Modularization of printed circuit boards through embedding technology and the influence of highly integrated modules on the product carbon footprint of electronic systems

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Goal of the Work

Assessment of the environmental performance of two virtual product models „produced“ by AT&S in Leoben, AT using the Product Carbon Footprint (PCF) method.

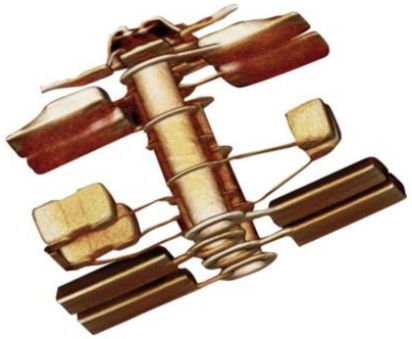
1. Standard PCB with surface mount technology
2. Highly integrated functional module - Embedded component packaging (ECP)

Comparison of the two technologies in regard to the product carbon footprint

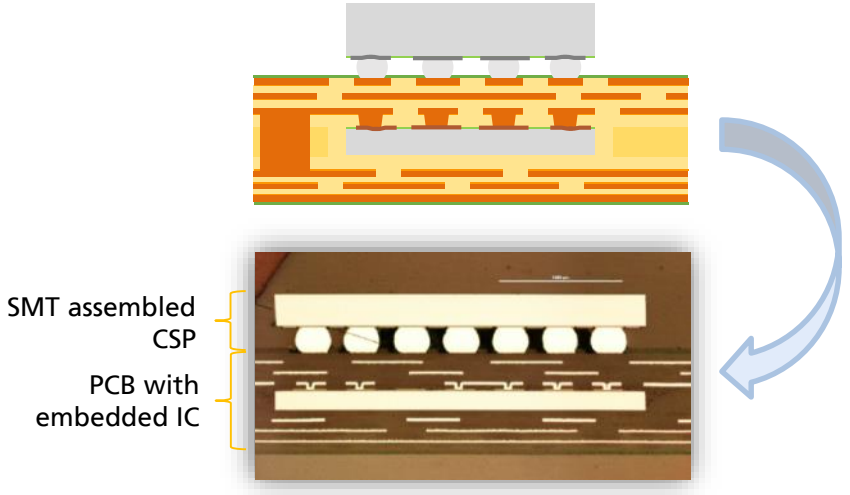
Miniaturized functional Modules by Embedding

ECP® (Embedded Component Packaging) uses the free space in an organic, laminate substrate (Printed Circuit Board) for active and/or passive components

Components are integrated in the core of the PCB and connected by copper plated micro vias

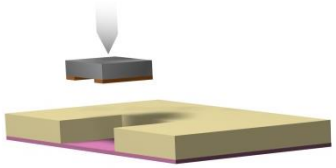


CT image of embedded capacitors in a 4 layer PCB

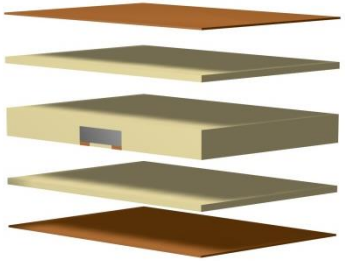


ECP® Process Flow

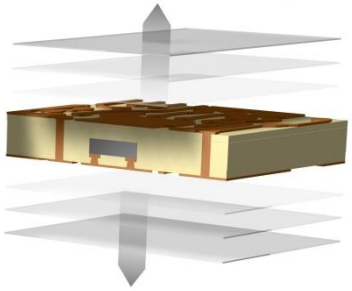
Center Core Embedding process (2 layer stack up)



- Core preparation
- Cavity cutting
- Carrier lamination
- Component assembly



- Soft lamination
- Carrier removal
- Final lamination



- Laser drilling (component interconnection)
- Mechanical drilling (PTH)
- Plating and structuring
- Testing

