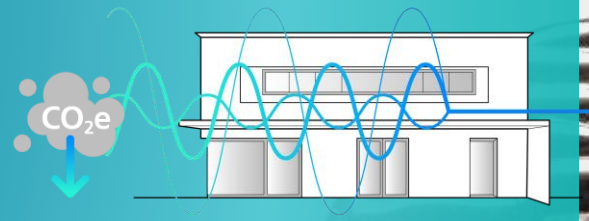
Fraunhofer IPA

Cirp 30 Jahre | Heimsheim
Date: 18.09.2024

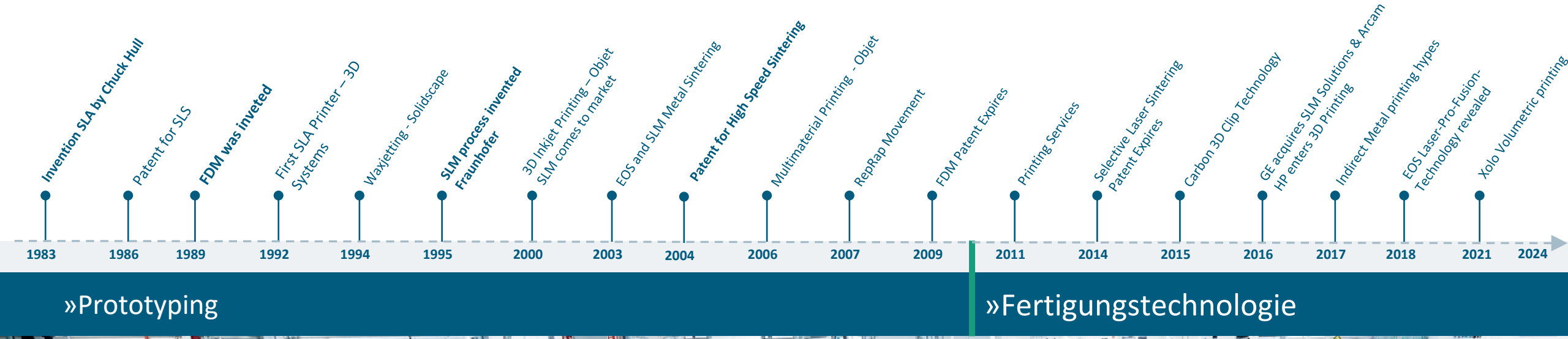


Projekteinblicke zur Industrialisierung von AM

Von Strategien für Pulvermanagement bis zum CO2-Footprint

Entwicklung der Additiven Fertigung

Historie



»Prototyping

»Fertigungstechnologie

»Skalierung der Fertigungstechnologie auf Produktionsniveau«

1. Powder Management for PBF-LB/B Processes

Powder Management for PBF-LB/B Processes

Reality vs. Vision powder supply

Vision / News

Powder Management for PBF-LB/B Processes

Reality vs. Vision powder supply

Vision / News

Still reality today

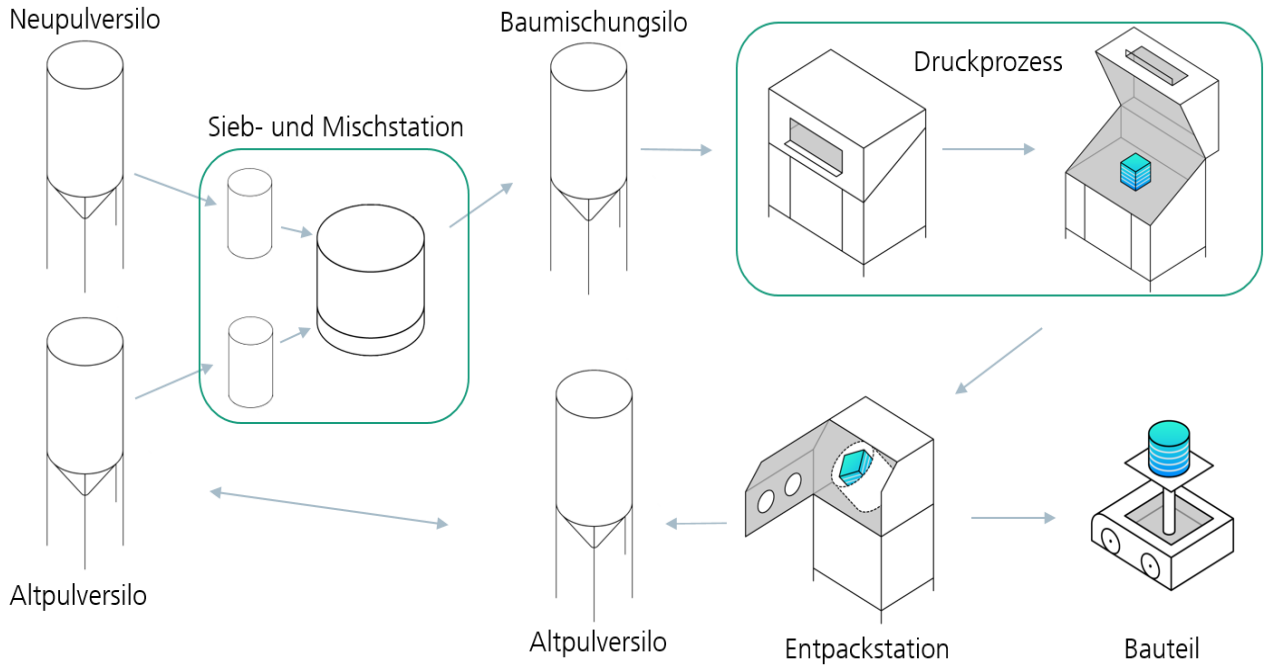
Powder Management for PBF-LB/B Processes

KMUi - AmPuls

- Development of a **powder cycle and refreshment system** for PBF-LB/P process
  - Modular
  - Scalable
  - Multi material
  - Minimize human interaction
  - Monitoring of the powder condition at all process stations
  - Closed (from environment)
  - Retrofitt to existing machines

  - Development of a **quality monitoring system** and data interfaces for continuous traceability of the powder material for AM processes across the entire production cycle
    - Design of the system to be developed (hardware and control architecture) to fit to current AM machines (PBF-LB/P) in a production environment

  - **Partners**:
    - Cirp GmbH
    - Process Control GmbH
    - Fraunhofer IPA



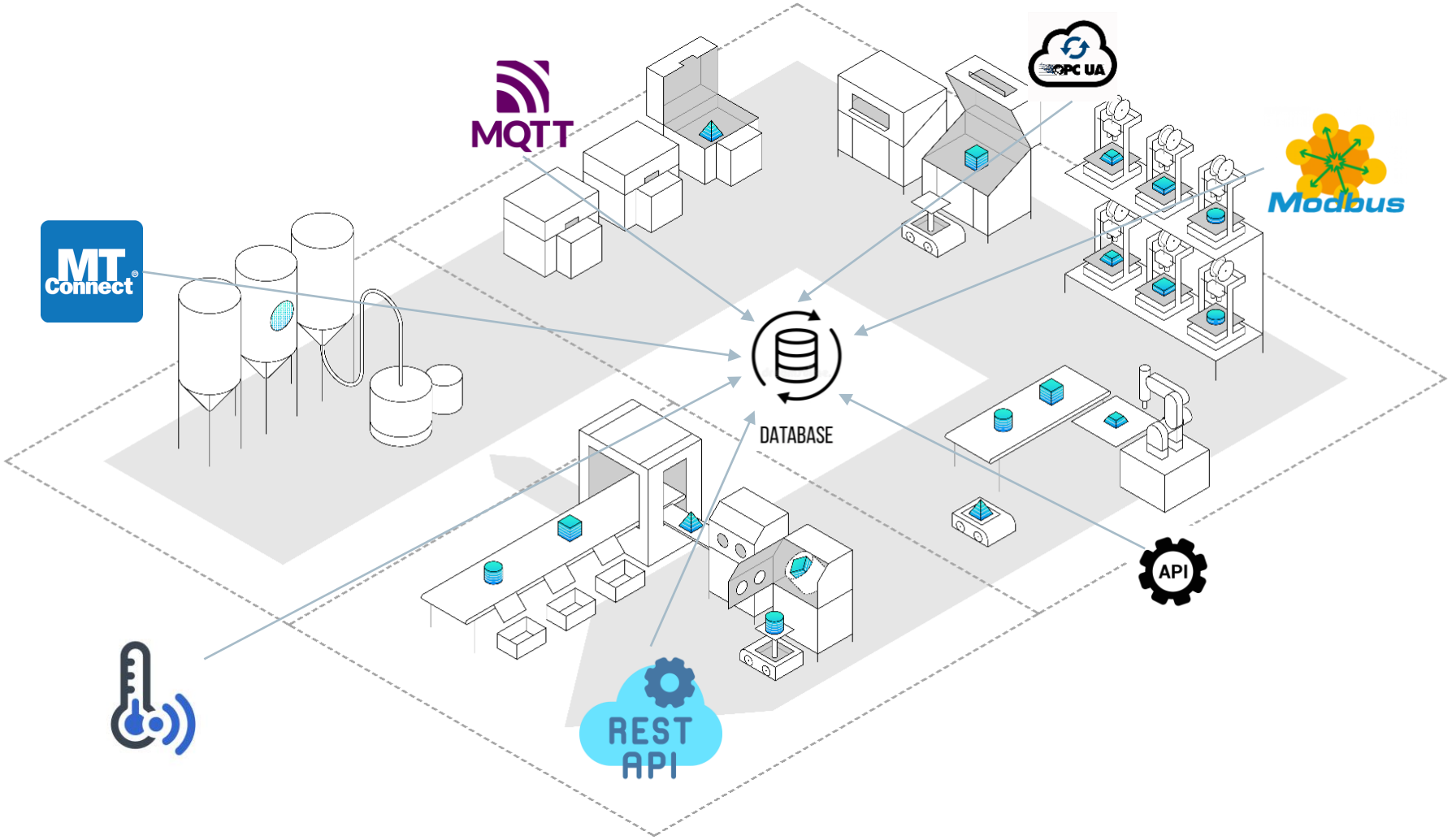
Partner: cirp PROCESS CONTROL GmbH Maschinen für die Kunststoffindustrie
Gefördert von Bundesministerium für Bildung und Forschung
Fraunhofer IPA

