Vorstellung der F&E Aktivitäten des Fachbereichs CO_2Refinery der TU-Wien

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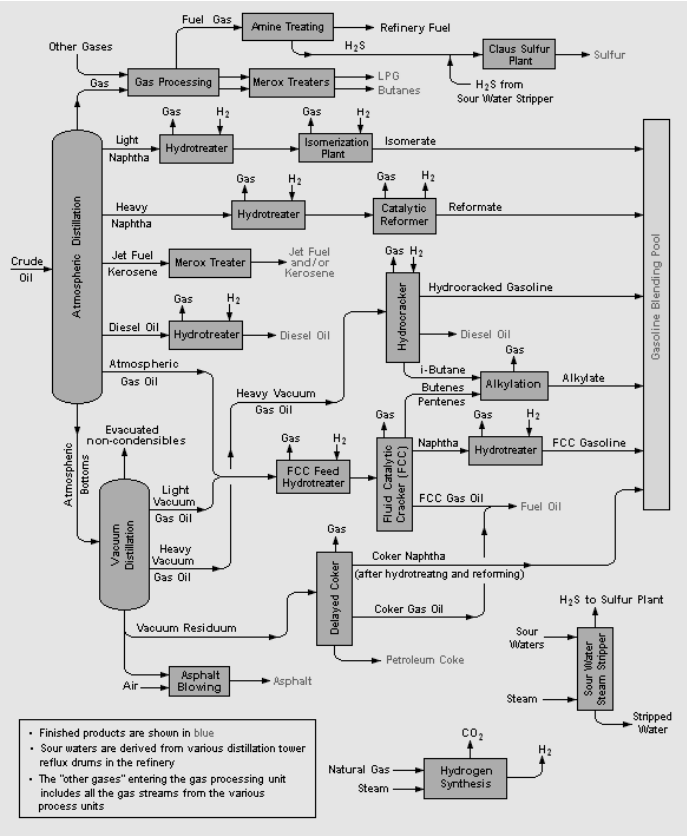
28.09.2023