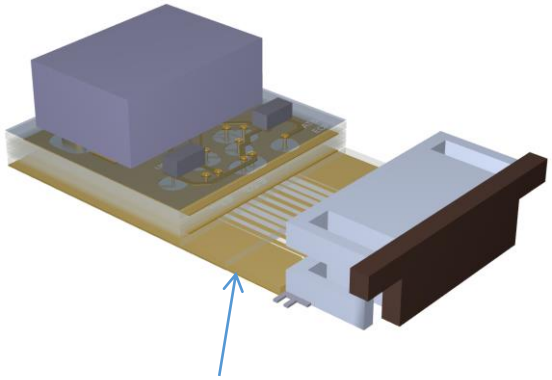
01 Core manufacturing → 02 Lamination → 03 Structuring

Why ECP® ?

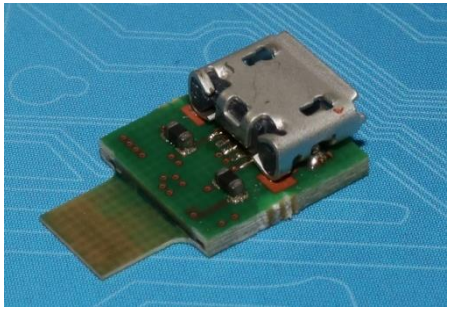
Unique selling propositions	… in detail
ECP is supporting the trend towards modularization	• Customization of footprint and module versions can be done due to digital imaging - no separate tooling necessary (e.g. QFN)
Miniaturization	• Footprint reduction • Higher component integration (additional assembly layer)
Electrical performance	• Improved signal performance (higher data rates) • Reduction of parasitic effects
Mechanical performance	• Higher durability and reliability through copper-to-copper connections (copper filled micro vias) • Package enables protective enclosure • High drop, shock and vibration tolerance
Thermal management	• Improved heat dissipation through direct copper connection • Improved heat dissipation FR4 versus air (compared to SMD)
Anti-Tamper and Security	• Hidden electronics preventing reverse engineering and counterfeiting
Additional functions – Reduction of overall cost – EMI shielding	• EMV shielding (partial or full shielding of a package) • Package is the housing → no additional molding required

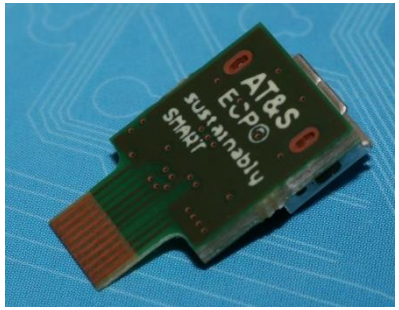
ECP® USB Module

Application	USB module
Package size / Type	10 x 15 mm Multi-component module
Substrate Construction/ Thickness	8 layer rigid flex 1158 um
# of embedded components	8 (diodes, capacitors and resistors)
Voltage	5V



