



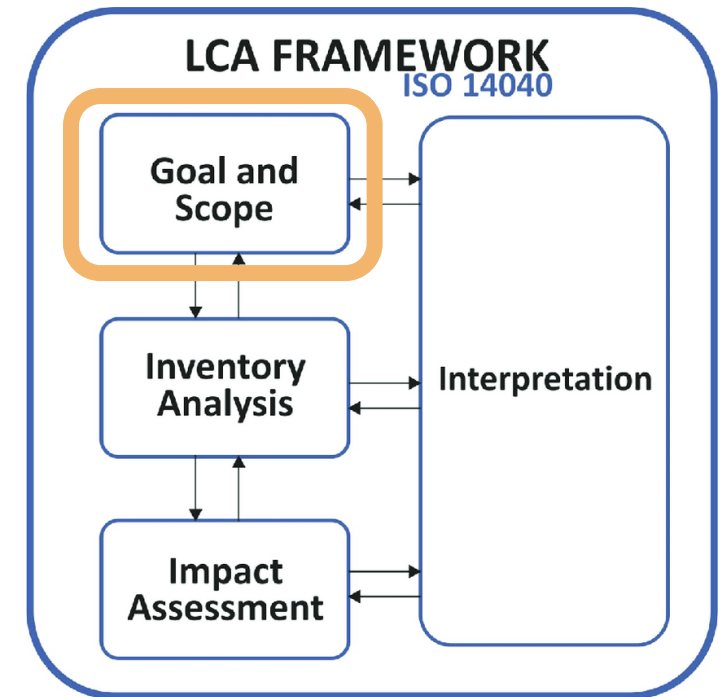
OPTIMAL Life Cycle Assessment

PRESENTED BY MARTIN BEERMANN, JOANNEUM RESEARCH - LIFE

OPTIMAL Life Cycle Assessment

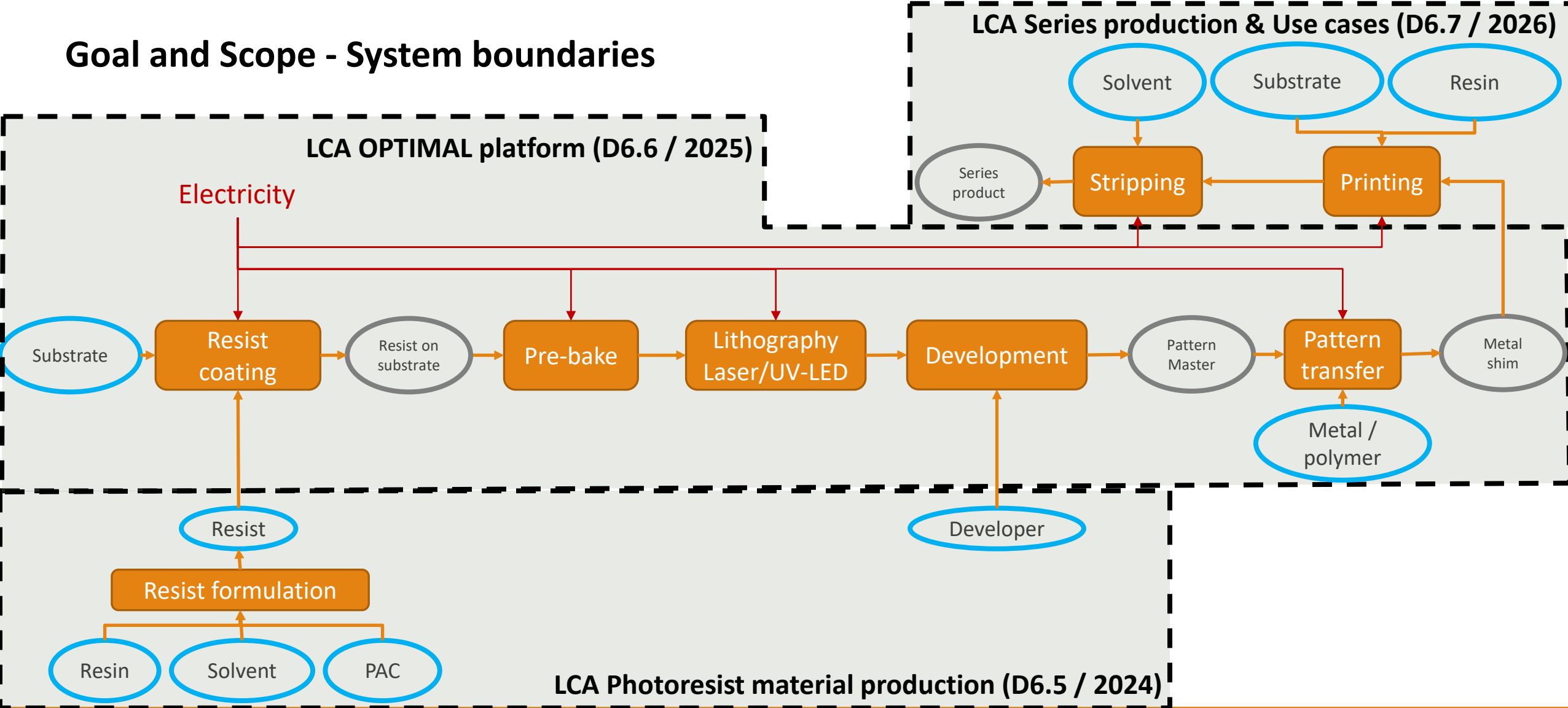
1) Goal and scope:

- Environmental effects of the **OPTIMAL** system compared to a **Reference system** as state-of-the-art:
 - **Energy savings** (due to increased writing speed, lower electric power per laser power, „first time right“)
 - **Materials + waste reduction** (due to „first time right“ - reduction of iterations, tailored resins, larger active area)
- **LCA in 3 steps:**
 - Production of 1 kg photoresist
 - Production of 2,000 cm² metal shim
 - 1 unit of final product in use cases