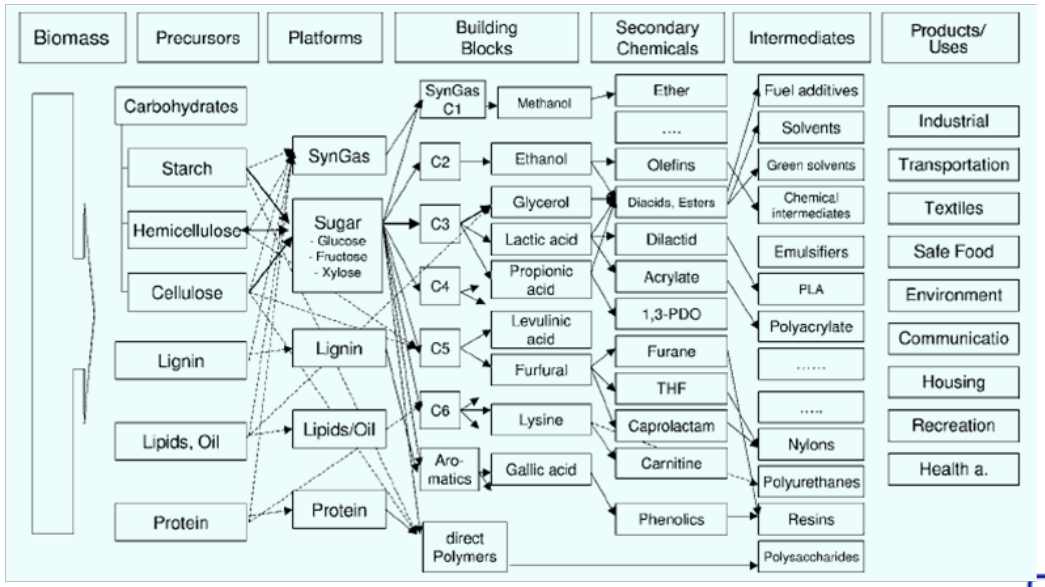
Good Circular Economy Practices

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Progress by innovation

TU Doctoral College – the research approach…

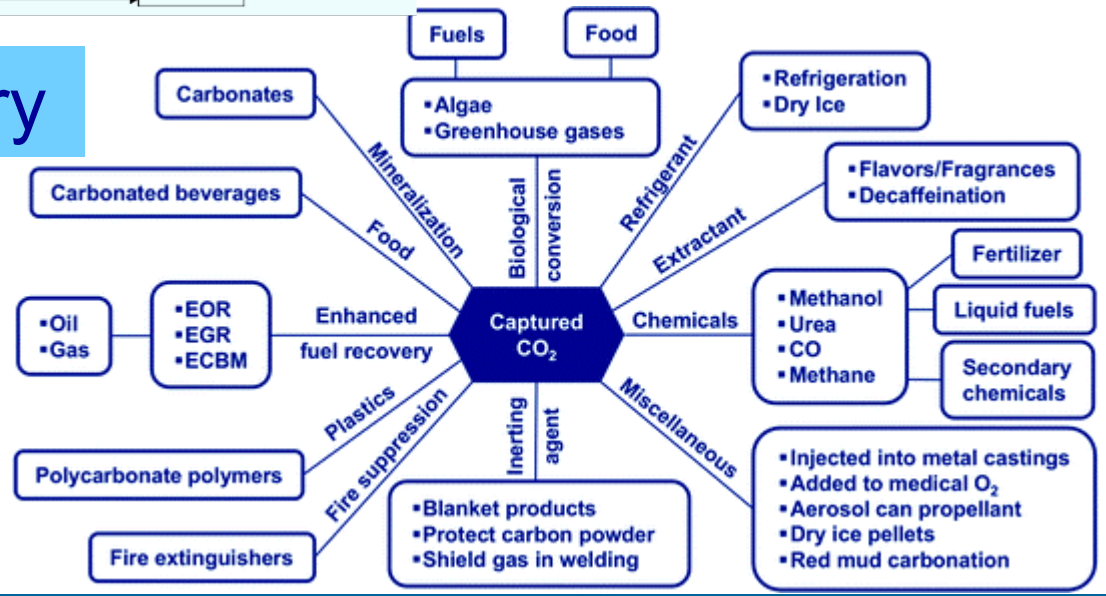
Fossil refineries





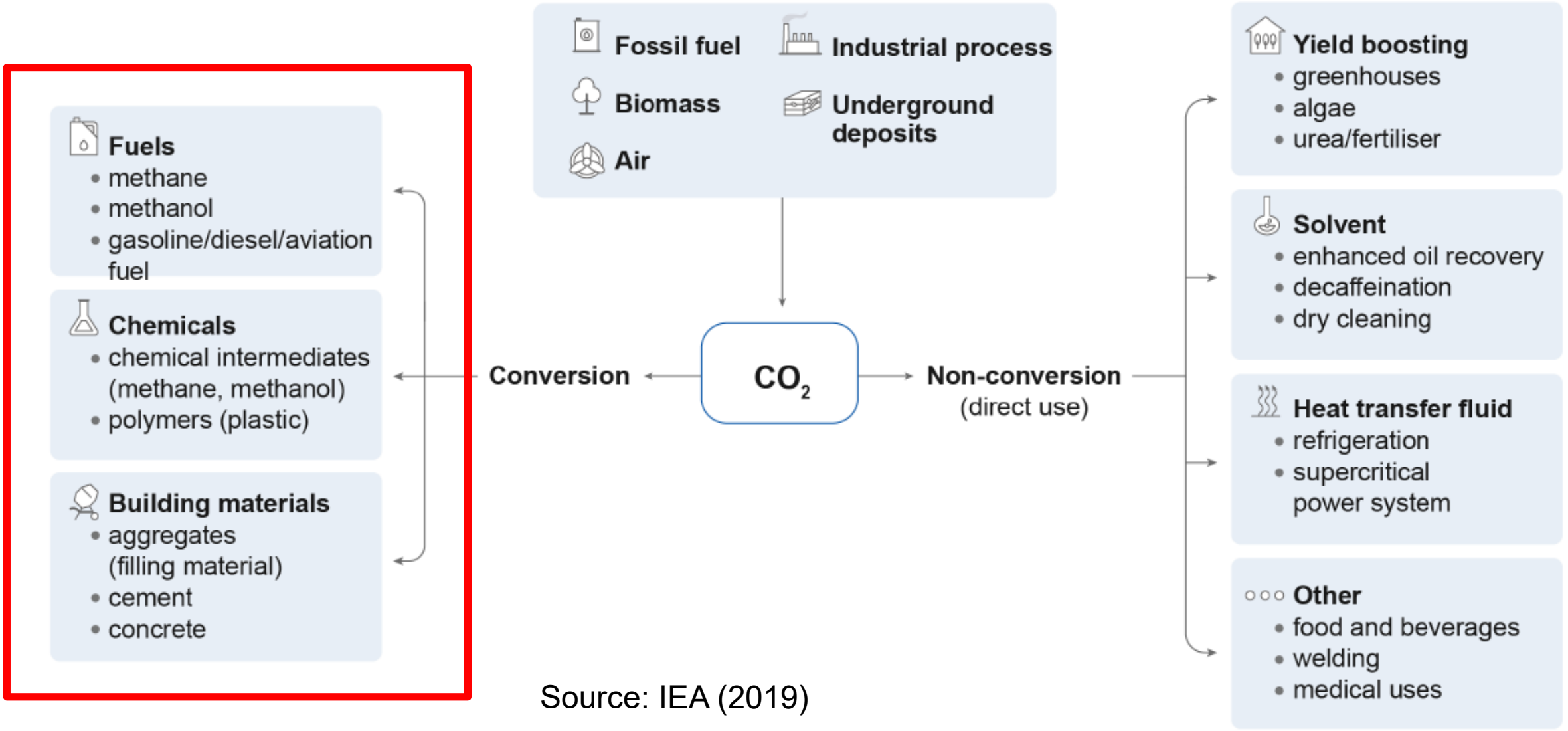
Biorefineries

CO_2Refinery



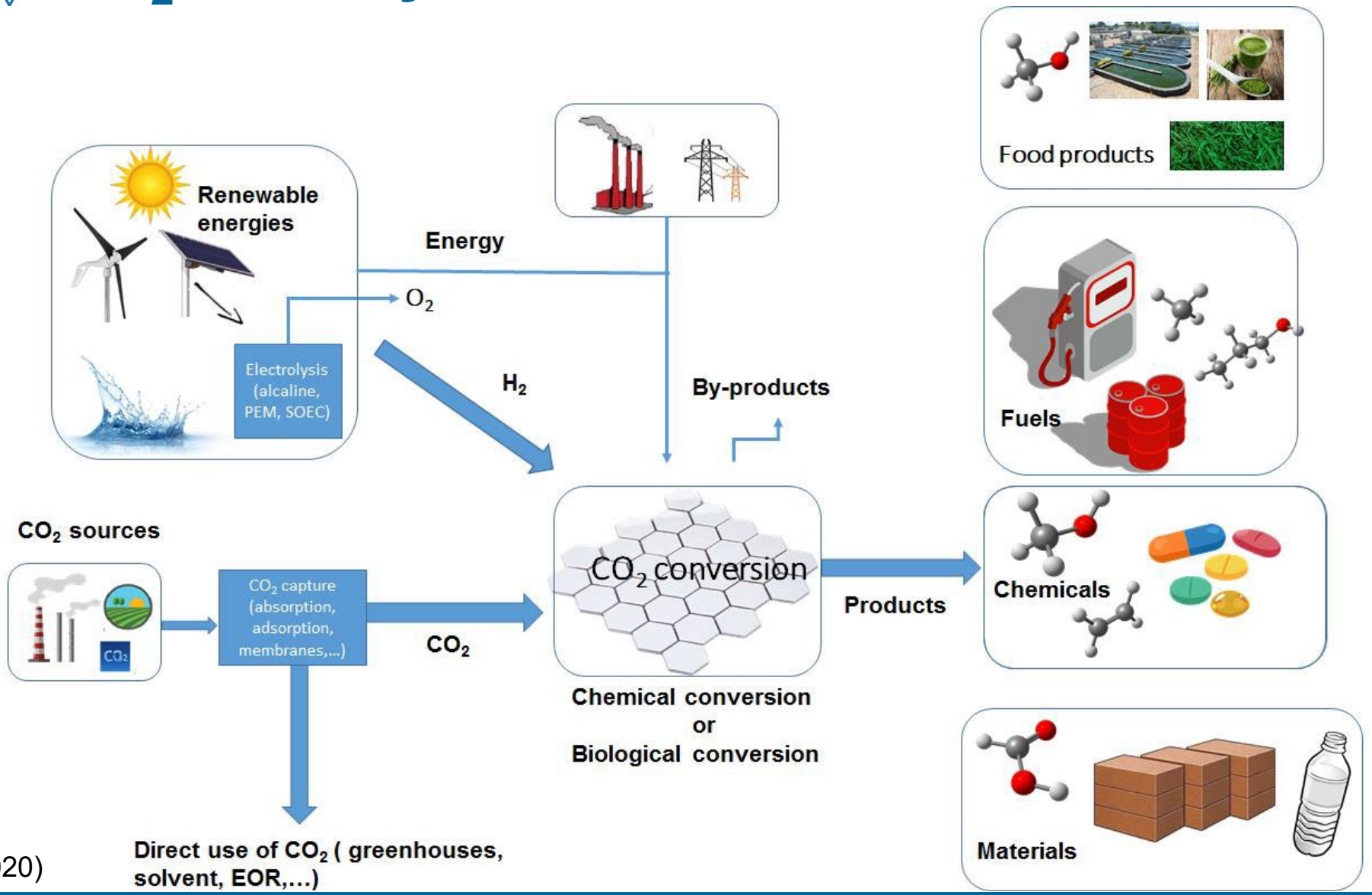
Circular AND integrated!

CO_2 utilization options (CCU)



Source: IEA (2019)

CO_2Refinery => Focus on Conversion Pathways



Source: LCA4CCU (2020)

CO_2Refinery => Focus on Scalability

Scalability
- Supply constraints
  - availability of key inputs (CO_2, H_2, low-carbon energy)
  - infrastructure (for transport of CO_2 and H_2)
- Demand for product or service

Competitiveness
- Cost of technology
- Input costs (CO_2, H_2, low-carbon energy)
- Cost of competing low-carbon products or services
- Market price

Climate benefits
- Origin of the CO_2
- Displaced product or service
- Energy input
- Retention time of carbon in product

Future market potential

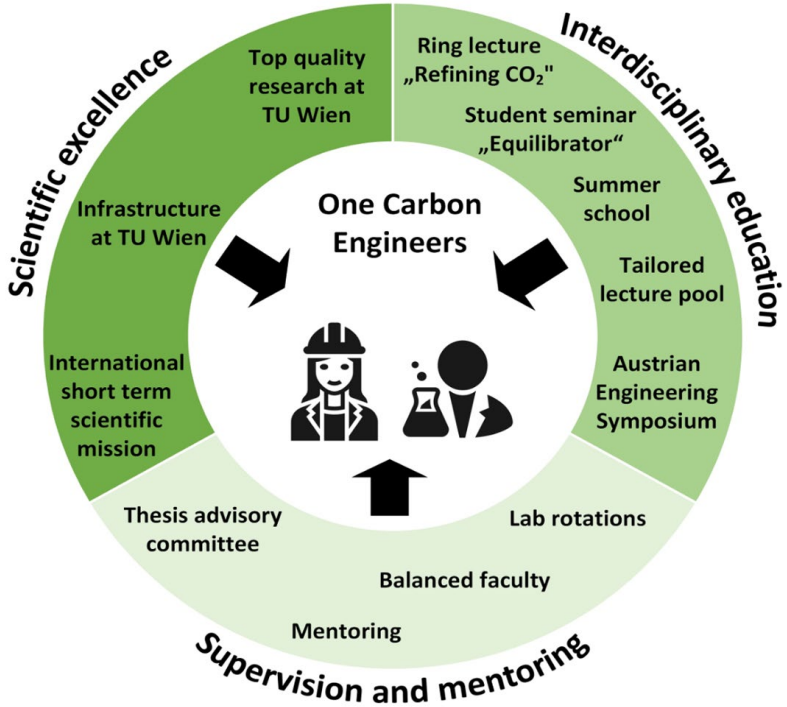
Policy and regulatory framework

Dive Brief (July 21, 2022):
"Green hydrogen prices have nearly tripled as energy costs climb",
according to S&P Global Commodity Insights