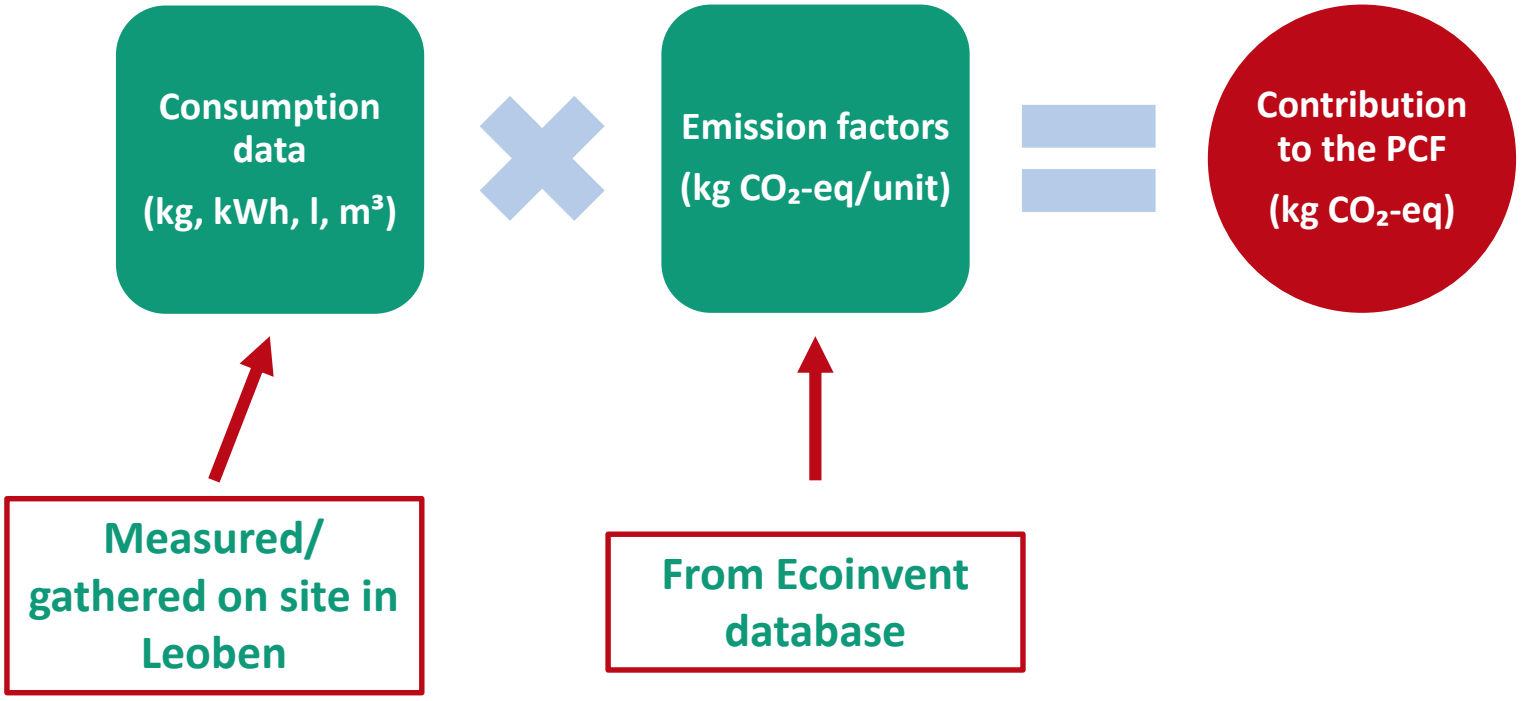
2.5D connector for flexible connection to mainboard





