LIFE CYCLE ASSESSMENT OF AN INGOT MANUFACTURING PROCESS USING SILICON POWDERS FROM RECYCLING

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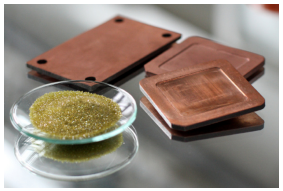
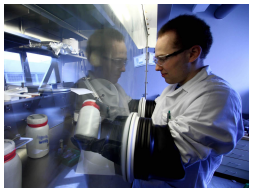
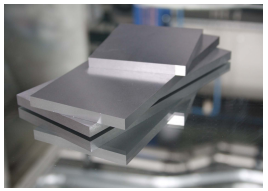

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- Recycling system for cSi PV systems
- Wafer production via hot pressing process
- Industrial process design
- LCC and LCA aspects
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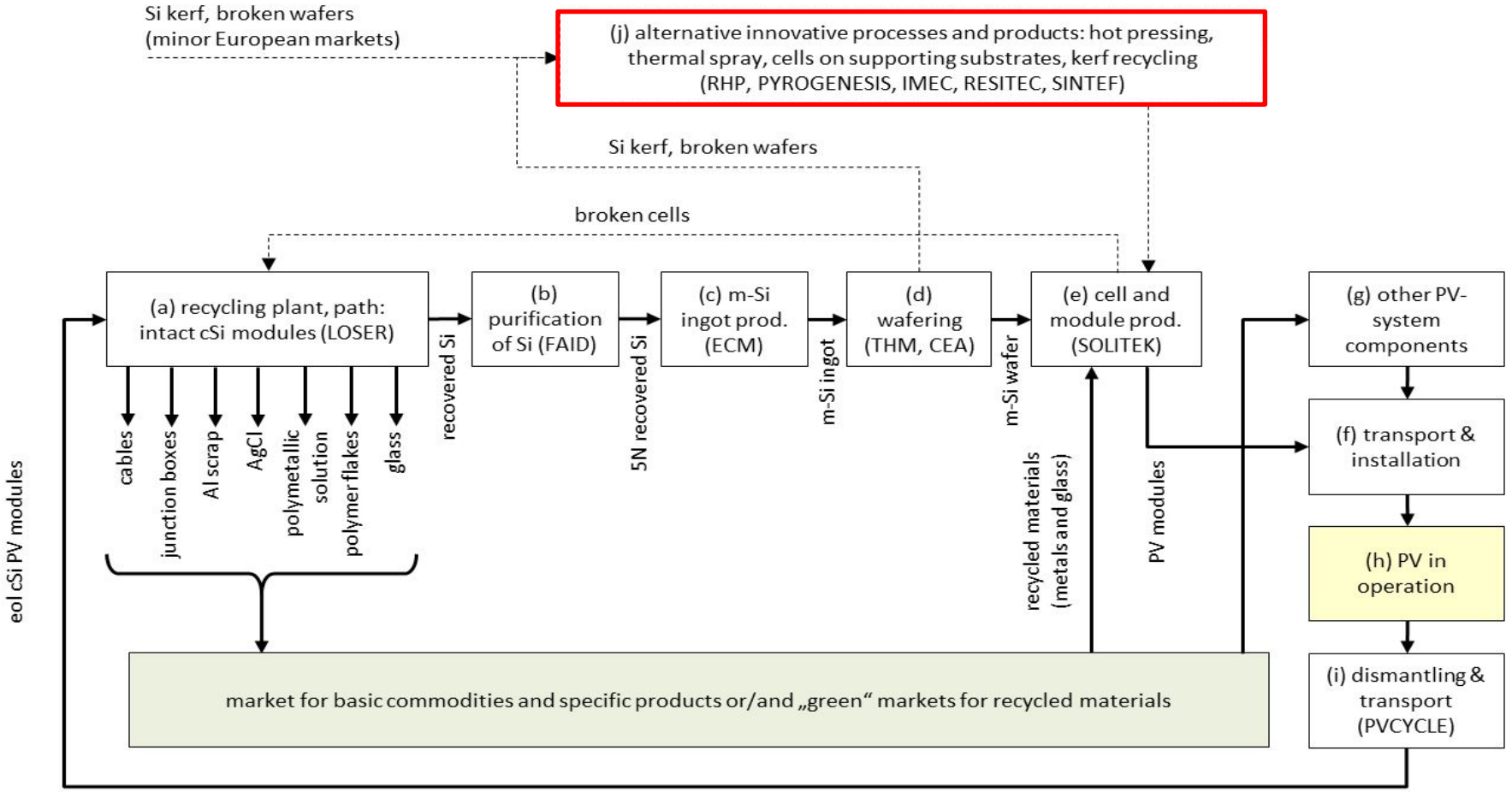