OPTIMAL Life Cycle Assessment

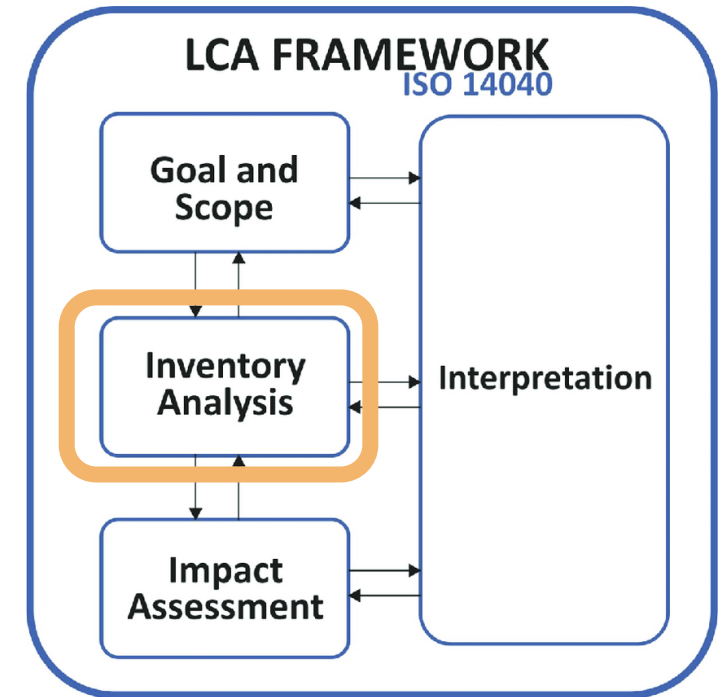
Goal and Scope - System boundaries



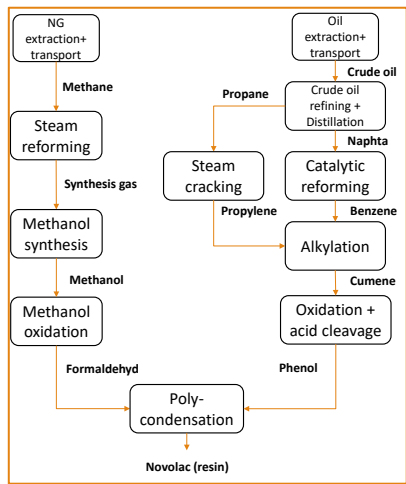
OPTIMAL Life Cycle Assessment

2) Life Cycle Inventory

- **Foreground data:** measured monitoring data
- **Background data:** upstream and downstream processes (e.g. production of chemicals)
 - Background data **in LCA databases** – ecoinvent + openLCA chosen for OPTIMAL
- **Approach to fill background data gaps for special chemicals**
 - **1.** Research on **synthesis paths** based on literature and patents
 - **2.** Setting up reaction **equations, stoichiometry** and mass balance
 - **3.** Estimation on the **energy** demand (less relevant for fine chemicals)
 - **4. Modelling** of the dataset and connecting to existing datasets.

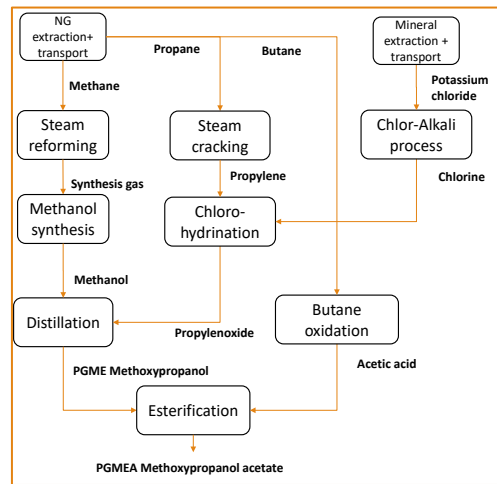


Upstream synthesis chain of Positive Resist / LCA modelling



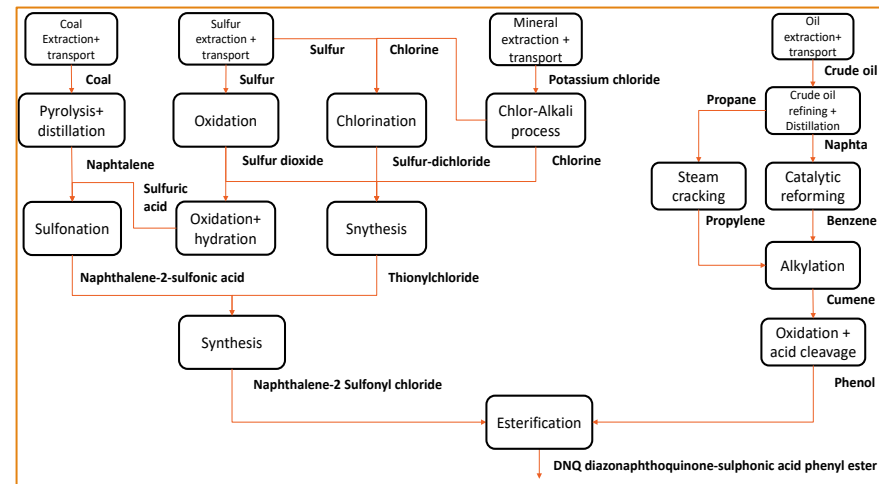
Resin

+

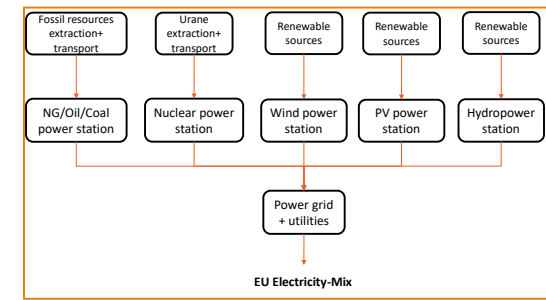


Solvent

+



PAC



+ Electricity-Mix (EU) for formulation of Resist

Positive resist ma-P 1200G



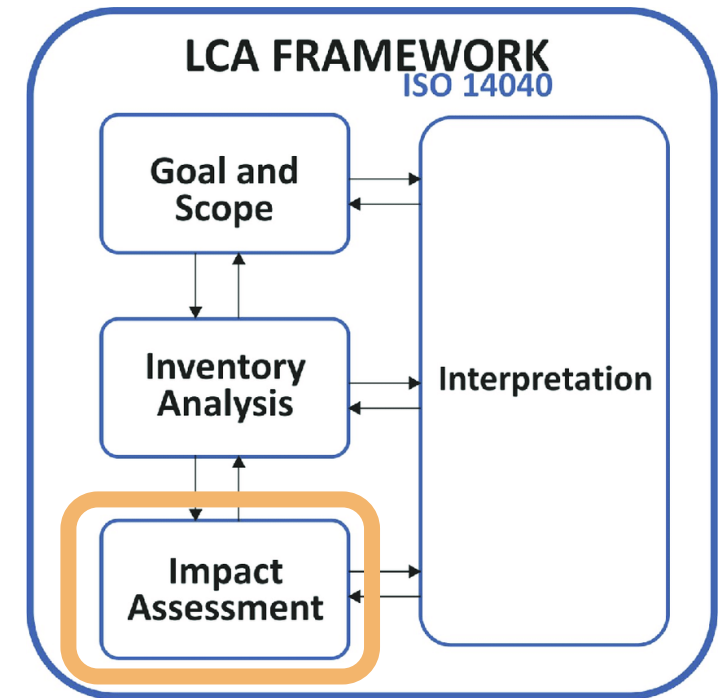
Detailed LCA modelling in ecoinvent

(16,365 linked processes)