Product Carbon Footprint

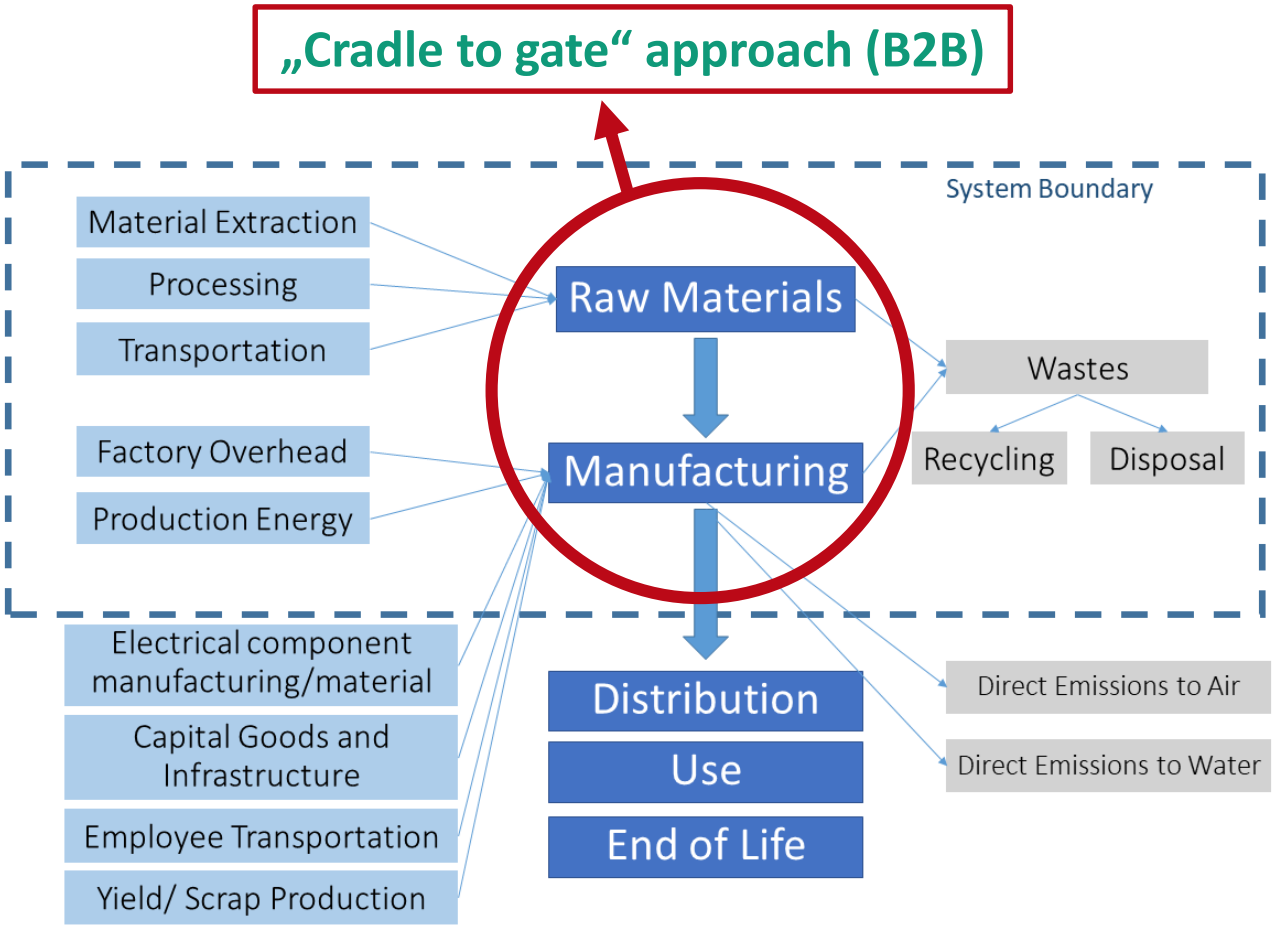
„Method to quantify all greenhouse gas emissions caused by a product over its life cycle.“



Method

Following **ISO 14067** – „Carbon Footprint of Products“

Functional unit for comparison: small PCB holding one component (transistor)



Virtual Product Models

No PCB is produced with both technologies

→ to make a valid comparison „virtual product models“ with the *same functionality* have to be designed.

Small module with mounted or embedded transistor.

SAME	functionality
DIFFERENT	processes size materials

Assessment of process flows

Gathering of information directly at production machines:

- Chemical meters
- Water meters
- Energy meters
- Direct mobile measurement of electricity on site