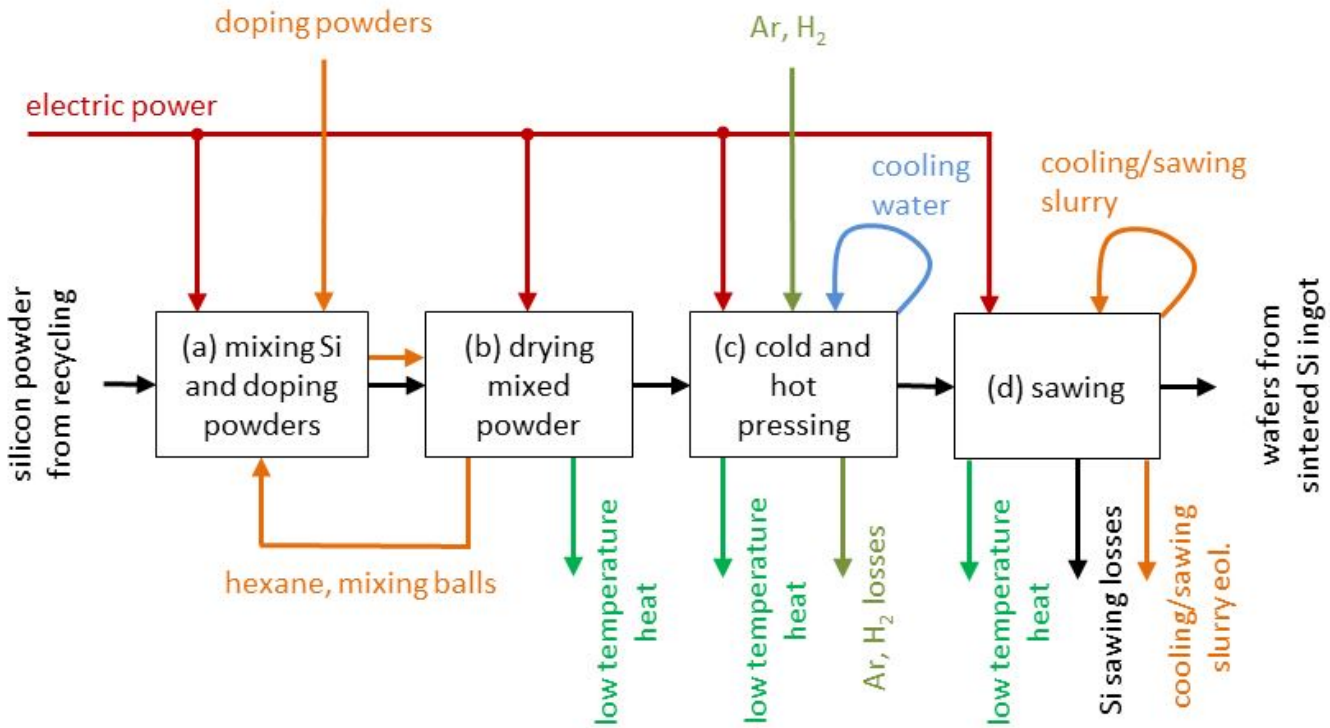
Horizon 2020 innovation action CABRISS

- Implementation of a **C**ircul**A**r economy **B**ased on **R**ecycled, reused and recovered **I**ndium, **S**ilicon and **S**ilver materials for photovoltaic and other applications
- joint initiative of 16 European companies
- Focus: make use of recycled waste materials (Si, In and Ag). CABRISS focuses mainly on a photovoltaic production value chain, thus demonstrating the cross-sectorial industrial symbiosis with closed-loop processes.

