Keramik für Speichertechnik und Recycling

Fraunhofer Institute of Ceramic Technologies and Systems, IKTS
Professur: Anorganisch Nicht-Metallische Werkstoffe, TU-Dresden
Prof. Dr. Alexander Michaelis

Annual Budget: 80 Mio. €

Staff: 800

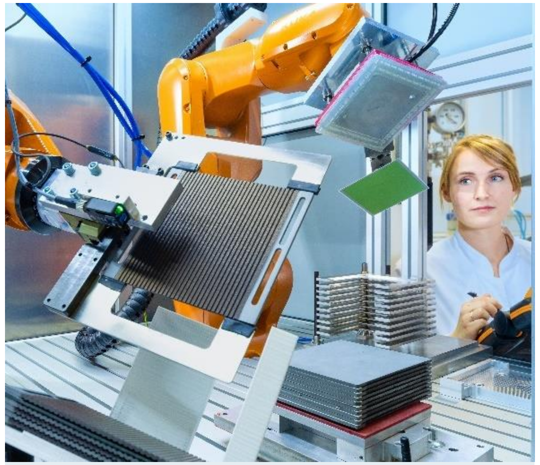
Structural ceramics	Correlative characterization, Digitalization, AI	Functional ceramics

TECHNISCHE UNIVERSITÄT DRESDEN

Fraunhofer IKTS

Fraunhofer Institute of Ceramic Technologies and Systems (IKTS)

Top 1 Fraunhofer / SOE
Top 2 Wasserstoff



Fuel cell and Electrolysis technologies

—

Fuel cells and high-temperature electrolysis cells – development and test from component to system.

Top 1 Fraunhofer

Solutions for Li-ion and NaNiCl batteries

—

Top-down and bottom-up development of new active materials.

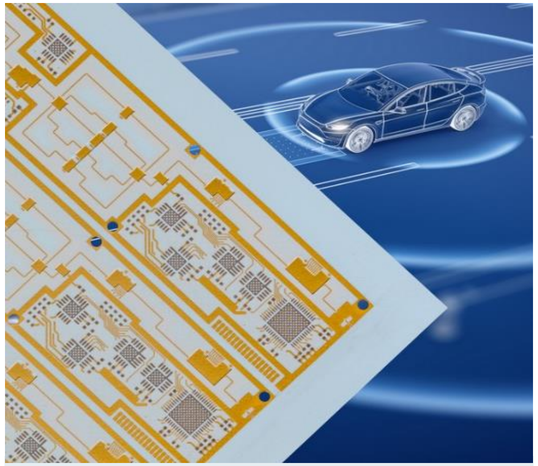
Top 1 Fraunhofer

Recycling and wastewater treatment

—

Process chain to recycle water, energy, and fertilizer from food industry residues.

Alleinstellung



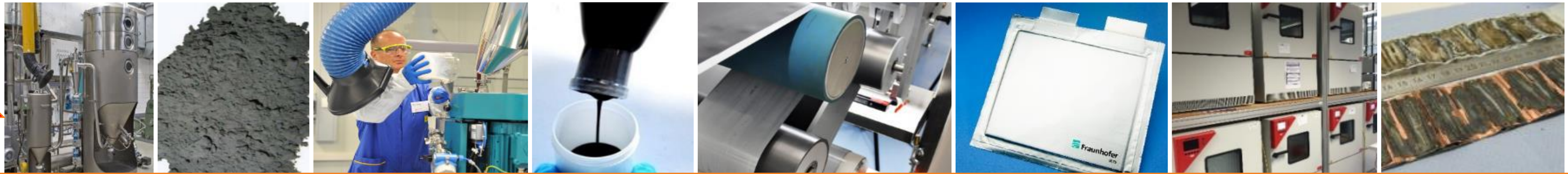
LTCC-based electronic packaging

—

High-frequency board for 77 GHz radar for driving assistance systems.

  Intern

TECHNISCHE UNIVERSITÄT DRESDEN
Fraunhofer IKTS



Recycling / Koordination BMBF: „green Battery“

Westansicht Verwaltungsgebäude mit zentralem Zugang und Behindertenstellplatz

Fläche: 5.300 qm

IKTS-BITC:
Batterie Innovations und Technologie Center

Freistaat Thüringen
Ministerium für Wirtschaft, Wissenschaft und Digitale Gesellschaft