Powder Management for PBF-LB/B Processes

Data interfaces in the AM environment

General requirements

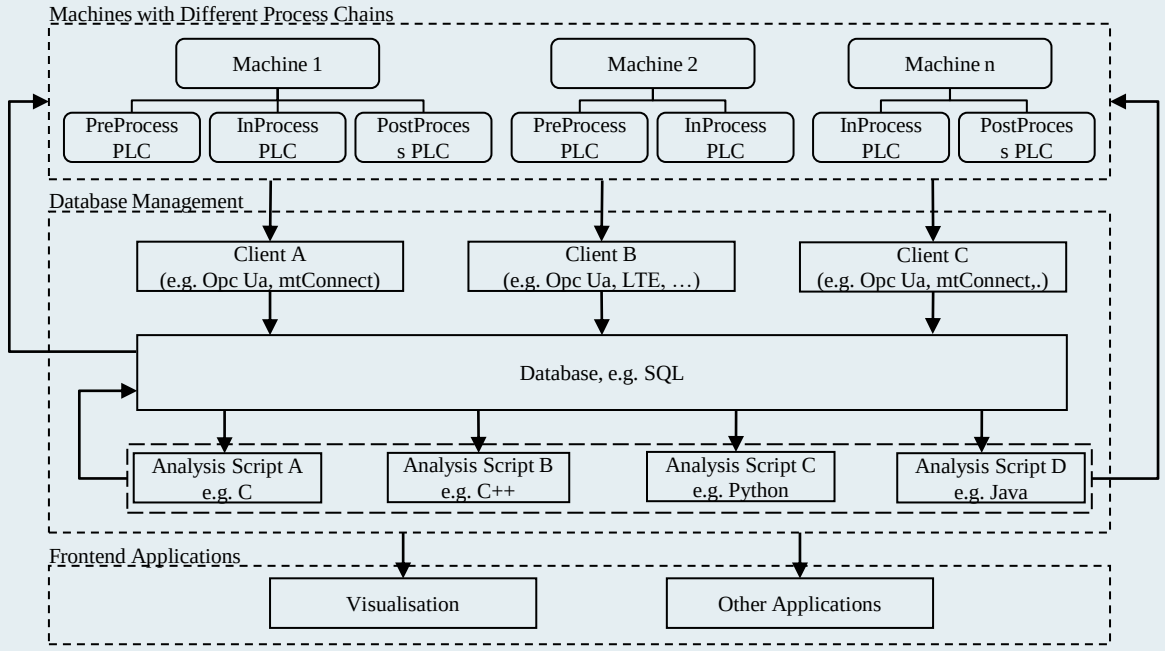
- Tracking powder status and ambient conditions across the entire process chain
- Modular expandability and scalability of the system (both hardware and software)
- Access to as many machine parameters as possible (inline)
- Use of standardised machine protocols such as OPC-UA / MTConnect
- Persistent data storage Storage and correlation of offline measurements
- Simple visualisation and evaluation of the recorded data
- Interface to MES / ERP systems



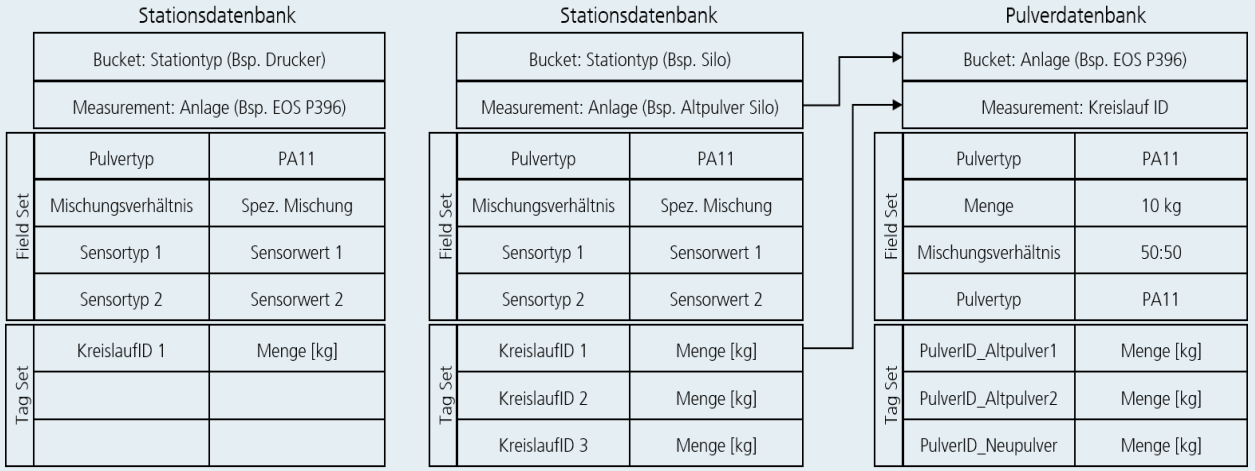
Powder Management for PBF-LB/B Processes

Data management

Concept



Database



Powder Management for PBF-LB/B Processes

Results

Equipment can be seen downstairs at Cirp

2. Material characterization and –conditioning for polymer-based PBF-processes

Material characterization and –conditioning for polymer-based PBF-processes

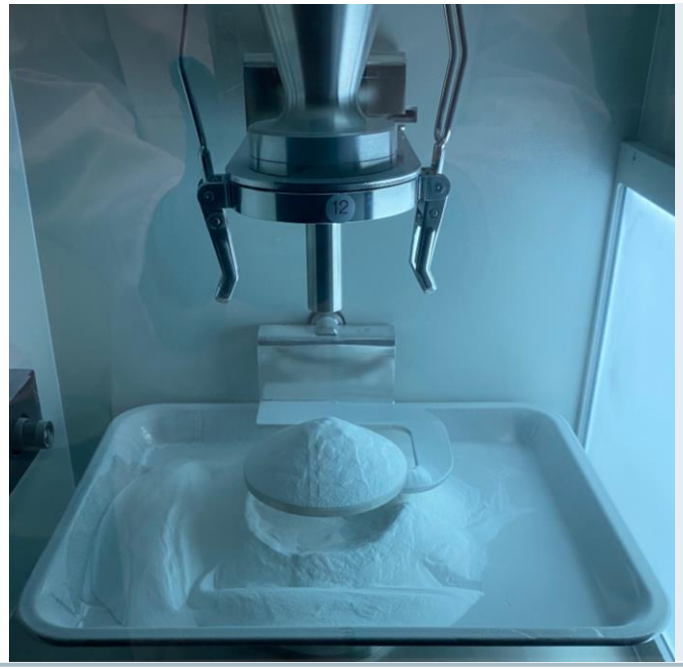
State of today

Requirements for AM series production

- Continuous **inline** tracking of all QM-relevant metrics (incl powder and build process)

Reality

- **Manual, offline** measurements / **incoming** goods **control**



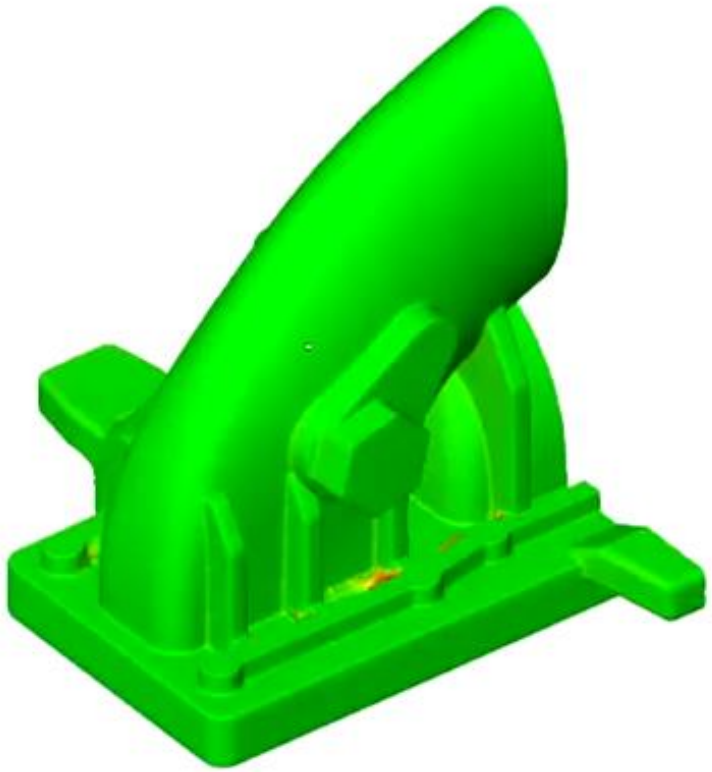
Material characterization and –conditioning for polymer-based PBF-processes

Influence of a higher aging-stage of the powder

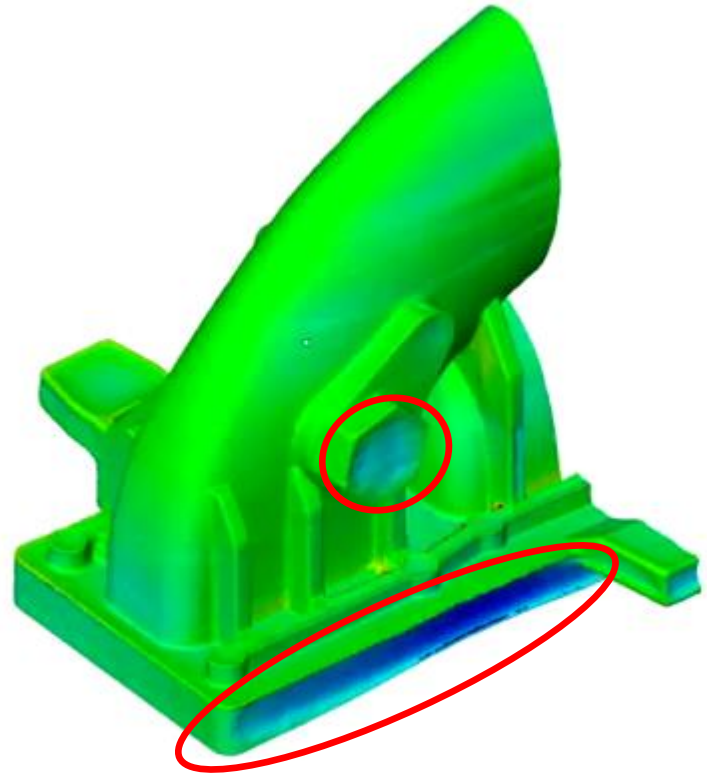
Aging effects of PA powder

- Defects on the surface
  - Sink marks
  - „Orange peel“
- Lower part density
- Reduced mechanical properties