Recycling system for cSi PV systems



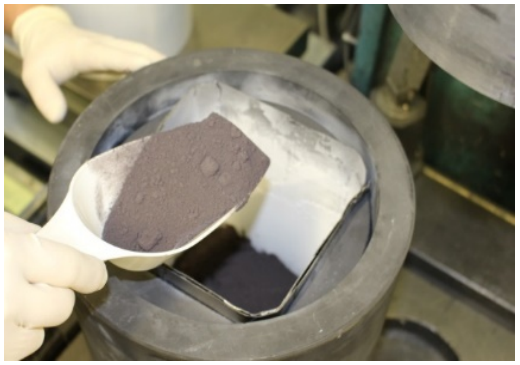
Wafer production via hot pressing process



Wafer production via hot pressing process

mixing

drying

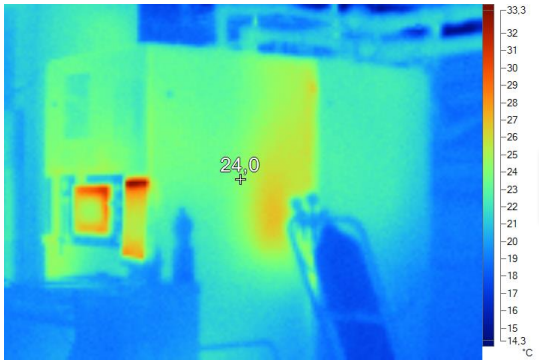


filling

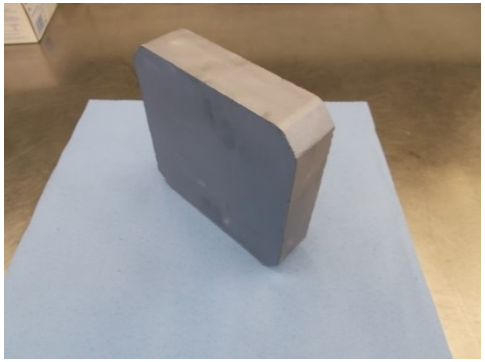
cold pressing

hot press

press with mold



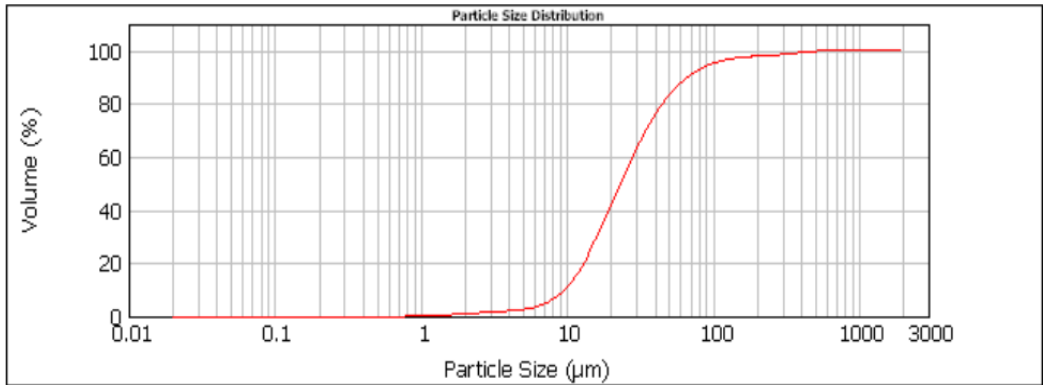
IR image (T_i=1350°C)