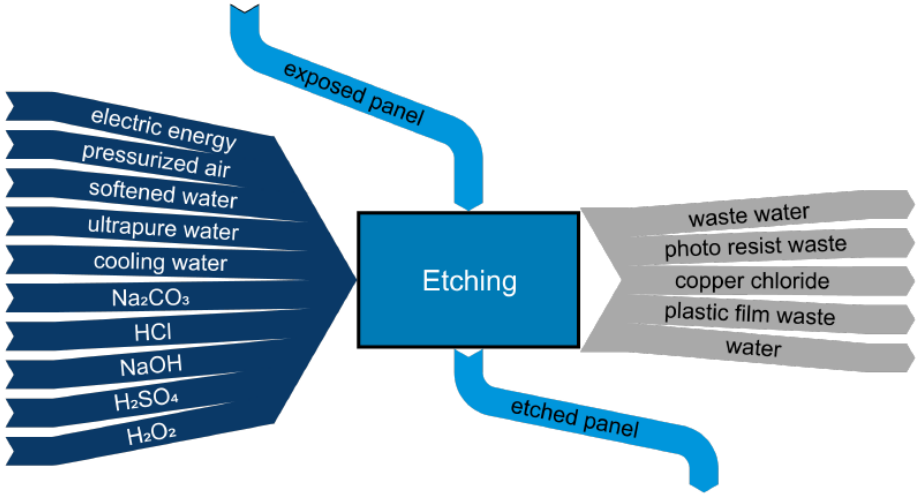
If no direct data available or no measurement possible, acquisition through:

- Yearly consumption data from controlling

Allocation of gathered data through:

- Throughput of products through machines in a given time
- Throughput of copper layers through a machine in a given time

Example of gathered data



Material	Unit	Value
Electric energy	kWh	1,122
Cooling water	l	22,068
Ultrapure water	l	1,395
Softened water	l	19,928
Hydrochloric acid HCl	l	1,222
Hydrogen peroxide H_2O_2	l	0,170
Caustic soda NaOH 1	l	0,086
Sodium carbonate Na_2CO_3	kg	0,036
Sulfuric acid H_2SO_4	l	0,022

Data Quality

Material- and energy consumption gathered on site: 99%

Emission factors: 90%

Transportation of suppliers: 53%

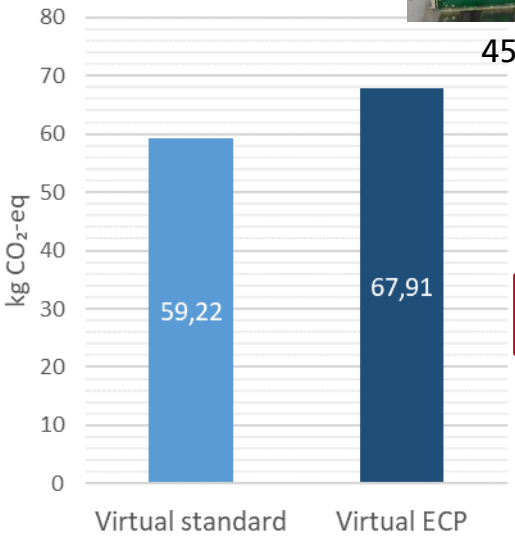
Transportation to recycling/dump: 95%

Amount of waste on site: 100% (Data from 2016)