OPTIMAL Life Cycle Assessment

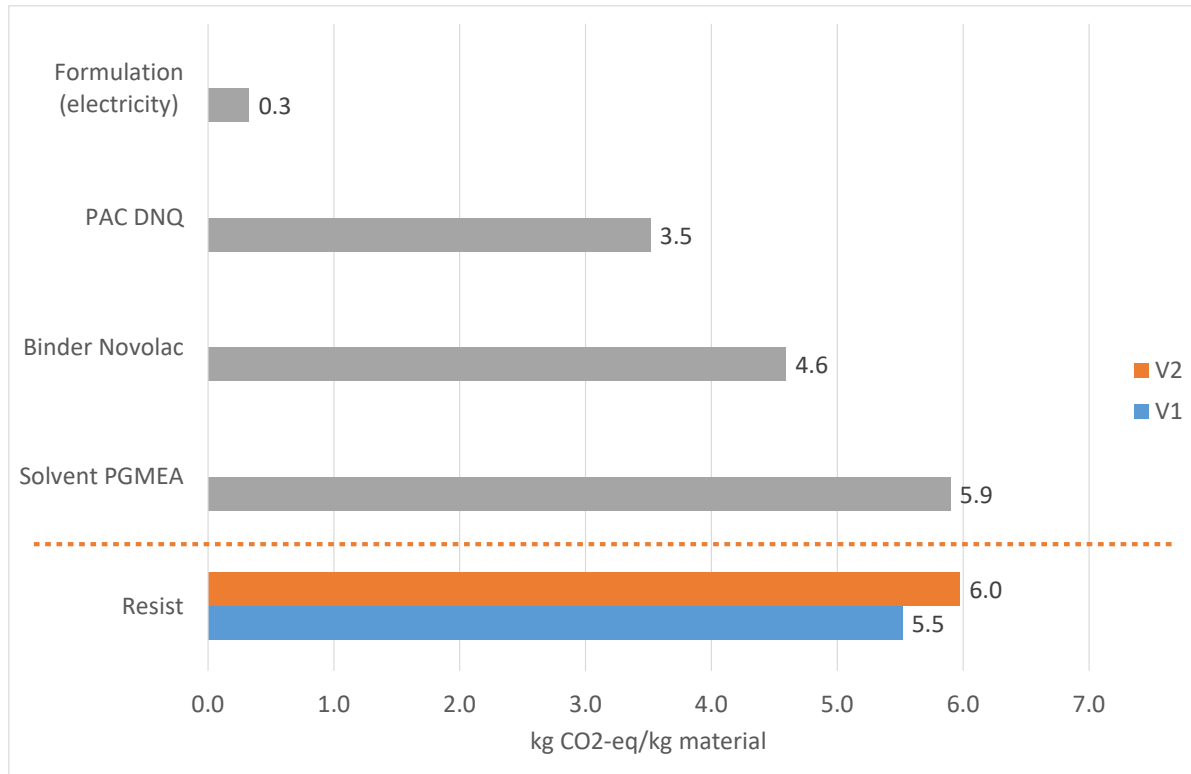
3) Life Cycle Impact Assessment

- Global warming potential
 - 1kg CO₂=1 CO₂e
 - 1kg CH₄=30 kg CO₂e
 - 1kg N₂O=273 kg CO₂e
- Primary energy demand
 - Fossil
 - Renewable
 - Nuclear
- Abiotic resource depletion
 - Fossil Resources (as mass)
 - Non-fossil resources (minerals,...)