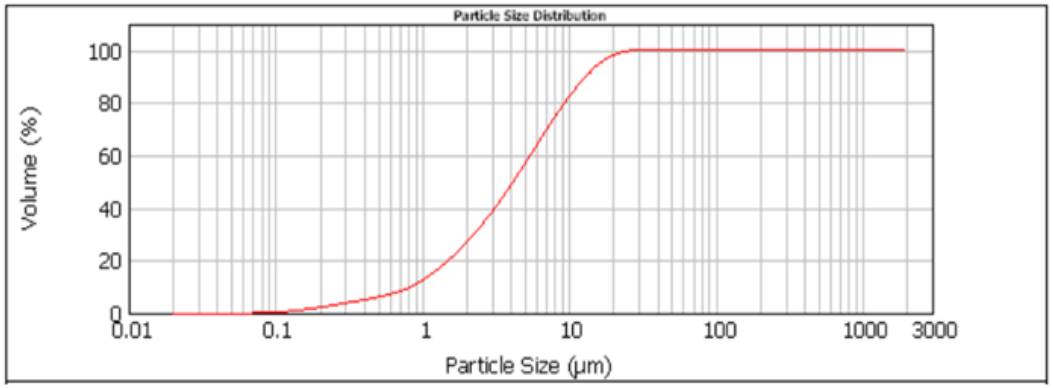
Si ingot 156 x156 mm^2

Wafer production via hot pressing process

PSD of successfully sintered samples:



Sample 1: density 92,0 %
Si: >99,2 % Fe: ≤0,06 %
Al: ≤0,7 % Ca: ≤0,02 %
Cr, Cl, Cu, Ti: ≤0,001 %
PSD: D10: 10µm
D50: 25-30µm
D90: 100-50µm



Sample 2: density 97,1 %
Si: >99,5 % Fe: ≤0,05%
Al: ≤0,15 % Ca: ≤0,02%
Cr, Cl, Cu, Ti: ≤0,001 %
PSD: D10: 1µm
D50: 5µm
D90: 15µm

Wafer production via hot pressing process

Multi parameter optimisation problem:

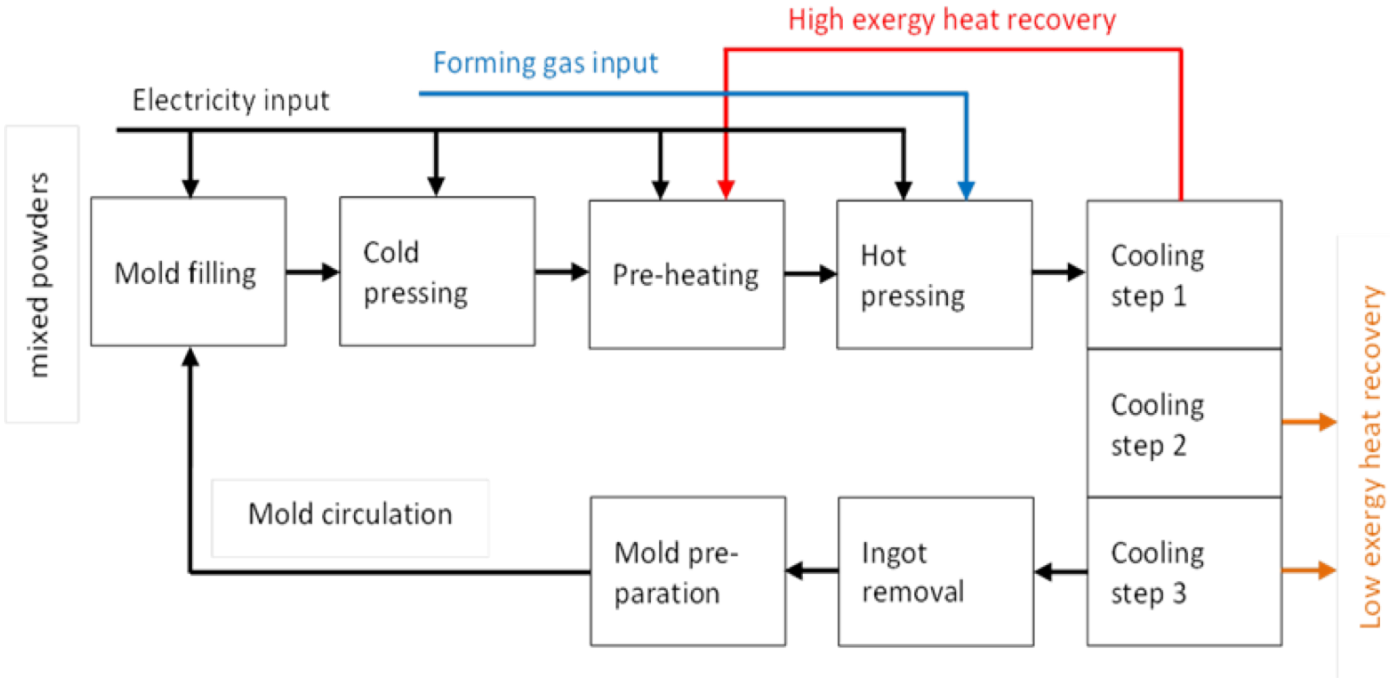
- Temperature regime during the process duration
- Pressure regime over the process duration
- Design of the graphite pressing mold
- Particle size distribution in the doped Si powder
- Chemical impurities of the Si powder
- Process atmosphere