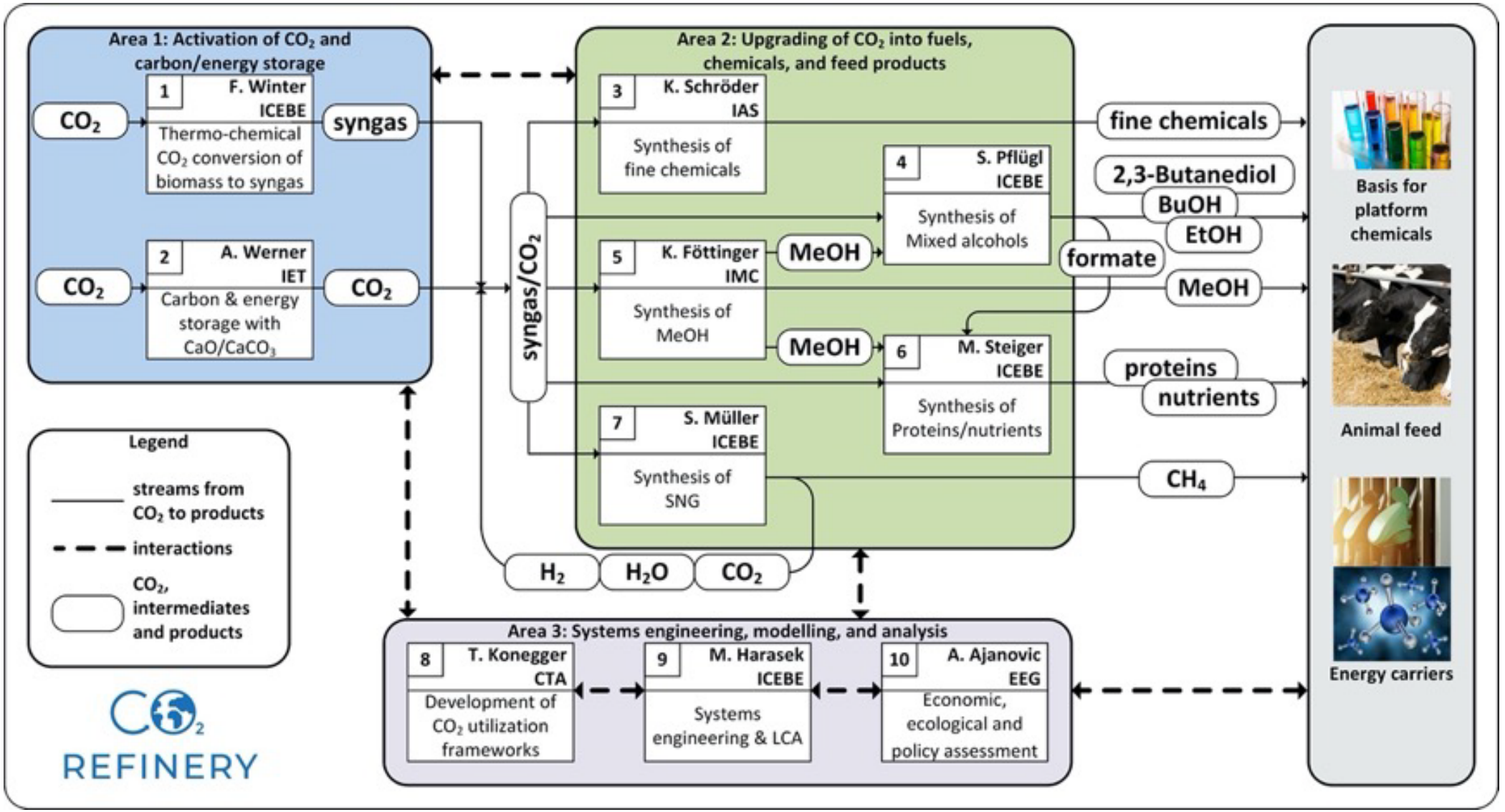
Source: IEA: „Putting CO_2 to use" (2019)

Key facts of our Doctoral College „CO_2Refinery“

- **10 PhD students**, funded for 48 months (May 2021 –April 2025)
- **10 research groups**, 6 TU institutes involved, 3 TU faculties involved
- **10 PIs hosting** the young researchers and providing infrastructure + 10+ co-PIs
- **5+ associated PhD theses** – constantly growing