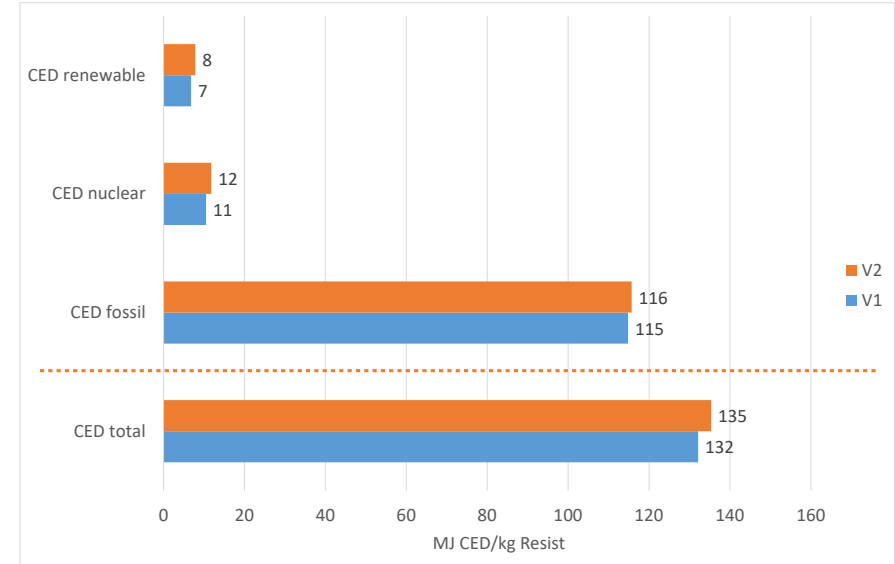


Environmental impacts of positive Resist

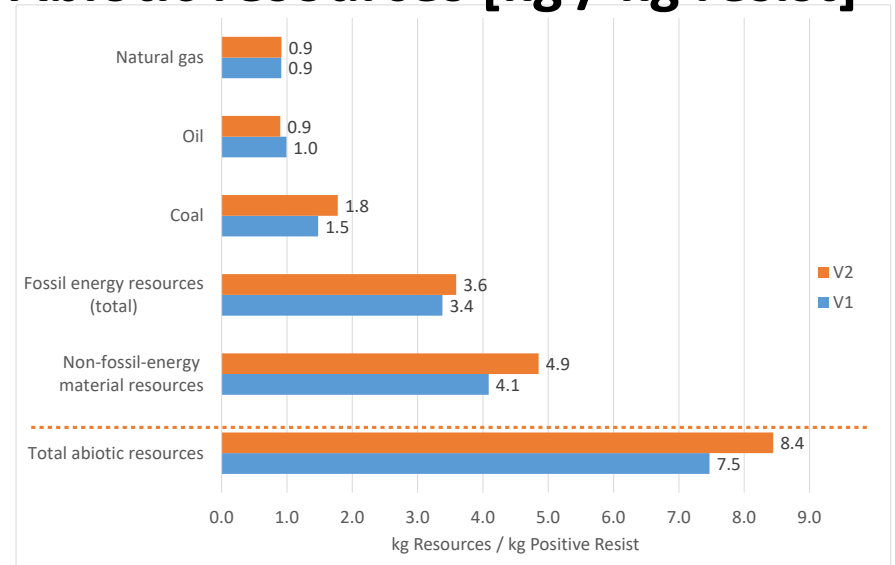
GWP [kg CO₂e / kg]; [kg CO₂e / kWh]



Cumulated Energy Demand [MJ / kg resist]

