CCU Aktivitäten des Lehrstuhls für Verfahrenstechnik, Montanuniversität

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VTiU

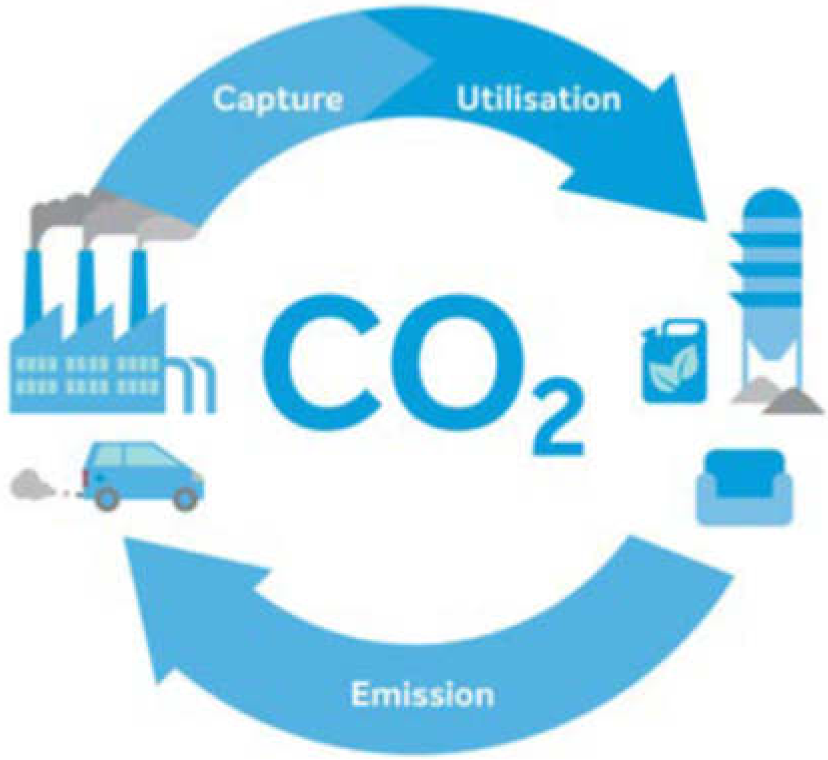
MONTAN UNIVERSITÄT LEOBEN

Begriffsbestimmung und Grundlagen

Begriffsbestimmung

Carbon Capture and Utilization (CCU)

- CCU ist die Nutzung von CO_2 in meist konzentrierter Form für die Herstellung von kohlenstoffhaltigen Produkten in chemischen und technischen biologischen Prozessen
- In einem erweiterten Sinn können aber auch natürliche biologische Prozesse (z.B. Aufforstung) mit einbezogen werden.



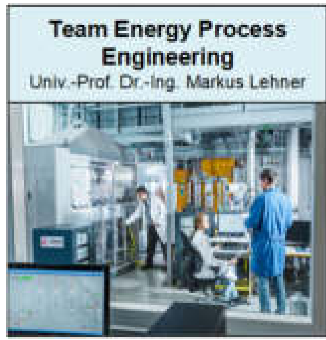
Prozesspfade zur CO_2 Nutzung

Technologiepfad	Potentielle Produkte	Attribute	TRL	Bindungsdauer
Chemisch	Chemikalien, Werkstoffe, Treibstoffe	Erfordert geeignete Katalysatoren	2 – 5	Tage – Monate - Jahre
Elektro- und photochemisch	Chemikalien, Werkstoffe, Treibstoffe	Nutzung von erneuerbaren Strom	1 – 4	Tage – Monate - Jahre
Karbonisierung	Karbonate (potentiell: Baustoffe)	Langfristige Bindung, Gesamt CO_2-Bilanz!	5 – 9	Jahrtausende
Biologisch	Chemikalien und Treibstoffe	Langsame Kinetik	3 – 9	Tage – Monate - Jahre
Enhanced Resource Recovery (CCUS)	Öl, Gas, Wasser, Geothermie	Nutzung bei dauerhafter Speicherung	5 – 9	Jahrtausende - Jahrmillionen

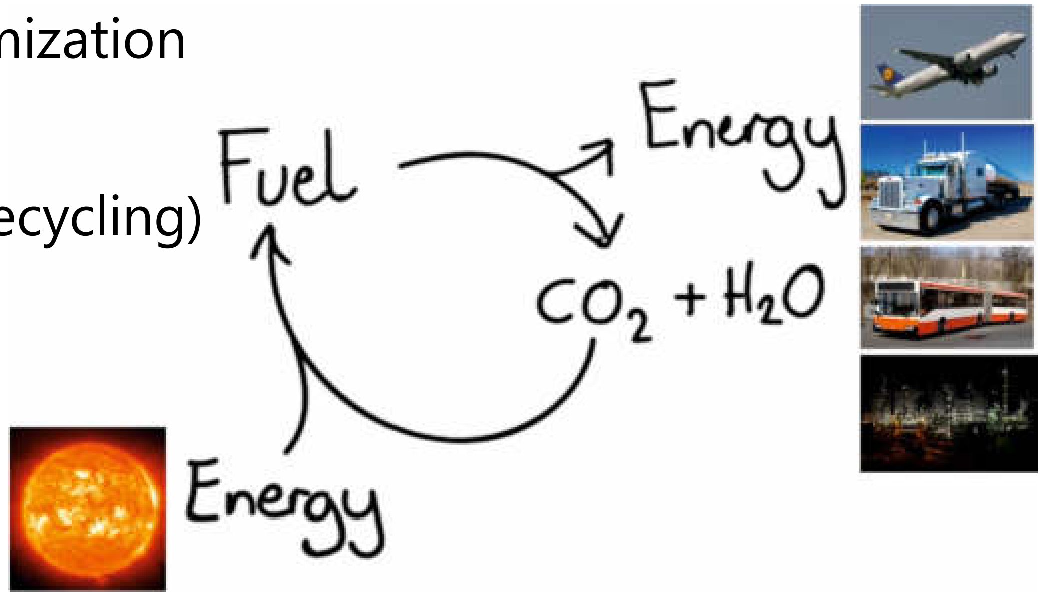
Forschungsziele und -methoden der Arbeitsgruppe Energieverfahrenstechnik am Lehrstuhl für Verfahrenstechnik der Montanuniversität Leoben