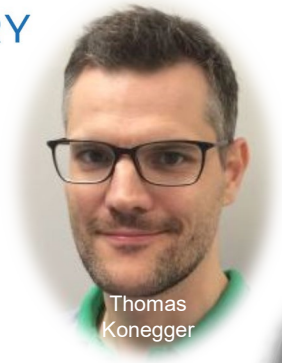


Ten interconnected research projects @ yet low TRL…



The team behind CO_2Refinery


Amela Ajanovic


Thomas Konegger


Bettina MIhalyi


Karin Föttinger


Florian Benedikt


Matthias Steiger


Katharina Bica-Schröder


Reinhard Haas


Stefan Pflügl


Anna Mauerhofer


Walter Wukovits


Andreas Werner


Stefan Müller


Valeria Elena


Christoph Rameshan


Michael Harasek

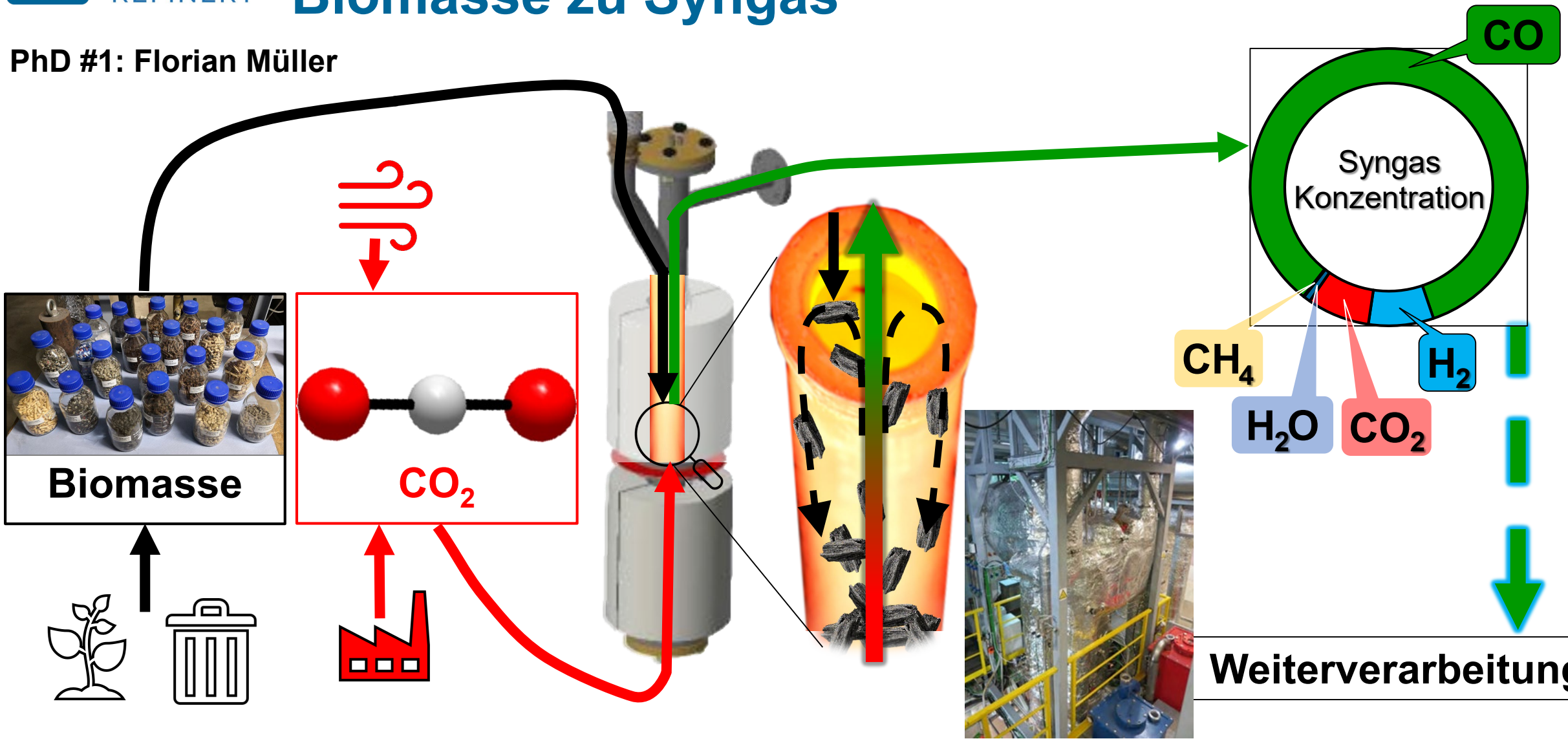

Katharina Novak


Franz Winter


Alexander Opitz

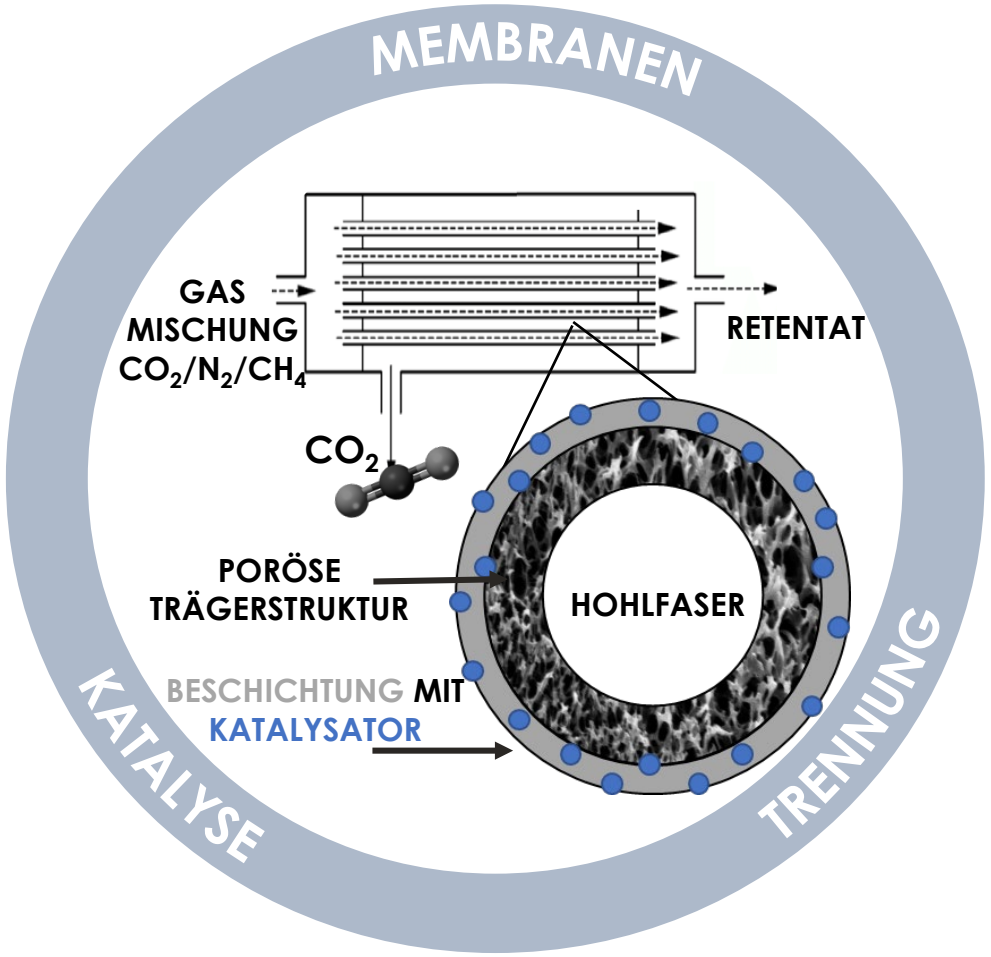
Thermochemische CO_2-Umwandlung mittels Biomasse zu Syngas

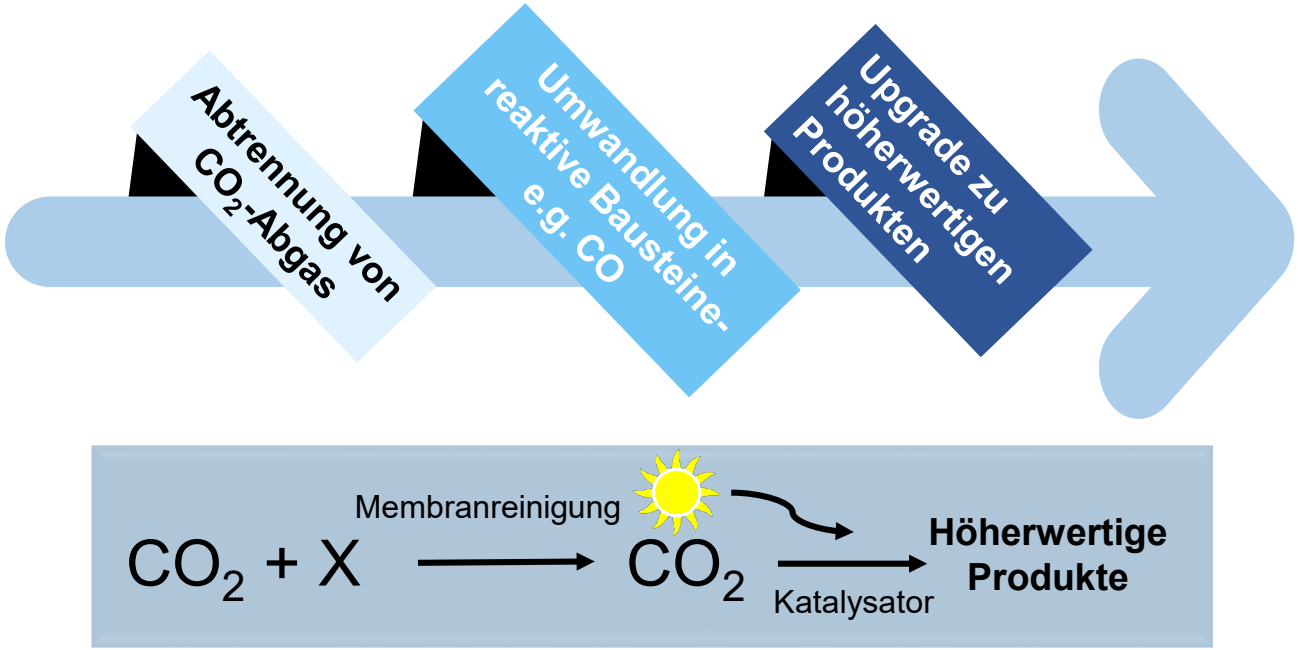
PhD #1: Florian Müller



Design und Anwendung von katalytisch aktiven Hohlfasermembranreaktoren

Julia Piotrowska[1], Michael Harasek[2] and Katharina Bica-Schröder[1]
[1]Institute of Applied Synthetic Chemistry |[2]Institute of Chemical, Environmental and Bioscience Engineering





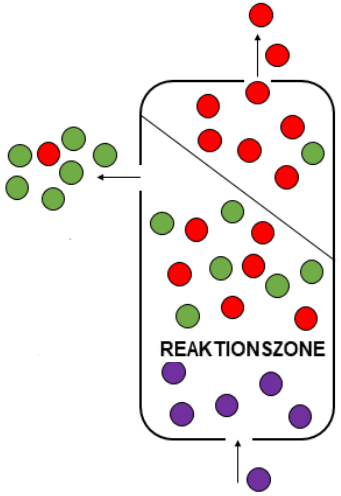
PhD #3: Julia Piotrowska

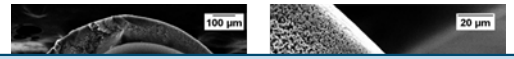
CO_2-Abscheidung und Konversion: Katalyse und Trennung

PhD #3: Julia Piotrowska

Membranreaktoren

- CO_2-Abtrennung und Umwandlung finden gleichzeitig statt.
- Durch Abtrennen eines Reaktionproduktes über die Membran kann da chemische Gleichgewicht positiv beeinflusst werden.



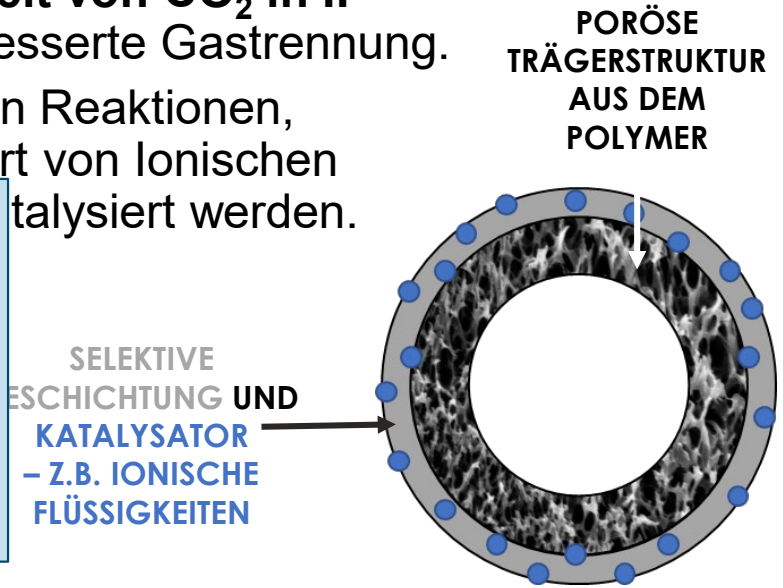


Mit Katalysator funktionalisierte Membranen

eschichtungsschicht kann mit

en katalytisch-aktiven Komponenten ngereichert werden

- Ionische Flüssigkeiten
  - **Hohe Löslichkeit von CO_2 in IF** – wichtig für verbesserte Gastrennung.
  - Große Vielfalt an Reaktionen, die in Gegenwart von Ionischen talysiert werden.