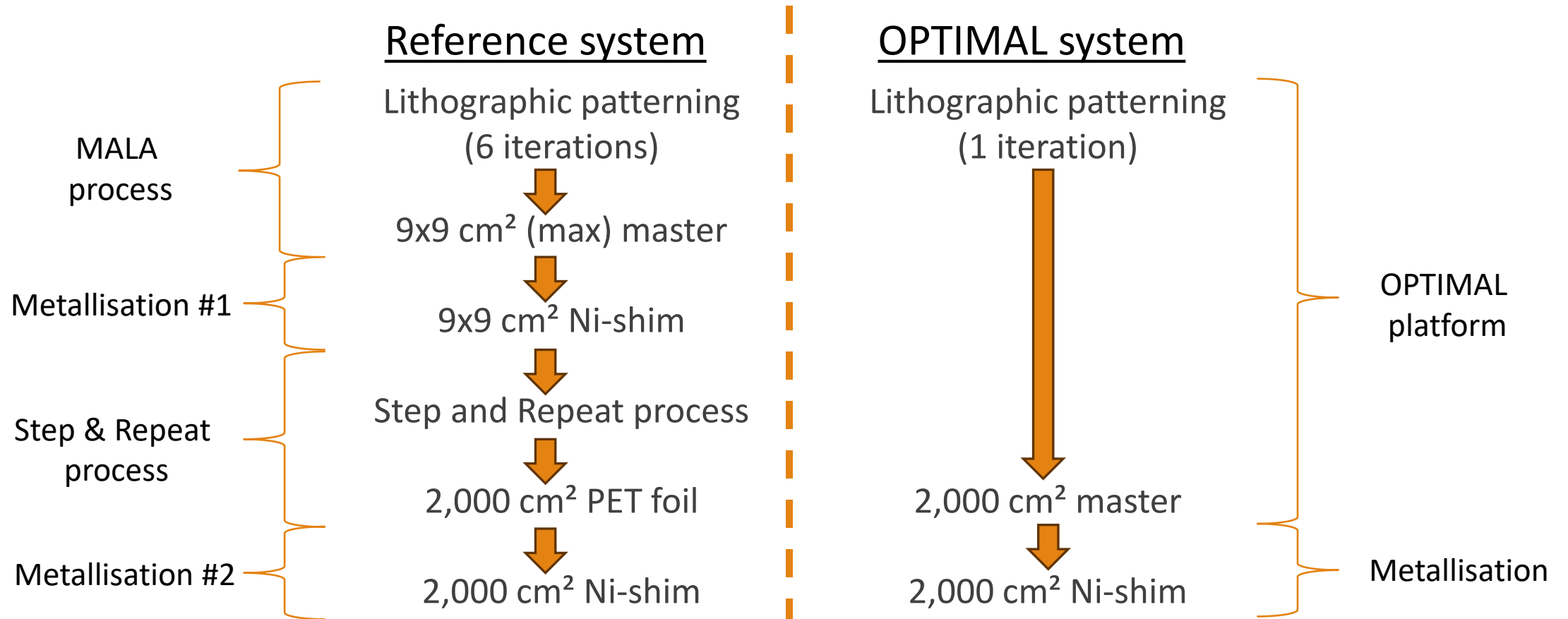


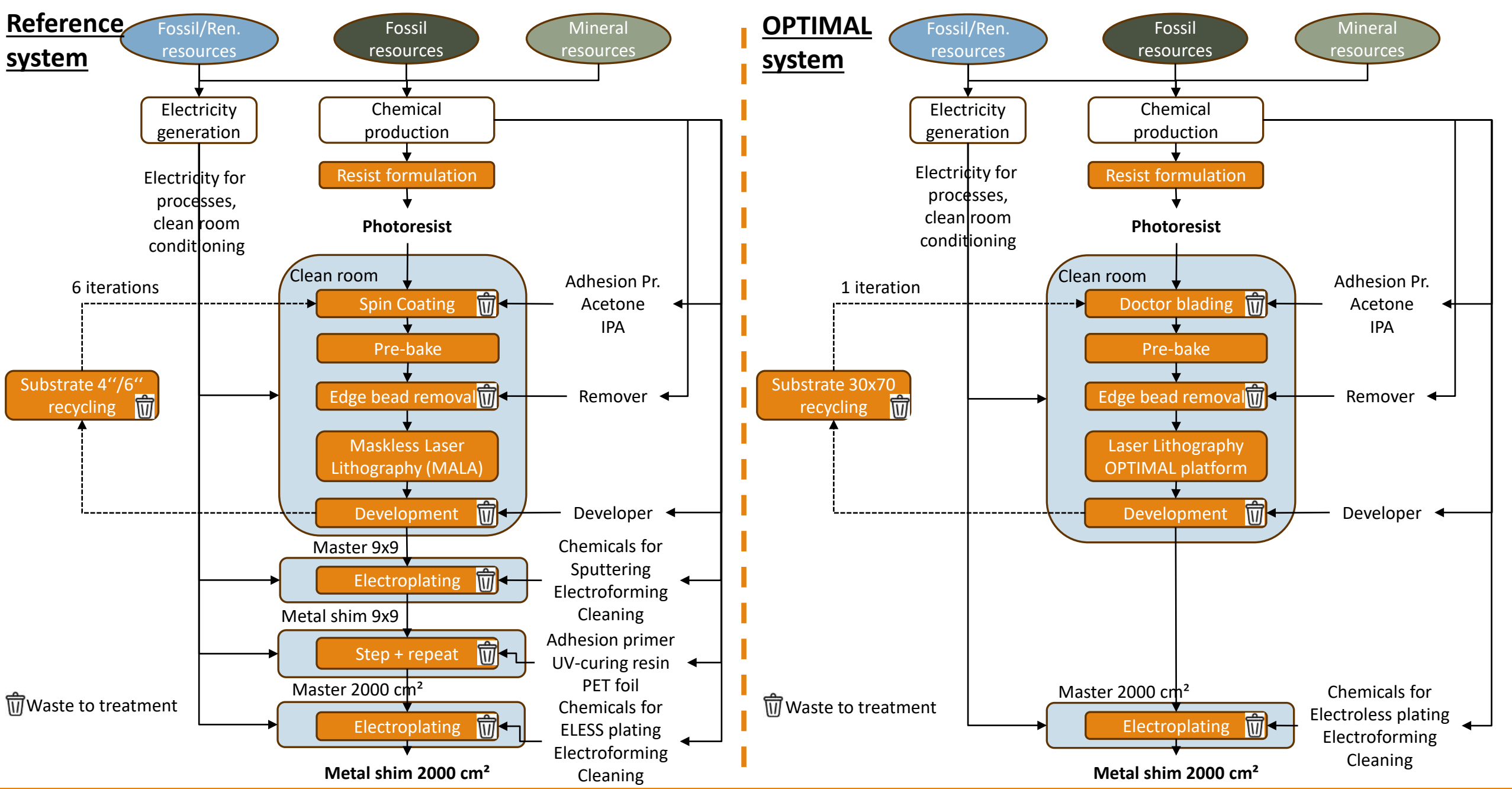
Abiotic resources [kg / kg resist]



OPTIMAL Life Cycle Assessment

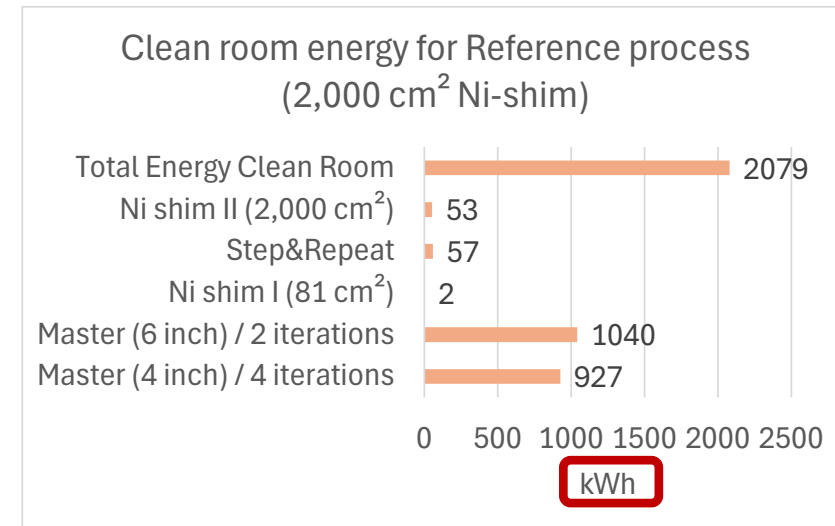
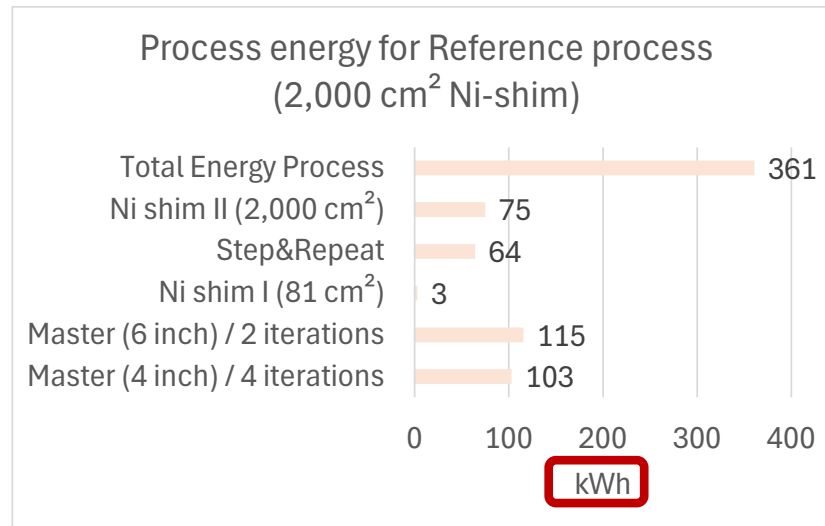
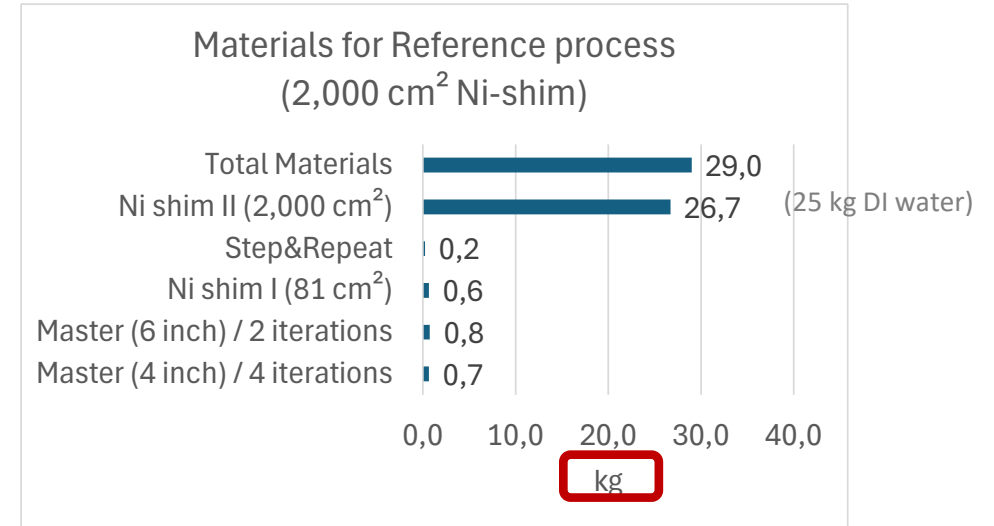
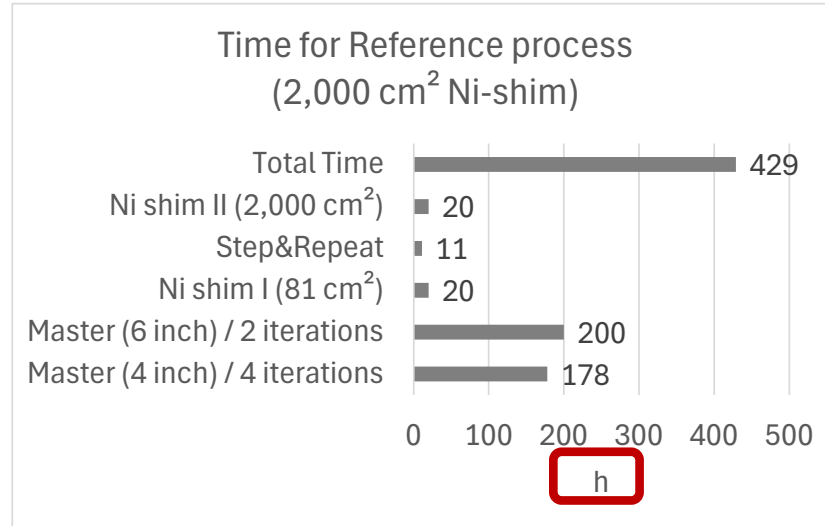
Comparison Reference system ↔ OPTIMAL system for production of 2000 cm² Ni shim
(MALA - JOR maskless laser system as „state-of-the-art“ reference process)