Energy Process Engineering Working Group

Objectives



- Integration of renewable energy in industrial production processes, sector coupling, long-term energy storage
- Utilization of CO_2 as resource in catalytic processes and mineral carbonation (CCU)
- Process and reactor development and optimization
- Long-term "side project":
  Thermal cracking of polyolefins (chemical recycling)



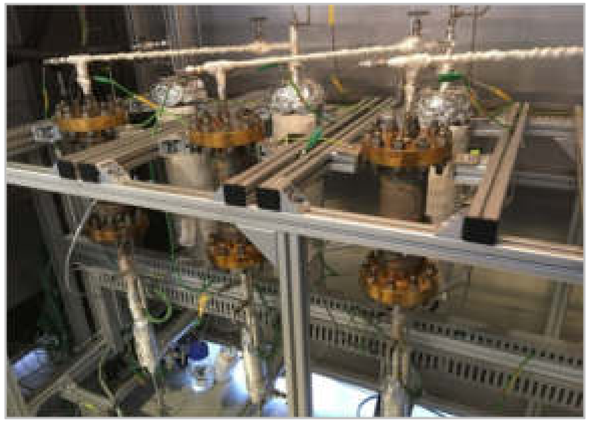
Energy Process Engineering Working Group

Applied Methods

- Process Simulation with ASPEN Plus
- CFD simulation including heat and mass transfer and chemical reaction with COMSOL Multiphysics
- Own routines in MatLab
- Laboratory experimental set-ups
- Pilot plants for catalytic methanation in mobile containers for field tests (TRL 4)

Laboratory set-ups @ VTiU

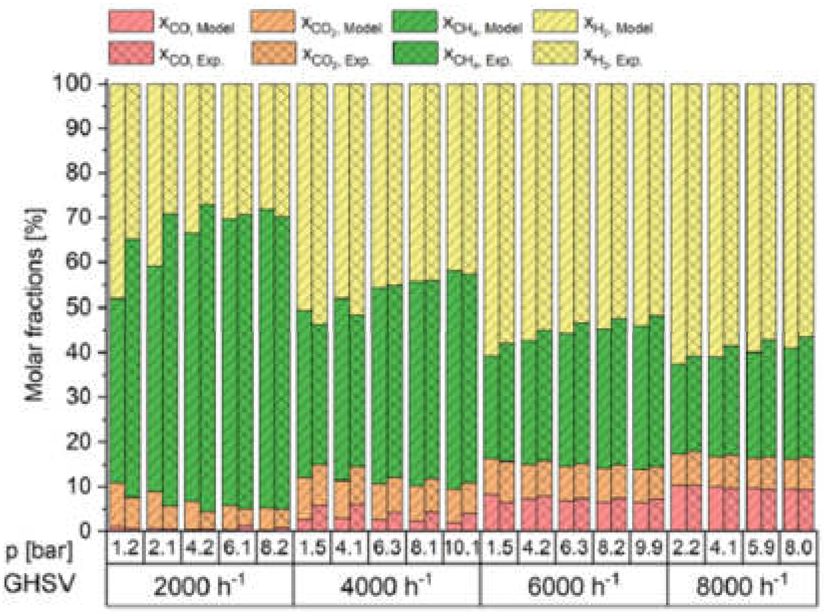
Laboratory plants for the examination of exo- and endothermic catalytic processes