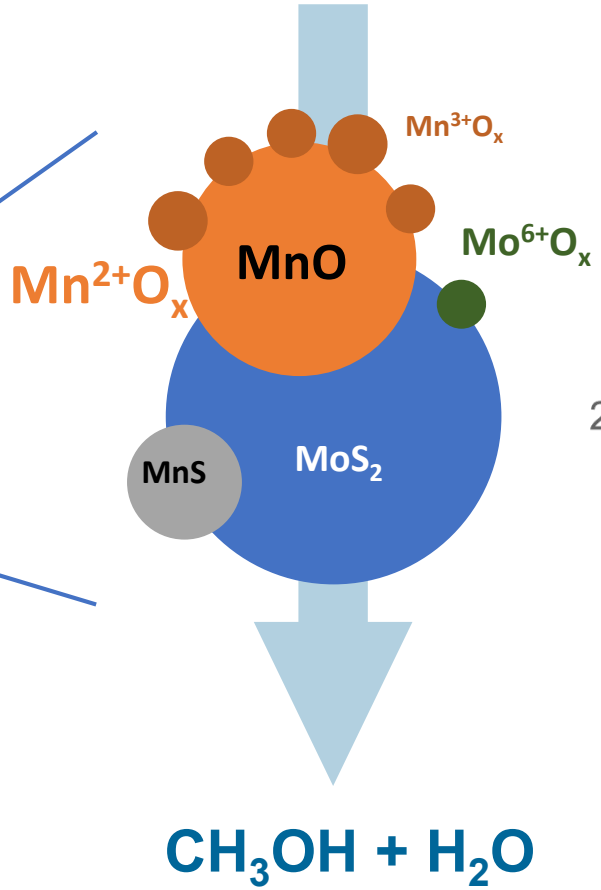


Synergien mit ERC-Grant (Katharina Schröder):
„CarboFlow - Streamlined carbon dioxide conversion in ionic liquids – a platform strategy for modern carbonylation chemistry"
2021-2025

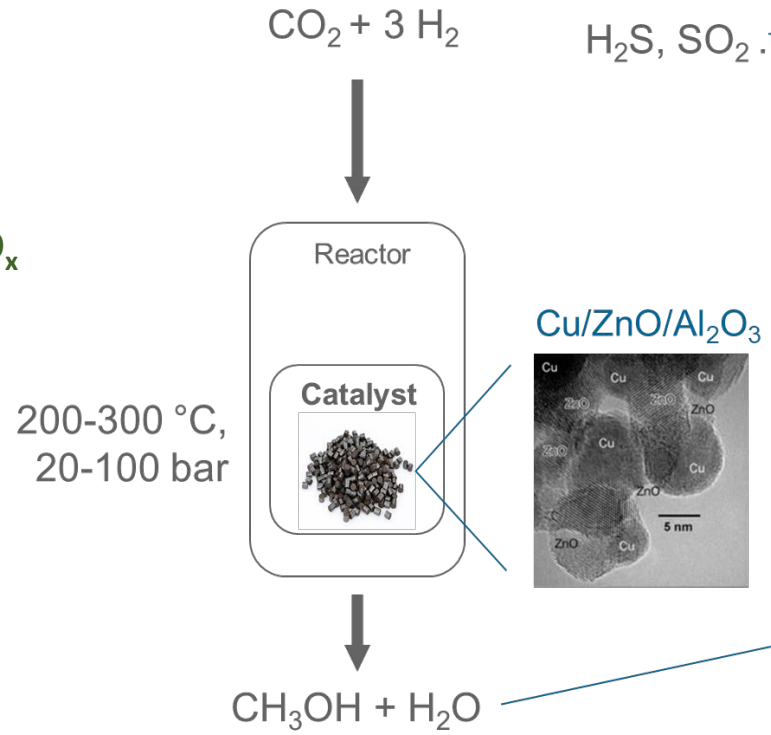
European Research Council
Established by the European Commission

Versatile and robust catalysts for CO_2 hydrogenation to methanol

$CO_2 + 3\ H_2$



$CH_3OH + H_2O$



PhD #5: Gustavo Andrade Silva Alves

Autotrophic and mixotrophic upgrading of CO_2 for chemical production

CO_2

PhD #4: Ivo van den Hurk

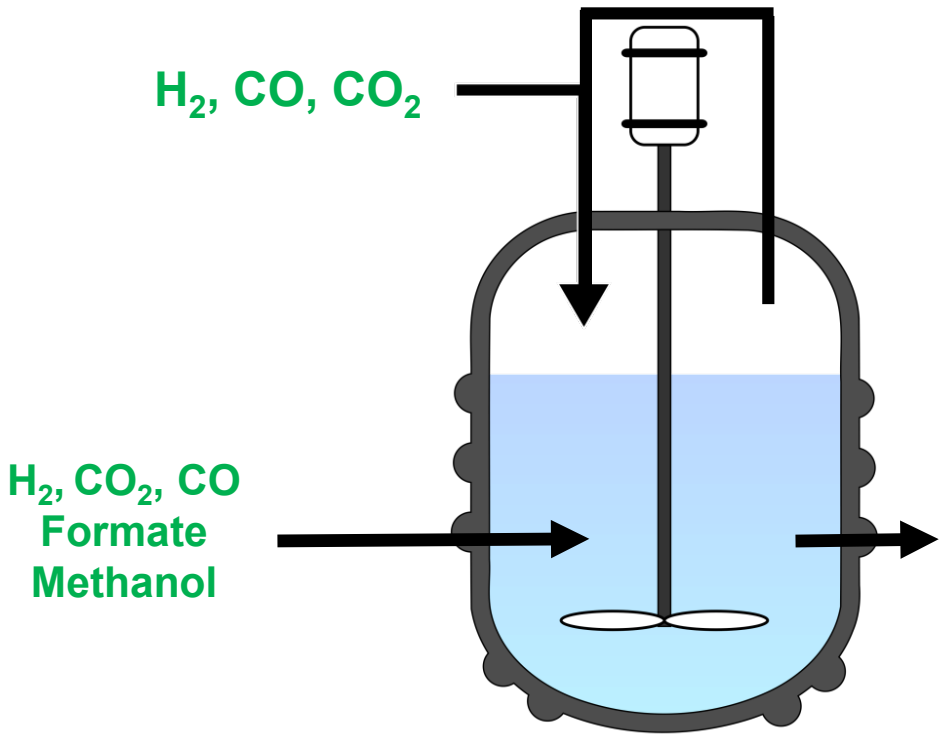
Chemicals & fuels

Formate / H_2 / CO / Methanol

FWF Austrian Science Fund

Synergies with FWF Starting Grant (Stefan Pflügl)
"Formate-based acetogenic bioproduction of fuels and chemicals"
11/2022 – 10/2025

Autotrophic and mixotrophic upgrading of CO_2 for chemical production

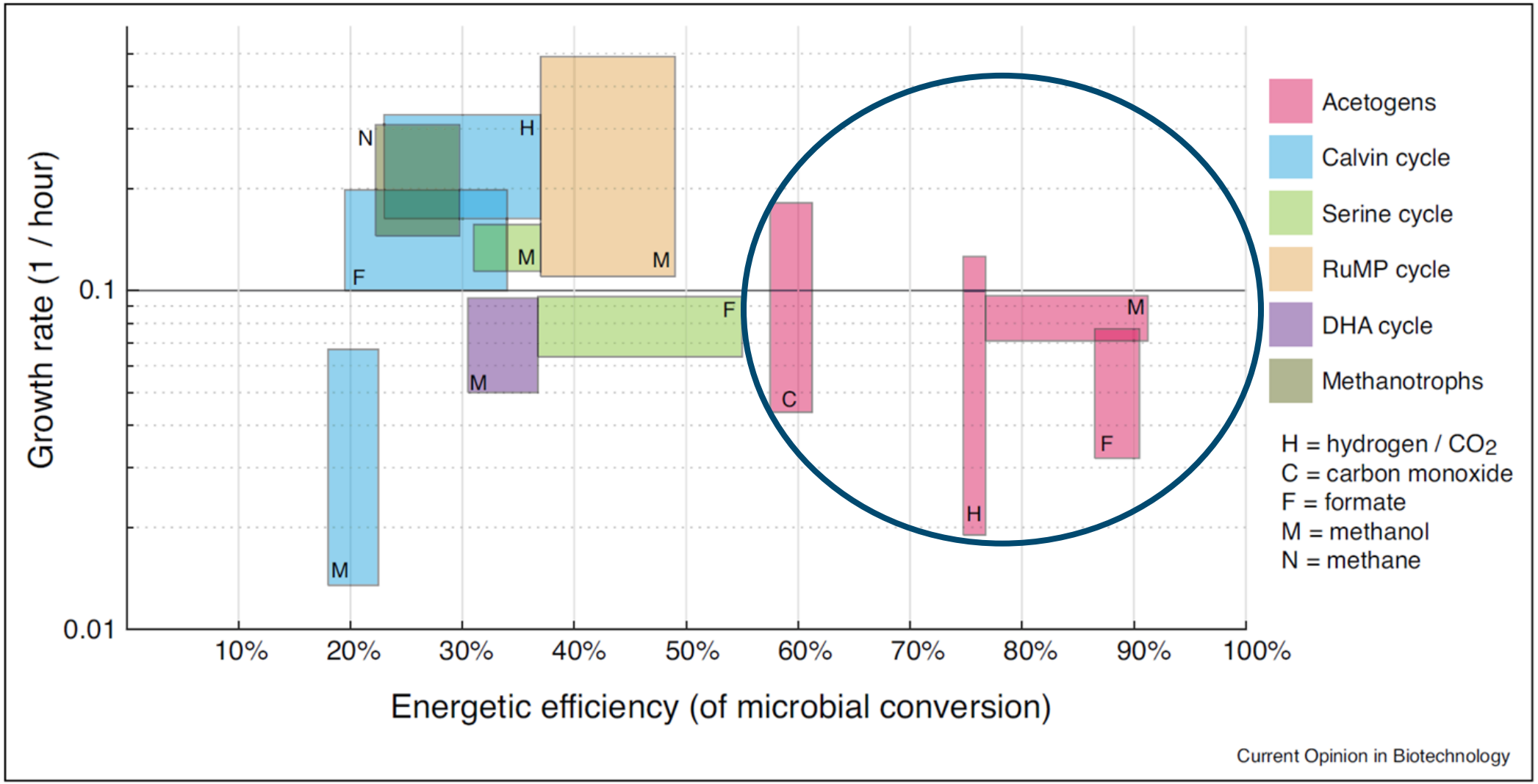


- Bacteria from many different genera
- Grow in a wide range of temperatures and pH
- Utilize one-carbon substrates
- Producers of multi-carbon products