OPTIMAL Life Cycle Assessment

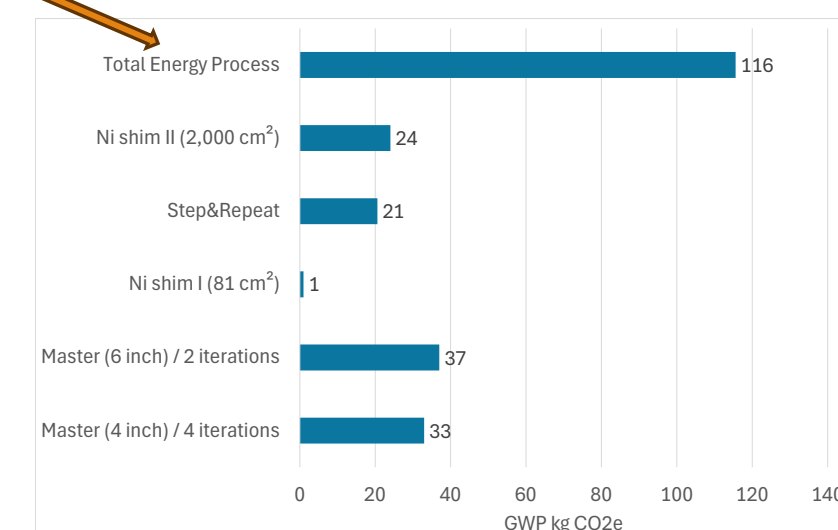
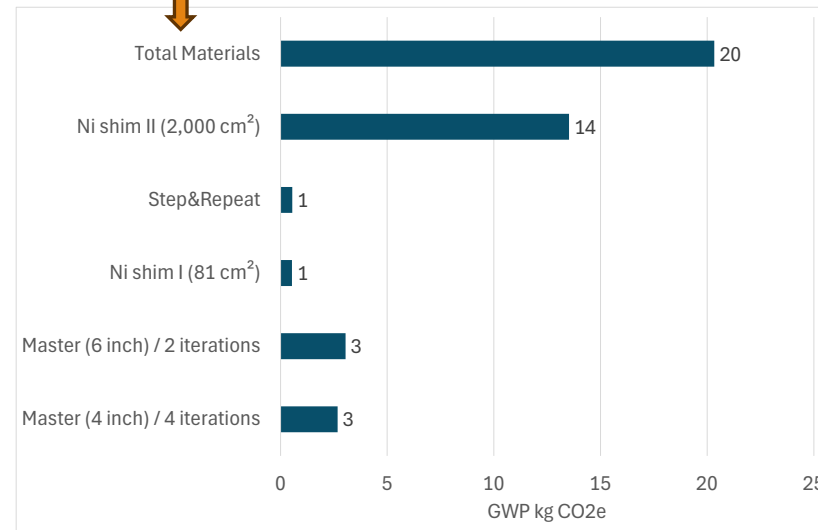
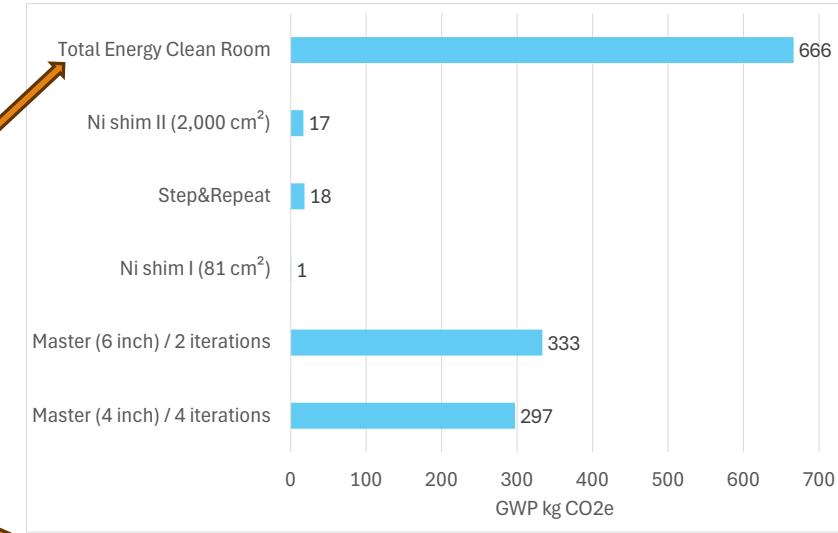
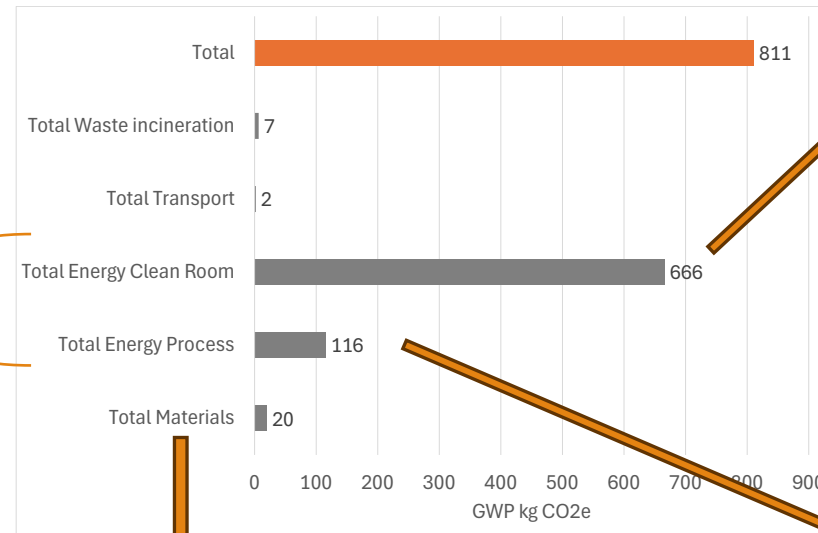
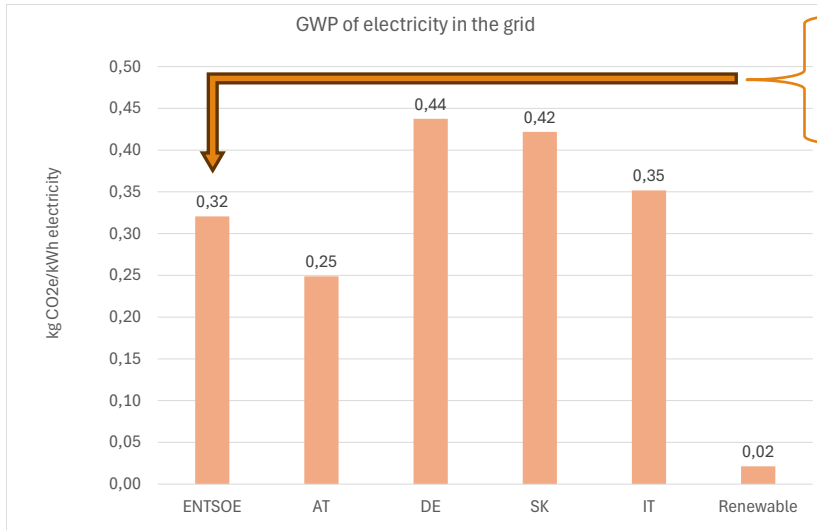
Reference System - Summary Foreground data