IKTS-BITC

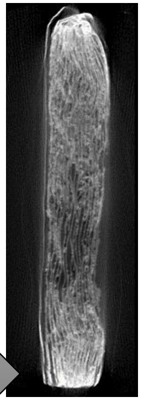
Fraunhofer IKTS

CATL solid power inside

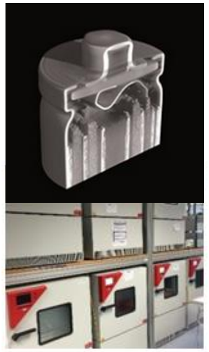
Fraunhofer IKTS

Batteries

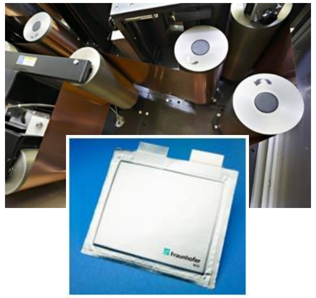
Materials & Scale-up



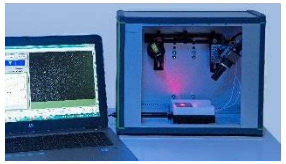
Analysis & Test



Design & Production

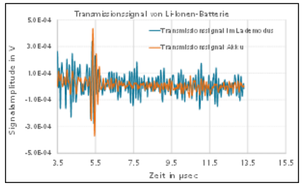


AI / AR of Production Data / Industry 4.0



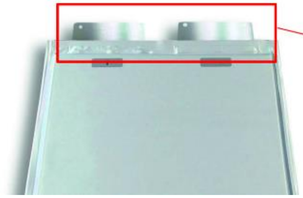
Advanced sensors

Machinery and tooling



Data science and AI

Imaging and NDT



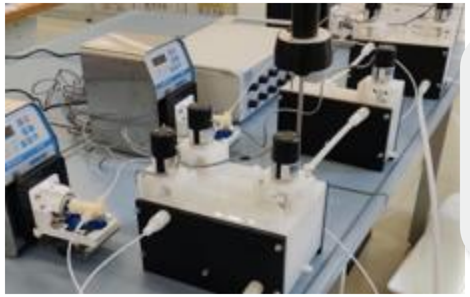
TECHNISCHE UNIVERSITÄT DRESDEN

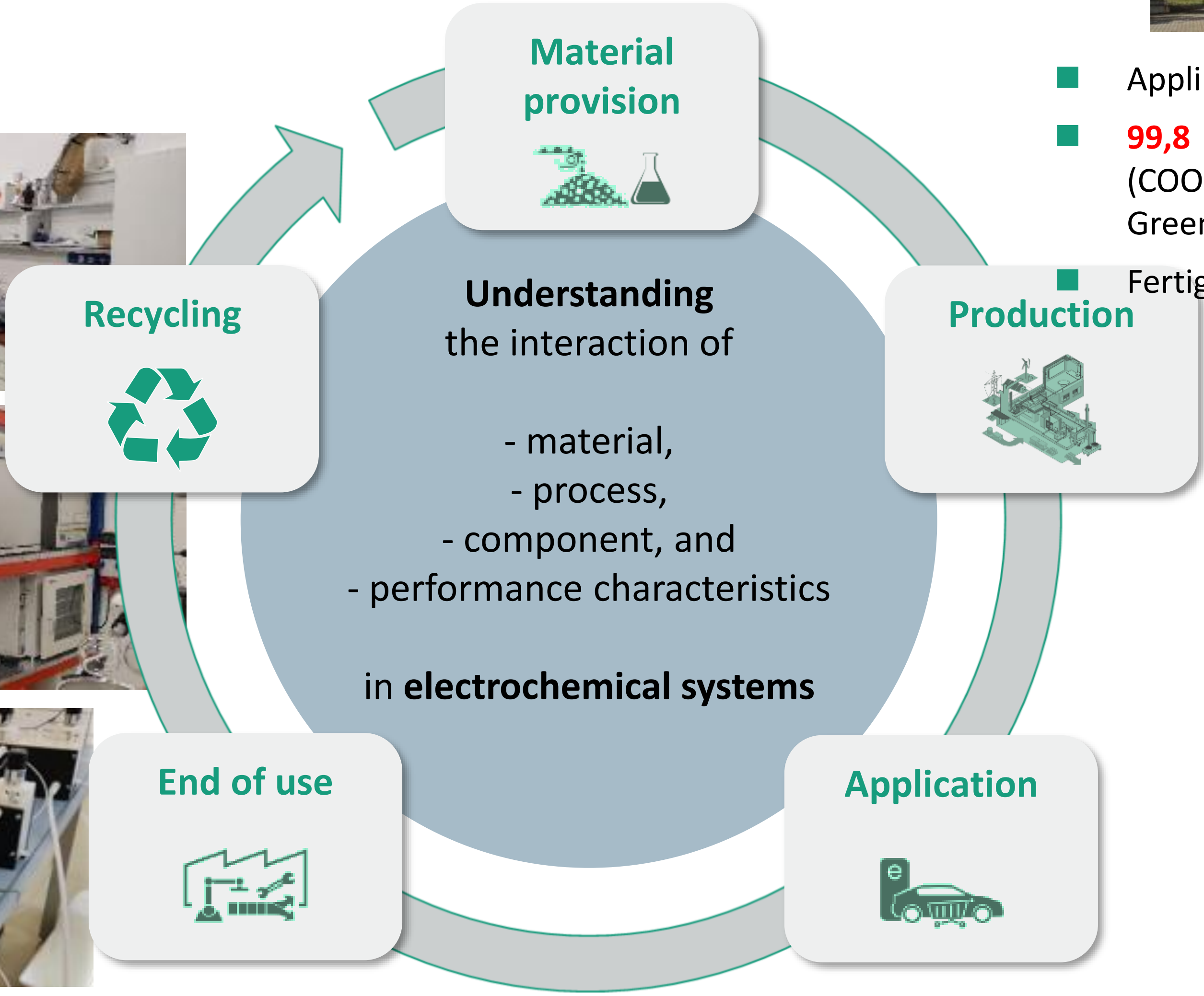
Fraunhofer IKTS

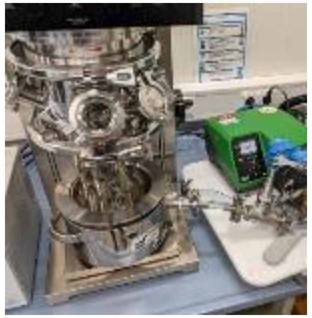
Standort Fraunhofer THM in Freiberg etabliert

Batterie-Kreislaufwirtschaft

- Applikationszentren Batterietechnologie und Recycling
- 99,8 Lithium-Recycling im Pilotmaßstab nachgewiesen (COOL-Prozess) → Einbindung in Kompetenzcluster GreenBatt
- Fertigung von Festkörperbatterien im Trockenraum







Fraunhofer IKTS

Application Center Battery Recycling

Hydrometallurgische Aufbereitung

Verfahren (z.T. in Kooperation mit TU Bergakademie Freiberg)

- COOL-Prozess → Li-Extraktion aus Primär- und Sekundärrohstoffen (Lepidolith, Zinnwaldit, Spodumen, **Lithium-Ionen-Batterien**)

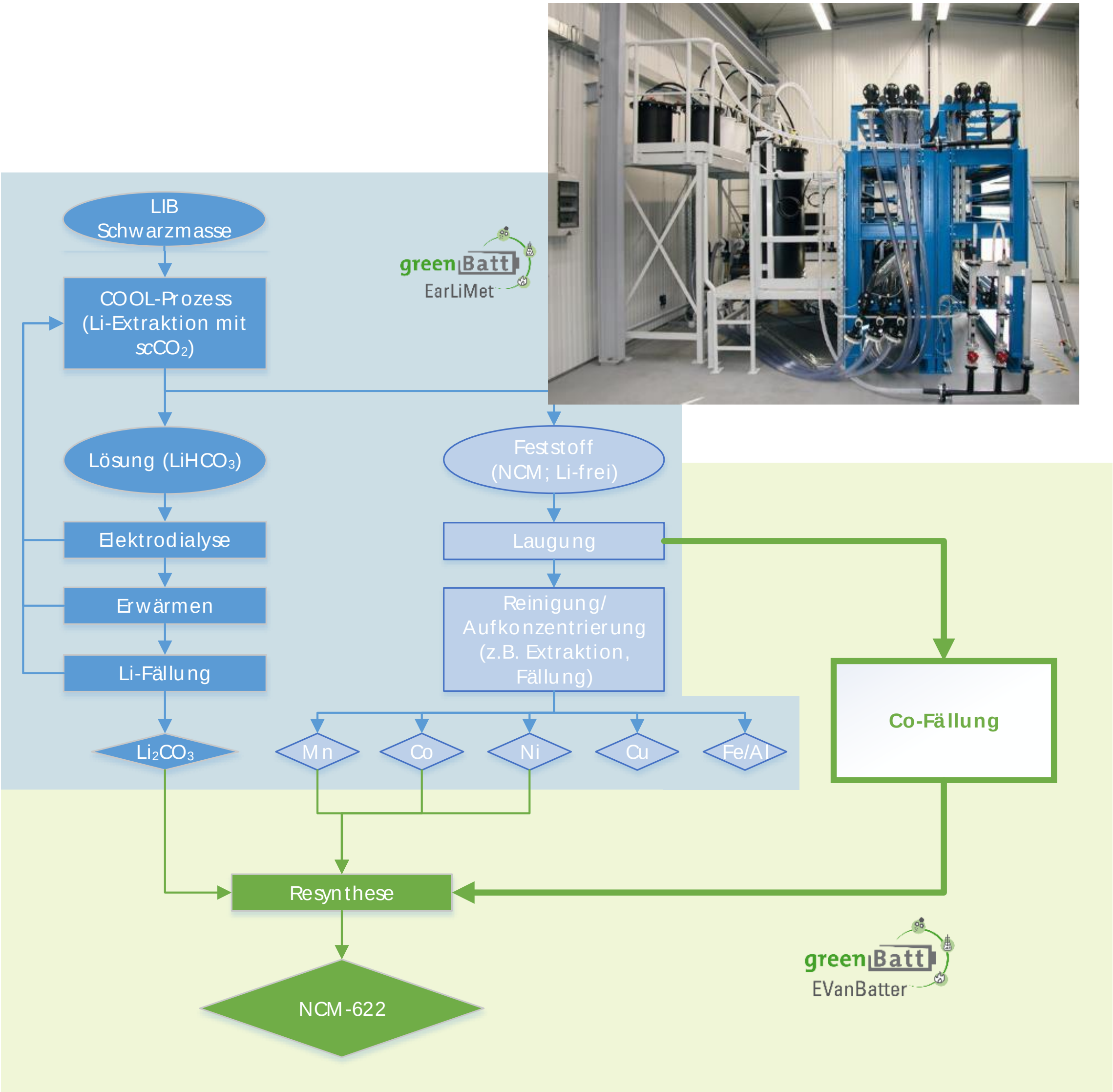
- Laugungen mit verschiedenen Säuren/ Laugen, bei unterschiedlichen Temperaturen/ Drücken

- **Scale-up durch IKTS**: von Labor- bis Technikumsmaßstab (15 -200 L)

- Reinigung/ Aufkonzentrierung: Flüssig/Flüssig-Extraktion, Membrantechnik (Elektrodialyse), Fällung

→ Li-Primärprodukt ist Li_2CO_3

Auch für mineralisch gebundenes Li anwendbar



Fraunhofer IKTS

DRESDEN BATTERY DAYS

Dresden Battery Days

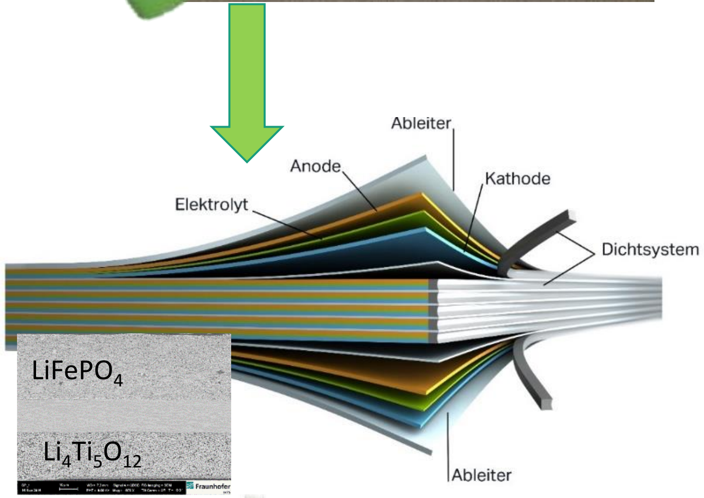
—

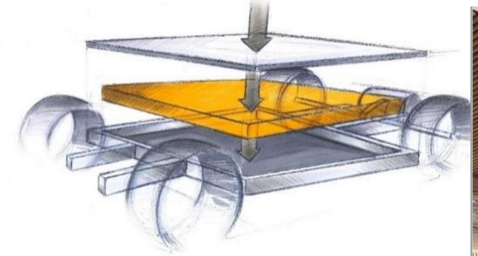
Symposium & Exhibition, September 25–27, 2023
Fraunhofer Institute Center Dresden