PhD #4: Ivo van den Hurk

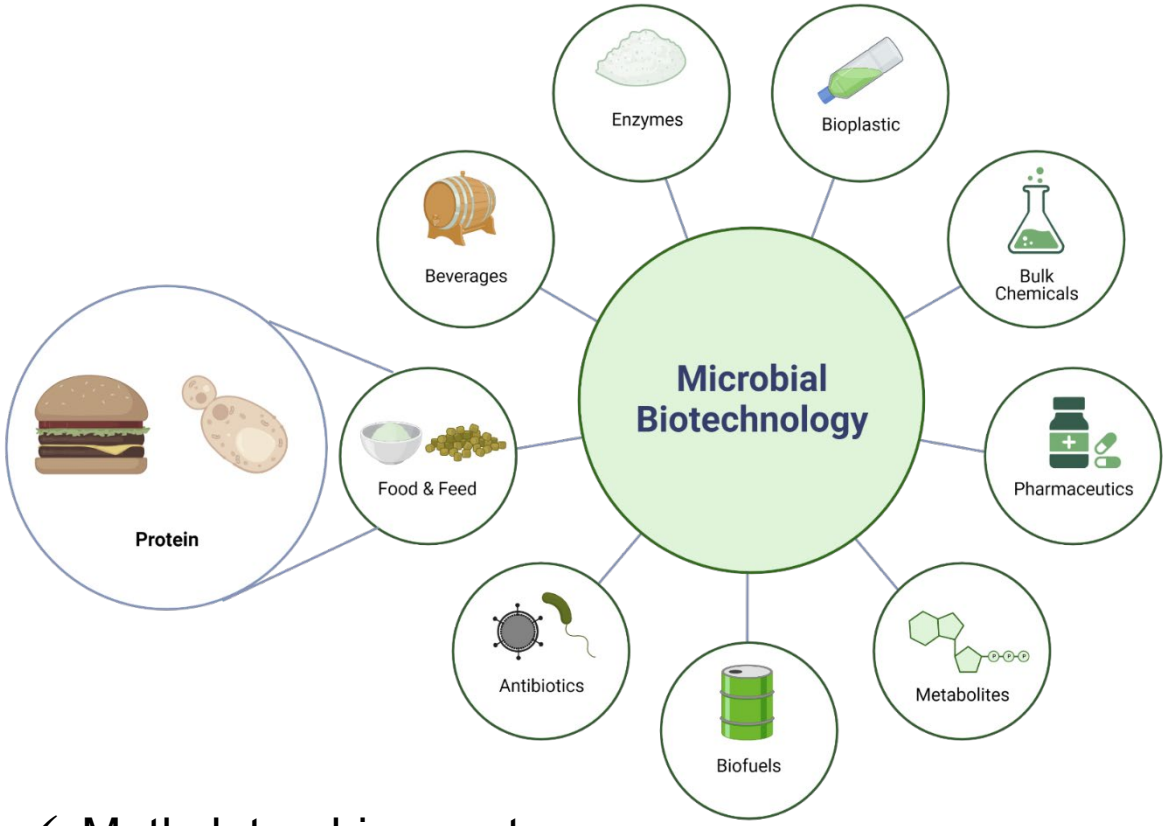
Acetogenic Conversion

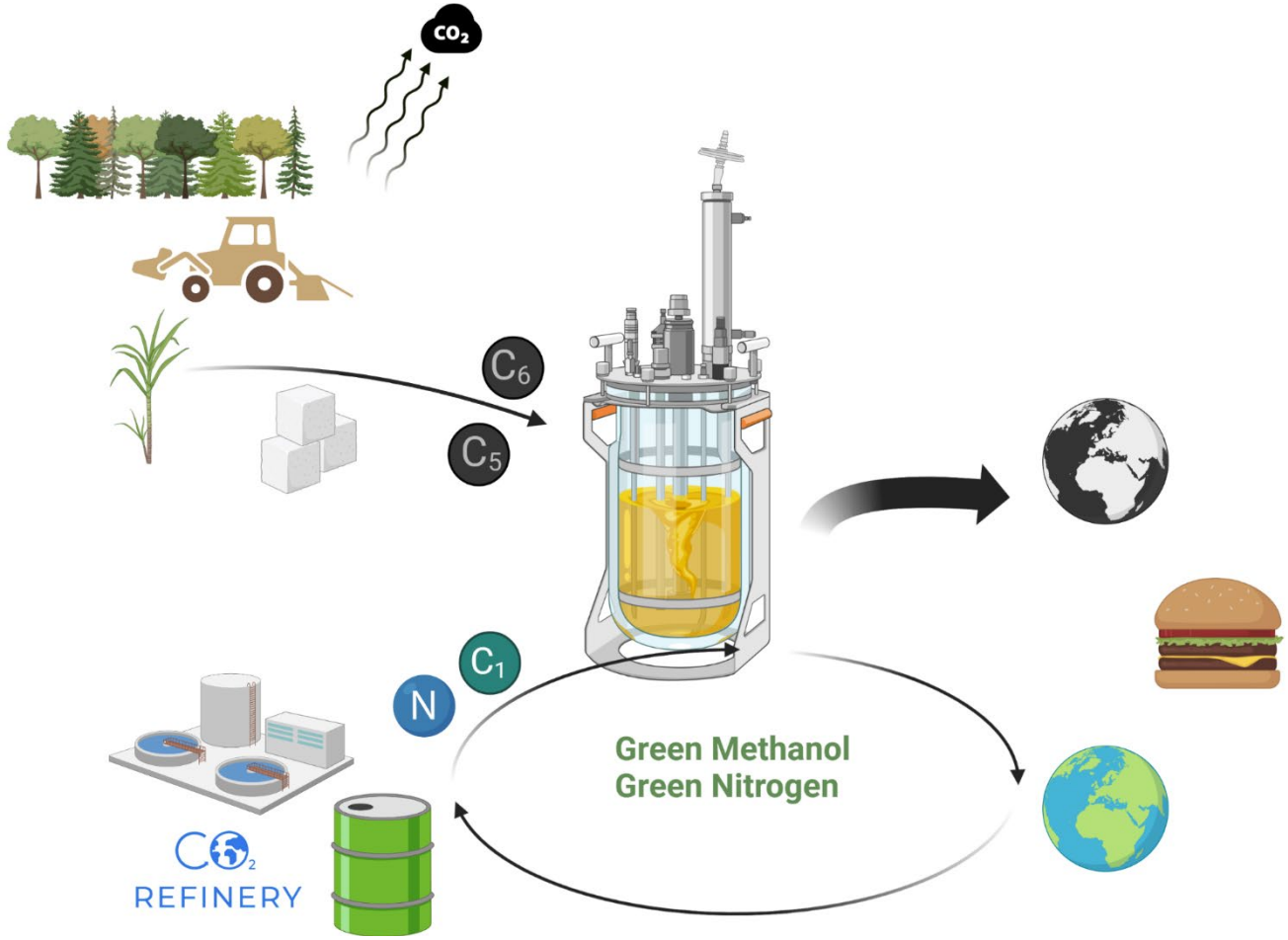
PhD #4: Ivo van den Hurk



FROM: HTTP://CURRENTAGRIC.BLOGSPOT.COM/2013/03/ACETOGENIC-BACTERIA.HTML

Methanol to protein - making methanol conversion more efficient



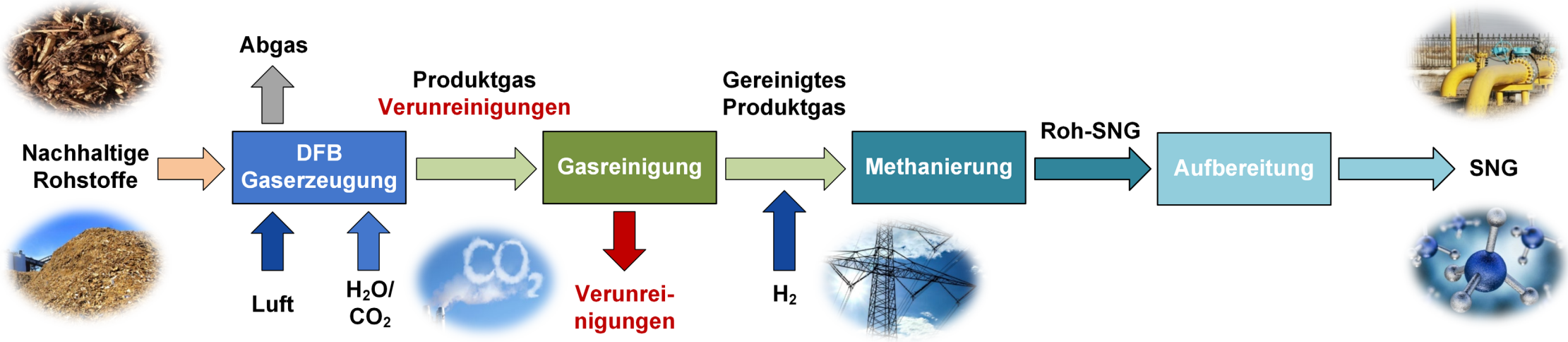


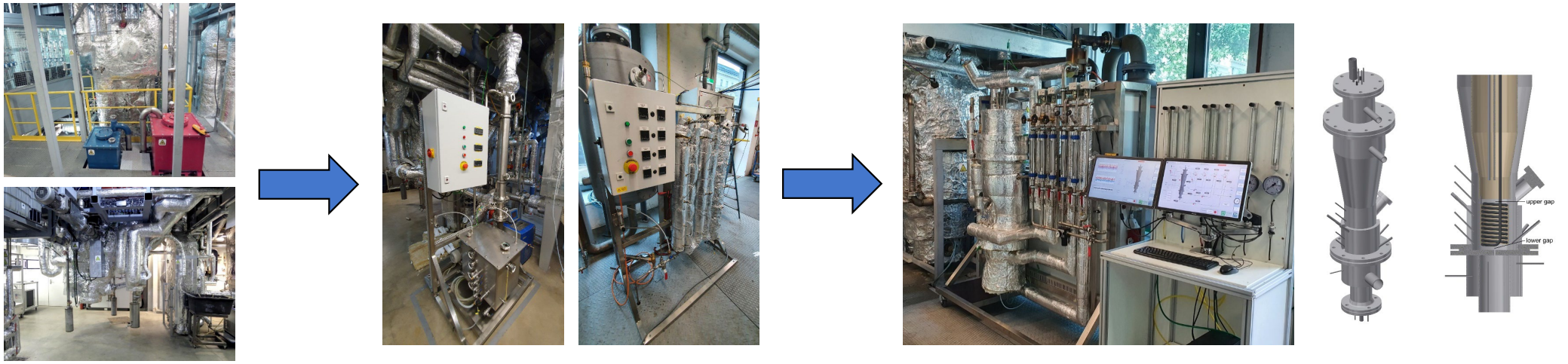
- ✓ Methylotrophic yeast
- ✓ *P. pastoris*
- ✓ *Metabolic engineering*
- ✓ *Yeast fermentation with sustainable feedstocks*

