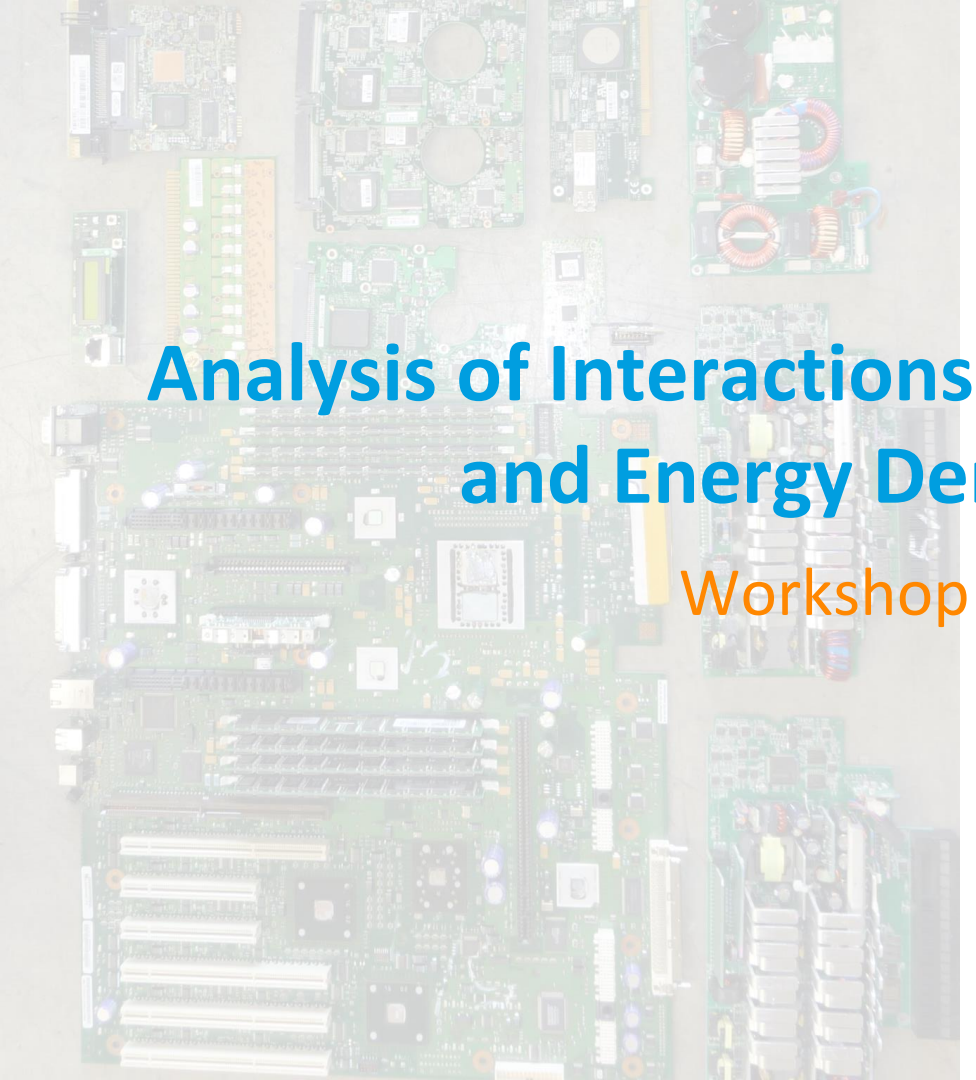

Analysis of Interactions Between Raw Material and Energy Demands for Data Centers

Workshop on Data Center Sustainability

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OFFIS Institute for Computer Science
16/12/2022

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Prof. Dr.-Ing. habil. Jorge Marx Gómez
Dr.-Ing. Alexandra Pehlken

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Increasing resource demands for professional data centers [borderstep 2018].

Increasing material resource demands for professional data centers:

Data quality for assessing data centers material consumption is poor [Hintemann 2010].

The possible impacts of resource savings from material recovery are unexplored.

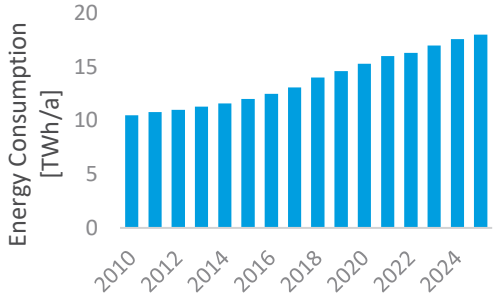

Fig 1. Data Center Electricity Consumption in Germany (forecast from 2019-2025. Source: borderstep, 2020)

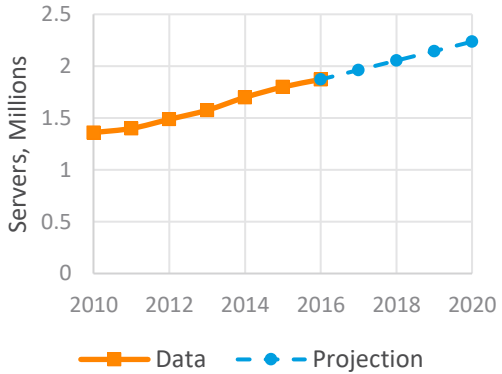

Fig 2. Number of servers in German DC. (Data source: eanalyzer.biz)

Fig 3. End-of-Life Server Components

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Principal Objectives:

> Analyze how the **primary energy consumption** and **material** demand in professional data centers are divided between the distinct phases of their lifecycle outside of the operational phase.

Secondary Objectives:

> Study which are the **interactions** between material consumption and primary energy during these stages.

> Evaluate what are the **energy impacts** of different scenarios for recycling.

> Assess which have been the improvements of **Data Quality** of the results.