Topic
“Steps to sustainable and circular battery value chain”

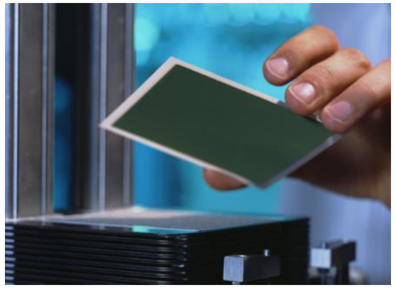
www.ikts.fraunhofer.de/en/communication/events/dbd_2023.html

Bipolar Battery / Solide State Battery / Fuel Cell

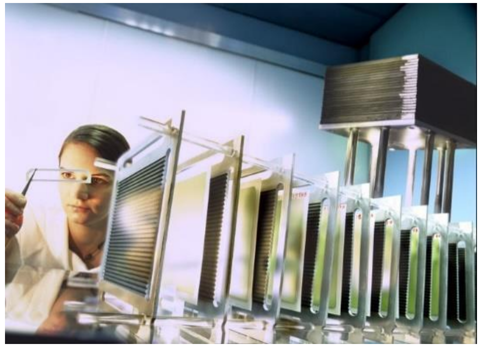


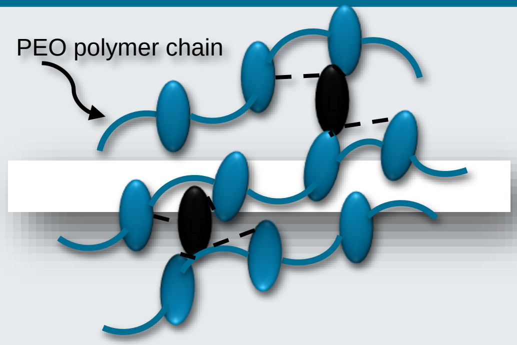
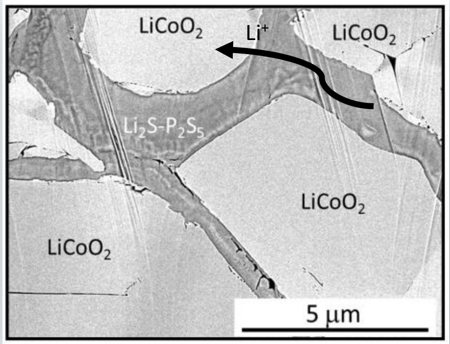
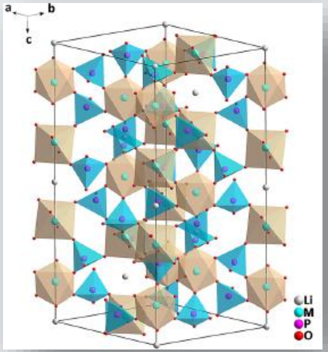


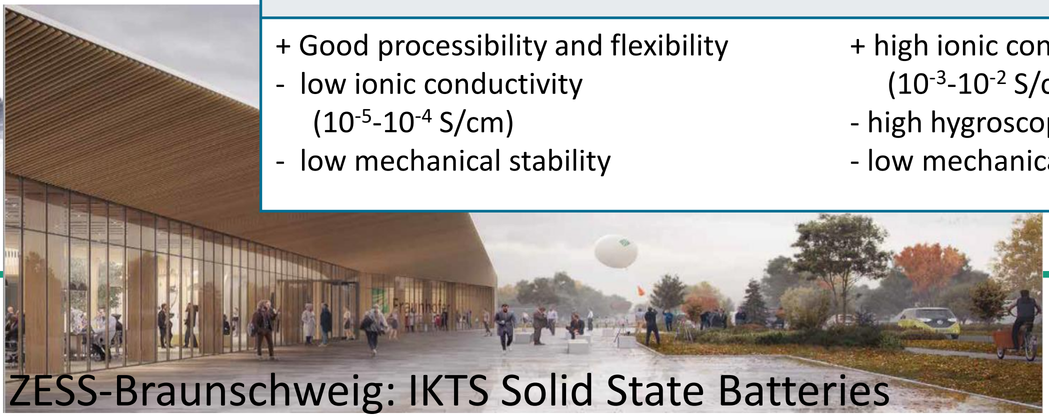
PEM-FC



SOFC



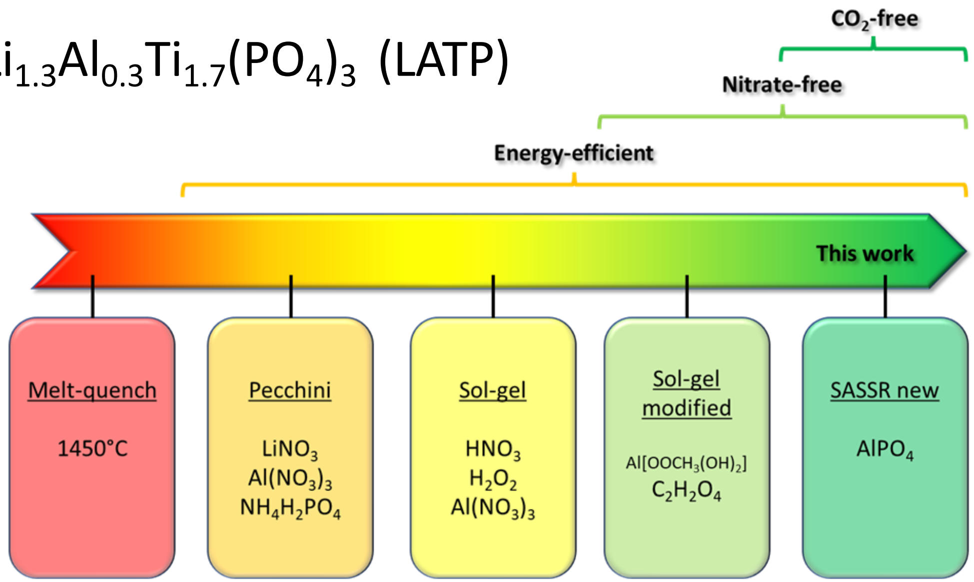
Polymers	Sulfides	Oxides
		
T. Niitani, et al., Electrochemical and Solid-State Letters 8 [8] A385-A388 (2005).	*A. Sakuda, et al., Scientific Reports 3, 2261 (2013).*	*Y. Ren et al., J. Am. Ceram. Soc. 98 [12] 3603-3623 (2015).*
+ Good processibility and flexibility - low ionic conductivity (10^{-5}-10^{-4} S/cm) - low mechanical stability	+ high ionic conductivity (10^{-3}-10^{-2} S/cm at RT) - high hygroscopicity - low mechanical stability	+ good ionic conductivity (< 10^{-3} S/cm at RT) + stable against air and high temperatures



Ceramic Solid State Li-Ion Battery

Optimizing synthesis of ceramic solid-electrolytes

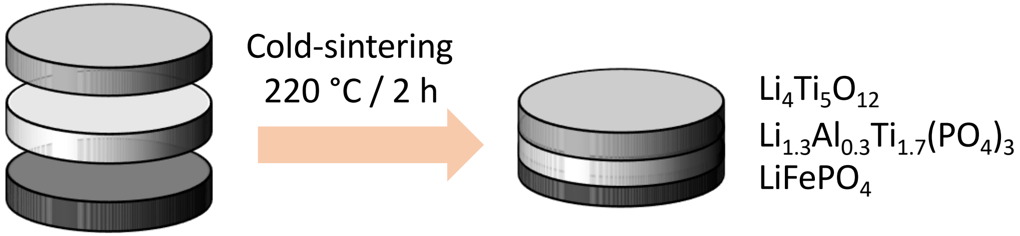
$Li_{1.3}Al_{0.3}Ti_{1.7}(PO_4)_3$ (LATP)



