SALCOS -
Decarbonization of the steel industry

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Diversified product portfolio

Steel and Technology

- Strip products
- Steel Service Center
- Heavy plates
- Sections
- Engineering services
- Injection molding machinery
- Line pipes
- Precision tubes
- Stainless tubes
- Stockholding trading
- International trading
- Beverage filling plants
Status Quo: Highly Efficient, Energetically Optimized, Fully Carbon Based Integrated Steelmaking

Total CO₂ emissions by SZFG: ~ 8 million t CO₂/a

Energy losses via flares only ~ 0.1 %
„DRP 2.0“ - Further Lowering the CO₂ Footprint via Additional, Flexible Electrolytical Hydrogen Input

Standard DRP

Increase of H₂ utilization via natural gas in reduction processes

Iron ore pellets

Utilization of volatile renewable energy: additional supply and utilization of H₂ possible

SALCOS

Direct reduced iron (DRI)

Lower specific investment, Lower specific renewable energy consumption compared to CCU

Sustainable «Carbon Direct Avoidance» approach
Overview: Transformation of Integrated Steelmaking to H₂ Enhanced DRP/EAF Based Steelmaking in Three Stages

Today
- Status Quo (Blast Furnaces, BOF)

Indicative: 2020 +
- Pilot phase (Stage 1a)
  - First Stage including all three necessary SALCOS Technologies
  - CO₂-Reduction Potential: -18% CO₂

Indicative: 2040 +
- Completion
  - H₂ Electrolyzer
  - EAF
  - Stage 3b size
  - CO₂-Reduction Potential: -82%*/-95%** CO₂

Indicative: 2050 +
- Completion
  - DRP

Individual Stages May Technically Also be Realized in Combination – Earlier or Later, Depending on the Actual Economic and Political Framework

* with the use of 55% hydrogen
** with the use of 100% hydrogen
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„Merit Order“ – CO₂-Mitigation per Unit of Applied Electrical Energy for Industry Relevant Processes

Power-to-Chemical
Power-to-Steel
Power-to-Mobility
Power-to-Power

Current World Market Size
(Summarized over all Possible Applications)

CCU as Basis for Methanol Production

SALCOS is the most efficient form of CO₂ mitigation for large scale industrial processes.

Source: Sternberg und Bardow, Energy Environ. Sci., 2015, 8, 389-400
(SALCOS® and Addition of World Market Size by SZAG)
The project relies heavily on the **access to electrical power** (favorably from renewable resources, e.g. wind energy in northern Germany) on a very large scale, both for hydrogen production and - later - electric arc furnace operation.

As a consequence, **preferential link-up to the grid extensions** planned for the future distribution of regenerative power in Germany is needed.

**Market instruments** to deal with possibly increased steel production costs due to CO₂ mitigation efforts have to be developed and deployed.

**A suitable** energy and climate **policy framework** has to be developed additionally, ensuring continuous economic viability.

**Technically ambitious and economically challenging concept.**

**Decarbonization is a task for European society as a whole:** **CAPEX funding and OPEX solutions are mandatory!**
Technological challenges

- **Extensive changes** to the existing, energetically optimized integrated steelworks
- Limitations of **flexible DRP operation** with increased levels of hydrogen to be defined
- Experience in the **operation of EAF**, to be adapted for EAF integration into the existing integrated steelworks
- Application of an adequate technology for **intermediate H₂ storage**
- Integration and **process optimization during normal operation**, while ensuring constantly high product quality
- Only a **large scale integration** offers the possibility of full utilization of the respective energy storage and grid stabilization capabilities

Together with the Fraunhofer Gesellschaft, the BMBF-funded SALCOS feasibility study MARCOR (German for: Feasibility study for the reduction of CO₂ emissions in metallurgical plants using regenerative energies) is being conducted.
Ceramic technologies for energy conversion
Solid Oxide Electrolysis (SOE)

- Hydrogen and syngas generation via solid oxide electrolysis
- Heat utilization allows for low electric energy consumption

\[
\frac{P_{el}}{\dot{V}_{H_2+CO}} \approx 3.1 \frac{kWh}{Nm^3}
\]

PEM and alkaline electrolysis:

\[
\frac{P_{el}}{\dot{V}_{H_2}} \approx 4 - 5 \frac{kWh}{Nm^3}
\]
Solid Oxide Electrolysis (SOE)
A key technology for the reduction of CO₂-emissions

- Carbon Capture and Utilization (CCU)
  - Syngas production by co-electrolysis
  - Coupling of electrolysis and synthesis
  - Industrial application
    - Lime works
    - Cement works

- Carbon Direct Avoidance (CDA)
  - Substitution of coal
  - Use of renewable hydrogen
  - Industrial application
    - Direct reduction of iron oxide in steel works
Feasibility study MACOR

WP 1
Framework
1.1 Analysis of European steel market
1.2 Competitive situation
1.3 Integration into local energy systems
1.4 Optional CO₂ utilization

WP 2
Process modelling of steel mill + DRI
2.1 State of the art
2.2 DRI-Integration + stationary operation
2.3 Dynamic operation + grid integration
2.4 Implementation plan

WP 3
Utilization of DRI in the blast furnace
3.1 Characterisation of DRI-material
3.2 DRI-application in the blast furnace
3.3 DRI-application in the arc furnace
3.4 Balancing and valuation of the process

WP 4
Techno-economic analysis
4.1 Interface definition
4.2 Economic evaluation
4.3 Storage strategy
Scope of the project

- Assessment of a step-wise integration of the direct reduction process for a gradual transition of process
- Evaluation of the CO₂ reduction potential and the energy demand of the process
First implementation stage: Production of Direct Reduced Iron (DRI) and utilization in the blast furnace

Results

- Significant reduction of the CO₂ emissions already by implementing a natural-gas-based reduction process
- Further reduction by the utilization of renewable hydrogen instead of natural gas
Integration of the direct reduction process has influences on the energy balance of the steel mill.
Material characterization

- Material analysis of the **direct reduced iron** prior to application in a blast furnace
Feasibility study

Economic feasibility depends on:

- Cost of energy carriers like coal, natural gas and electricity
- Additional costs for electricity, network charges, …
- Costs of CO₂ certificates
Conclusion and outlook

- **SALCOS** is an industry-scale modular concept for a stepwise transformation of integrated steel mills to a hydrogen-based steel production with the potential to reduce CO₂ emissions up to 95 %

- Probably, the first-time large-scale combination of innovative and established process technologies

- **Flexibility of energy input**: natural gas as well as hydrogen from renewables

- Compared to Carbon Capture and Utilization the specific energy demand per ton of CO₂ is much lower

- The influence of the DRI process on energy balance of the steel mill was evaluated via process modelling

- The economic feasibility strongly depends on the framework conditions and on cost for energy carriers

- Next steps:
  - Experimental validation of DRI utilization in a blast furnace
  - Further development of process modelling
  - Techno-economic evaluation of the concept
Thank you very much for your attention!