Samples from different aging-stages of powder without conditioning / refreshment



PA2241FR – 50% refresh rate



2x used PA2241FR - 0% refresh rate

Material characterization and –conditioning for polymer-based PBF-processes

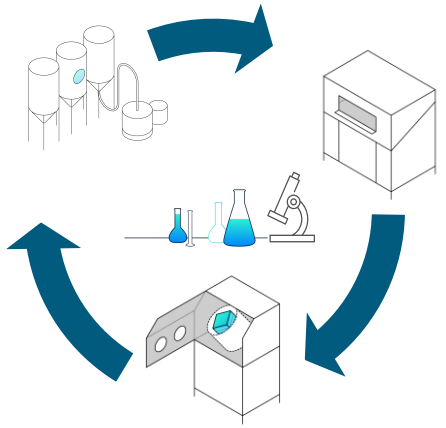
Challenges of circular powder use in polymer-based PBF processes

Challenges

- **Achieving constant quality** based on recycled powders can be contradictory to maximized utilization of used-powder
- **Understanding the influences** of each processing step on powder properties is crucial to ensure constant powder-quality on long-term perspective
- **Optimization of each process step** to increase the powder re-use
- **Quality certification** for critical applications (e.g. medical, aviation,…) hardly possible when re-using powder

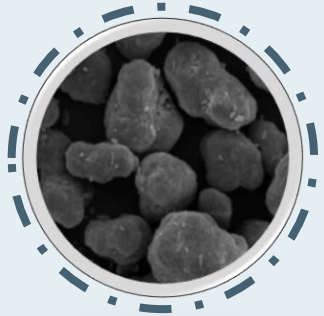
Potential Benefits of in-depth material characterization

- **Precise adjustment of powder-properties** based on a closed-loop system
- All processes (pre- / in- / post-process) can be adjusted and optimized to the specific needs of powder materials
- **Reduction of powder-waste** based on optimized processes



Material characterization and –conditioning for polymer-based PBF-processes

Ageing effects



Physical ageing e.g. agglomeration, solid phase crystallization

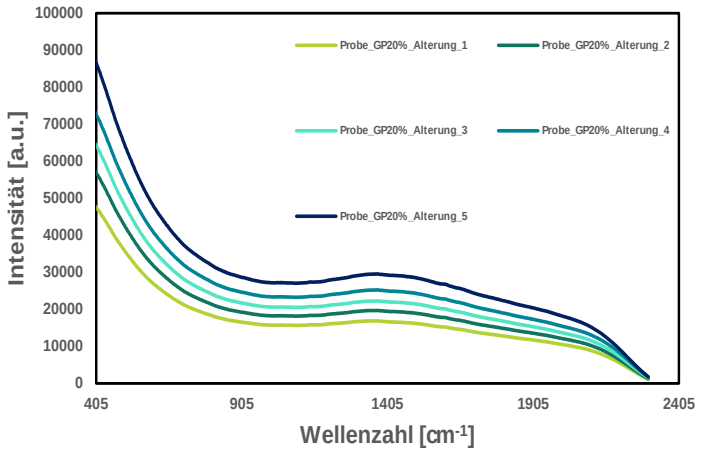
Chemical ageing e.g. thermal oxidation, post-condensation/hydrolysis

Material characterization and –conditioning for polymer-based PBF-processes

Summary

Summary of ongoing investigations

- **Physical powder ageing** does not appear to be significant within the processes investigated.
- **Physical powder ageing appears** to be reversible through the processing steps.
- **Chemical powder ageing**, on the other hand, shows a significant influence, particularly in the area of viscosity change with increasing thermal ageing.
- The investigations **using Raman spectroscopy** show promising approaches for use as **in-line analytics.**



Get to know more

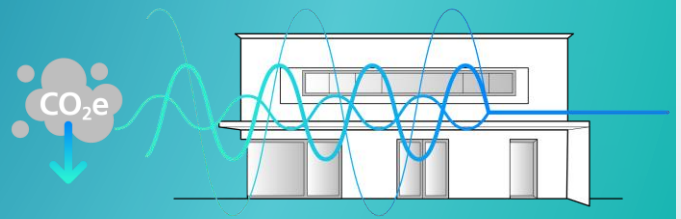
24. WEBINAR - ADDITIV IM SÜDWESTEN

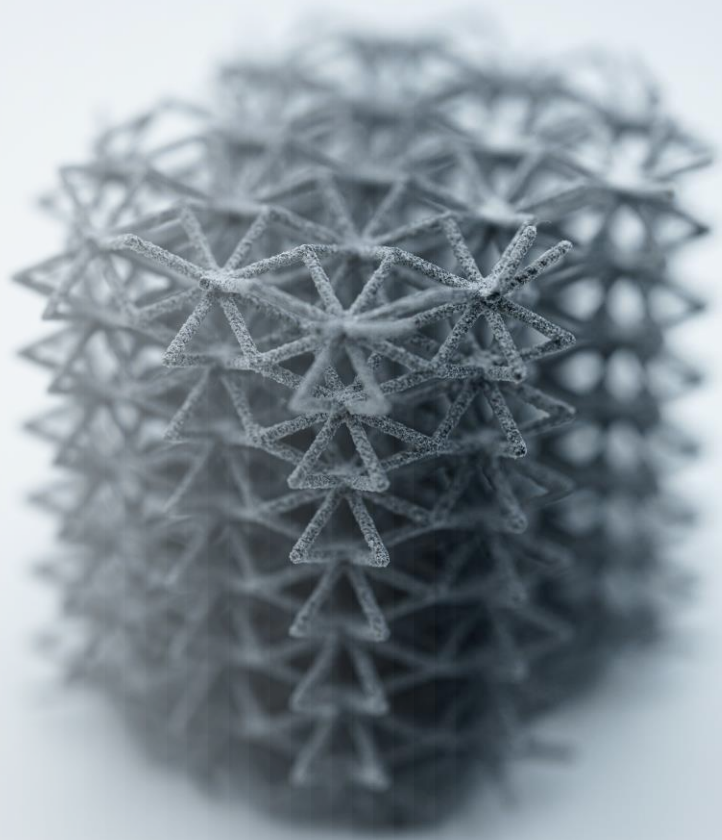
Beiträge von: Fraunhofer IPA, AM-Flow B.V., alphacam GmbH

Mittwoch, 25. September 2024
9:00 Uhr bis 10:30 Uhr

Simon Höhn (Fraunhofer IPA): »Alterungsverhalten von #Kunststoff|pulvern im Lasersintern und dessen Einfluss auf Bauteileigenschaften«

3. Life cycle assessment of a PBF-IR/P process





Funded by:
Baden-Württemberg
MINISTERIUM FÜR WIRTSCHAFT, ARBEIT UND TOURISMUS

Life cycle assessment of a PBF-IR/P process

Project Overview

Project goal and scope

- Quantification of greenhouse gas emissions of SAF Technology (cradle-to-gate)
- Functional Unit: one build job