PhD #6: Shirvani Roghayeh

Produktion von Erdgas aus nachhaltigen Rohstoffen

PhD #7: Alexander Bartik

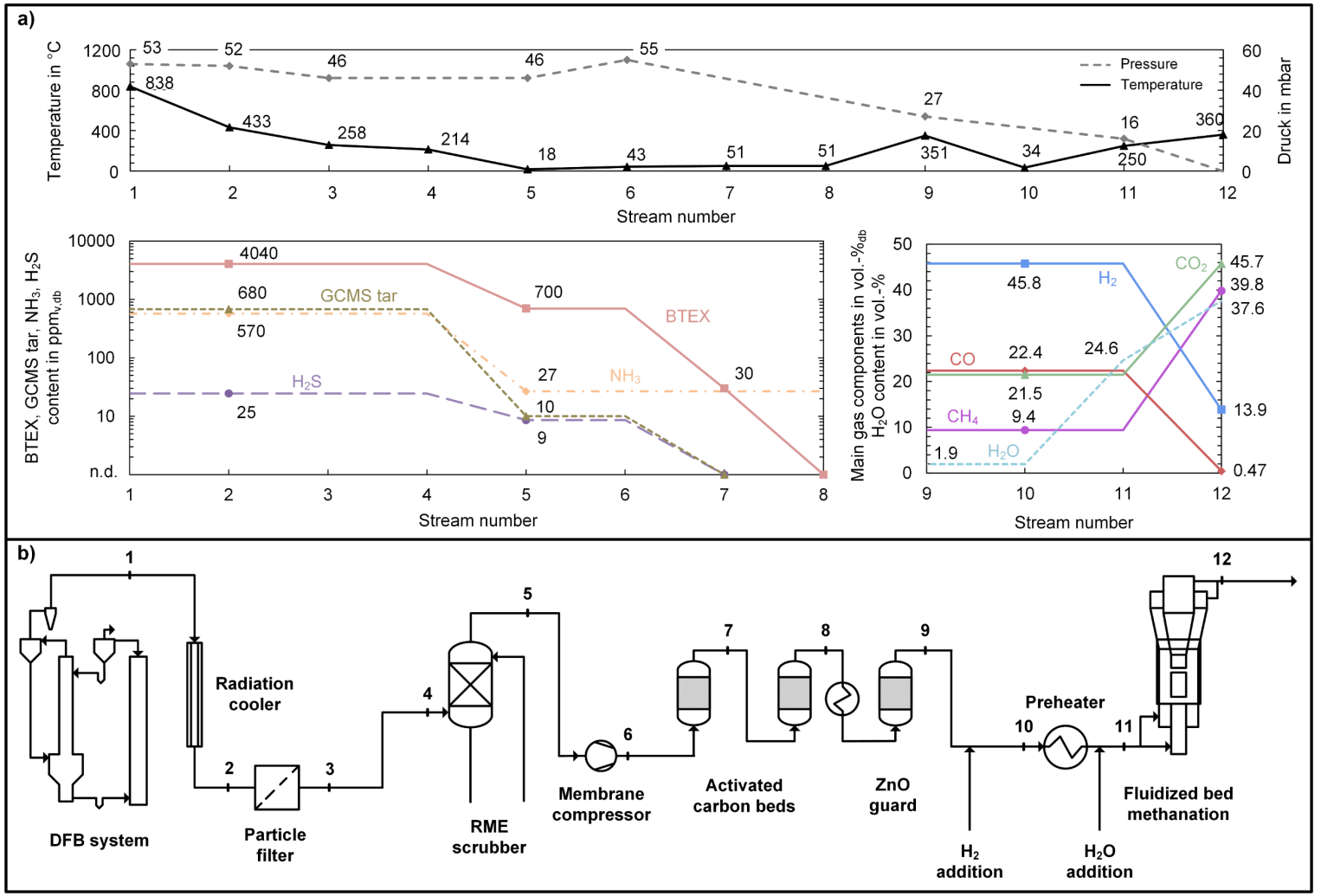




Untersuchungen im VT-Technikum der TU Wien

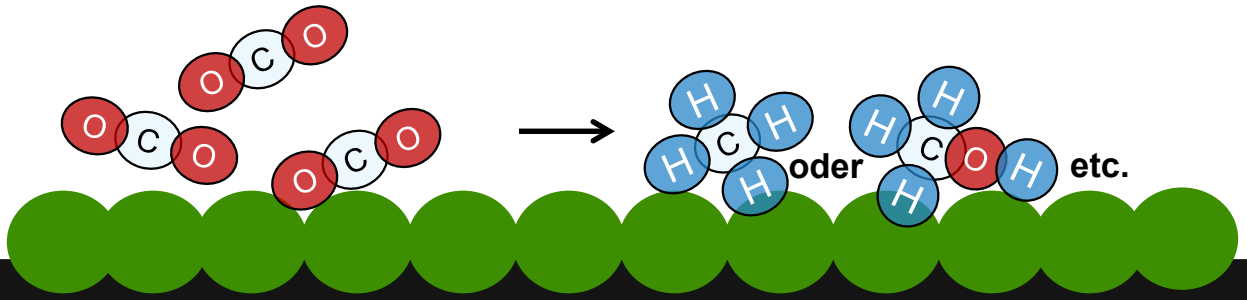
- Experimentelle Untersuchung im Technikumsmaßstab
- Gaserzeugung aus verschiedenen Reststoffen
- **Optimierter Katalysator für Wirbelschichtanwendungen**
- Optimierte Prozesskette durch H_2-Zudosierung und in-situ Adjustierung der Synthesegaszusammensetzung