Industrial process design

- Lab scale production is not competitive
- Lab scale LCC and LCA key figures are obviously worse than conventional cSi wafer production
- Industial process upscaling requires substantial process design changes
- Hot pressing process requires heat recovery and task sharing measures for lowering cumulated energy and increasing throughput

Industrial process design

Draft of an industrial scale Si ingot production line with hot pressing process

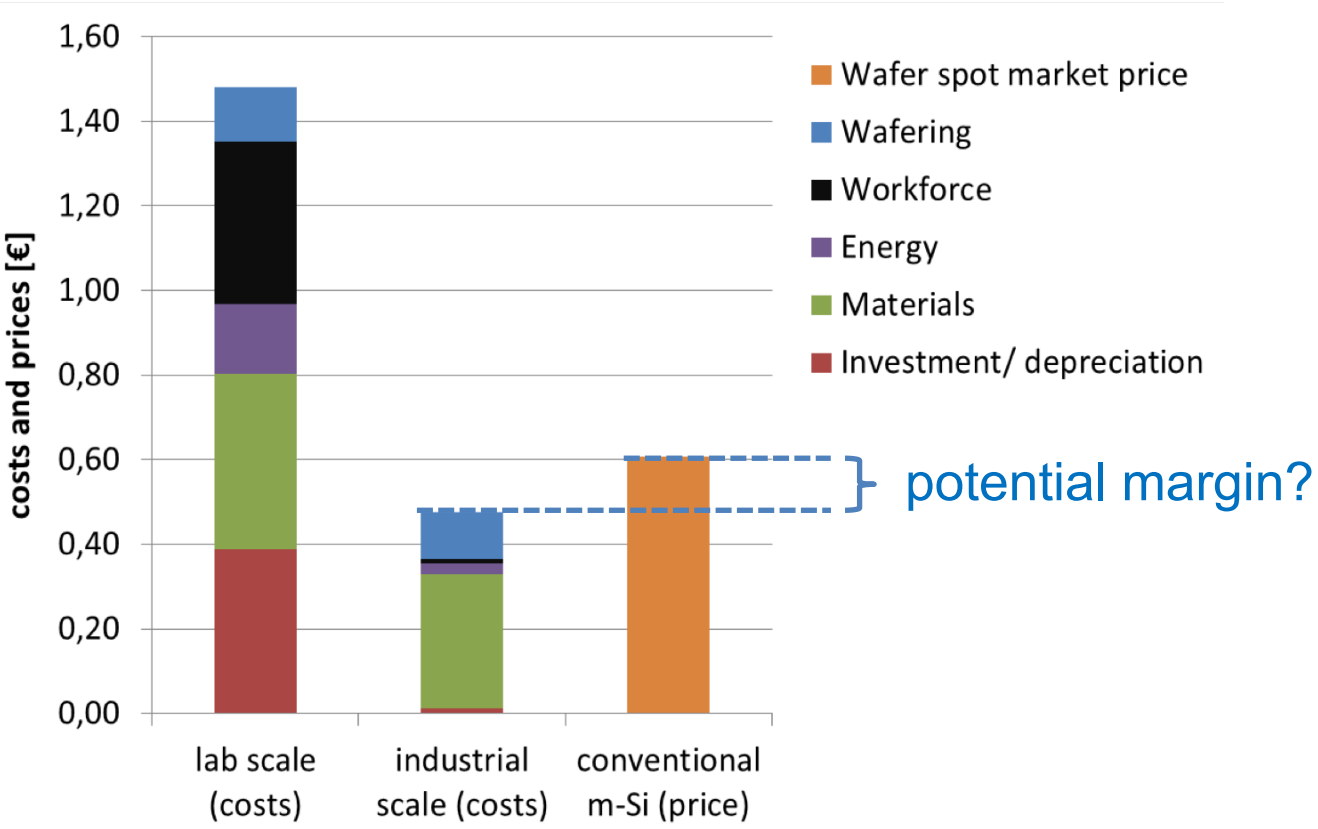


Industrial process design

- Costs for wafers from hot pressed ingots decreased from 1.48 €/wafer (lab scale) to 0.48 €/wafer (industrial scale)
- Cumulated electricity consumption for wafers from hot pressed ingots decreased from 1.4 kWh_{el}/wafer (lab scale) to 0.4 kWh_{el}/wafer (industrial scale)