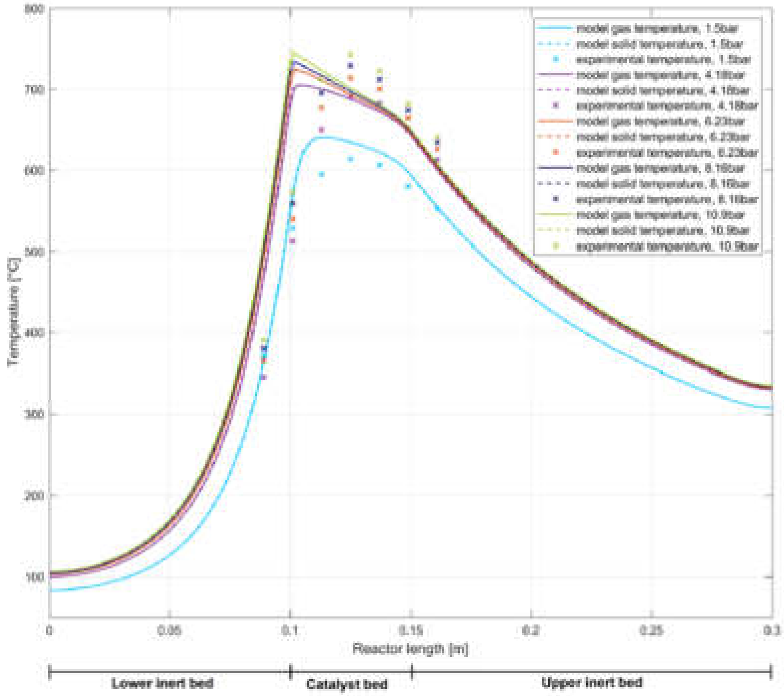


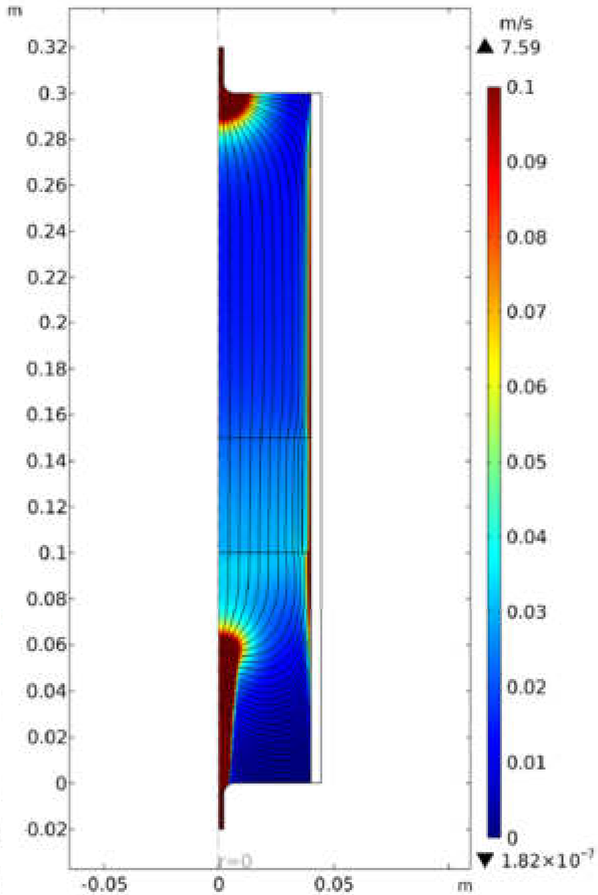
Reactor and Process Simulations

CFD simulations (Comsol) with reaction and heat/mass transfer

- Polytropic fixed bed reactors w/wo active cooling
- Reactor model development for up-scaling





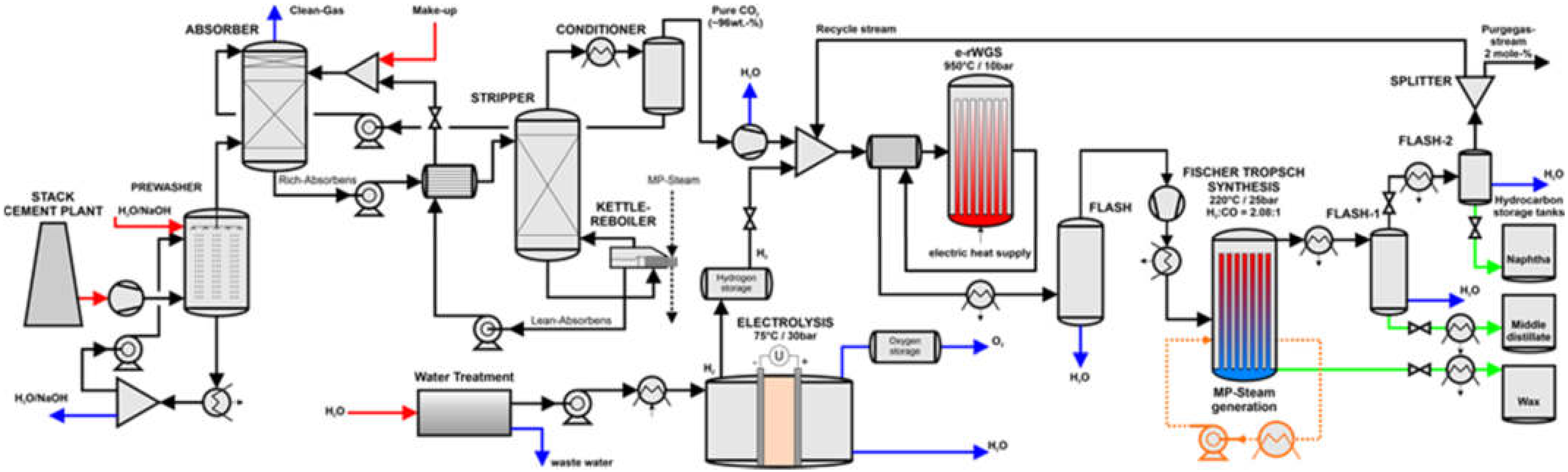


A. Krammer, M. Peham , M. Lehner: 2D heterogeneous model of a polytropic methanation reactor. Journal of CO2 Utilization 62 (2022) 102059. https://doi.org/10.1016/j.jcou.2022.102059

Reactor and Process Simulations

Process simulations (AspenPlus)

- Optimization of CCU process chains
- Determination of key performance indicators and CAPEX/OPEX estimations



Markowitsch C, Lehner M, Kitzweger J, Haider W, Ivanovici S, Unfried M et al. [Conference EnInnov 2022 TU Graz] C2PAT - Carbon to Product Austria. [February 18, 2022]