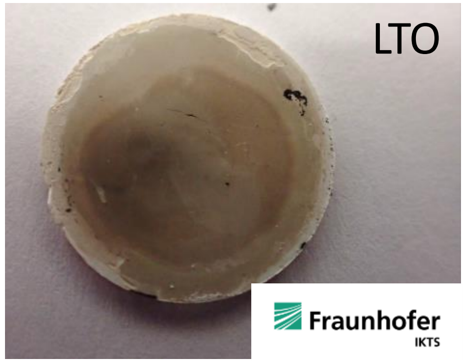
- Optimization of synthesis to reduce complexity, cost and environmental impact (maintaining performance)
- Precursors: cheaper and less CO_2 emission
- Processing: Reduction in thermal treatments

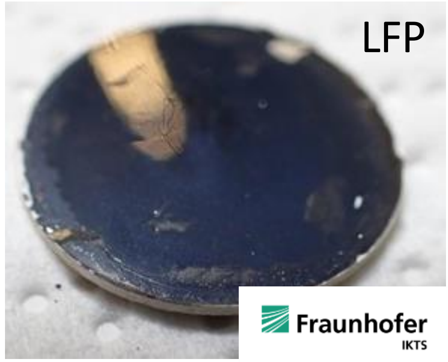
➔ Reducing cost (at least 10%), work hours (at least 20%), energy input (43%) and CO_2 emission (100%)

Cold-sintering of ceramic solid-state battery



- First demonstration of cold sintered all ceramic solid-state-battery based on LTO anode, LATP separator and LFP cathode
  - Single step sintering of all components
  - Sintering temperature of only 220 °C for 2 h
- Cold sintering has high potential as low energy sintering method



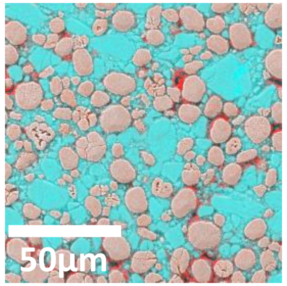


TECHNISCHE UNIVERSITÄT DRESDEN

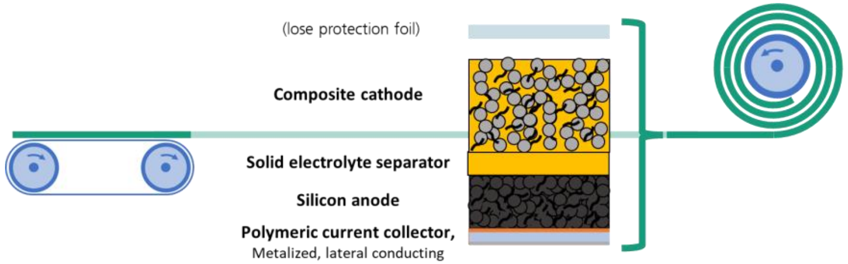
Fraunhofer IKTS

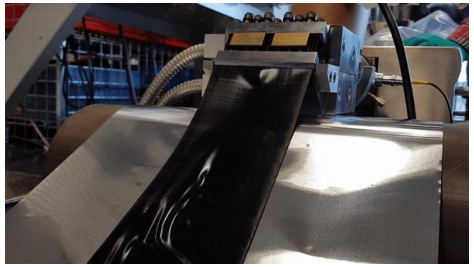
Elektroden- und Zellfertigung für Festkörperbatterien

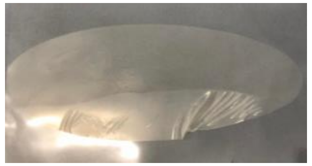
Sulfidische Festelektrolyte



Rolle zu Rolle Fertigung von Festkörperbatterie-komponenten unter Trockenraumbedingungen





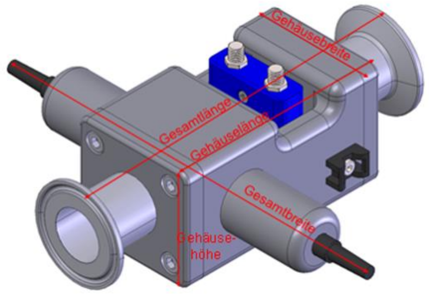


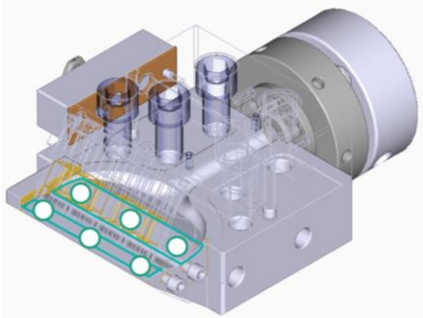
- Verarbeitung hydrolyseempfindlicher Materialien demonstriert (Sulfidbasierte Festelektrolyte ohne H2S-Bildung möglich)
- Einsatz skalierter Mischtechnologien (Labor 1 – 10 g vs Technikum 10 – 100 g)
- Verschiedene Formgebungsverfahren: Rakel, Schlitzdüse, Walzen
- Übertrag auf R2R-fähige Extrusion von Festkörperbatteriekathoden (~ 1 kg)

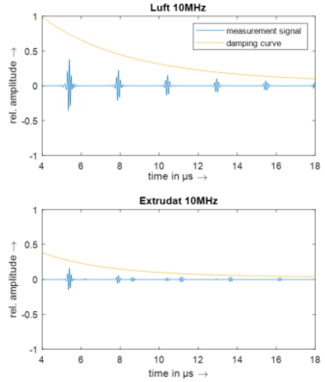
Monitoring Solutions

Inline-Measurement to monitor mixing of highly viscous battery pastes and foil extrusion

Monitoring of raw materials in dosing zone by eddy current and ultrasonics





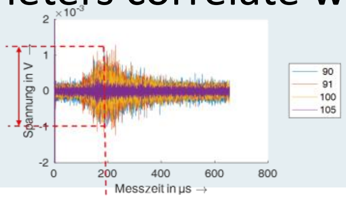


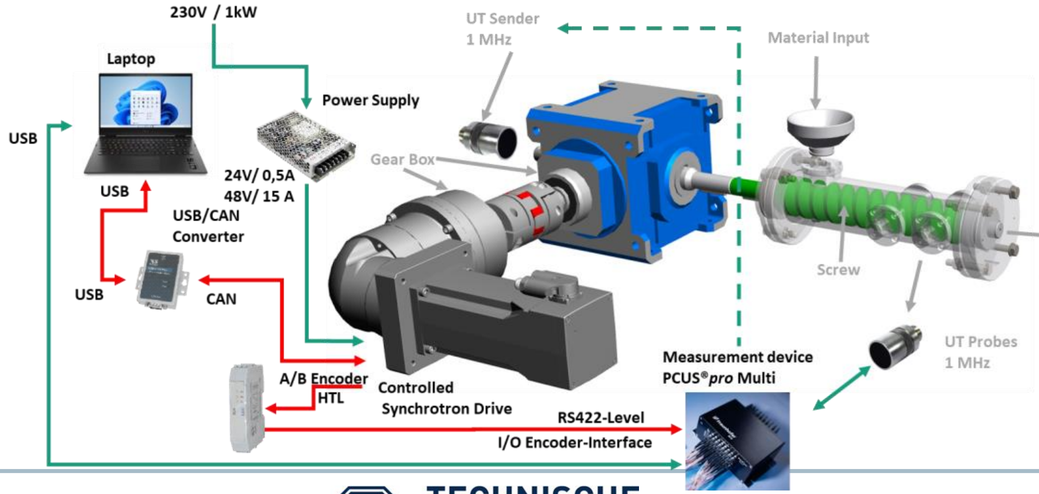
Combination of Eddy current and Ultrasonic sensor data

Monitoring of extrusion quality by multisensory nosepiece and instrumented die

Extrusion monitoring concept of "emitting screw" is patented by IKTS

- Ultrasound is coupled into screw and detected along extrusion line
- Extrudate parameters correlate with ultrasound modification





TECHNISCHE UNIVERSITÄT DRESDEN

Fraunhofer IKTS

There are many possibilities to create a battery

However, the optimum battery: **wish list**

1) Low cost, readly available, safe, non-toxic materials with high electrochemical voltage
2) Solid state electrolyte
3) Rechargeable / high cycle stability (> 4000) / life time
4) Recyclable
5) High technical maturity