1 **Definition of goal and scope**

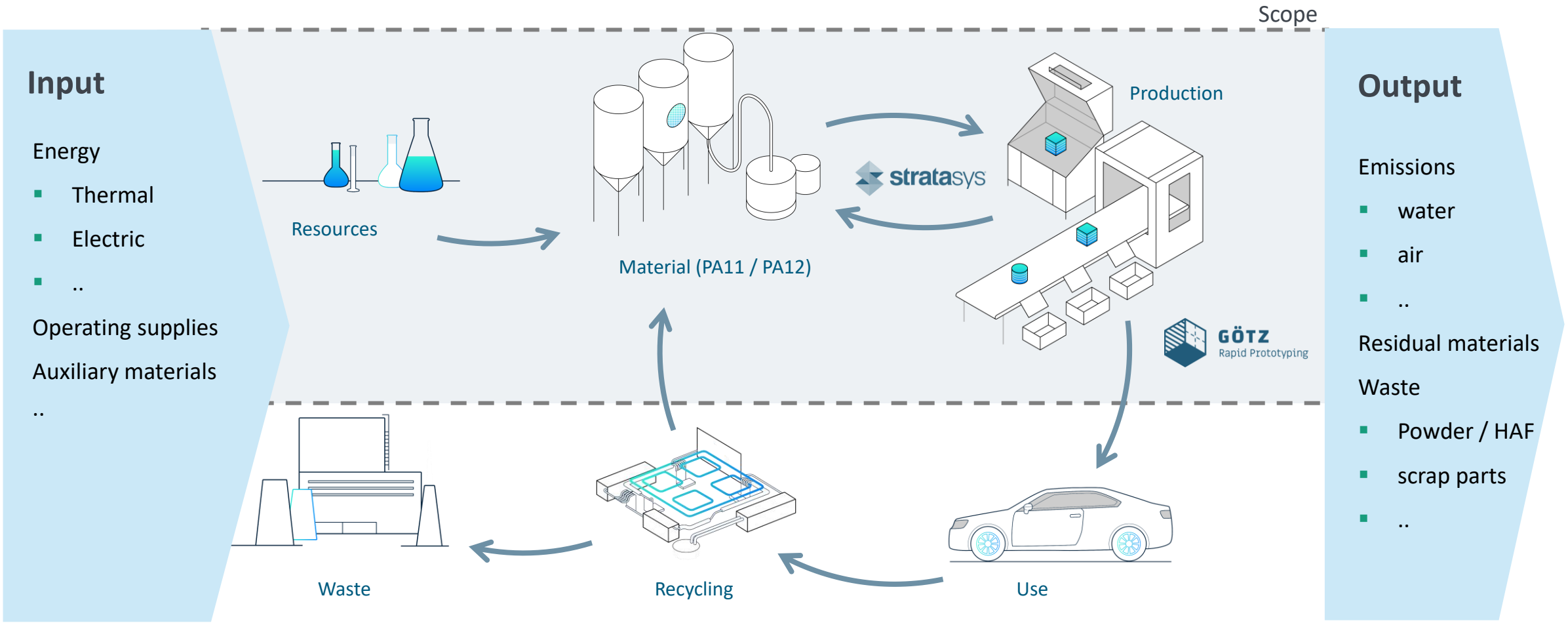
2 **Data collection**

3 **Life cycle impact assessment**

4 **Identification of ecological optimization potential**

Life cycle inventory for a PBF-IR/P process

Cradle-to-Gate



Life cycle assessment

Goal and scope

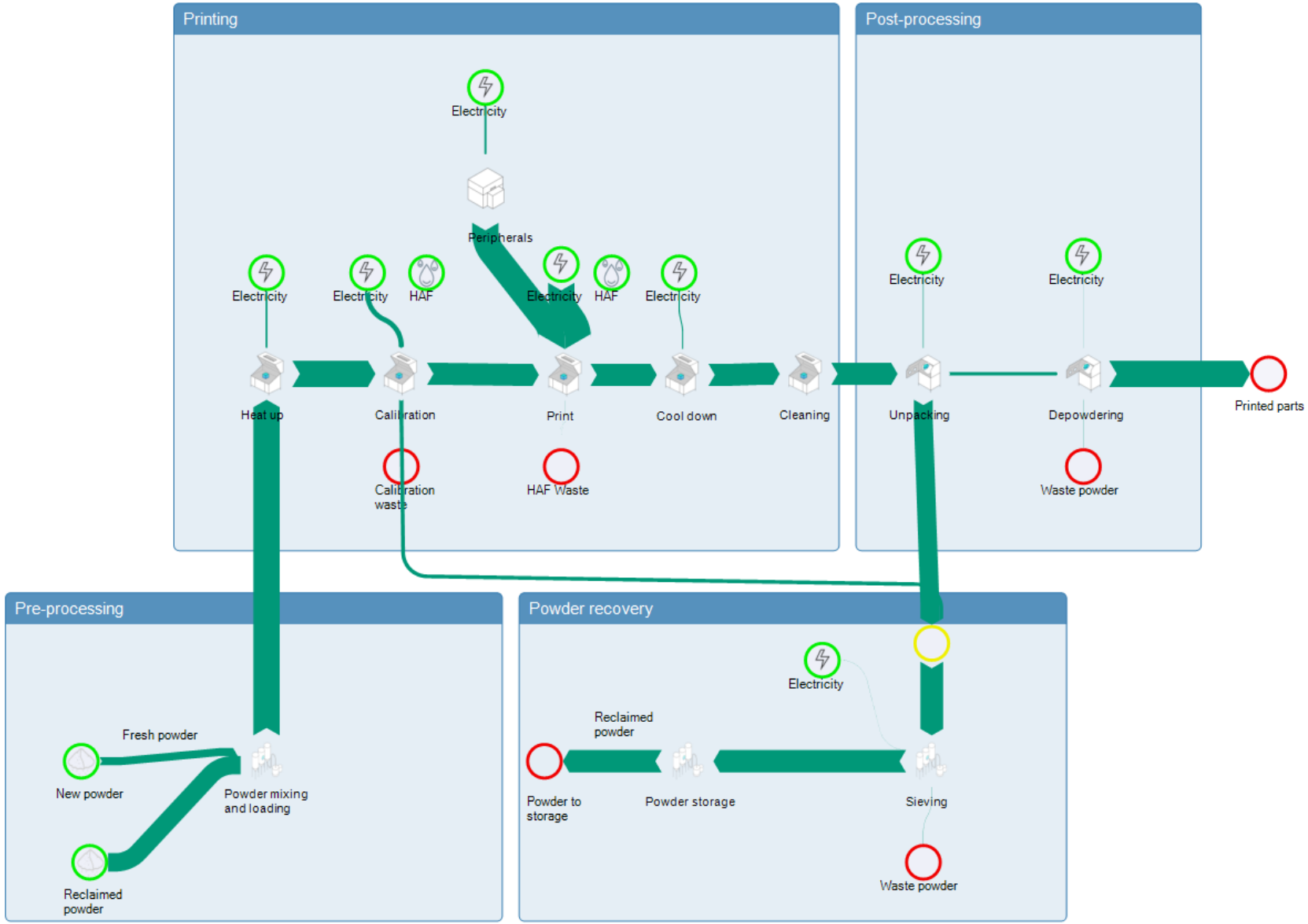
Functional unit:
One build job

System boundaries:
Cradle to gate

LCA software:
Umberto 11

Database:
Ecoinvent version 3.9

Impact assessment method:
Climate change IPCC 2013

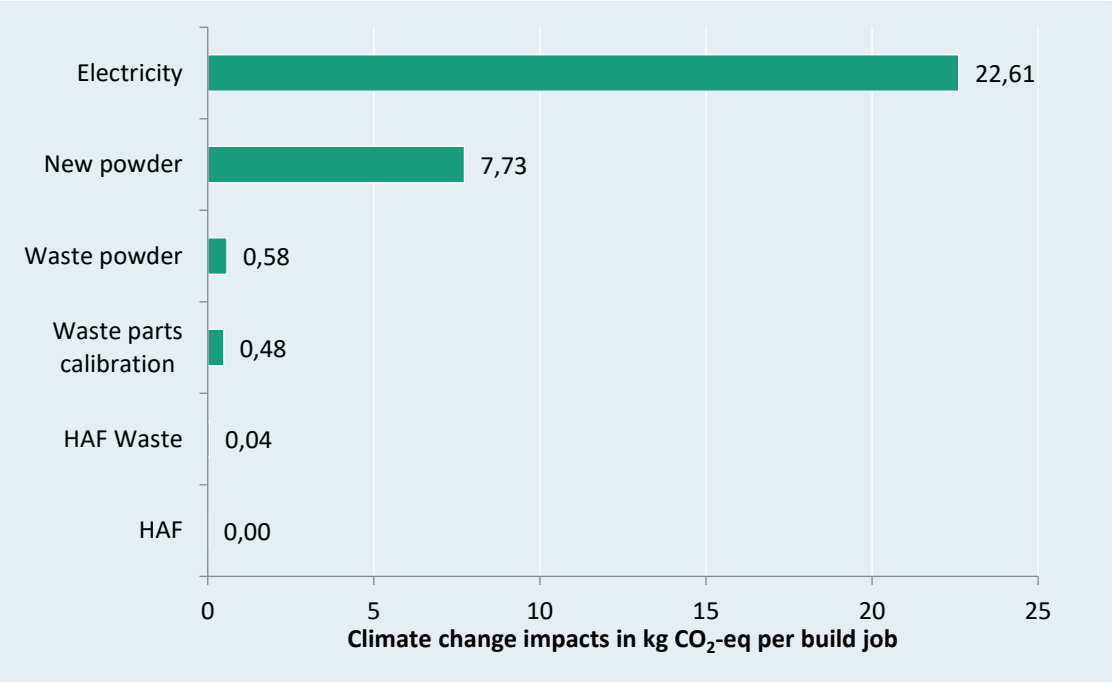


Overview of results for the reference print job

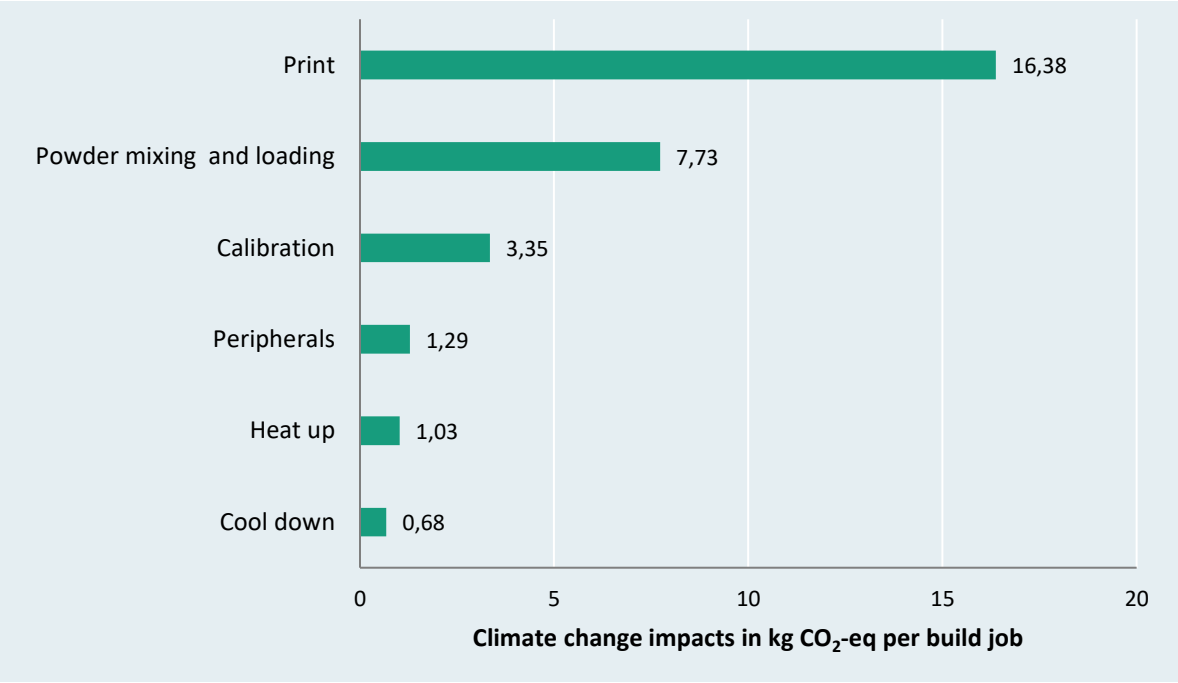
Impacts by entry and by process

Nesting density: 11.4%
Material: PA11
Share of new powder: 30%

Impacts by Entry



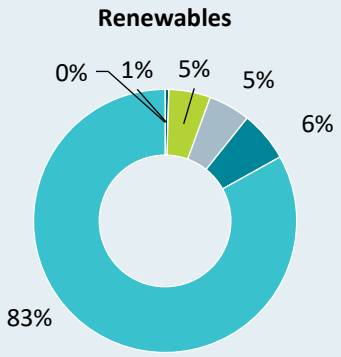
Impacts by Process

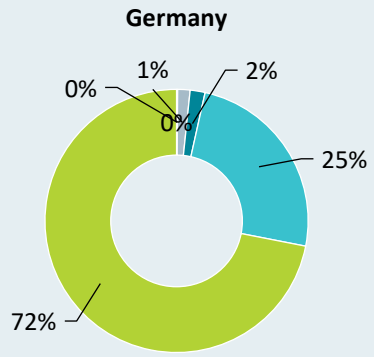


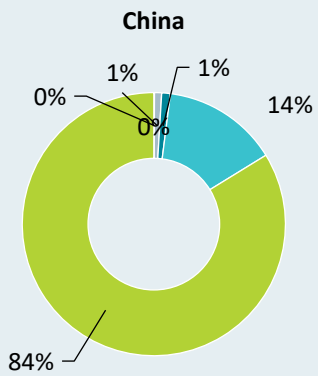
The highest share of climate change impacts is due to the electricity consumption. Process-wise the highest impacts occur during printing, followed by the powder mixing and loading.