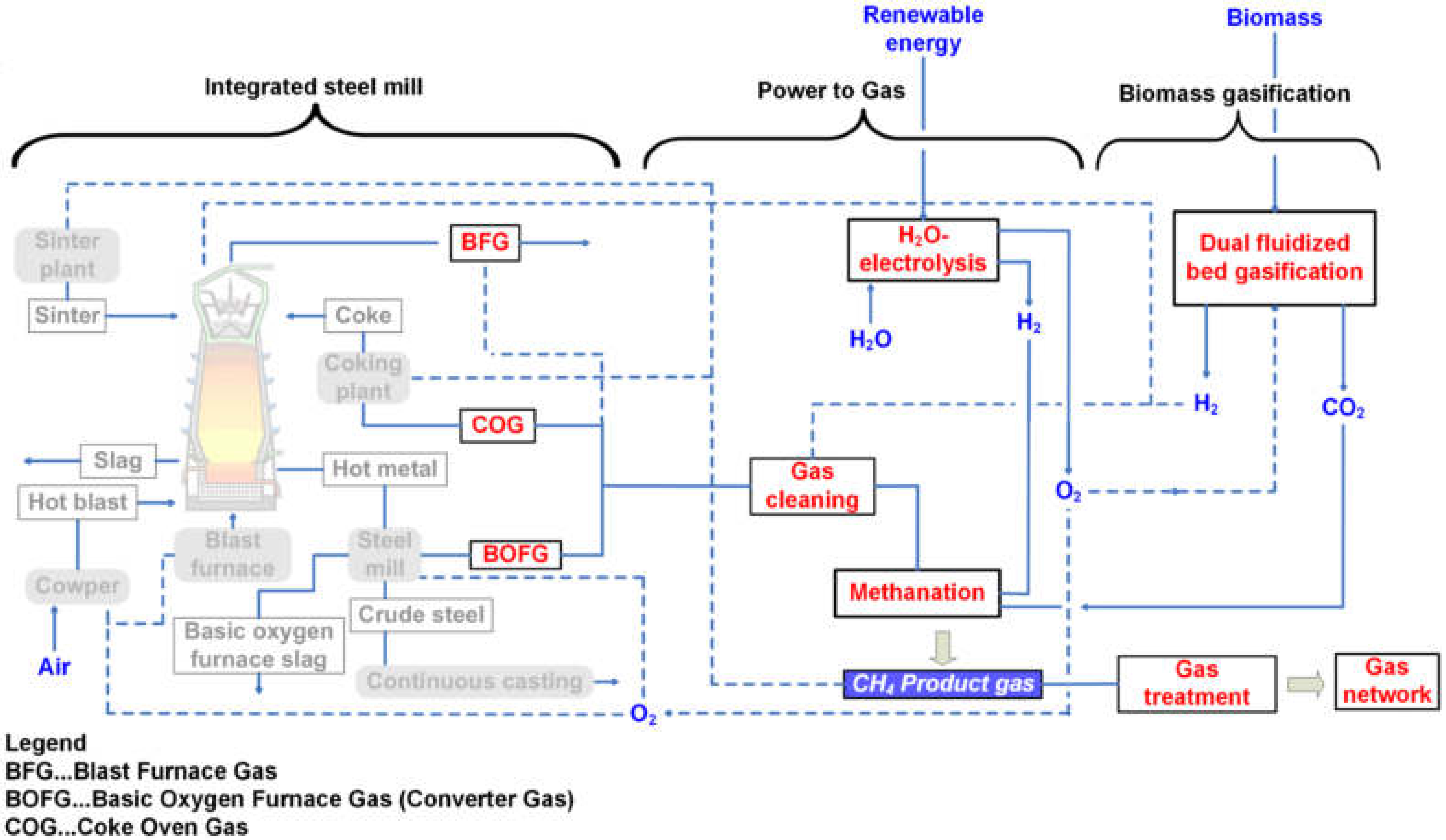
Laufende und abgeschlossene Projekte (Auswahl)

Closed CO_2 Loop in Steel Production

Integration in existing industrial processes

"Renewable Steel Gases"

- Direct conversion of blast furnace gas (CO, CO_2, N_2) with green hydrogen to "diluted" SNG
- Substitution of fossil natural gas saves up to 1 Mio. to CO_2/a"



A.R. Medved, M. Lehner, D.C. Rosenfeld, J. Lindorfer, K. Rechberger: Enrichment of Integrated Steel Plant Process Gases with Implementation of Renewable Energy. Johnson Matthey Technol. Rev., 2021, 65, (3), 453–465. https://doi.org/10.1595/205651321X16161444481140

Power-to Gas Pilot Plant

Renewable Gas Field (Gabersdorf, Styria, Austria)

Targets:

- Chemical storage of renewable electric power in pilot scale
- Direct conversion of biogas (containing of CO_2 + CH_4) to “green” SNG
- Injection of SNG into the gas grid
- Load flexible operation with proprietary reactor and catalyst technology

