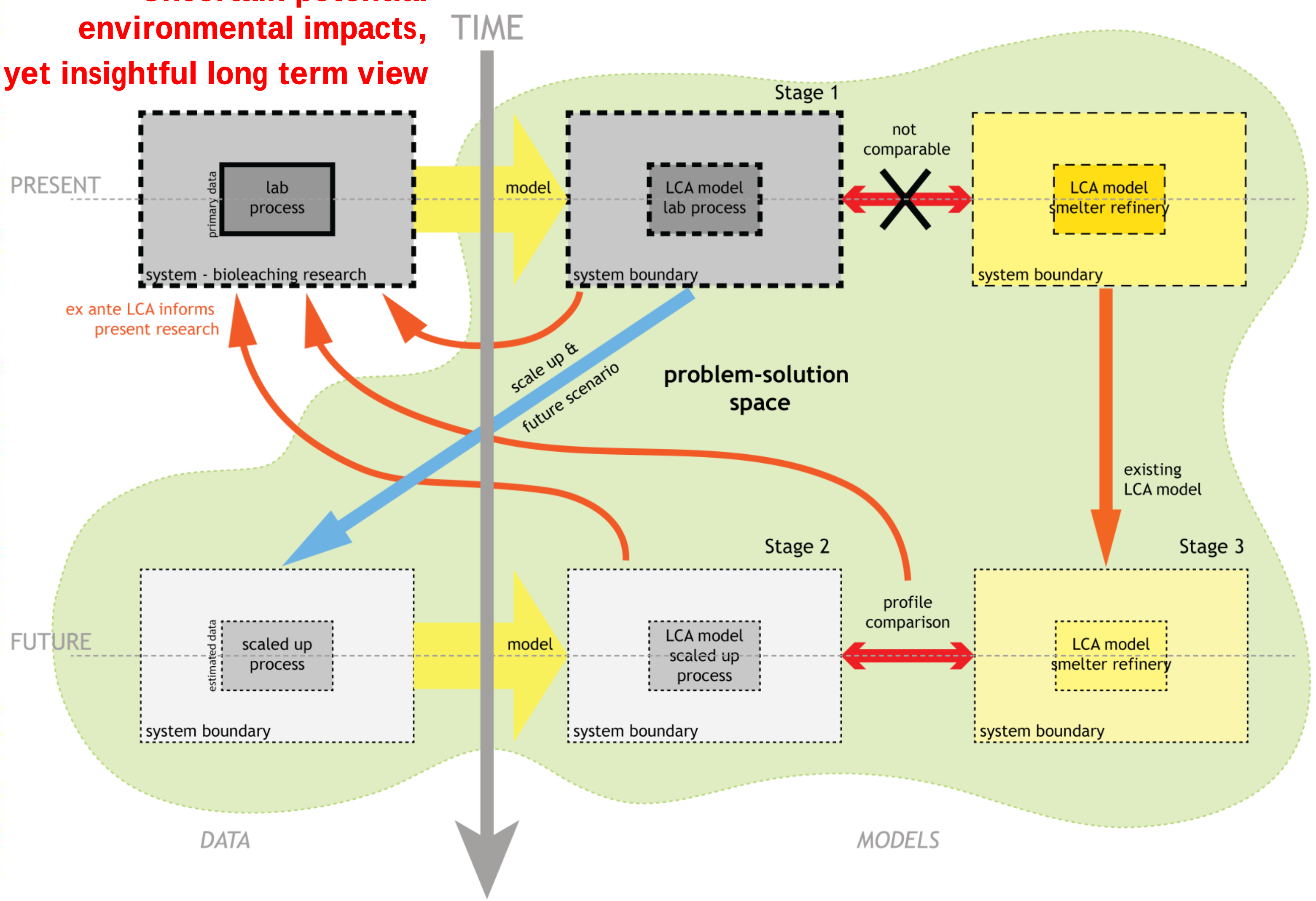


Technology development & LCA

Conclusions

Uncertain potential environmental impacts, yet insightful long term view



Conclusions

- LCA displays potential hot-spots, despite uncertainties.
- Novel technology has inferior profile – developmental challenge for novel technology gains definition early on.

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• LCA displays potential hot-spots, despite uncertainties.

• Novel technology has inferior profile – developmental challenge for novel technology gains definition early on.

• LCA approach broadens research scope - systems approach, long term view, environmental aspects, view of technology

• Applying lessons from existing context is an effective scenario definition strategy.

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- LCA displays potential hot-spots, despite uncertainties.
- Novel technology has inferior profile – developmental challenge for novel technology gains definition early on.

- LCA approach broadens research scope - systems approach, long term view, environmental aspects
- Applying lessons from existing context is an effective scenario definition strategy.

- Prospective LCA + exploratory scenario is of great service as a developmental design tool.
- Effectiveness of multidisciplinary research collaboration between institutes.

Recommendations

- Further refine LCA in subsequent development stages of the process.
- Disseminate this technique as a systems approach tool.

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- Validate approach through testing on other novel technology cases.
- Strengthen estimative/simulation component.

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- Validate approach through testing on other cases.
- Strengthen estimative/simulation component.

- Try more precocious application on research proposals & design concepts in industry.
- Expand approach with social & economic aspects.

More information

- **Complete MSc thesis**:

"Applying a life cycle perspective to research on metal recovery from electronic waste using bioleaching"
http://repository.tudelft.nl/view/ir/uuid:ad116c32-ea7c-40eb-955a-ba96d62ac5c8/

- **Article in Journal of Cleaner Production**:

"Applying an ex-ante life cycle perspective to metal recovery from e-waste using bioleaching"

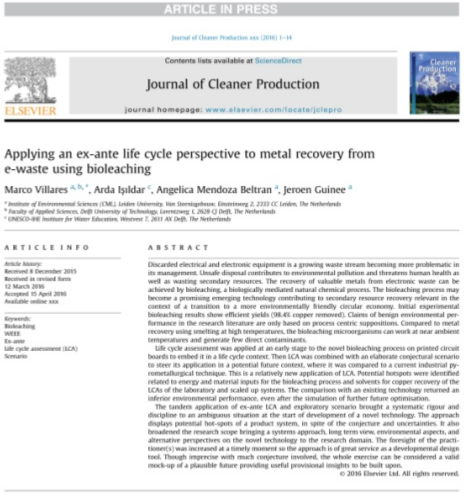
http://dx.doi.org/10.1016/j.jclepro.2016.04.066

- **Article in Journal of Life Cycle Assessment**:

"Does ex ante application enhance the usefulness of LCA?

A case study on an emerging technology for metal recovery from e-waste"

http://dx.doi.org/10.1007/s11367-017-1270-6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Applying an ex-ante life cycle perspective to metal recovery from e-waste using bioleaching

Marco Villares, Arda Işıldar, Angelica Mendoza Beltran, Jeroen Guinee

ARTICLE INFO

ABSTRACT