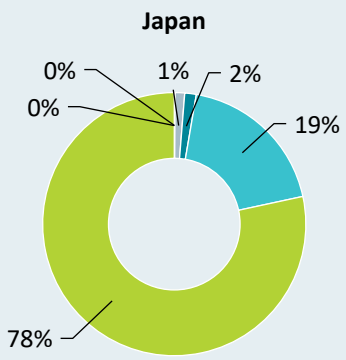
Overview of results for the reference print job

Comparison of different electricity mixes

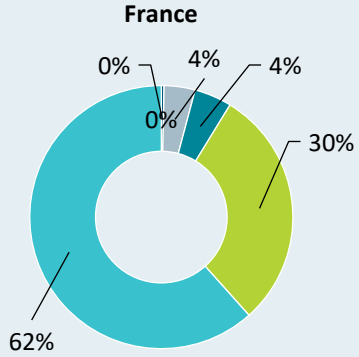


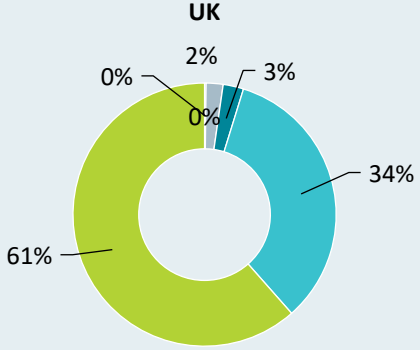


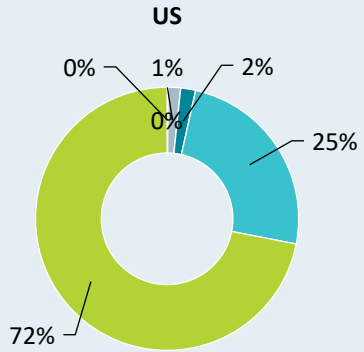


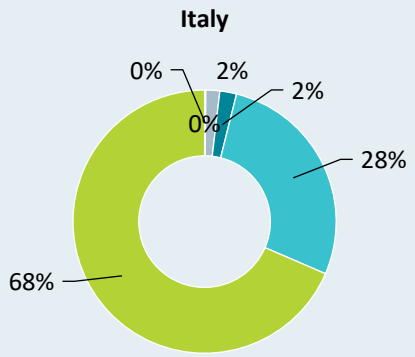


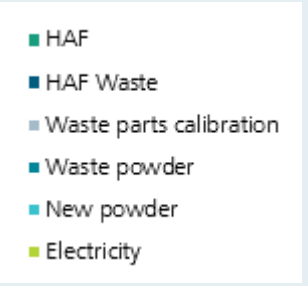
In countries with a low-carbon electricity mix the environmental impacts from powder production gain importance









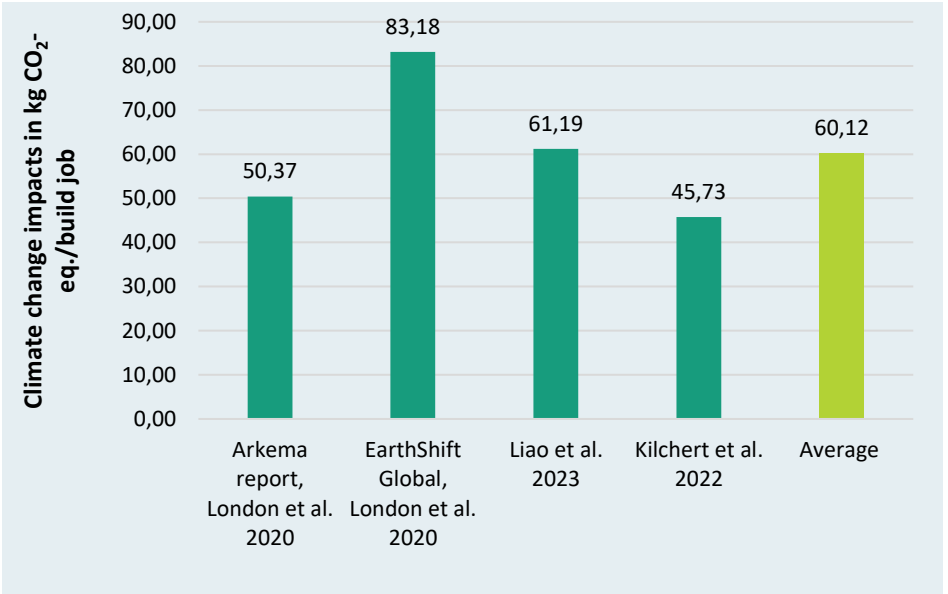


Life cycle impact assessment

Comparison PA11 and PA12

High variance in literature

Total results with different emission factors for PA12 retrieved from literature:



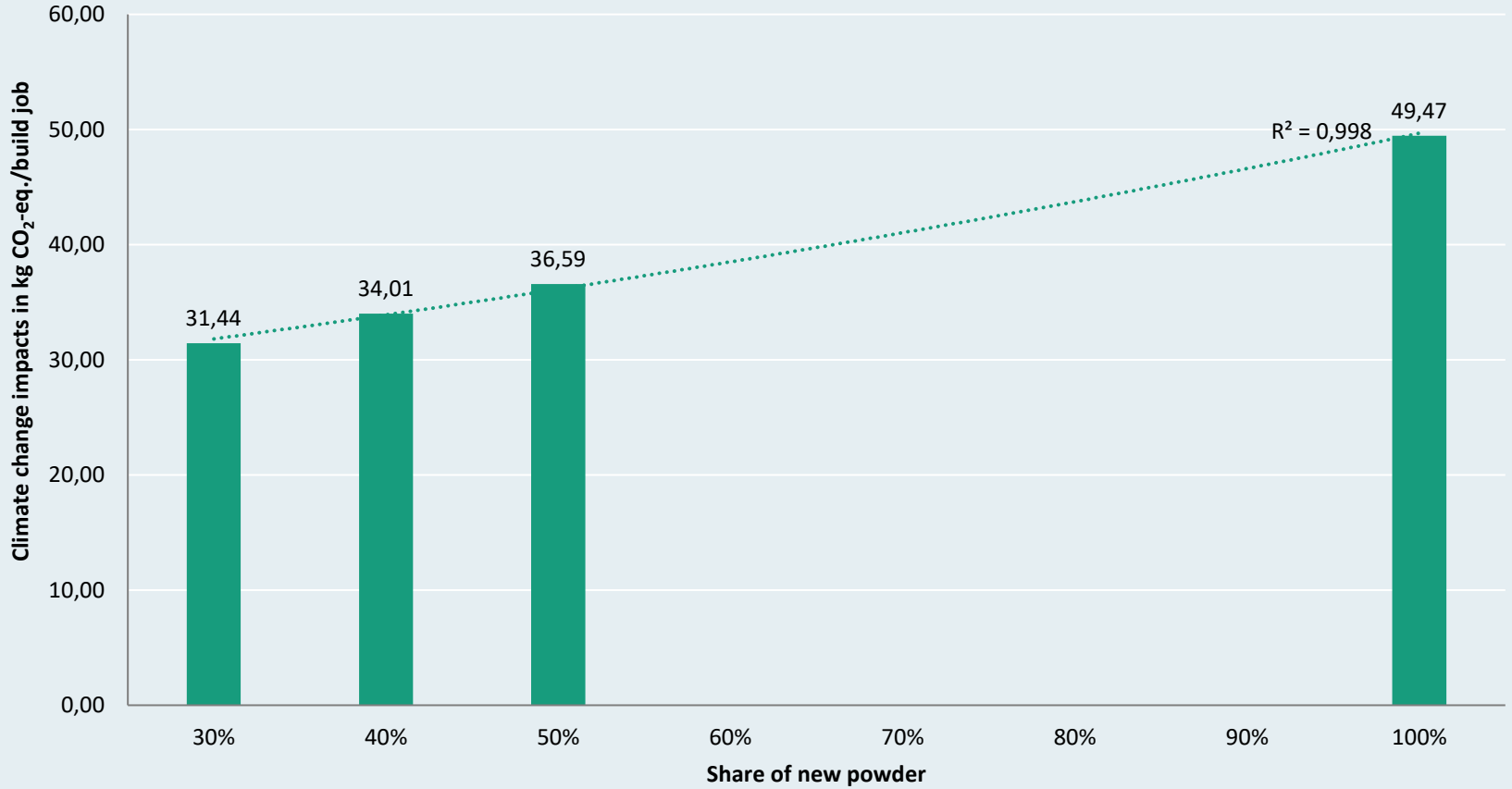
Build density: 11.4 %, Energy measurement only conducted for PA11 (same values were assumed for PA12)

The use of PA11 instead of PA12 reduces the climate change impacts by almost 50%*