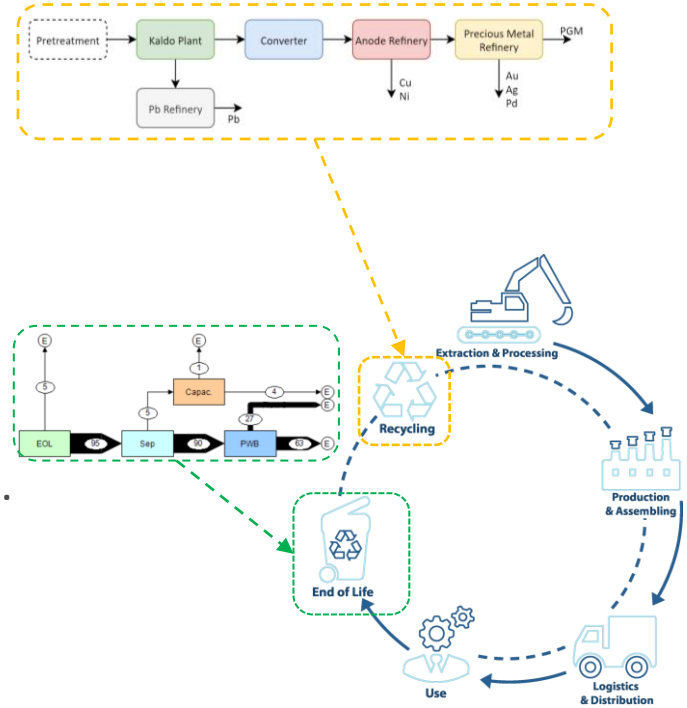

Fig 4. Stages in a product environmental lifecycle and examples of EOL.
(Sources: Bigum 2011, Li et al. 2019, weloop.org)

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Attempted Gap Closing

Overview of Methodology

Table 2. Attempted gap closing and methods.

	Concept	Thesis Objectives
Data Sources/ Inventories	Parts/Devices Composition Data	Update from Lab Analysis (mairec, TUHH) Update Inventory Data
	Embodied Energy	LCA modelling
	Raw Material Consumption	LCA modelling, update material data
	Material Recovery	LCA modelling for material recovery
Indicators	Indicators for Energy Consumption	Cumulated Energy/Exergy Demand for DC and components. GHG Emissions
	Indicators for Material Consumption	Critical Material Consumption Indicators for DC and components
	Resource Efficiency	Dependence of indicators
Data Qual	DQ Assessment	DQ Assessment and uncertainty modelling

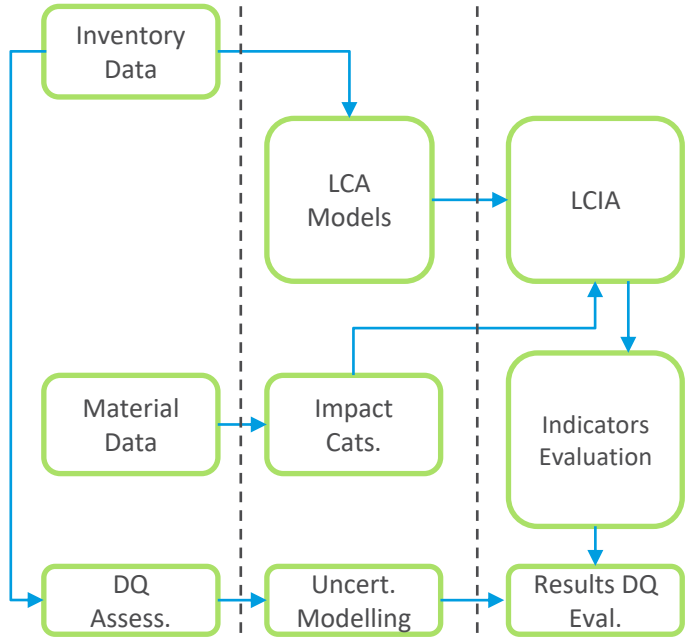

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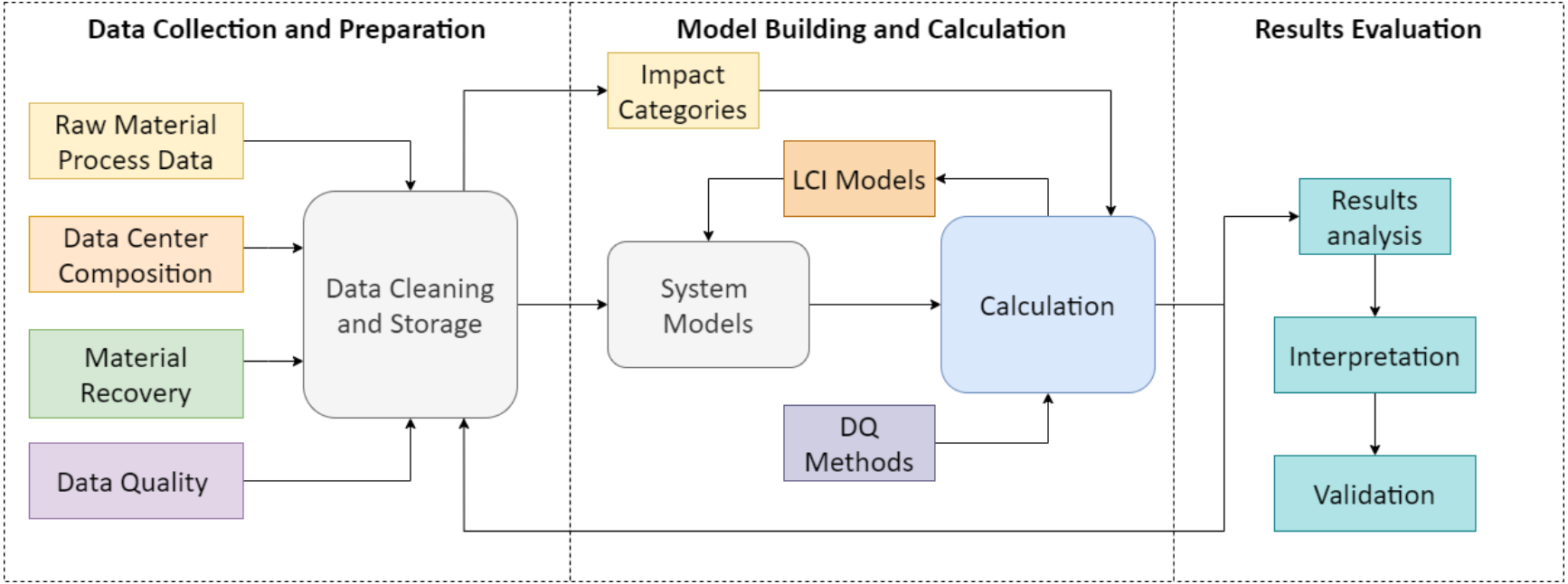
Fig 6. Overview of research methodology