Li:	-3.05 V	76 pm
Na:	-2,71	102
Mg:	-2,36	
Zn:	-0,76	
Pb:	-0,12	
H_2:	0	
Cu:	0,34	
C:	0,74	
O_2:	1.22	
Au:	1.42	

$$\boxed{NiCl_2 + 2Na \leftrightarrow Ni + 2NaCl, \quad E_0 = 2{,}58\ V}$$

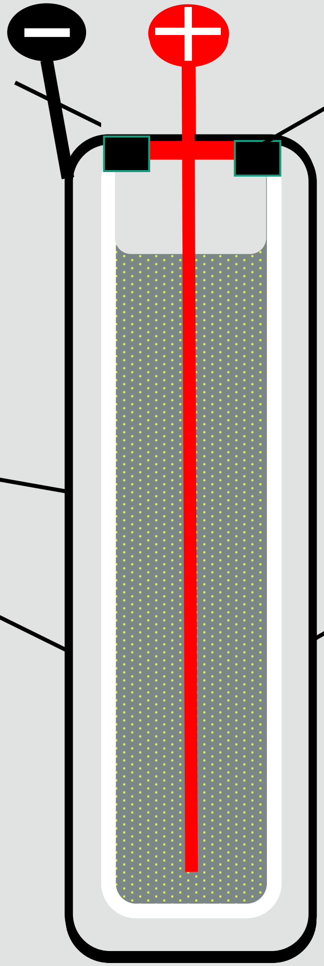
Sodium is **the** hot issue in battery technology, right now

Sodium Nickel Chloride Batteries – Technical Background

The sodium nickel chloride battery cell

Current collector

Cell Lid



Sodium Beta Alumina Ceramic Electrolyt

Cell Case

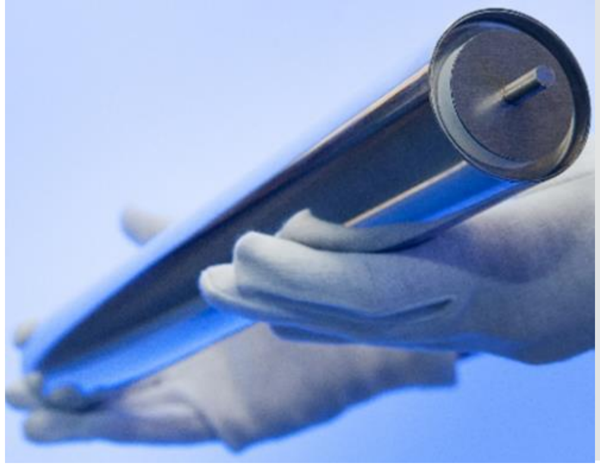
Cathode:

Table Salt

Nickel

Molten Salt Secondary Electrolyte

Additive

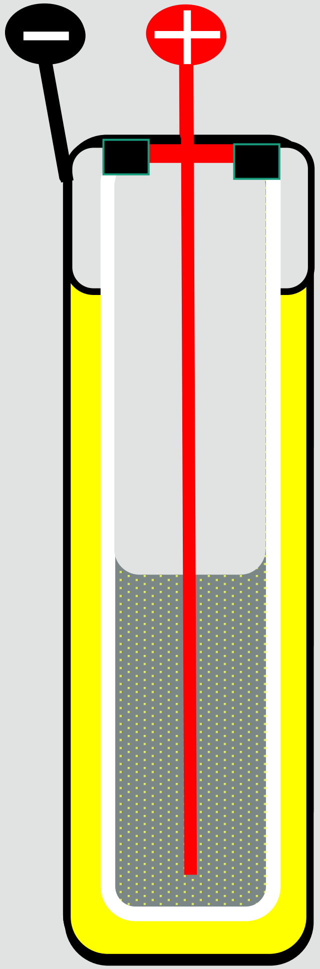


Sodium Nickel Chloride Batteries – Technical Background

- Operational temperature
  250°C - 350°C
- Overall cell reaction

$$\mathrm{Ni} + 2\mathrm{NaCl} \underset{\text{discharge}}{\overset{\text{charge}}{\rightleftharpoons}} \mathrm{NiCl_2} + 2\mathrm{Na}$$

- OCV = 2.58 V (300 °C)
- Cell Assembly in Discharged State



Charge and discharge process

NaNiCl Battery Pilot Line@ IKTS Hermsdorf, Germany

Altech Advanced Materials AG: Altech enters into joint venture with Fraunhofer IKTS to manufacture solid-state batteries

Heidelberg (pta043/13.09.2022/19:30) -

Altech Group to hold 75% in the joint venture to commercialise solid-state sodium-alumina battery with Fraunhofer-Institut für Keramische Technologien und Systeme IKTS
100 MWh/a CERENERGY® battery project in Schwarze Pumpe, Saxony
The technology, which has been developed by IKTS for over ten years, is now entering the stage of final industrial product development for global marketing
Research and development for the implementation of the detailed profitability study is significantly accompanied by Fraunhofer IKTS.

>200 Mio € Invest in Schwarze Pumpe „train 1“

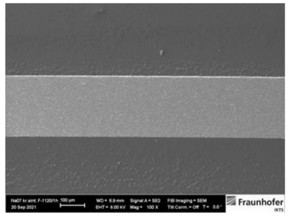
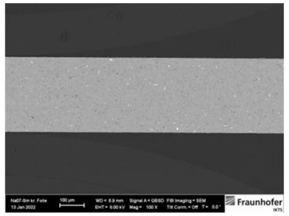
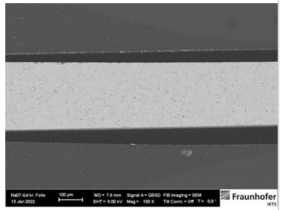
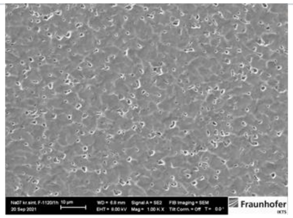
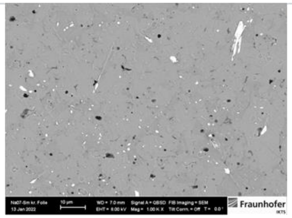
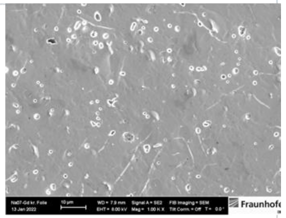
Altech Advanced Materials AG (AAM / the Company) (FRA: AMA1) together with Altech Chemicals Limited, Australia has formed a subsidiary, Altech Energy Holdings (Altech Group). Altech Advanced Materials holds a 25% stake in the new Altech Energy Holdings.

Altech Group has entered into a joint venture agreement with the Fraunhofer Institute for Ceramic Technologies and Systems (IKTS), a leading German battery institute, to commercialise a solid-state sodium- alumina battery (CERENERGY®). For this purpose, Altech Batteries GmbH will be founded jointly, with Altech Energy Holding GmbH owning 75 %. The aim of Altech Batteries GmbH is to build a production plant for CERENERGY® solid-state batteries. The first line with an annual output of 100 MWh is to be implemented at the Schwarze Pumpe site in Saxony.

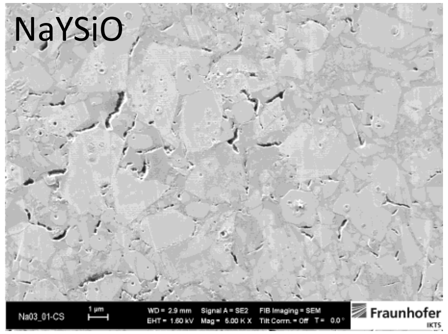
Ceramic Solid State Na-Ion Battery

Glass ceramic Solid Electrolyte

- Conventional sintering

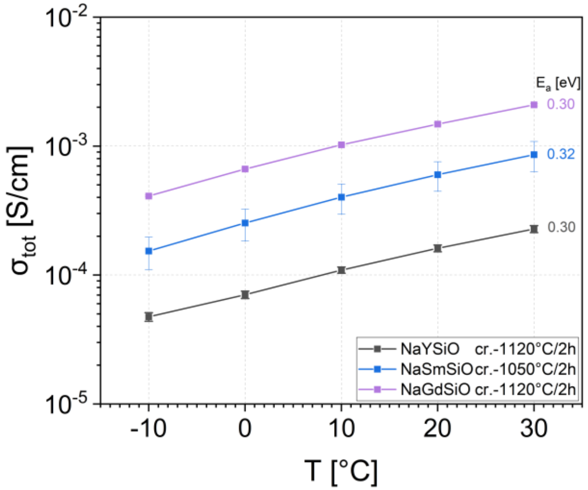
Composition	$Na_5YSi_4O_{12}$	$Na_5SmSi_4O_{12}$	$Na_5GdSi_4O_{12}$
Sintered Crystallized powder			
			