**average PA12 value from literature*

Life cycle impact assessment

Comparison new PA11 powder ratio share

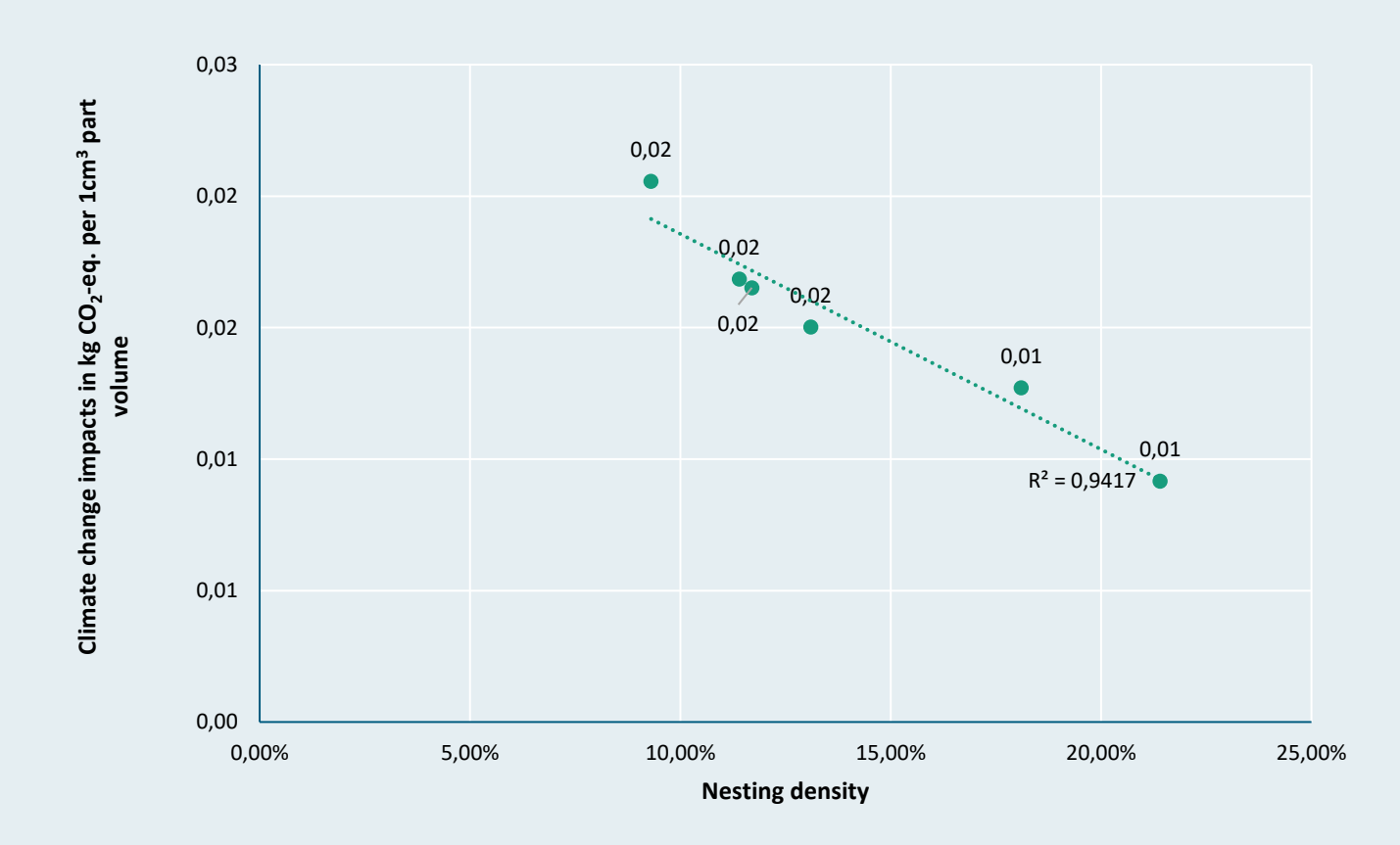


Reusing powder significantly reduces the environmental impacts

→ greenhouse gas impacts with 100% new powder are 60% higher than with 30% new powder

Life cycle impact assessment

Comparison of different nesting densities (PA11)



Higher nesting densities reduce environmental impacts per part volume

Print job overview:

Nesting density	Number of parts	Climate change impacts per part [kg CO_2-eq.]	Volume of parts [cm³]
11.40%	58.00	0.54	1866
9.30%	42.00	0.77	1574
18.10%	19.00	1.73	2580
13.10%	126.00	0.23	1968
21.40%	244.00	0.13	3443
11.70%	82.00	0.39	1917

Summary
What did we learn?

Sustainability terminology:

Life cycle assessment (LCA); Product carbon footprint (PCF); Greenhouse gas emissions; Functional unit (FU); System boundaries; …

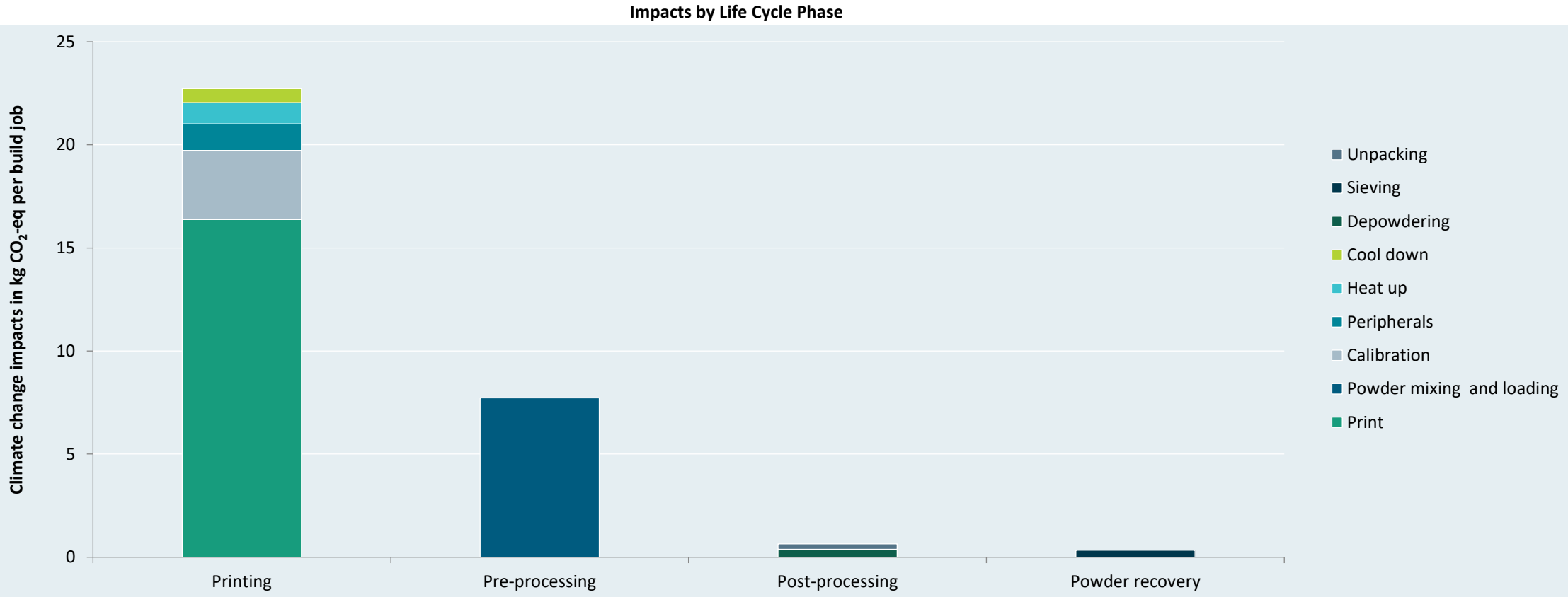
The first step in **reducing emissions** is to **account** for them - what you can measure, you can manage.

Contact

Jan Janhsen, M.Eng.
Group Manager | Department Additive Manufacturing
Phone +49 711 / 970 - 1144
jan.janhsen@ipa.fraunhofer.de

Overview of results for the reference print job

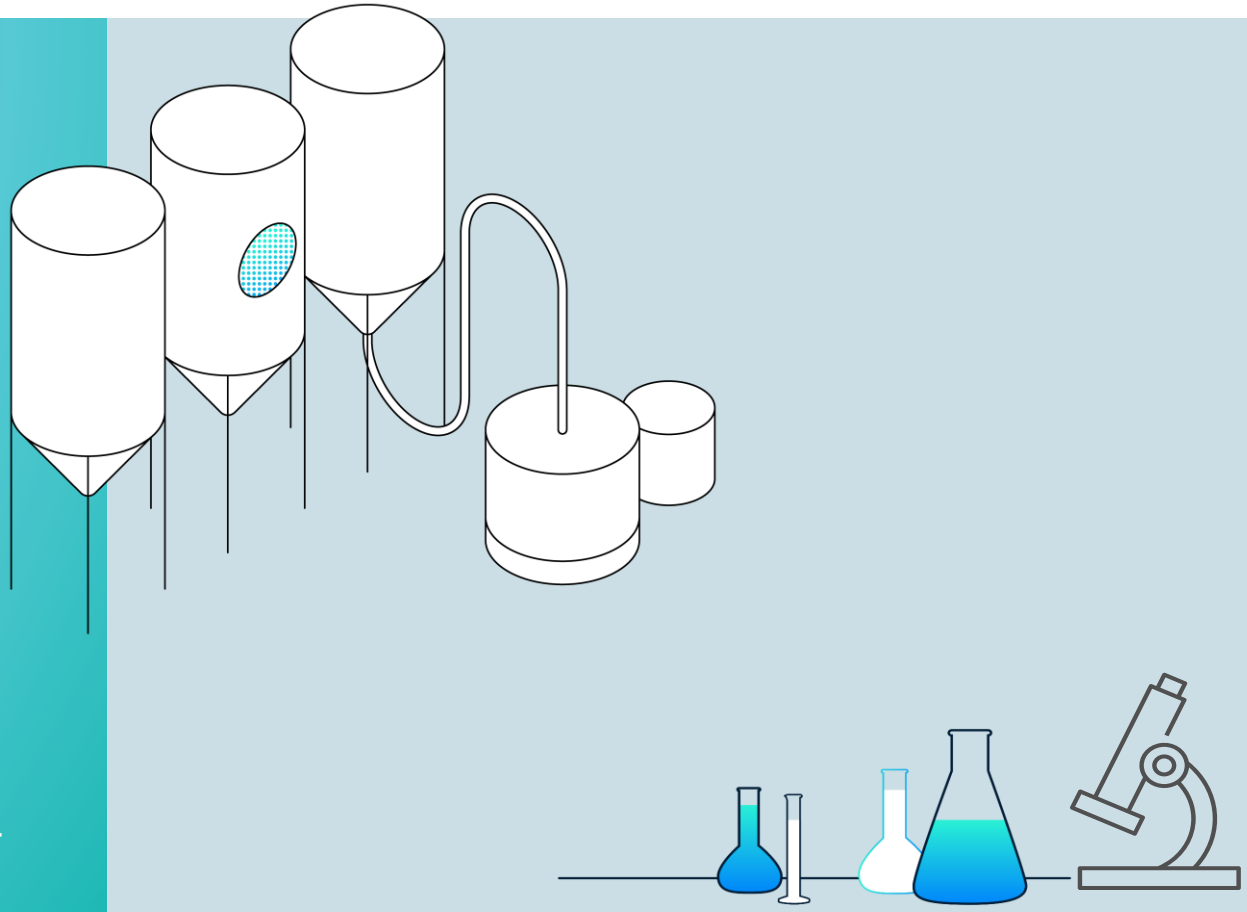
Impacts by life cycle phase



Material characterization and –conditioning for polymer-based PBF-processes

Service portfolio

- Precise adjustment of powder-properties based on a closed-loop system
- Correlation of powder characteristics and resulting parts properties
- Development of PBF-P/LB and PBF-P/IR process parameters for specific polymer-powders
- Optimization of PBF-P process chains focusing on powder handling and -conditioning