Data Collection

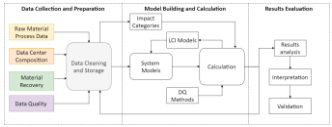
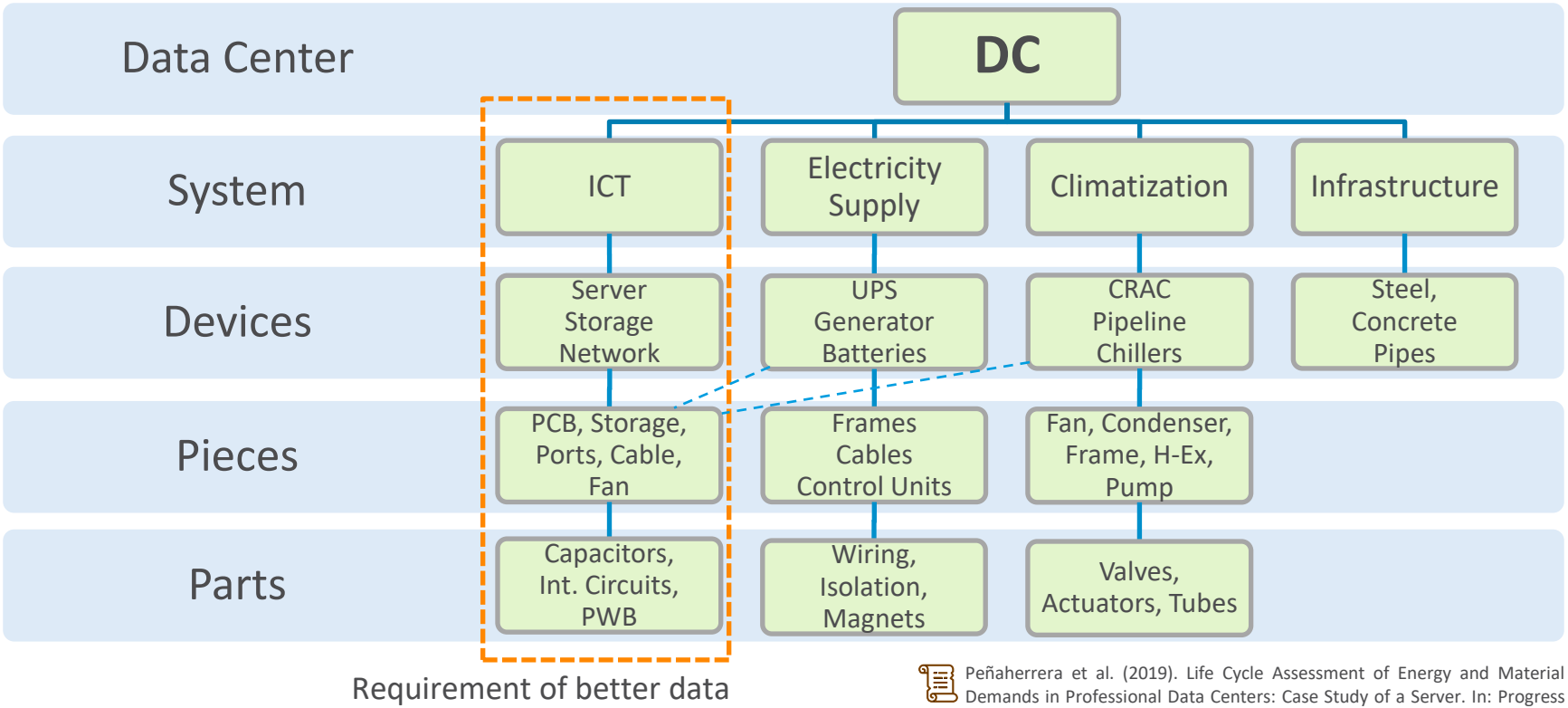


Fig 8. Hierarchical Structure of a Data Center.



Peñaherrera et al. (2019). Life Cycle Assessment of Energy and Material Demands in Professional Data Centers: Case Study of a Server. In: Progress in Life Cycle Assessment

DC = Data Center, ICT = Information and Communications Technology, PCB = Printed Circuit Board, PWB = Printed Wiring Board, H-Ex = Heat Exchanger

Data Collection

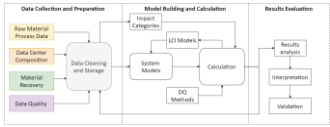
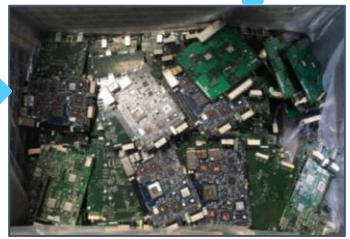


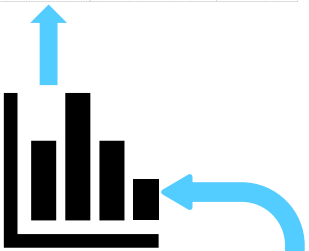
Fig 9. Analysis of material composition of data center components

Servers

PCB-Categories

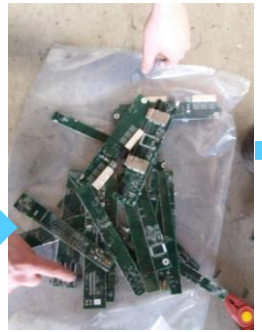


Parts



Analysis

Cutting

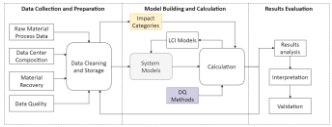


Pulverization

Pehlken et al. (2020). Abschlussbericht Verbundprojekt TEMPRO: Total Energy Management for Professional Data Center. BMWi.