- Cold sintering



- High total conductivities could be achieved

material	σ [S/cm] at RT
β-Al_2O_3 [2]	$3 \cdot 10^{-4}$ - $5 \cdot 10^{-3}$
NASICON [2]	10^{-4} - 10^{-3}
NaYSiO	$1.6 \cdot 10^{-4}$
NaSmSiO	$8.6 \cdot 10^{-4}$
NaGdSiO	$2.1 \cdot 10^{-3}$




Fraunhofer
IKTS
International Sodium Battery Symposium SBS4
Symposium & Exhibition, September 4–5, 2023
Fraunhofer Institute Center Dresden
Topics
• High-temperature sodium batteries
• Solid-state sodium batteries
• Liquid and polymer electrolyte sodium batteries
• Novel designs and manufacturing technology
• Simulation, reaction mechanisms and longevity
www.ikts.fraunhofer.de/en/communication/events/sbs4.html

„Tertiary batteries“: Solid Oxide Fuel Cells (SOFC)

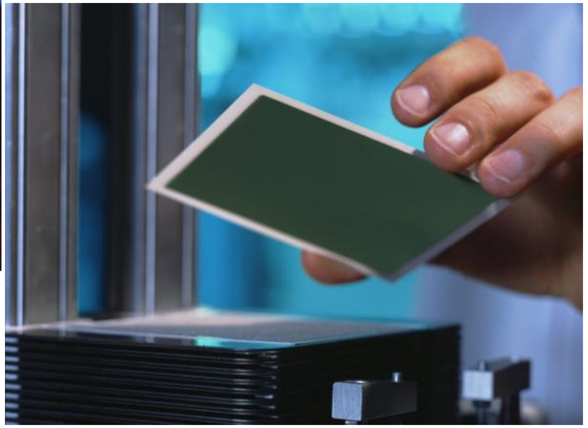
Solid Oxide Electrolysis (SOE)

„Dis-charge“: power from H_2

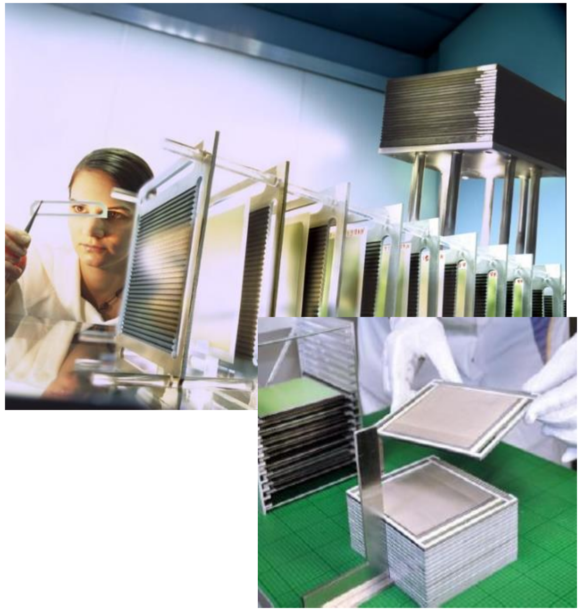
„Charge“ : H_2 from power

Ceramic Material

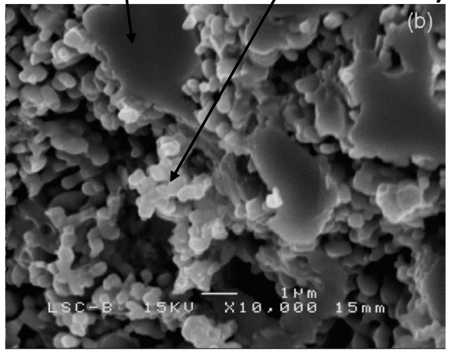
MEA: ESC

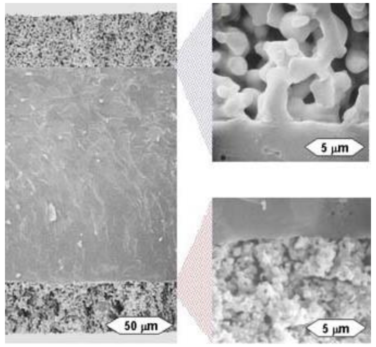


Stack



System





Fuel Cell and Electrolysis @IKTS / IKTS-History

SIEMENS PLANSEE Webasto Feel the Drive H.C.Starck

Take over of Siemens IP

InDEC BV staxera:

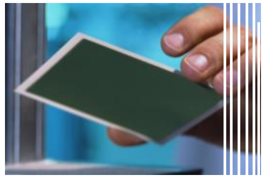
Vaillant mtu onsite energy h2e

sunfire FuelCell Energy Ultra-Clean, Efficient, Reliable Power mPower GmbH

Partners

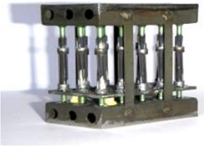
Spin Off´s

1996 2005 2006 2008 2009 2012 2014 2018 2020

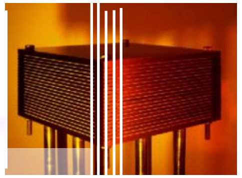


MEA

MK 100



μ-Tubes



MK 300

MCFC

MK 350

MK 352

SOFC – Component Development

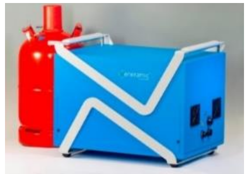
SOFC/SOEC – Stack + Module

SOFC / MCFC – Systems

SOEC – Systems

PEM

eneramic by Fraunhofer



Power range: 1 W 100 W KW MW

Biogas SOFC-System

Micro CHP

Biogas MCFC-System

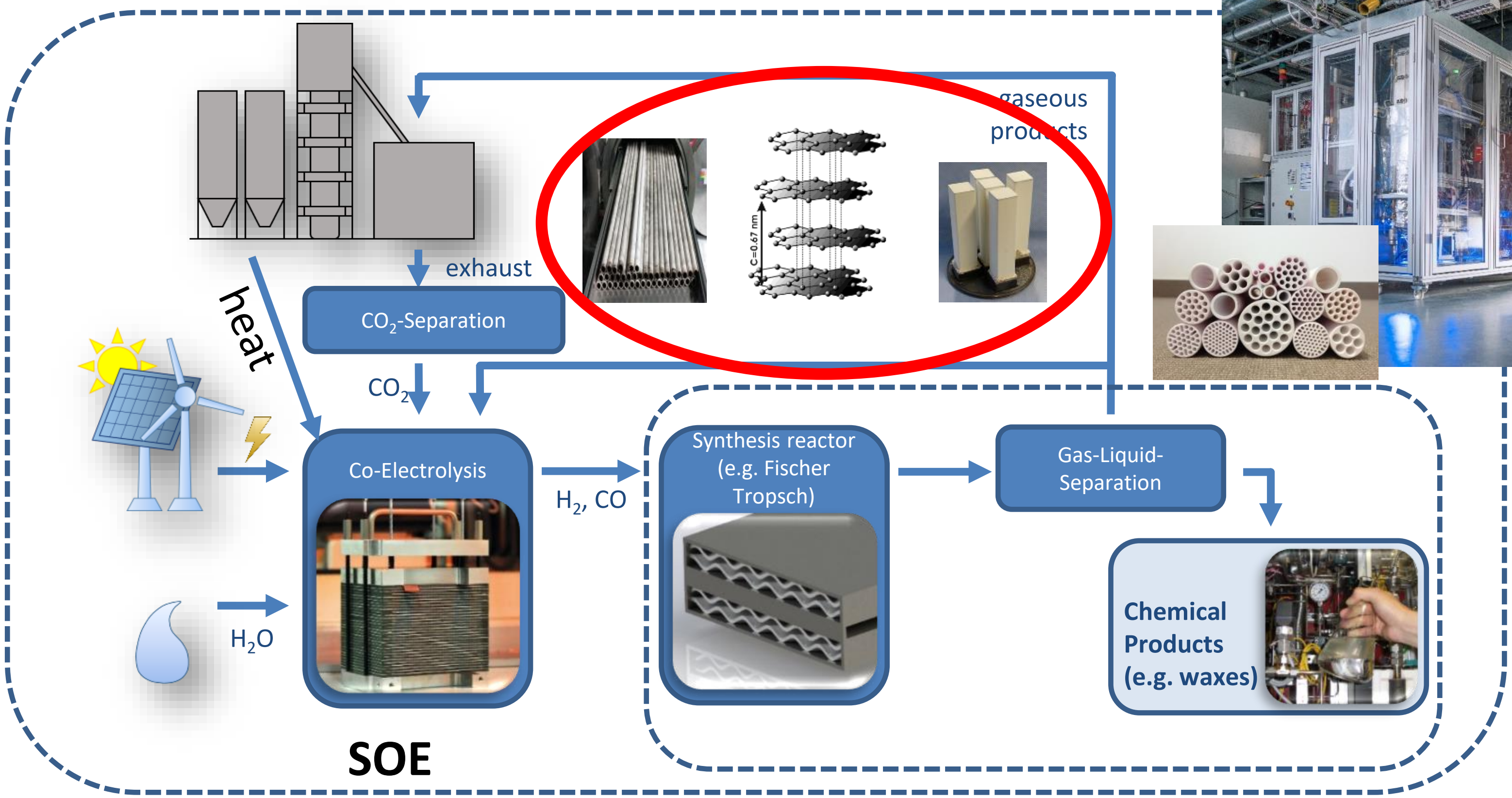
Integrated SOEC + FT

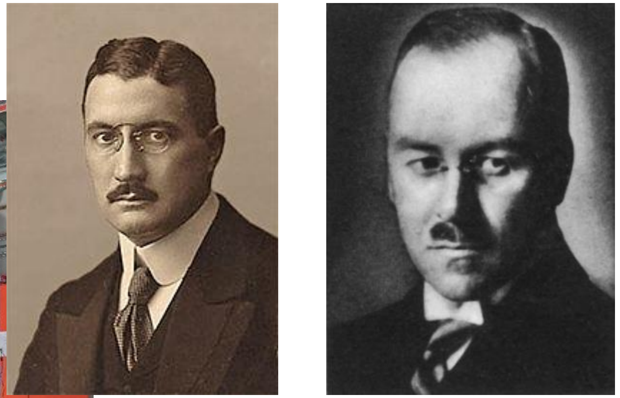
SO(F/E)C = solid oxide (fuel/electrolysis) cell

TECHNISCHE UNIVERSITÄT DRESDEN

Fraunhofer IKTS

SOE (solid oxide electrolysis) → Energy Storage





STROM
ALS ROHSTOFF

Combination of Co-Electrolysis and Fischer-Tropsch Synthesis for efficient production of high cost chemicals

Utilization of waste heat is essential for high efficiency

SOE-Stacks already available for Co-Electrolyisis

Synthesis gas

Fischer-Tropsch synthesis

Methane | Methanol | Higher Alcohols | Diesel/Jet fuel | Waxes | ...

Fraunhofer
IKTS

Hydrogen colors

We need green hydrogen → Electrolysis

H2

grey

- Beased on NG and coal
- high CO_2-Emissions
- ca. 1,6 €/kg

$$CH_4 + H_2O \rightleftarrows CO + H_2O$$
$$CO + H_2O \rightleftarrows CO_2 + H_2$$

Turquoise

- NG (methane) pyrolysis
- C stored or used
- ca. 2,7 €/kg

$$CH_4 \rightleftharpoons C + 2\,H_2$$

blue

- Beased on NG and coal
- CO_2 stored (CCS)
- ca. 3,0 €/kg

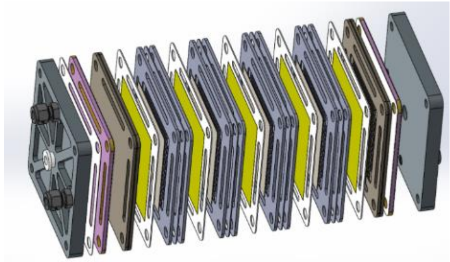
GREEN

- Use of renewable energy / Electrolysis
- no CO_2
- 2,5 €/kg

Pink

- Use of nuclear power for electrolysis
- no CO_2

Green H_2 requires Electrolysis !



SOE → USP!!

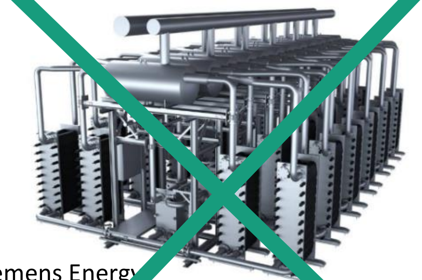
- Co-Electrolysis !!
  (active CO_2 removal from environment
  → **CO_2 negative**)
- **30 % higher efficiency** due to
  active heat usage!!
- Reverse mode SOFC/SOE

Alkaline Electrolysis (AEL)

- Established in Industry scale
- > 4,2 kWh/Nm³ H_2

IKTS Focus

~~**PEM-Electrolysis (PEMEL)**~~



© Siemens Energy

- ~~First mid-scale Application~~
- ~~> 4,2 kWh/Nm³ H_2~~

Solid Oxide Electrolysis (SOE)

©IKTS

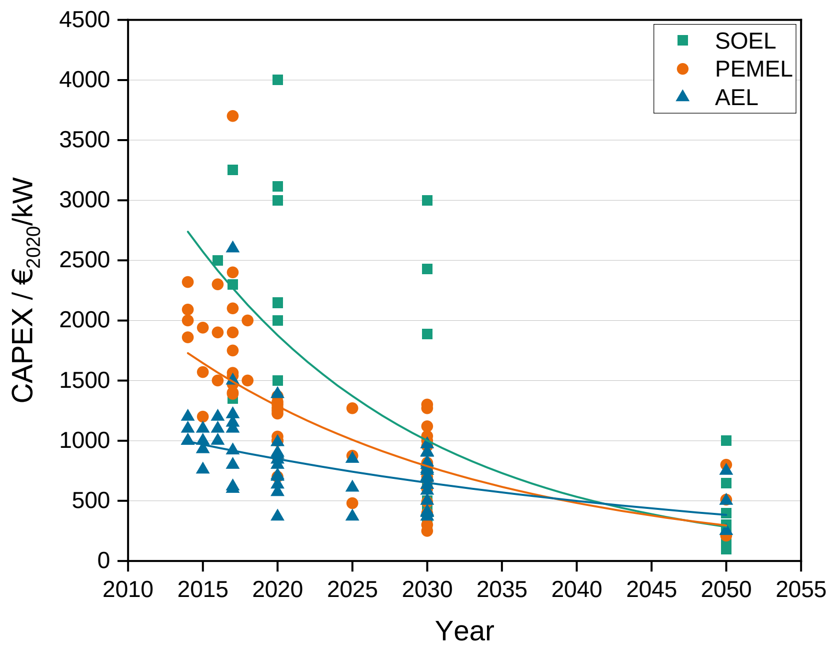
- Ready for up-scaling
- > 3,0 kWh/Nm³ H_2 + CO