OPTIMAL Life Cycle Assessment

Reference System – Global Warming Potential kg CO₂e / 2000 cm² metal shim

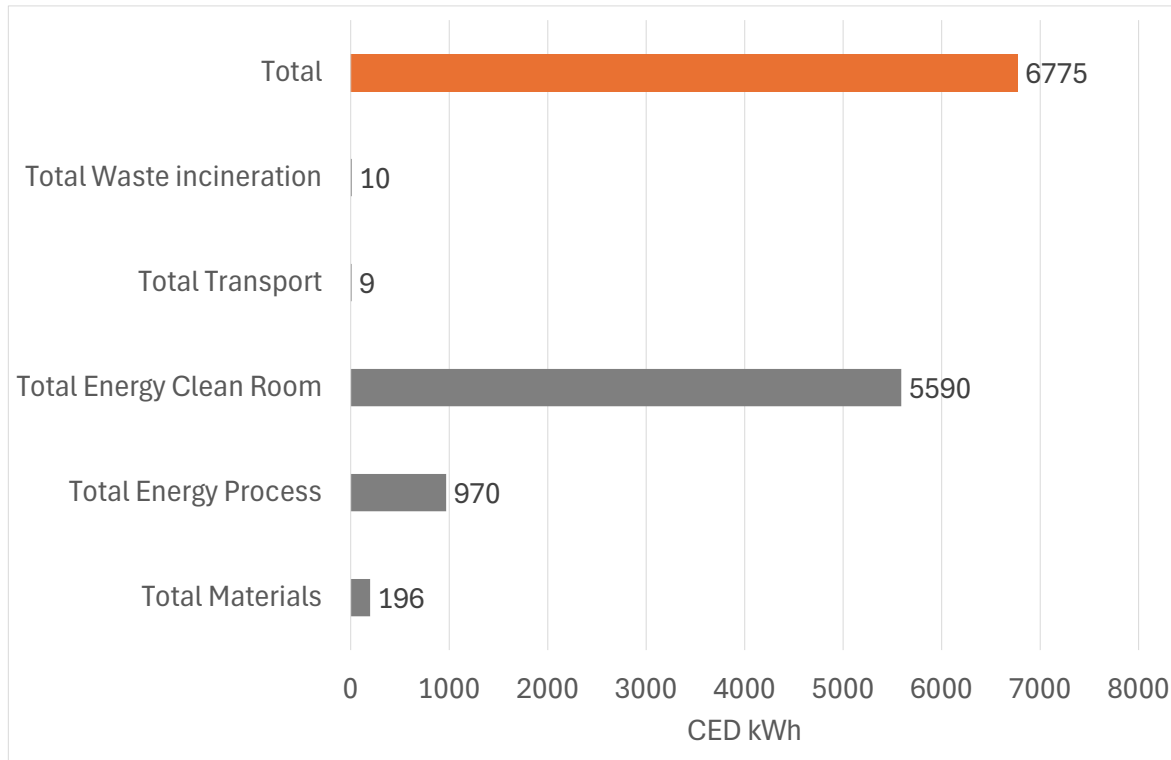
GWP electricity ~ physical mix in EU-grid