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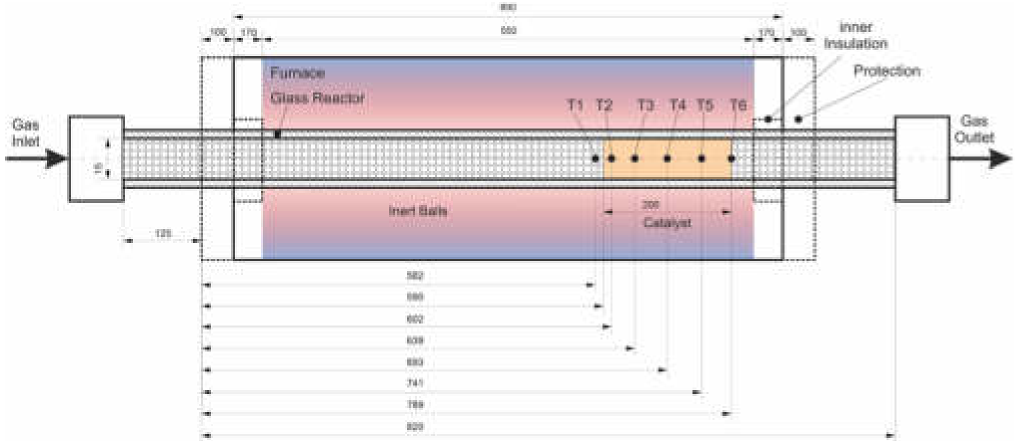
Conversion of CO_2 to CO in reverse watergas-shift reaction (rWGS)

Process and reactor development for rWGS

$$CO_2 + H_2 \leftrightarrow CO + H_2O \qquad \Delta H_R^0 = 41\ kJ/mol$$

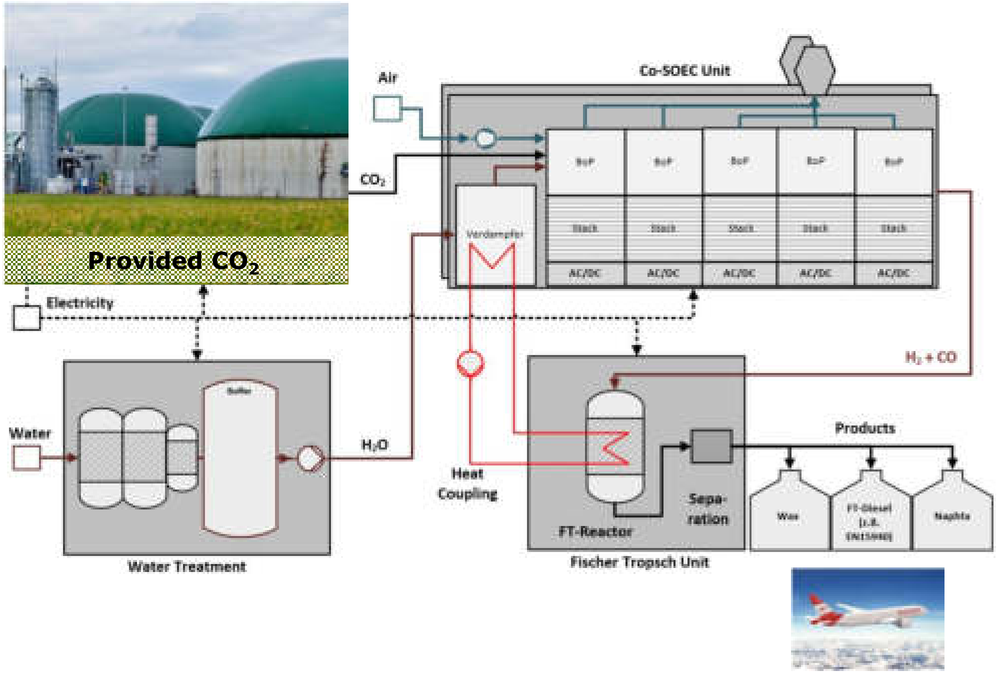
<u>**Targets:**</u>

- Important reaction for catalytic utilization of CO_2
- Optimization of rWGS process conditions
- Catalyst with improved CO selectivity, suppression of methane formation
- Experimental investigation of the rWGS reaction and kinetic as well as process modelling
- Development of rector concepts