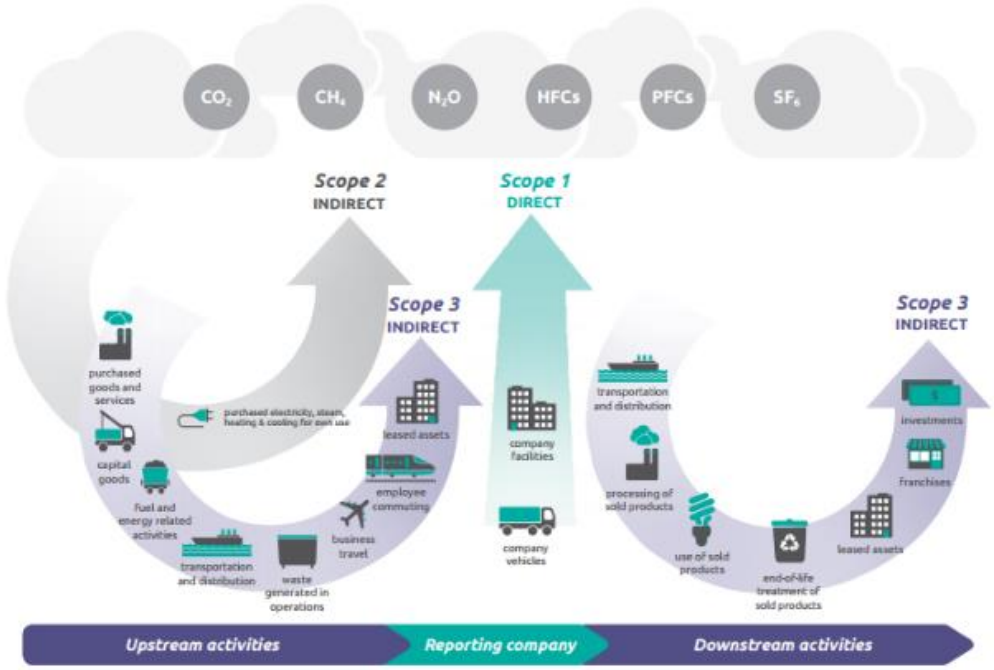


Corporate Carbon Footprint vs. Product Carbon Footprint

What‘s the difference?

Corporate Carbon Footprint (CCF)

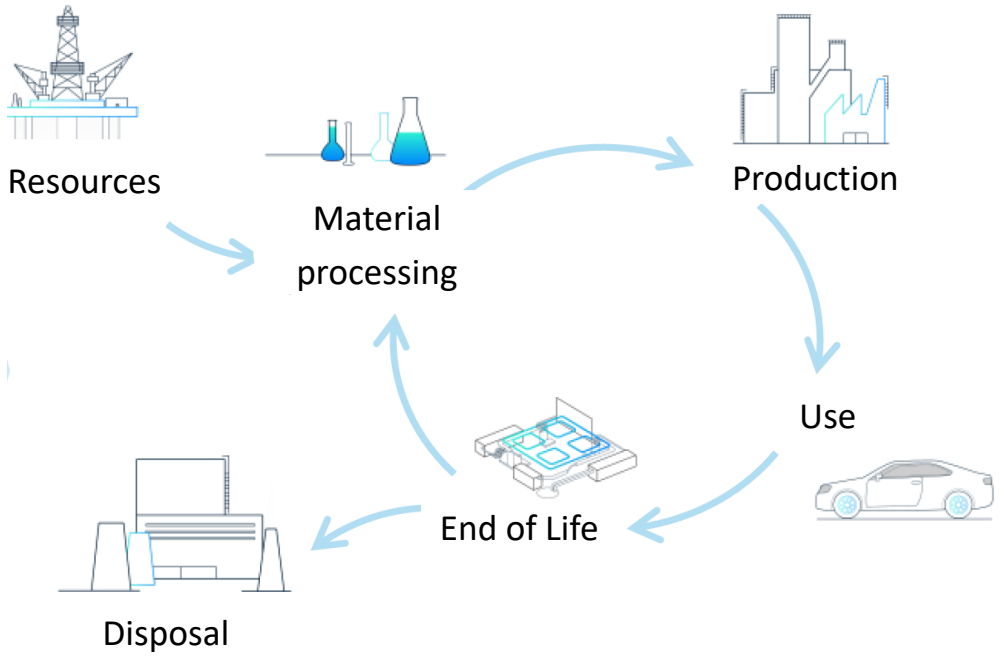
Total greenhouse gas emissions produced by a company's operations



Source: GHG protocol

Product Carbon Footprint (PCF)

Total greenhouse gas emissions generated throughout the lifecycle of a product



Product carbon footprint

Why and how?

WHY?

Comparison

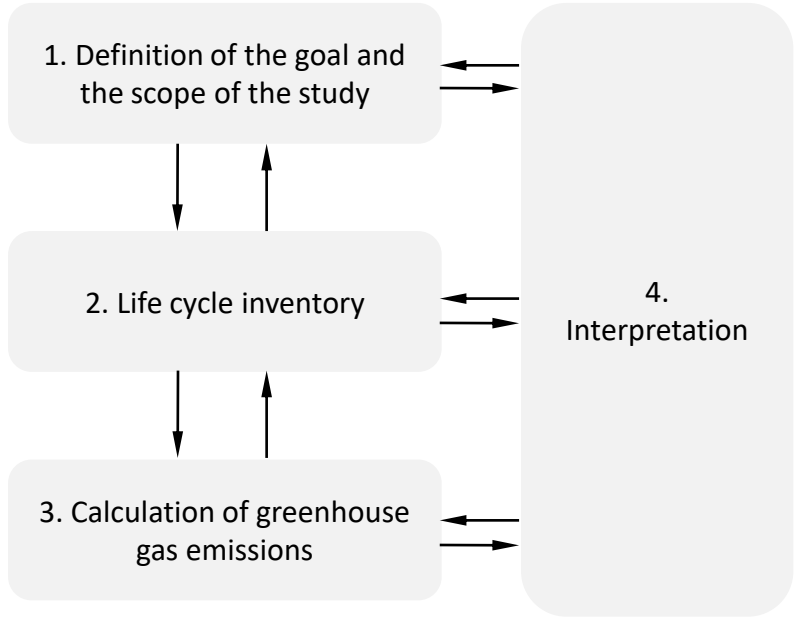
Transparency

Optimization

Hotspots

Cost benefits

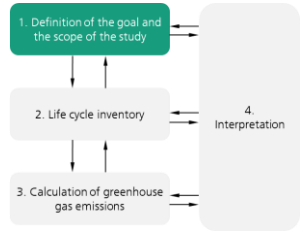
HOW?



Source: ISO 14040/44

Product carbon footprint

Goal and scope definition



Goal definition

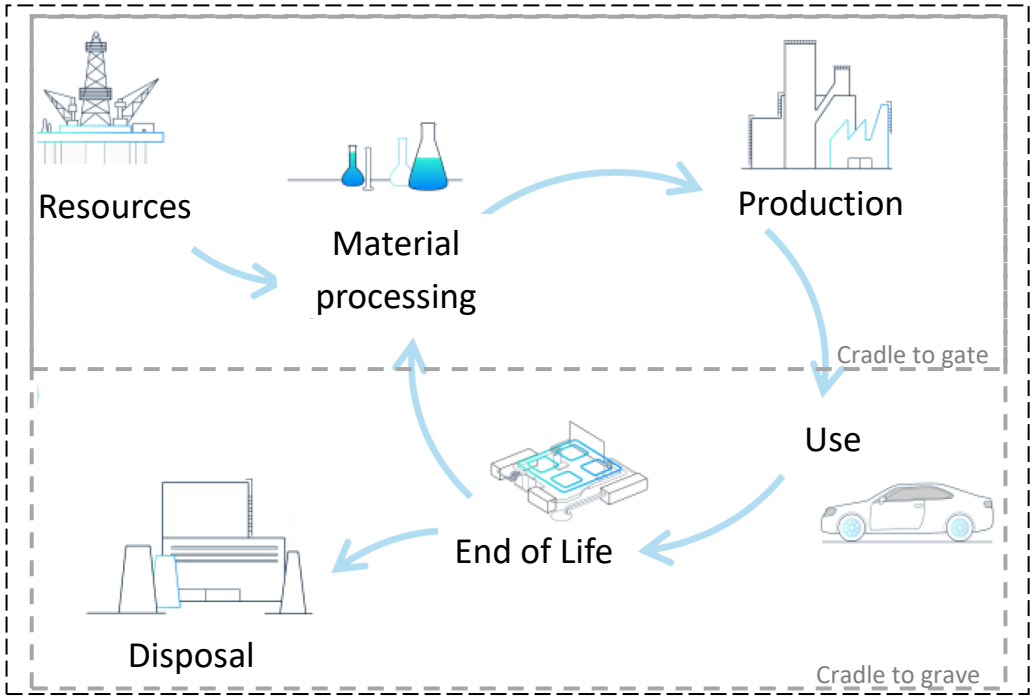
Determination of the goal according to the following points:

- the intended application
- the reasons for implementation
- the target group(s) addressed

Scope definition

- Functional unit: what we assess
- System boundaries: what we don’t assess
- Methodological choices: how to assess