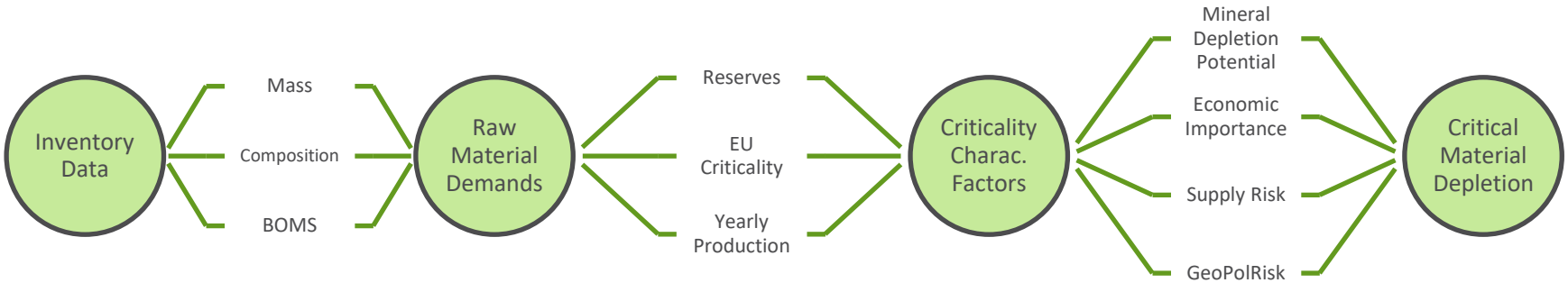
Model Building

Proposal of a Criticality Indicators Set



- Abiotic Depletion Potential to quantify depletion rate (van Oers et al. 2020)
- Combination with EU **Supply Risk** and **Economic Importance** to assess criticality of material resource depletion (EC 2020)

Fig 11. Building of Indicators



Koch, Peñaherrera & Pehlken (2019). Criticality and LCA – Building comparison values to show the impact of criticality on LCA. 7th International Conference on Sustainable Development.

Model Calculation Outputs

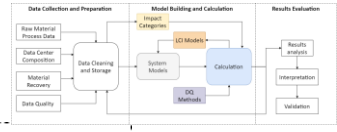
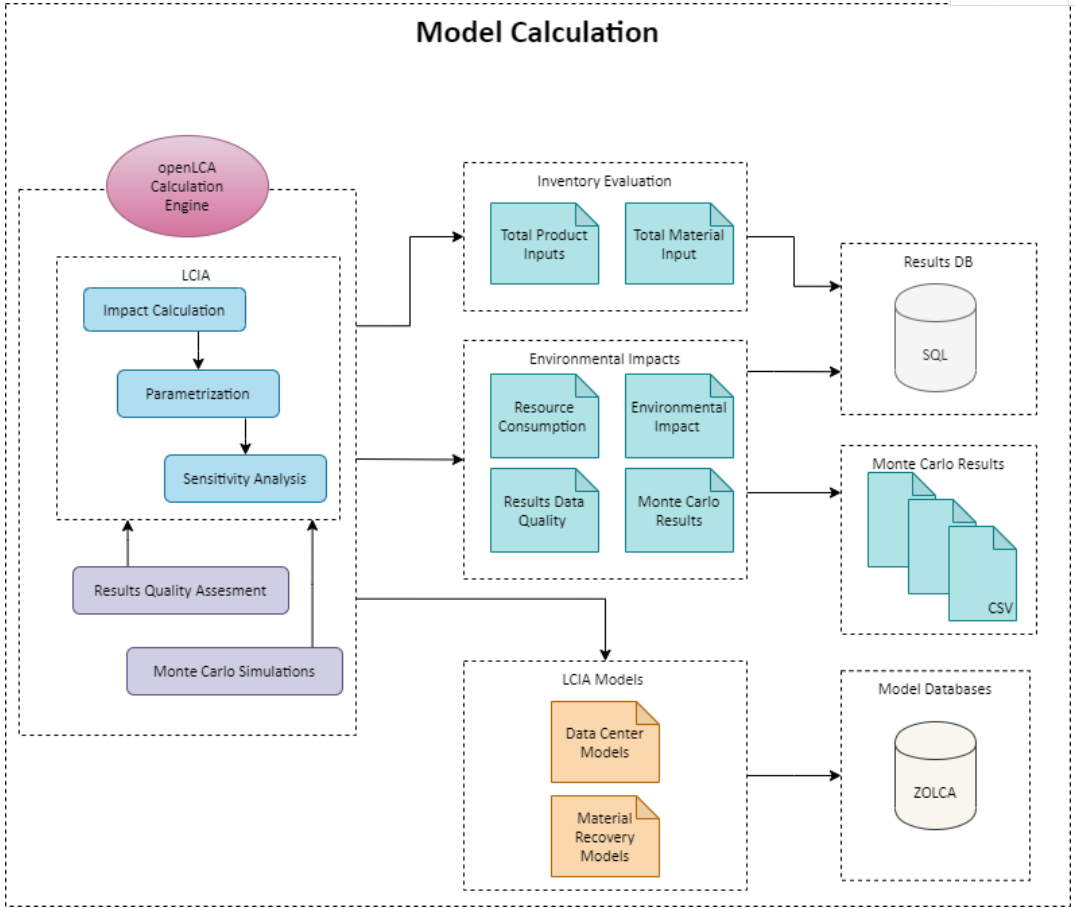


Fig 13. Outputs of Model Calculation



Peñaherrera et al. (2021). Softwarearchitektur für die Bewertung des Ressourcenbedarfes in Rechenzentren durch ganzheitliche Ressourceneffizienz. INFORMATIK 2021

Peñaherrera et al. (2019). Development and Application of Metrics for Evaluation of Cumulative Energy Efficiency for IT Devices in Data Centers. In: Cascade Use in Technologies 2018.