HiPoLiq – Demonstration of 200kW PtL Plant

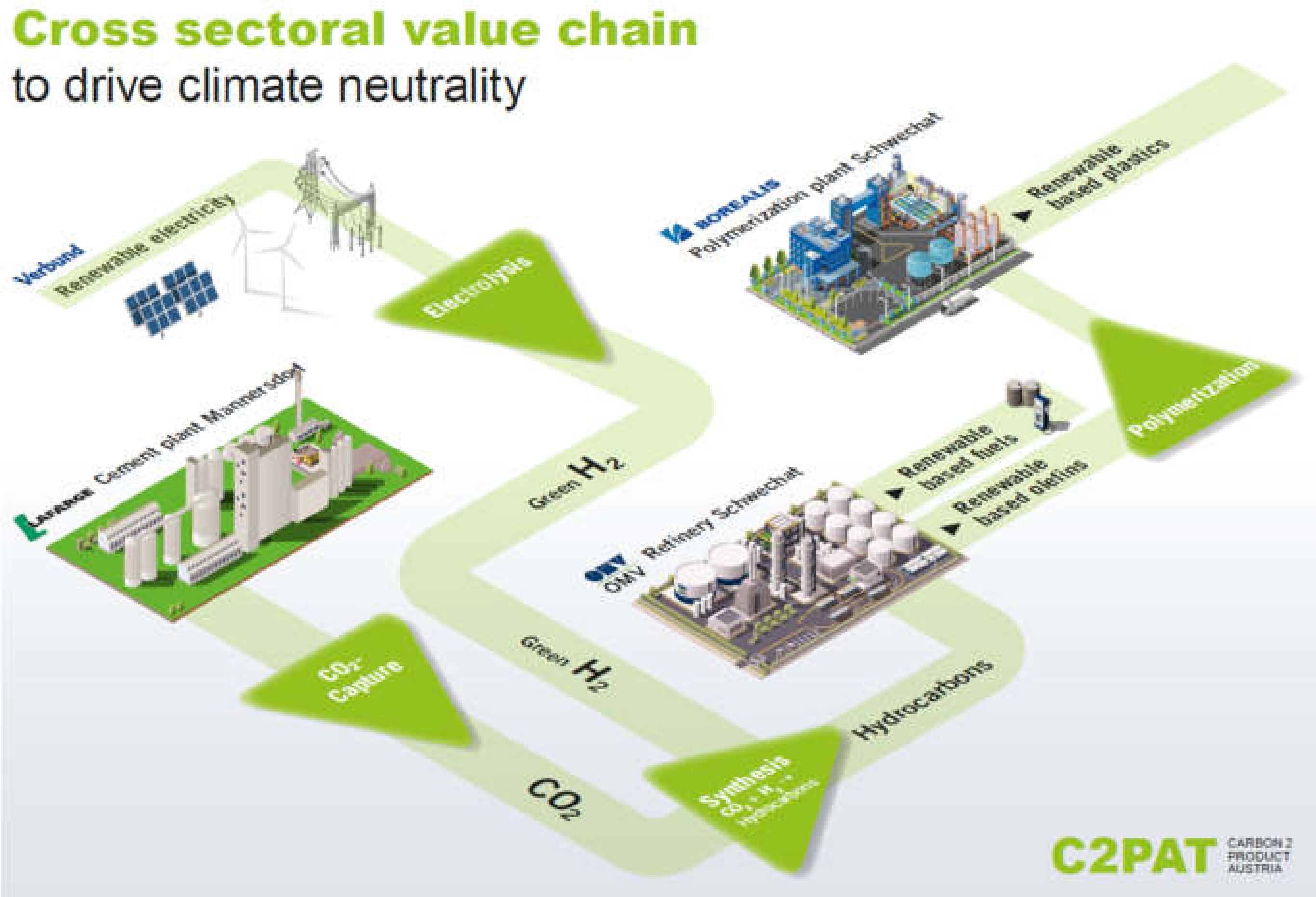
AVL



- **$200kW_{el}$ renewable Power**
- **CO_2 from renewable sources**
- **Production per year**
  - Kerosin: 30.000 L
  - Wax: 30.000 L
  - Naphta: 30.000 L
- **Overall efficiency by >55% with the key technology:**
  - Co-SOEC
  - Heat coupling FT Synthesis & Electrolysis
  - Optimized FT reactor & operation
- **Project duration 3 Years**
- Y1 Build up (09/2023-08/2024)
- Y2&3 Demonstration (09/2024-08/2026)

Carbon to Product Austria (C2PAT): Power-to-Liquid Plant Study

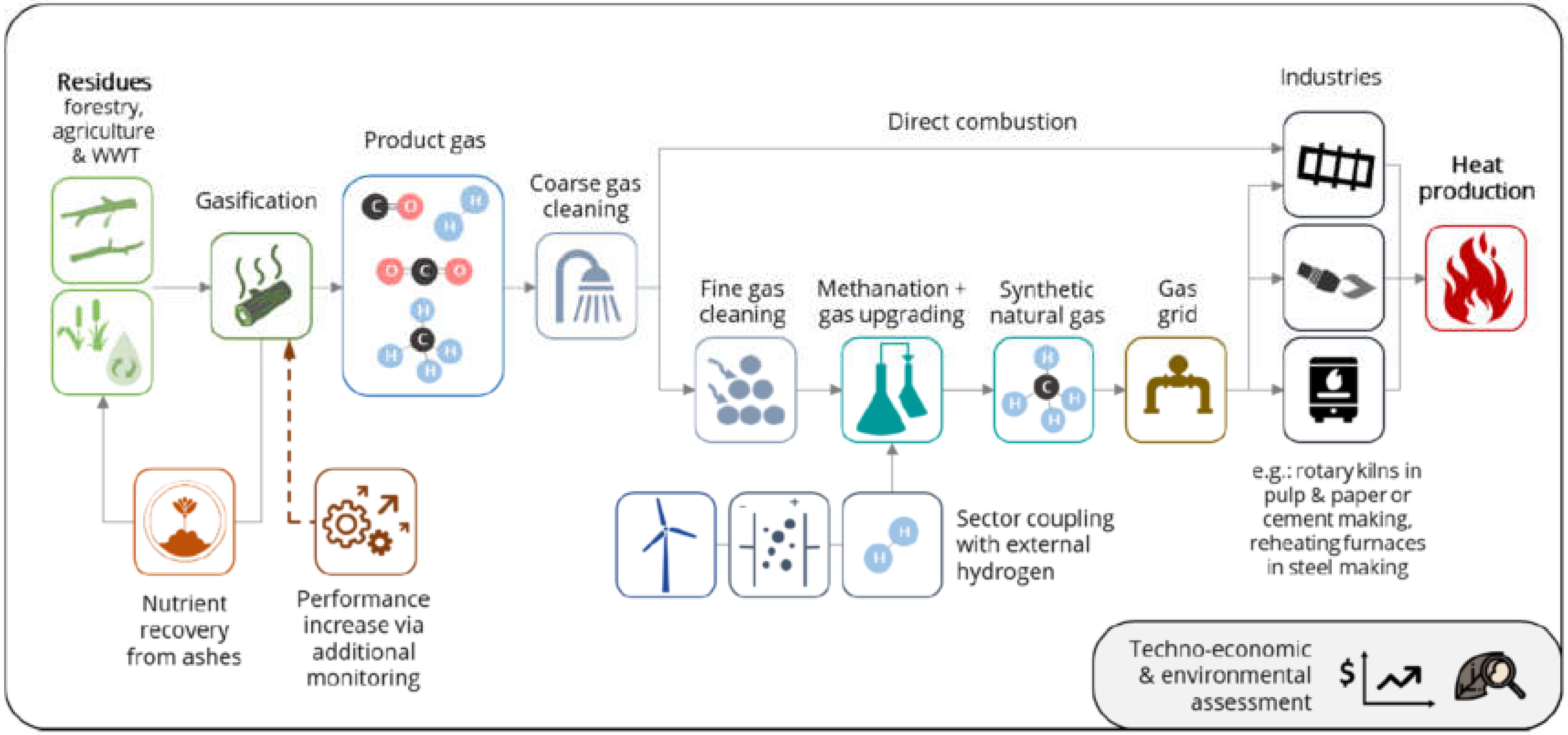
Production of polyolefins (PP, PE) from CO_2 and green hydrogen