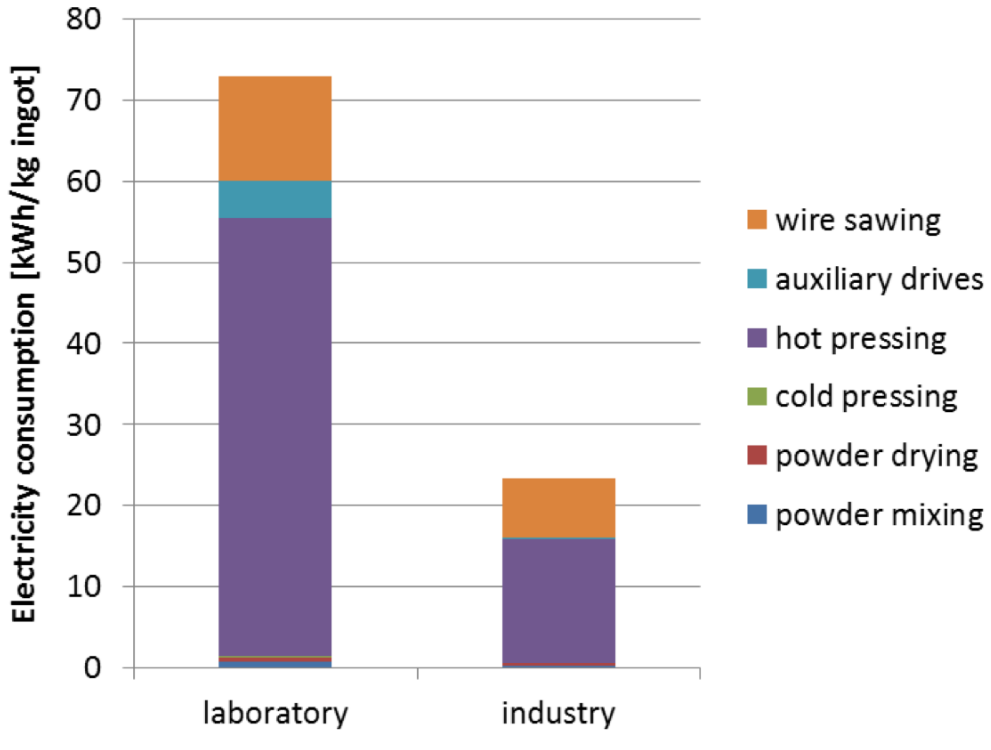
LCC and LCA aspects

Comparison of hot pressed wafer costs vs. market prices



LCC and LCA aspects

Comparison of lab scale and industrial process cumulated electricity consumption



Summary and conclusions

- Hot pressing of Si ingots from PV waste materials is technically feasible
- Hot pressing of standard sized Si wafers with a minimum thickness of 1.5 mm is also feasible but the surface quality is low
- LCC and LCA investigations show promising results in case of industrial production
- Prices for Si powder and doping powder have a strong impact on competitiveness in case of industrial scale production

Thank you for your attention