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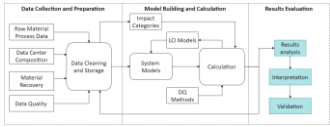

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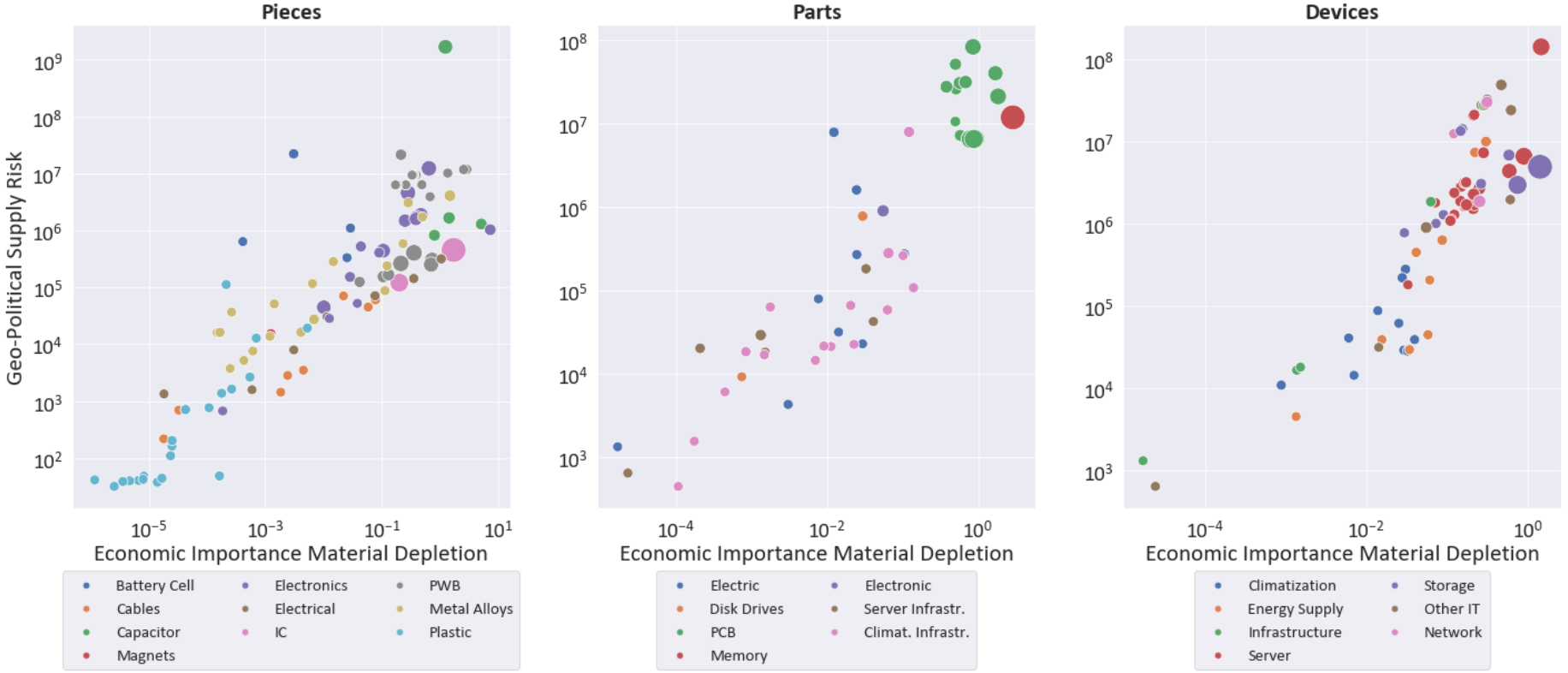
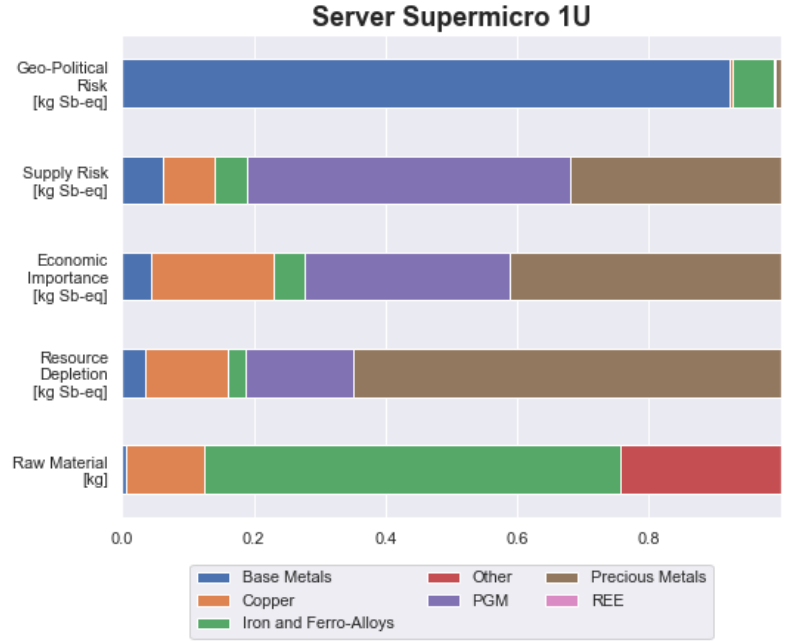
Fig 16. Impacts of different product systems at different tiers for Data Center devices. Bubble size represents specific primary energy demand



Results

Contributions of Materials to Total Impacts

Fig 17. Contributions of Materials to Material Depletion Midpoint Impacts



Peñaherrera et al. (2021). How to Measure Criticality in Environmental Impact Assessments? In: ProMETS Workshop