Partner:

OMV, Borealis, Verbund, LafargeHolcim, Montanuniversität Leoben, VTiU Verfahrenstechnik des industriellen Umweltschutzes

ERA-Net Project BioHEAT

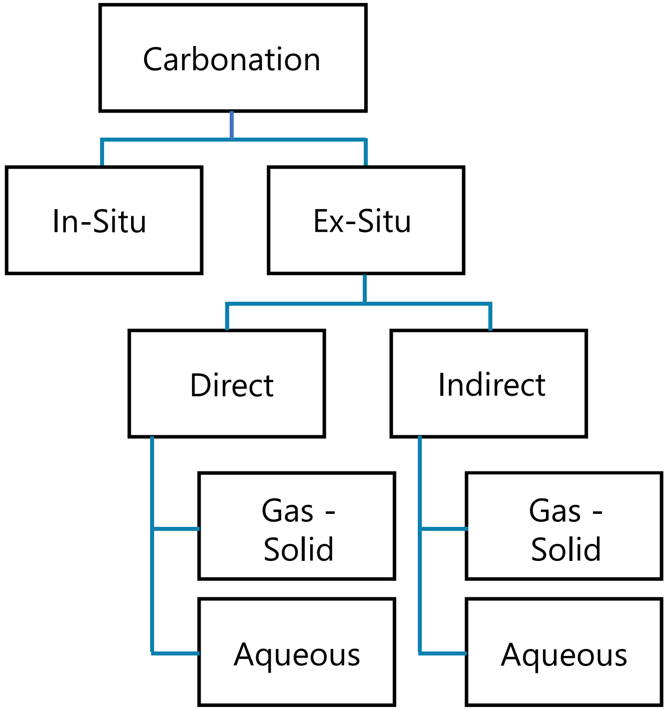


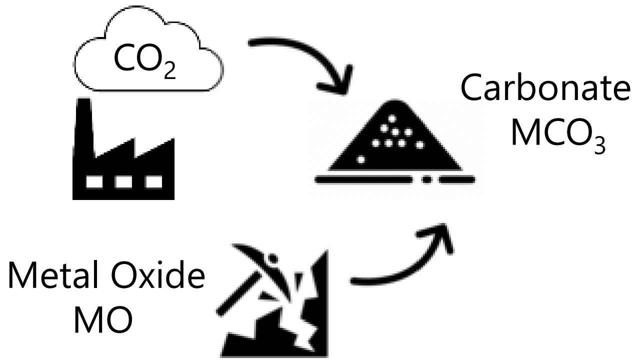
Assessment of a sustainable bio-refinery process based on the gasification of opportunity fuels into heat for industrial processes