Results

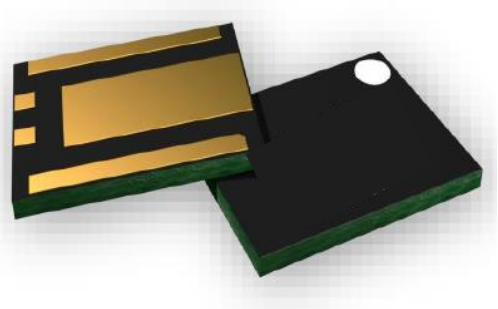
PCF/panel

457 mm x 609 mm

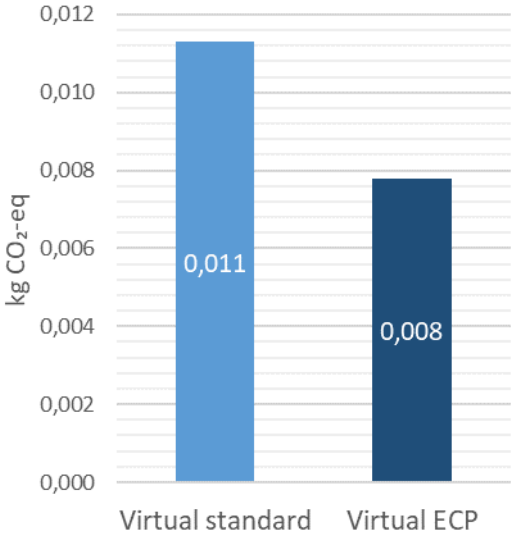


Size impact

PCF/PCB

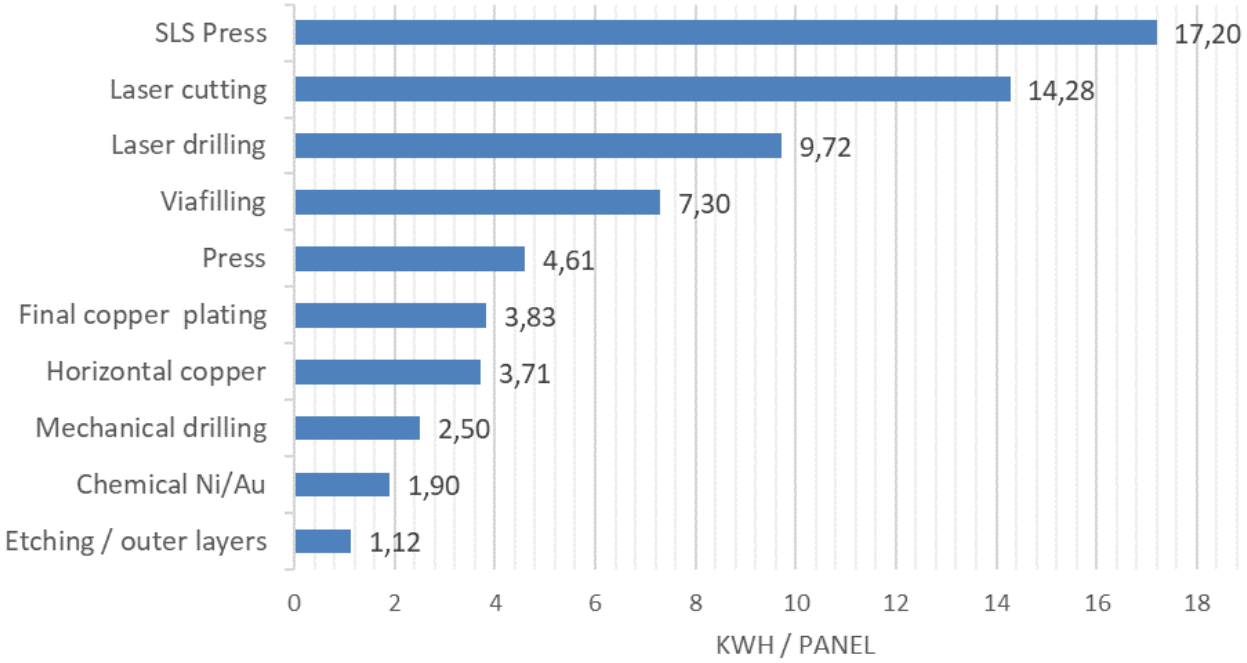


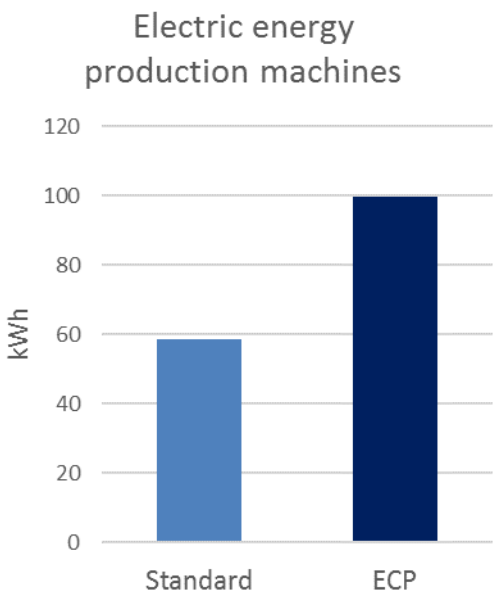
tandard: 5,7 mm x 5,7
ım
CP: 4,55 mm x 4,35 mm