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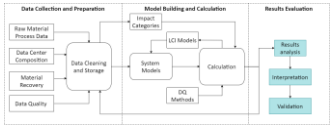
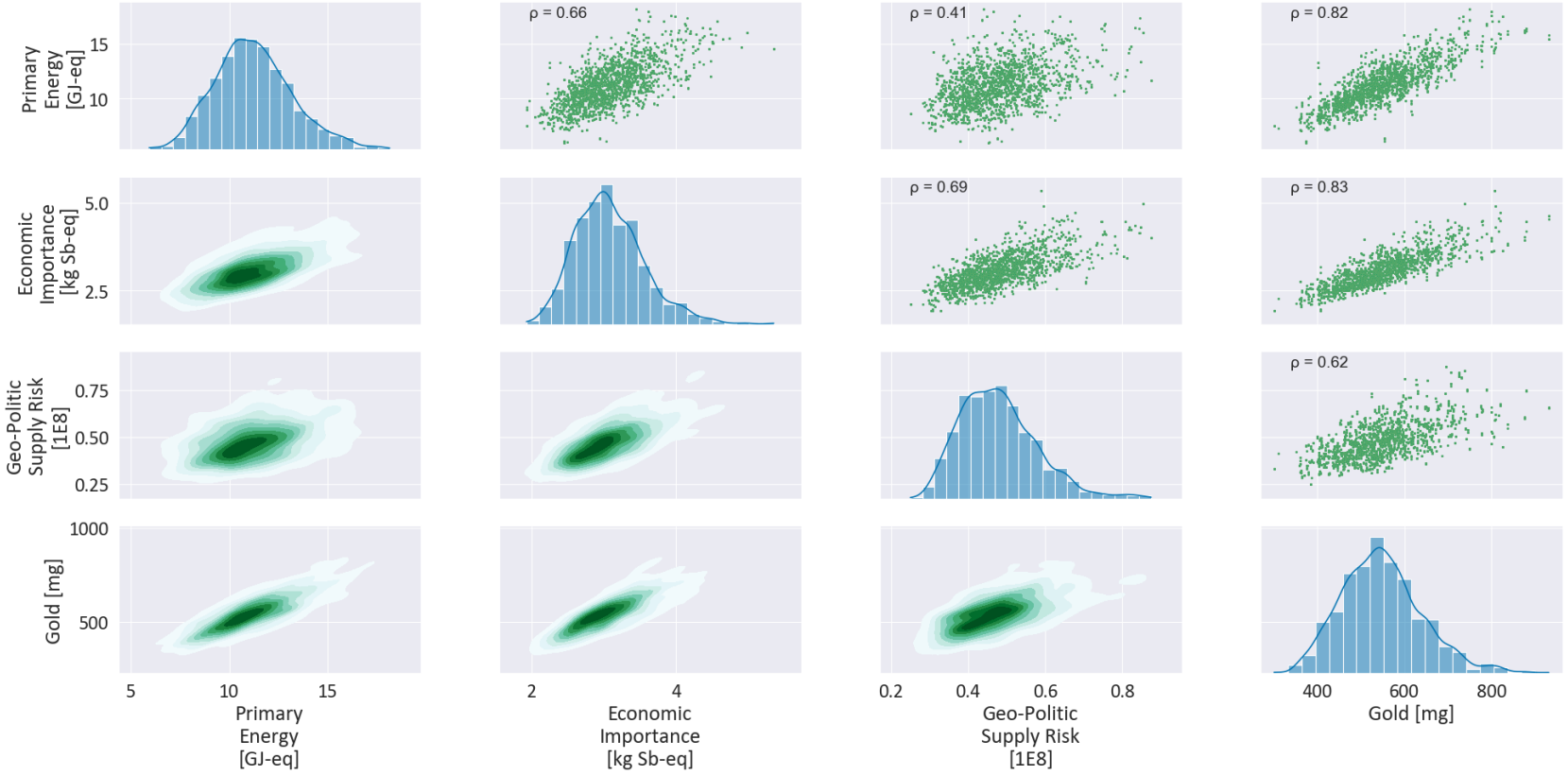


Fig 19. Correlations between the indicators for a Product System – Server - 1U



Results

Change on uncertainty values

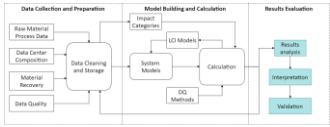
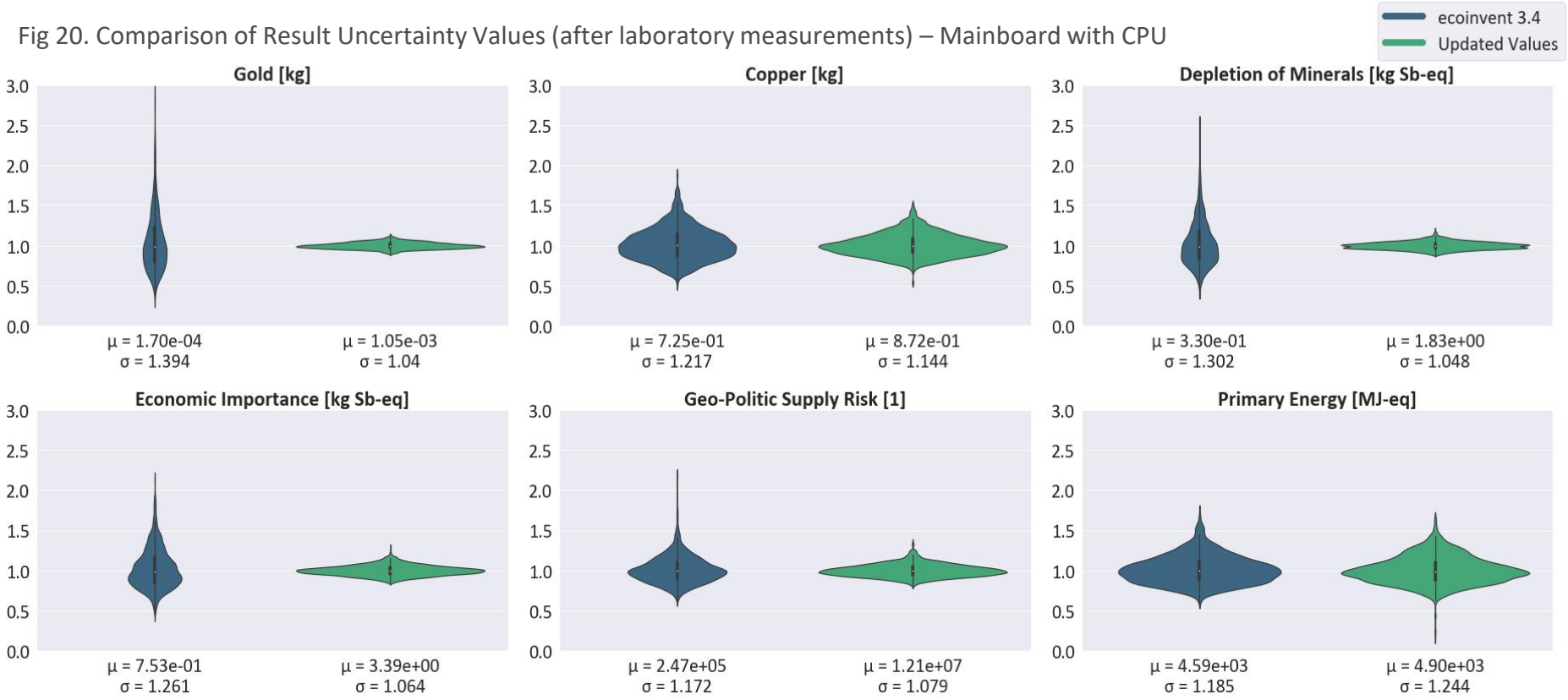