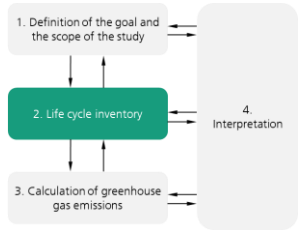
System boundary



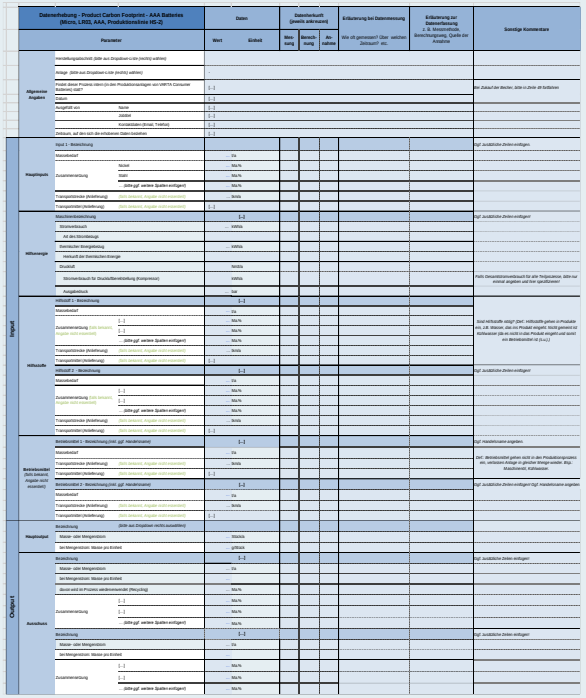
System boundary

Product carbon footprint

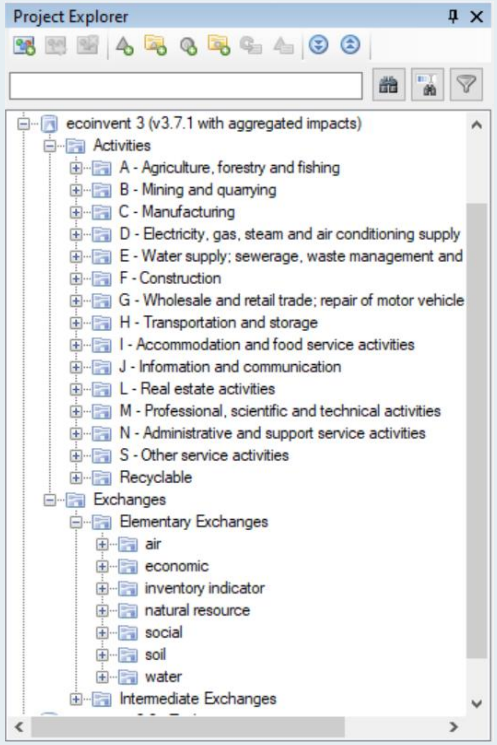
Life cycle inventory



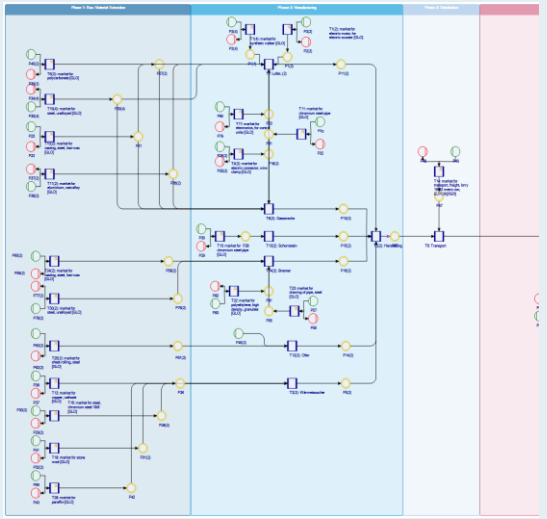
Data collection



Dataset selection

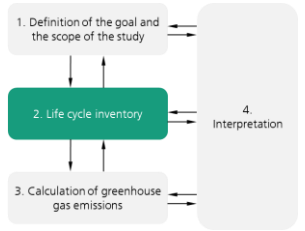


Transfer to LCA software

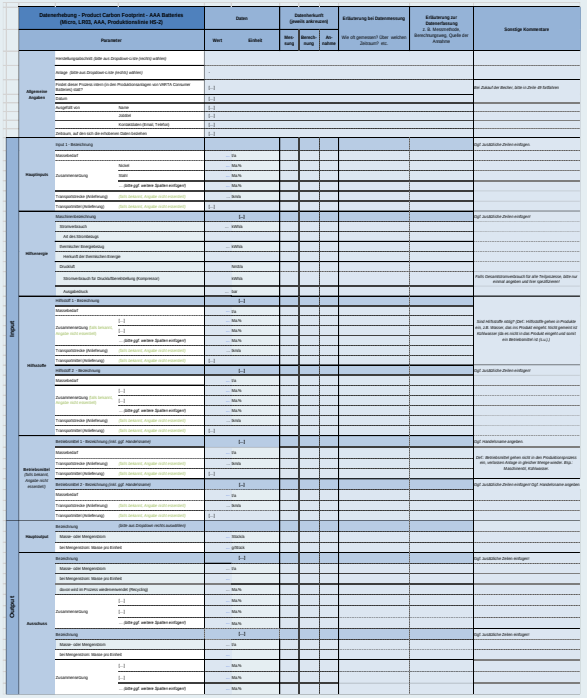


Product carbon footprint

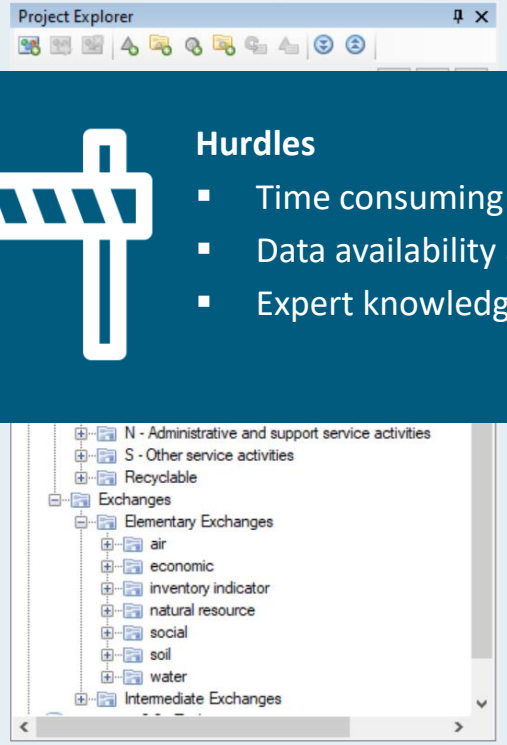
Life cycle inventory



Data collection



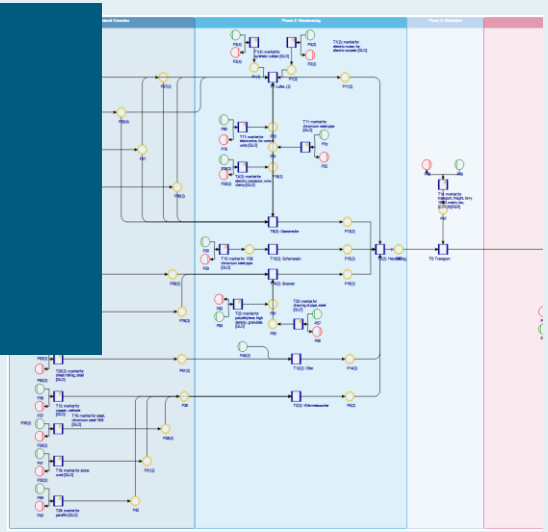
Dataset selection



Hurdles

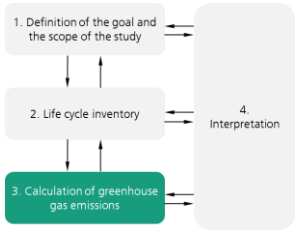
- Time consuming
- Data availability and database costs
- Expert knowledge

Transfer to LCA software



Product carbon footprint

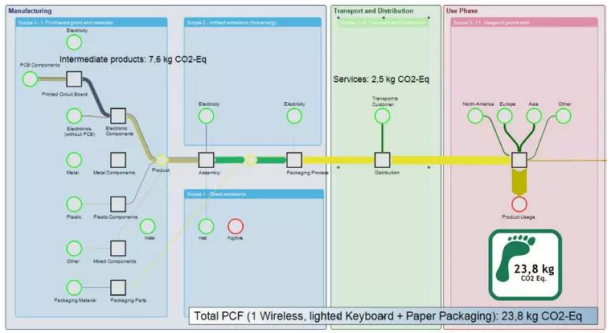
Evaluation

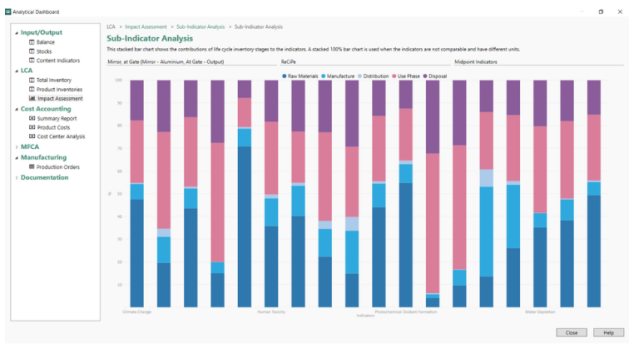


Calculation of Greenhouse Gas Emissions:

Multiplication of activity data with emission factors and GWP results in emission in CO_2 equivalent

Activity data [Unit]	×	Emission factors e.g. [kg CO_2 /unit]	×	GWP e.g. GWP CO_2 = 1 CH_4 =25 …	=	Emission in CO_2 equivalent [kg CO_2eq.]

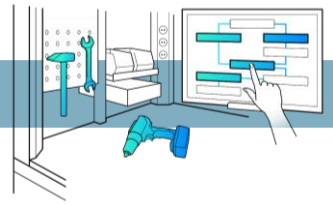


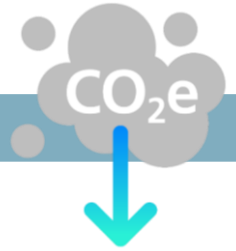


Source: https://www.ifu.com/de/umberto/oekobilanz-software/

Current status and next steps

Data collection





1 **Definition of goal and scope**

2 **Data collection**

3 **Life cycle impact assessment**

4 **Identification of ecological optimization potential**