IKTS Focus

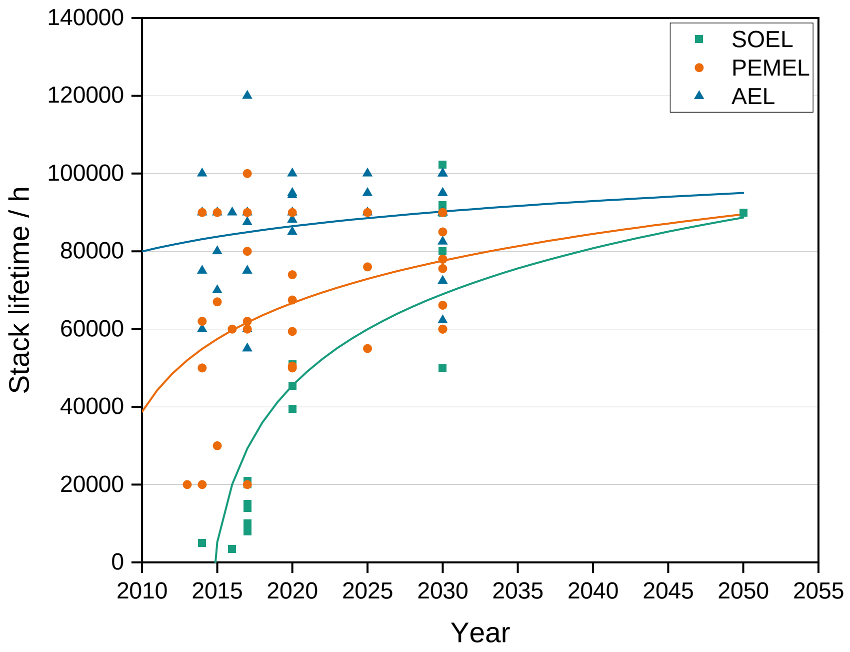
Brennwert H_2 = 3,54 KWh / Nm³

Expected development of electrolysis technology

Estimated Equipment cost and stack lifetime



Equipment cost



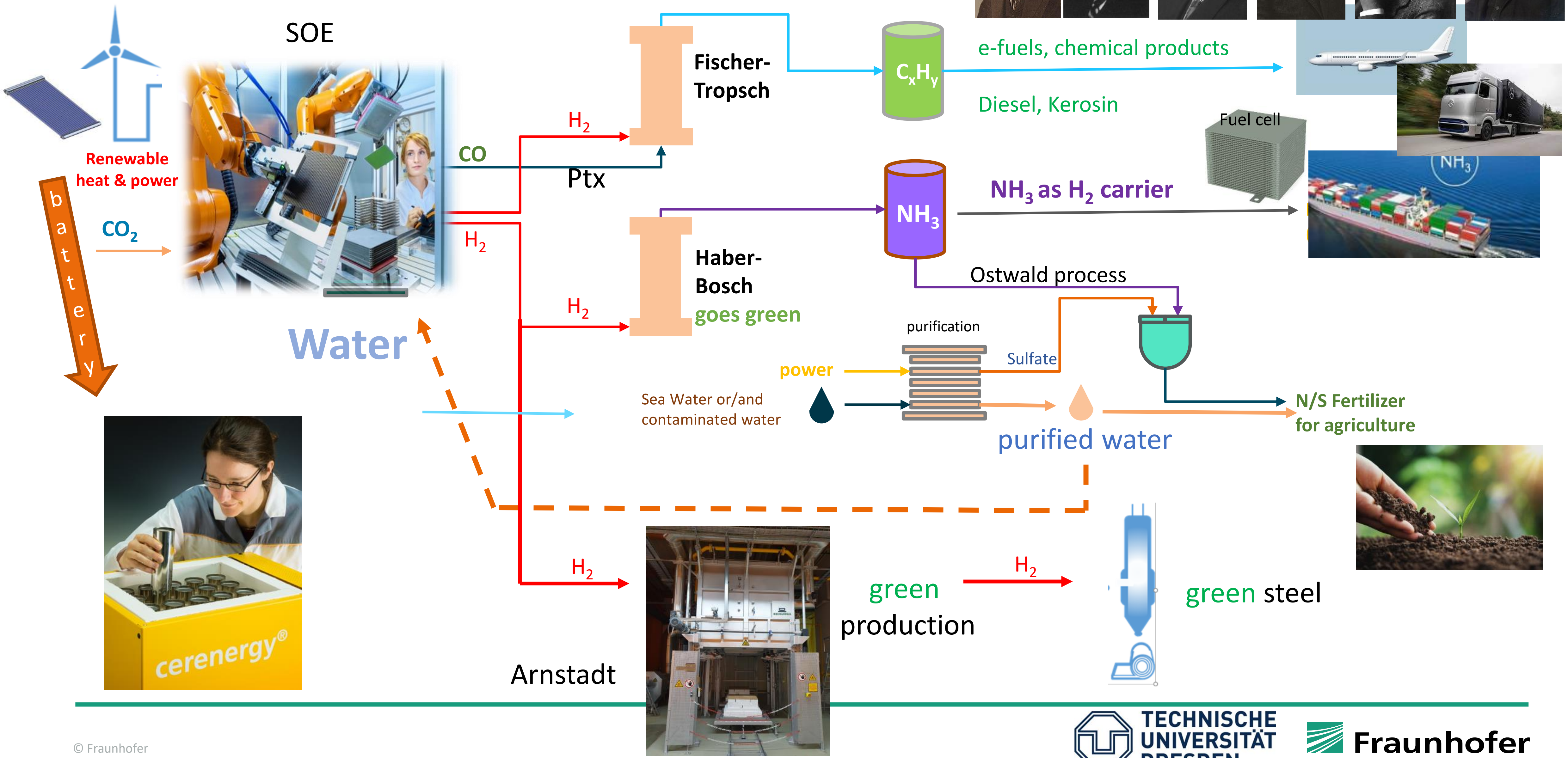
Stack lifetime

- Equipment cost for electrolyzers are expected to converge at 300 € kW_{el}^{-1}
- According to the forecasts the stack lifetime will improve significantly

TECHNISCHE UNIVERSITÄT DRESDEN

Fraunhofer IKTS

Hydrogen economy of the future: The IKTS Approach



THANK YOU FOR YOUR ATTENTION

Ceramics for a gre(at)en future!!

SOFC/SOE testing and laboratory infrastructure at IKTS

Fraunhofer
IKTS

Fraunhofer-Institut für Keramische
Technologien und Systeme IKTS

Backup

SOE-basierte Wertschöpfungsketten

Nutzung von CO_2 als Rohstoff in der Stahlindustrie

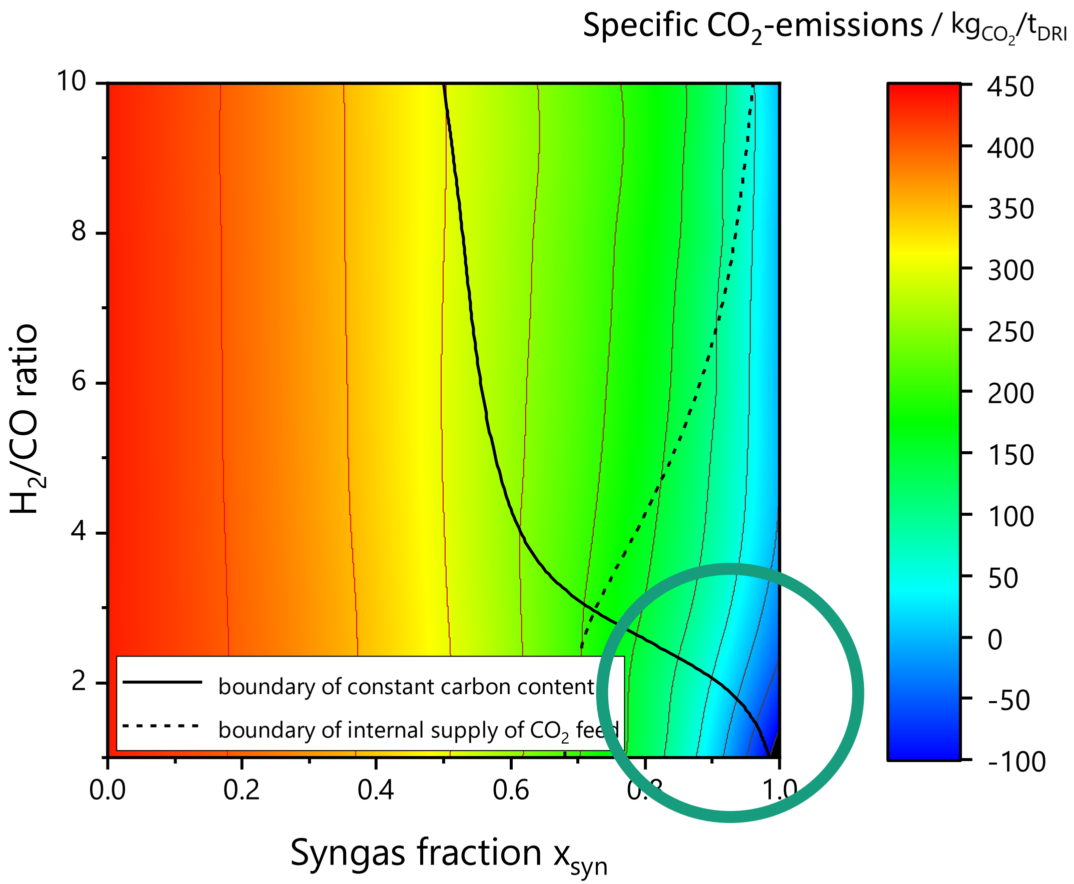
- Durch die Nutzung von CO als Reduktionsmittel kann die Erdgas substituiert warden, ohne dass die Produktqualität gemindert wird

  → Downstream Processing kann weiterhin gemäß dem Stand der Technik durchgeführt werden

- Für niedrige H2/CO-Verhältnisse kann Kohlenstoff im Roheisen gebunden werden

  → Lokal CO_2-negative Roheisenproduktion möglich

Technologiedemonstration im Rahmen des Projektes



Analytical & preparative Workflow