Fig 20. Comparison of Result Uncertainty Values (after laboratory measurements) – Mainboard with CPU



Results

Structure of Models for Recovery

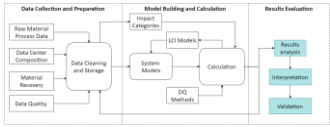
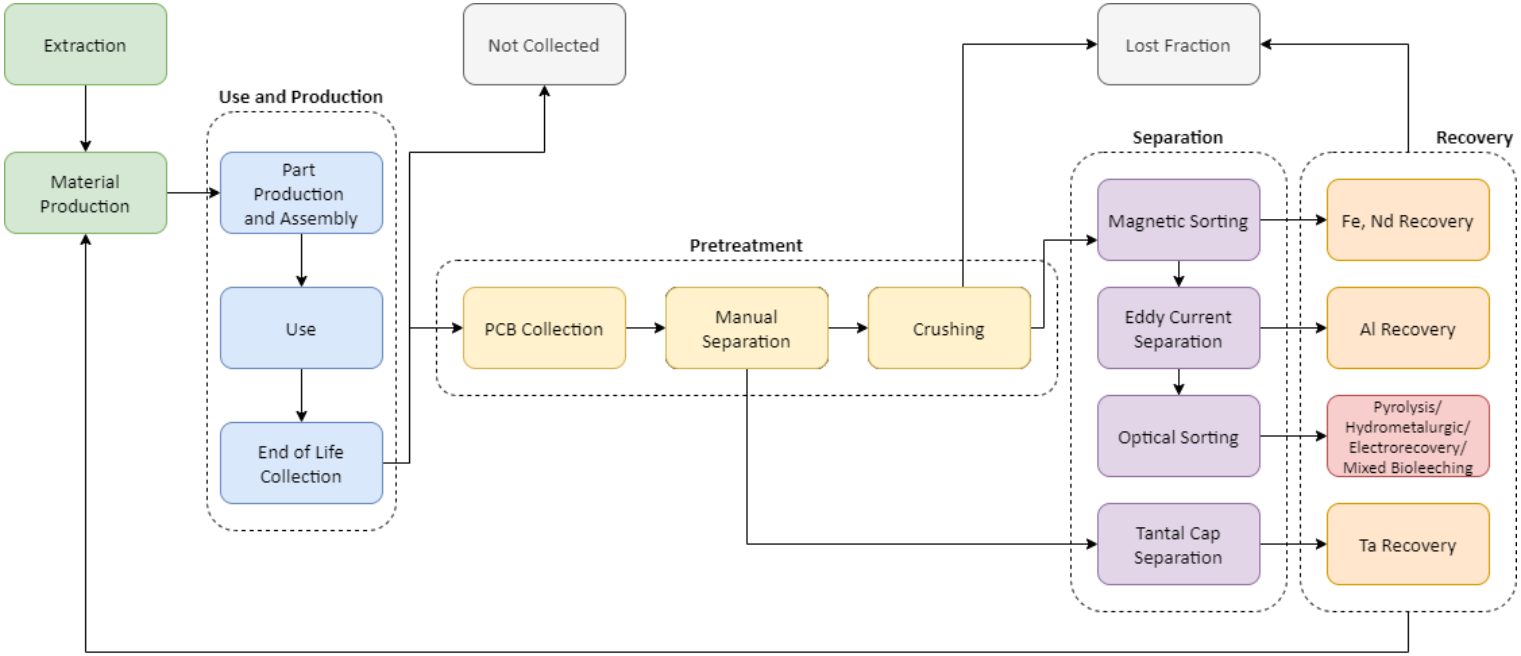


Fig 21. Process chain for Recovery of Materials from PCB



Peñaherrera (2019). Evaluation of Material Consumption and Recycling Scenarios of Professional Data Center Components. In: 9th International LCM Conference.