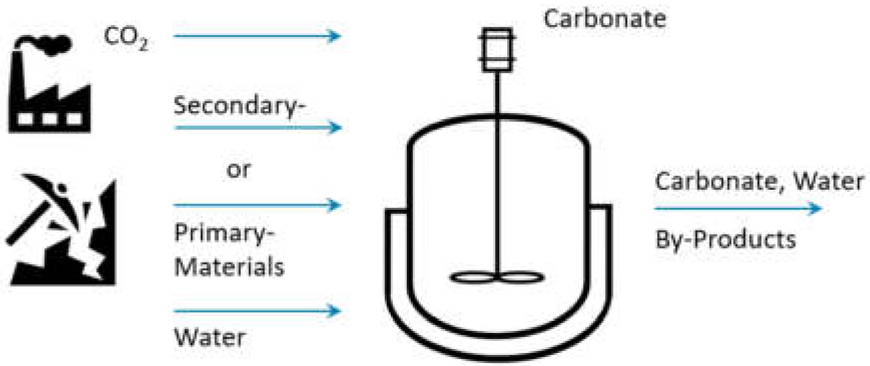
Mineral Carbonation

Long-term storage and potential utilization of CO_2 in carbonates

- In-Situ: Subsurface carbonation
- Ex-Situ: Aboveground carbonation



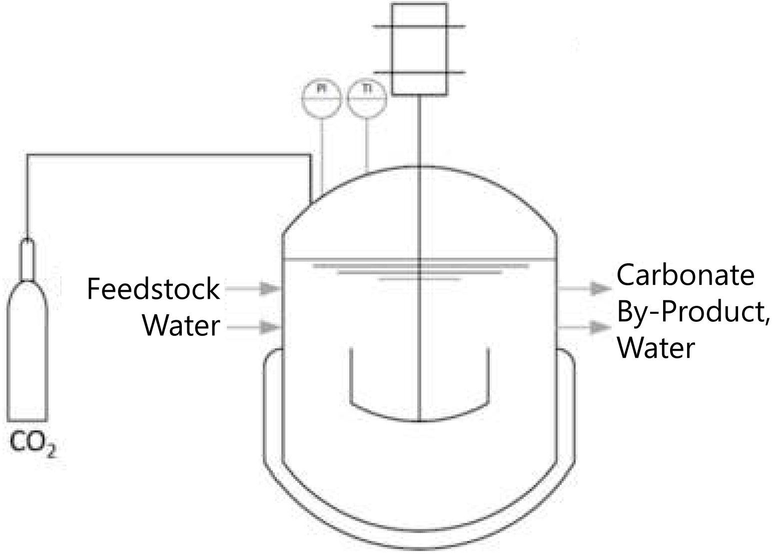




Mineral Carbonation @ VTiU

Raw materials and laboratory set-up

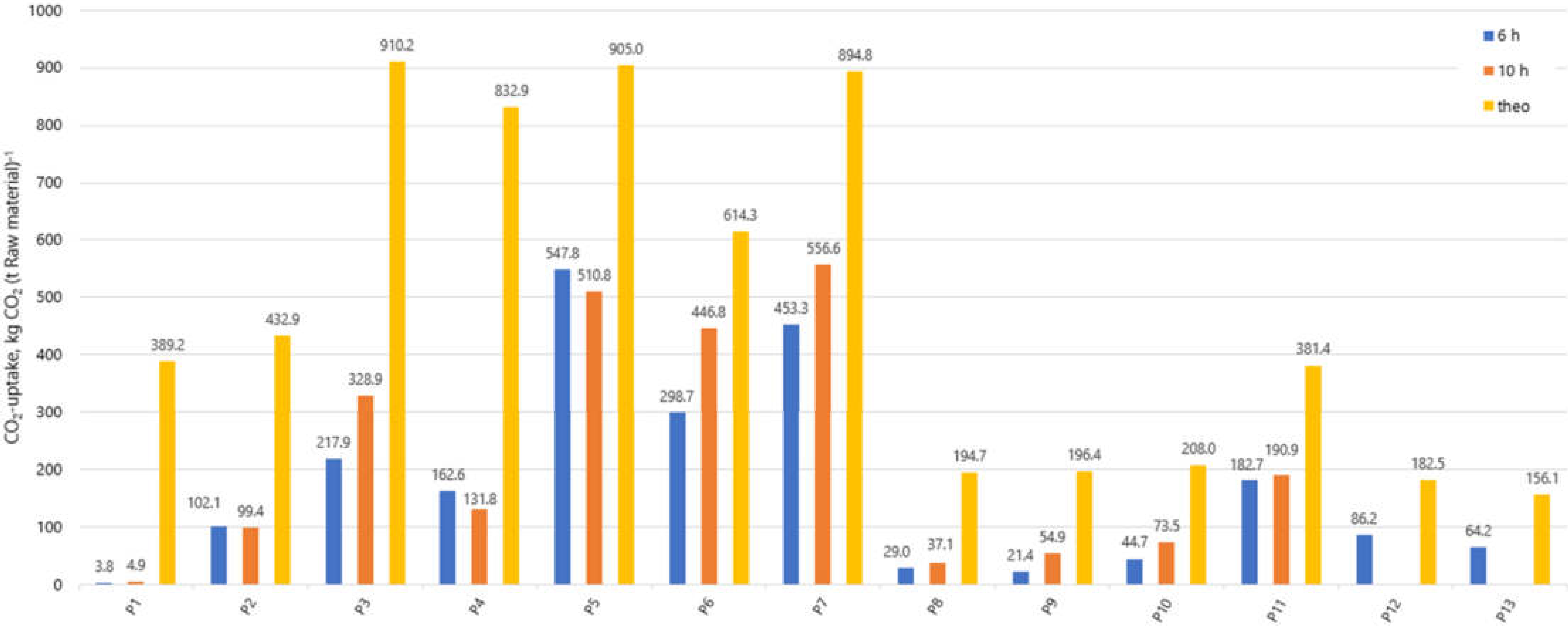
- Primary and secondary feedstocks
  - Mostly Ca, Mg: high availability
- Primary – rocks & minerals
  - Serpentinite ($Mg_3Si_2O_5(OH)_4$)
  - Olivine (Mg_2SiO_4)
  - Wollastonite ($CaSiO_3$)
- Secondary - Recyclate
  - Slags (e. g. steel mill)
  - Ash (z. B. Fly ash, boiler ash)
  - Dust (z. B. Cement plant dust)
  - Construction waste
- Content of metal oxides decisive



Examplary Results of Mineral Carbonation

CO_2-Uptake of Samples

Serpentinite	Refractories	Waste Incineration	Waste Paper Incineration	Paper Industry
P1, P2	P3-P7	P8-P10	P11, P12	P13



Empfehlungen für FTI-Aktivitäten

Demand for R&D in CCU area

- Optimization of **carbon capture technologies**, including Direct Air Capture
- Development of a **CO_2 transportation infrastructure** including a legal framework
- Optimization of CCU processes in terms of their efficiency, cost reduction through scaling and learning curves (**funding of pilot plant installations**)
- Development of novel catalytic, electro- and photochemical as well as (technical)-biological CCU pathways (**basic and applied research**)
- **Legal framework** for CCU, particularly to credit CCU products in the ETS system

Vielen Dank für Ihre Aufmerksamkeit!

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