Main processes

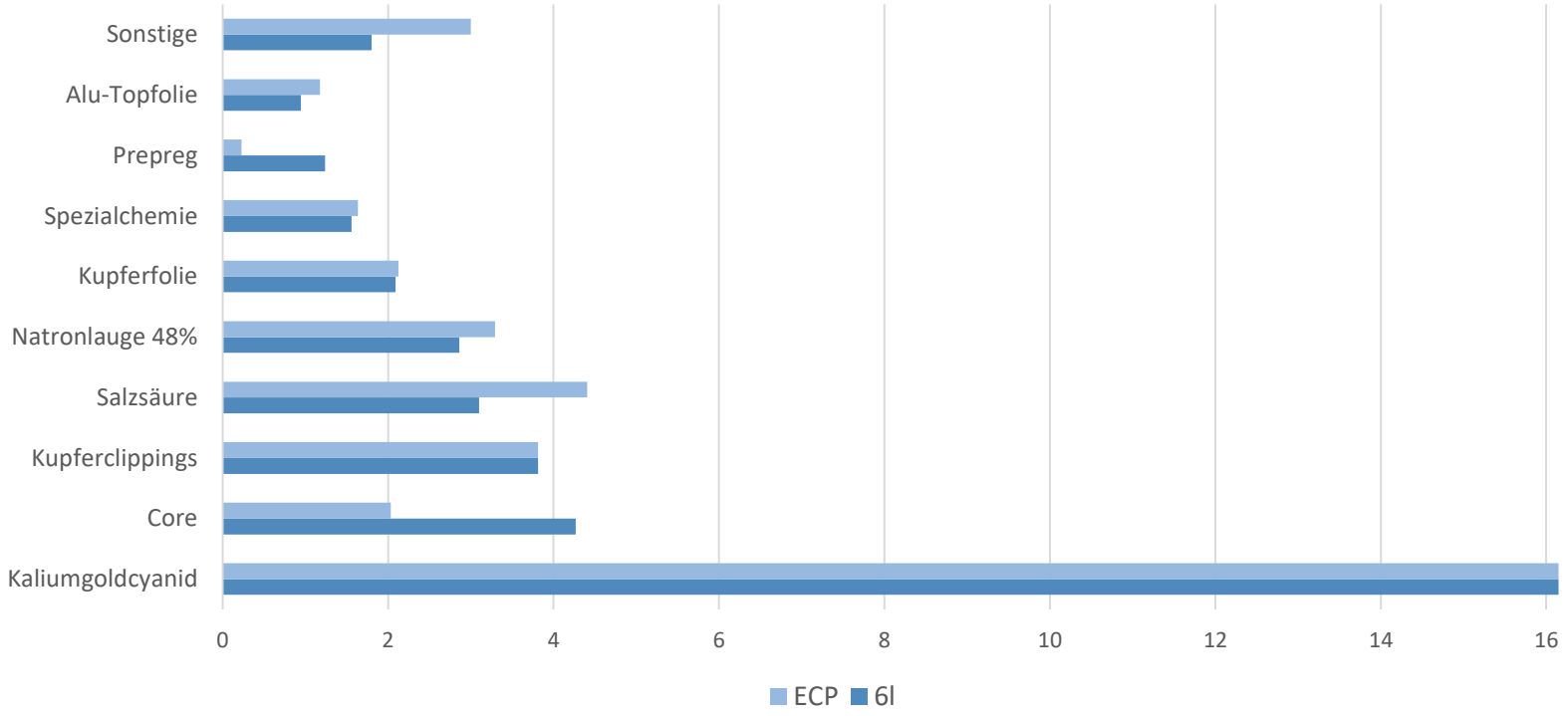
What processes are contributing the most to PCF regarding energy consumption?