Results

Avoided Impacts through recovery

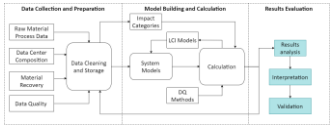
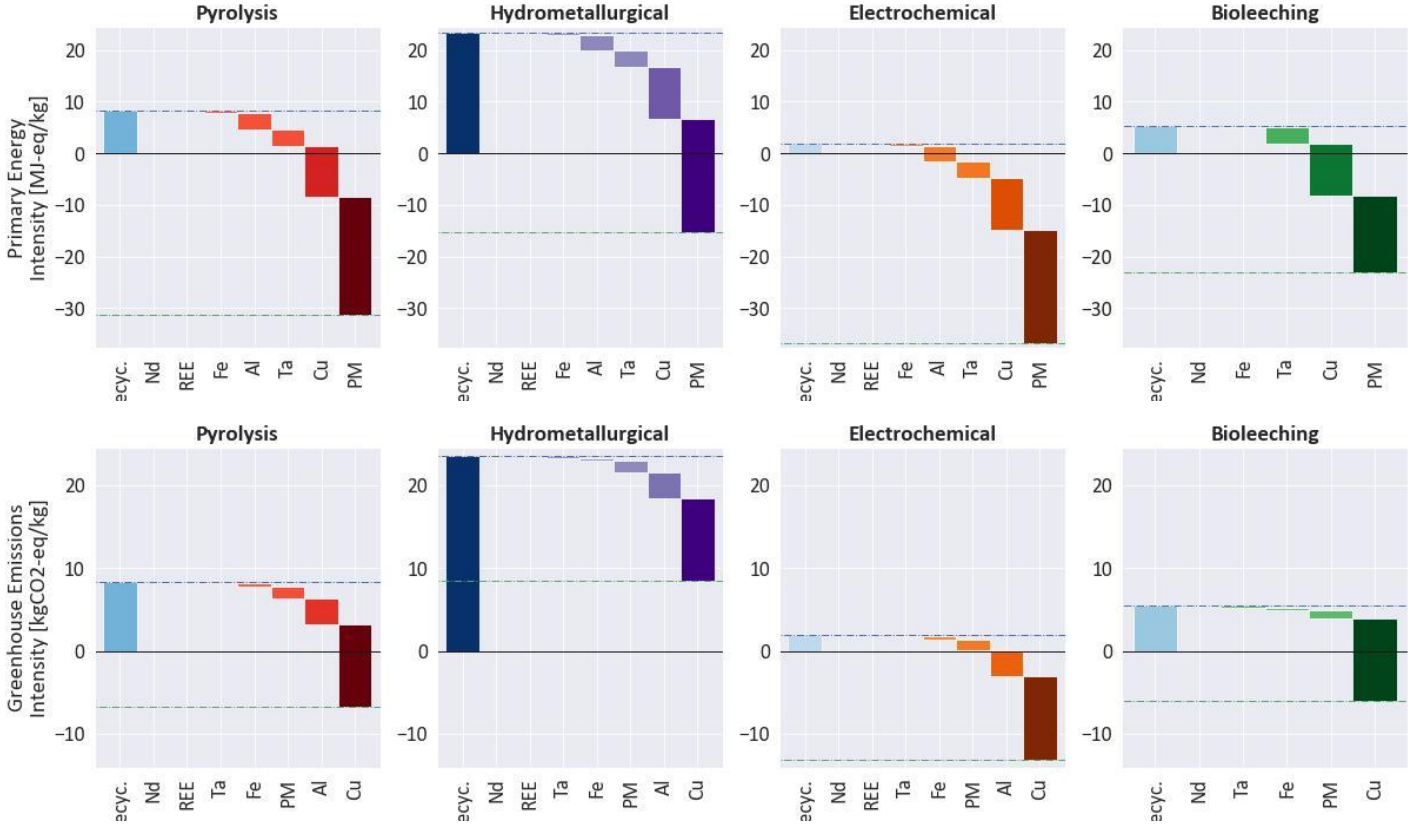


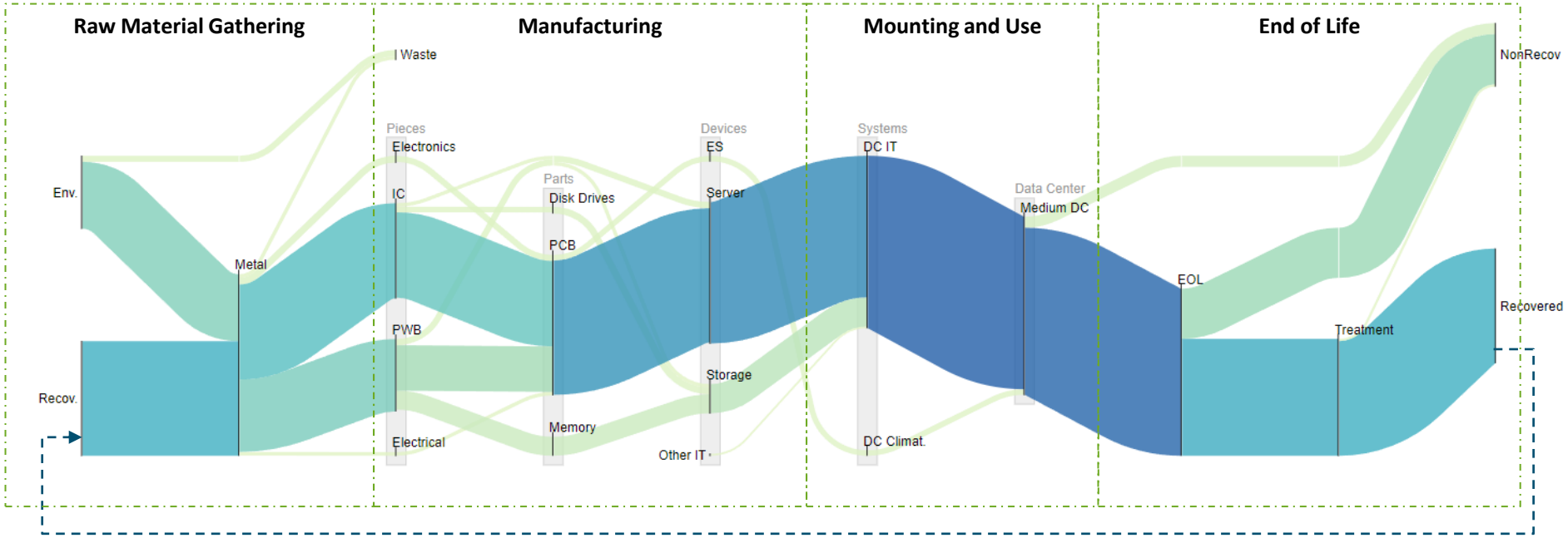
Fig 22. Distribution of Avoided Impacts from Printed Circuit Board Recycling



Results

Material Flow Analysis with Recovery Process

Fig 23. Sankey Diagram Flow of Gold with EOL Treatment by Pyrolysis.



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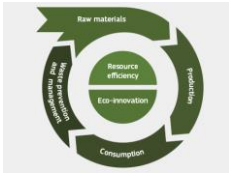
- Research methods focus on **data gathering** from component analysis and development of **case studies.**
- Data improvements showed **higher critical material content** in PCBs, which resulted in **higher specific environmental impacts.**
- Most benefits of recovery are reflected on improving **circularity** of critical materials.
- Savings on GHG and primary energy are **dependent** on which technology is used for recovery.
- Developed indicators on resource consumption can be incorporated in holistic **resource saving strategies** and circular economy policies.
- Indicators were used to evaluate other technologies, showing the applicability of the developed **methodologies**.

Source: sdgs.un.org

Peñaherrera et al. (2019). Quantifying the Environmental Impacts of Battery Electric Vehicles from a Criticality Perspective. In IEEE (Ed.): ICE – IAMOT Conference 2022. Nancy, France.



Source: ec.europa.eu

Thanks for the Attention

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