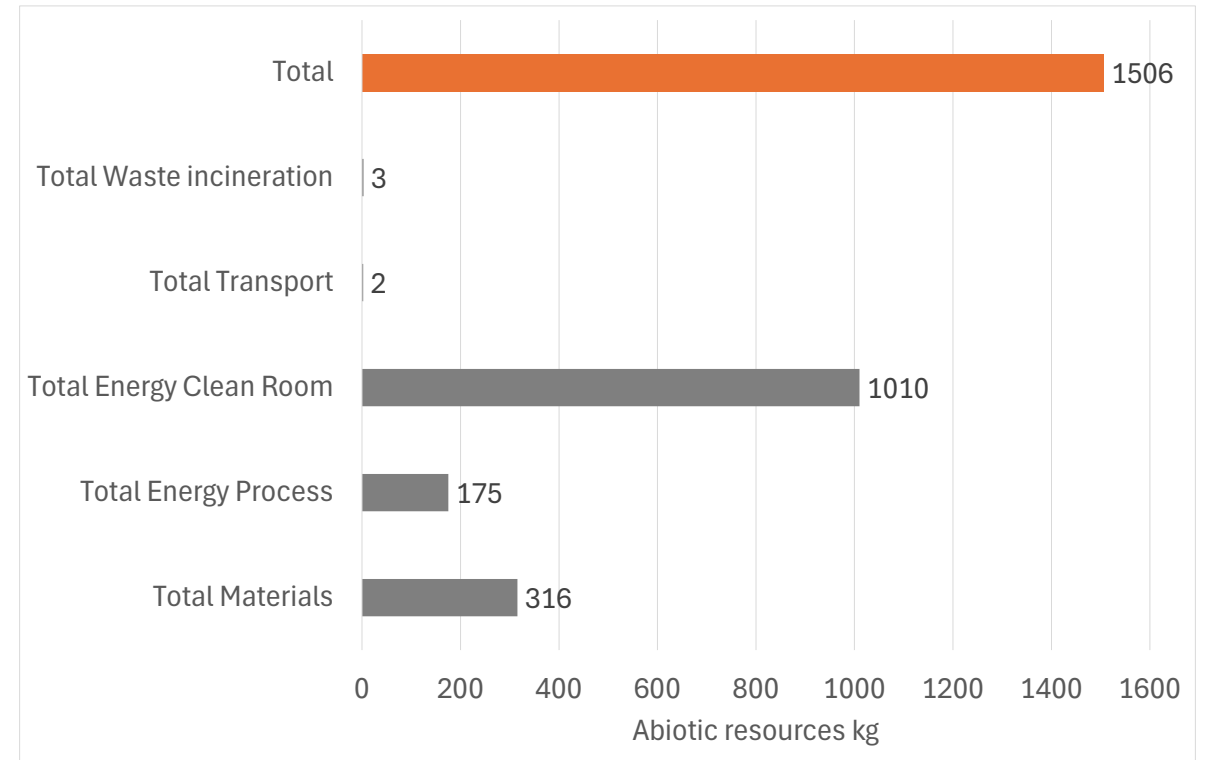
OPTIMAL Life Cycle Assessment

Reference System – CED and Abiotic Resources / 2000 cm² Ni-shim

Cumulated Energy Demand
[kWh / 2,000 cm² metal shim]



Abiotic resources
[kg / 2,000 cm² metal shim]



OPTIMAL Life Cycle Assessment

Summary of LCA results

Summary of the main LCA results of resist and developer materials

	Positive resist PR	Developer PR	Negative resist NR	Developer NR	Unit
GWP total	5.7	0.8	7.0	5.9	kg CO ₂ e/kg
CED total	133	17.6	134	128	MJ/kg
CED fossil	115	15.3	115	113	MJ/kg
Fossil resources	3.5	0.1	3.1	3.5	kg/kg
Non-fossil resources	4.4	1.6	8.0	5.1	kg/kg

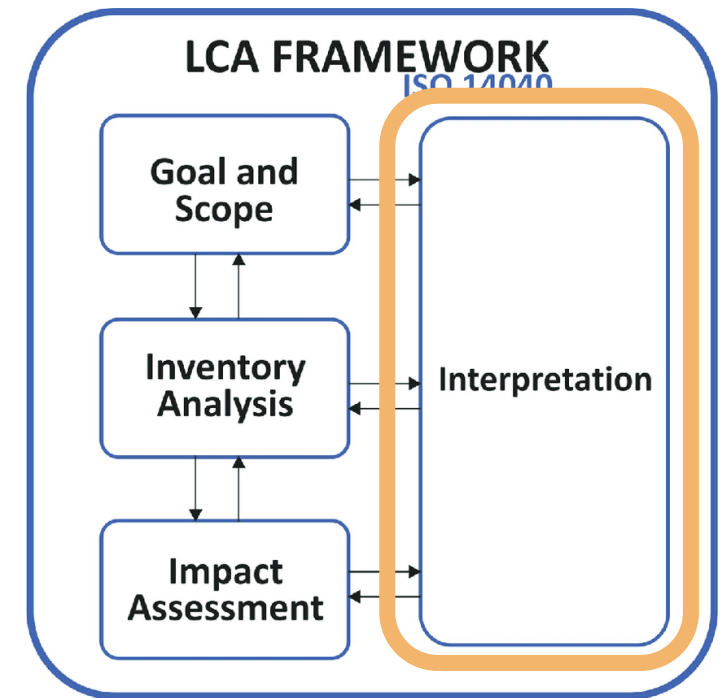
LCA results of Reference and OPTIMAL system to produce a 2,000 cm² metal replica of a micro structured polymer master

	Reference system (total)	Reference system (only energy)	OPTIMAL system (only energy, preliminary)	Unit	Relative decrease by OPTIMAL (only energy, preliminary)
GWP total kg CO ₂ e	811	782	359	kg CO ₂ e	-54%
CED total kWh	6,775	6,560	3,006	kWh	-54%
Abiotic resources kg	1,507	1,185	544	kg	-54%

OPTIMAL Life Cycle Assessment

4) Interpretation

- **Electricity demand contributes 96% to total GWP** of 811 kg CO₂e for a 2,000 cm² Ni-shim (82% clean room, 14% processes). This is due to
 - electrical power for clean room: 0,13 kW / m² (40 m²) + Long processing time (> 400h) + EU electricity emission factor
- **High relevance of OPTIMAL project by reducing the processing time**
 - Increase of laser writing speed from 1cm²/h (MALA) to 1cm²/min (OPTIMAL) is estimated to result in **reduction of more than 50 % time = energy = GWP** by the OPTIMAL process!



Thank you for your attention!

Contact details

Martin Beermann, Elisabeth Schwarz-Funder

JOANNEUM RESEARCH Institute LIFE (JOR)

martin.beermann@joanneum.at

+43 664 602 876 7632



**Funded by
the European Union**