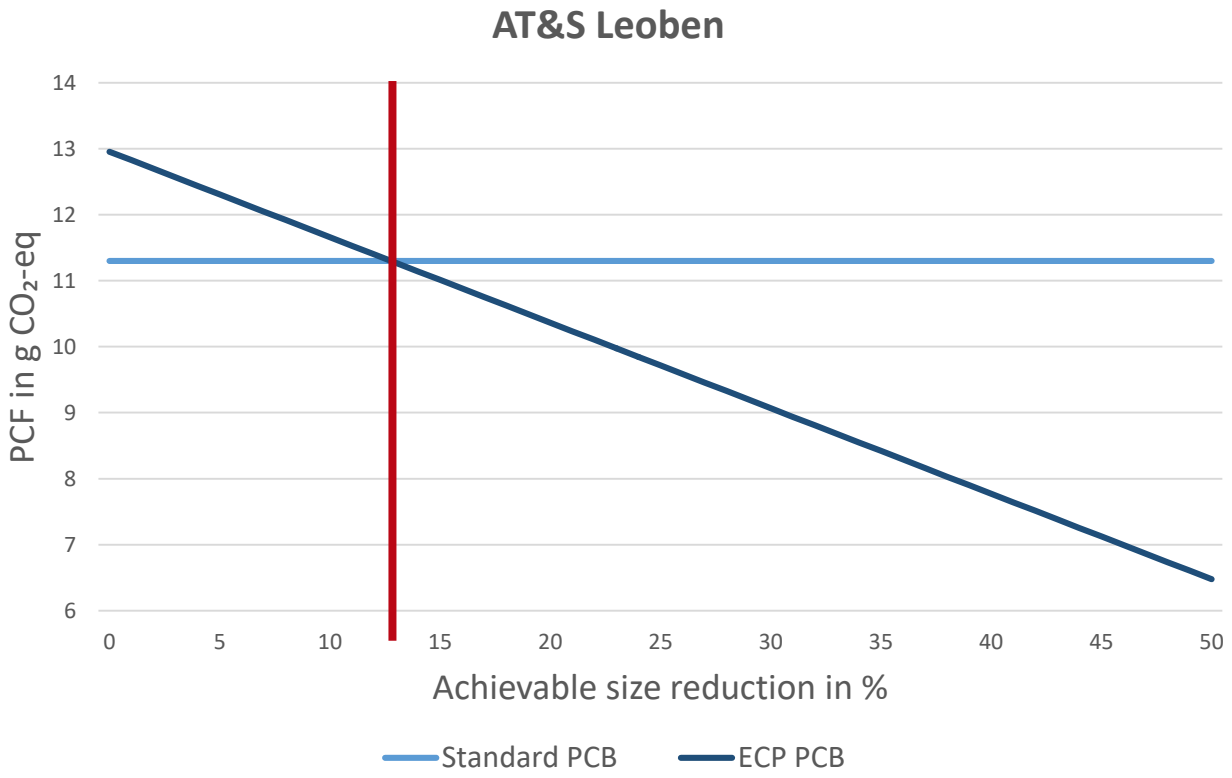
Main Materials

Which materials are contributing the most to PCF?



Influence of Size Reduction

How is the possible size reduction influencing the overall results?



Results/Conclusio

Electric energy consumption twice as high regarding ECP technology, can be compensated through size reduction, starting at 13% miniaturization

Largest PCF contributors:

- Metals (copper, gold)
- Hydrochloric acid
- Electric energy consumption

Next step:

Automated PCF assessment at manufacturing plant in Leoben using a CO_2 Calculator (in development)

Aknowledgement

The presented work was prepared within the scope of the sustainablySMART project.

The project sustainablySMART has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement no. 680640.

SUSTAINABLY SMART

Thank You!

Tobias Kupka, AT&S AG

AT&S