PhD #7: Alexander Bartik



Porous ceramic frameworks for CO_2 utilization

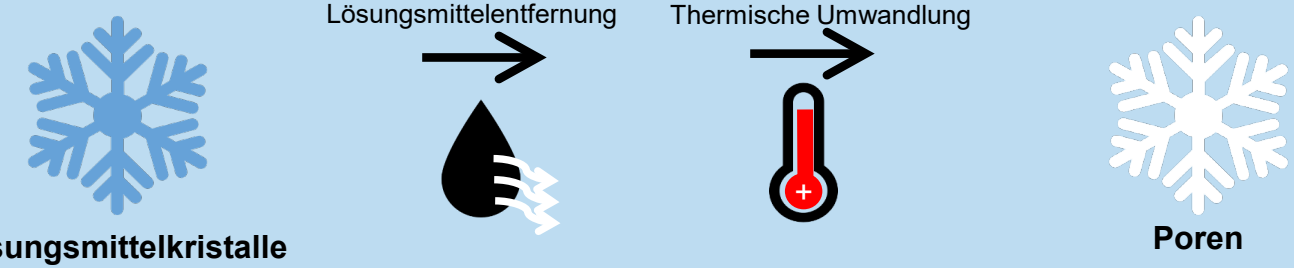
PhD #8: Katharina Rauchenwalder

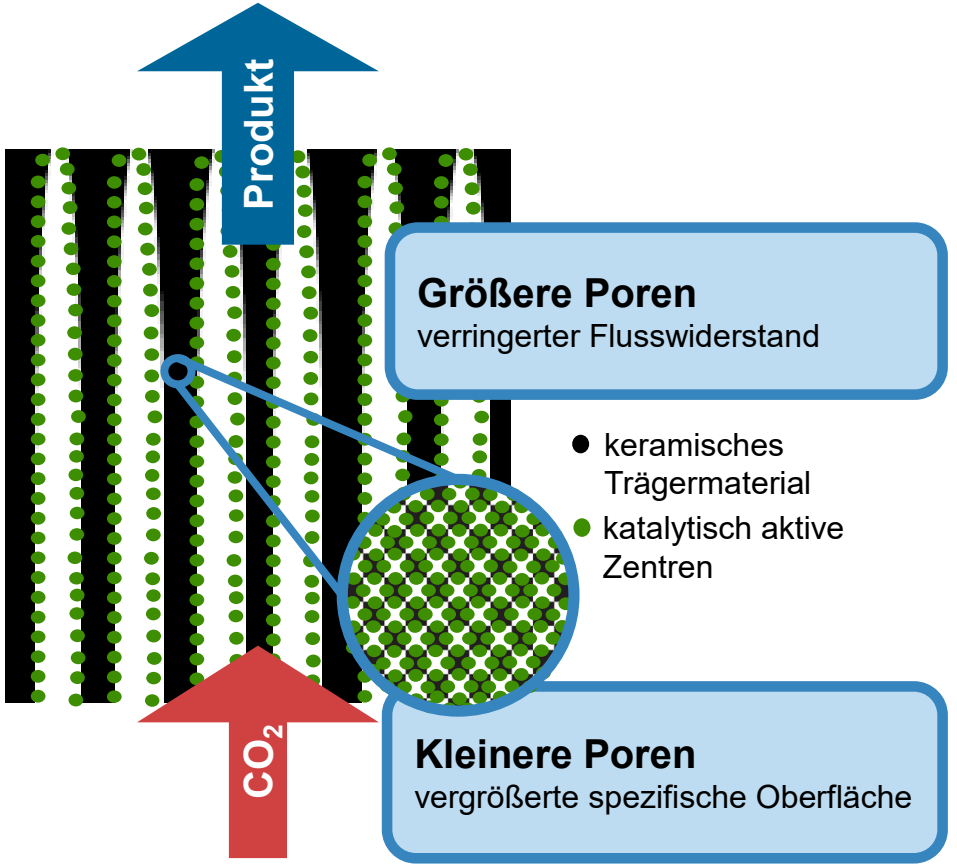


Poröses keramisches Trägermaterial

- Herstellung von Keramiken mit **ausgerichteten Porenstrukturen**.
- Design von Porenstrukturen in unterschiedlichen **Größenhierarchien.**
- Verankerung von reaktiven **Metallzentren** für **CO_2 Umwandlungssprozesse.**

Ice templating

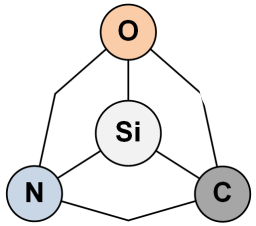




Porous ceramic frameworks

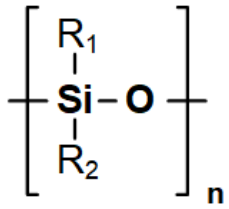
PhD #8: Katharina Rauchenwalder

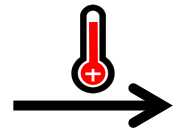
Polymer-derived ceramics	PDCs	konventionelle Keramiken
Chemische Modifizierbarkeit	+	~
Formgebung	+	~
Niedrigtemperaturbehandlung	+	~
Mechanische Stabilität	+	+
Chemische Stabilität	+	+
Thermische Stabilität	+	+
Bauteilschwindung	~	+



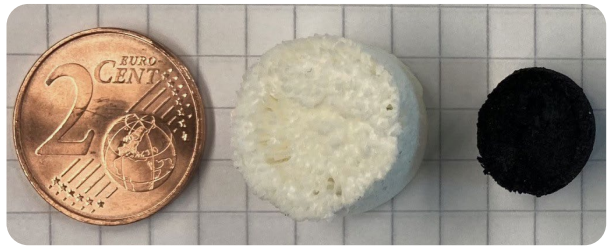
SiOC

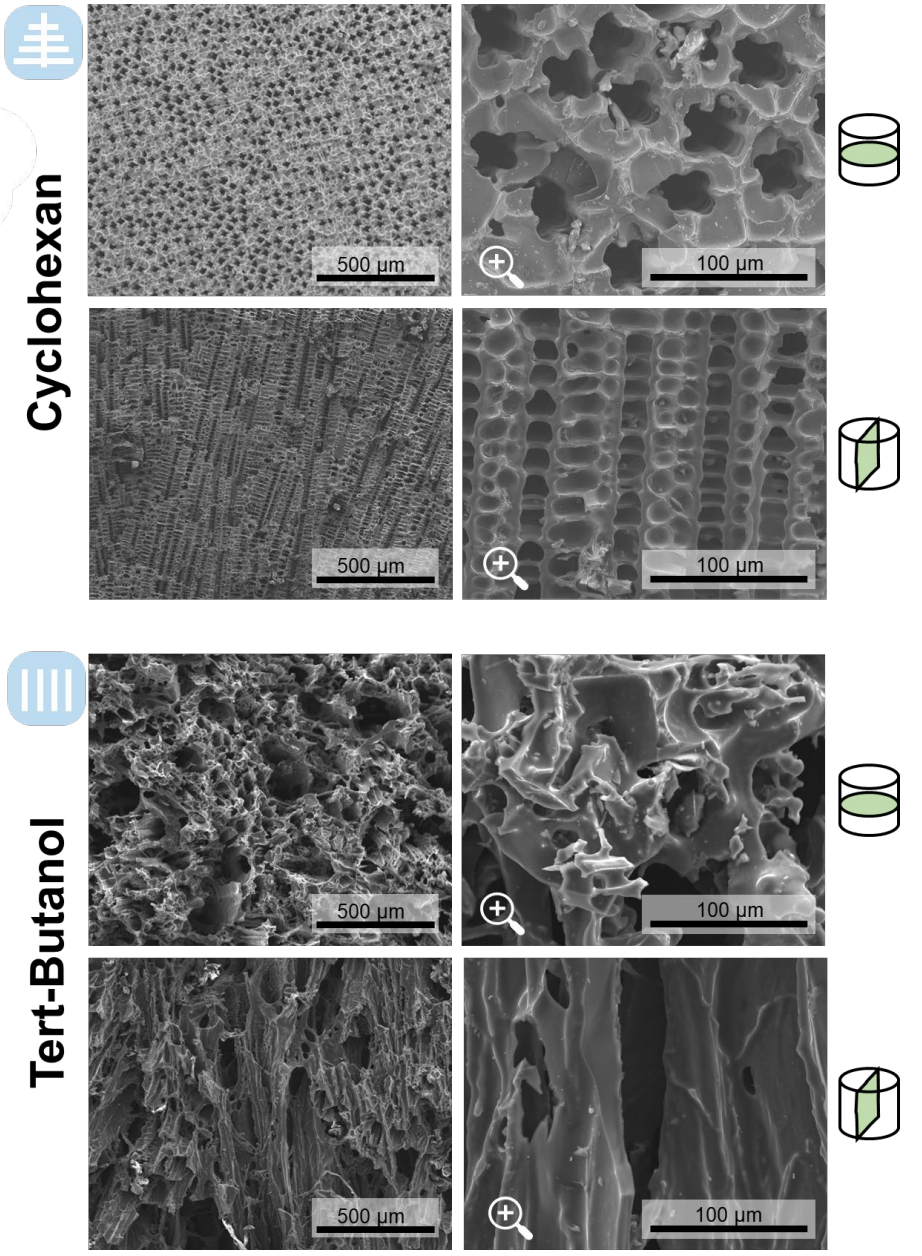
~ 30 % lineare Schwindung
~ 60 % keramische Ausbeute
~ 70 % Porosität





SiOC

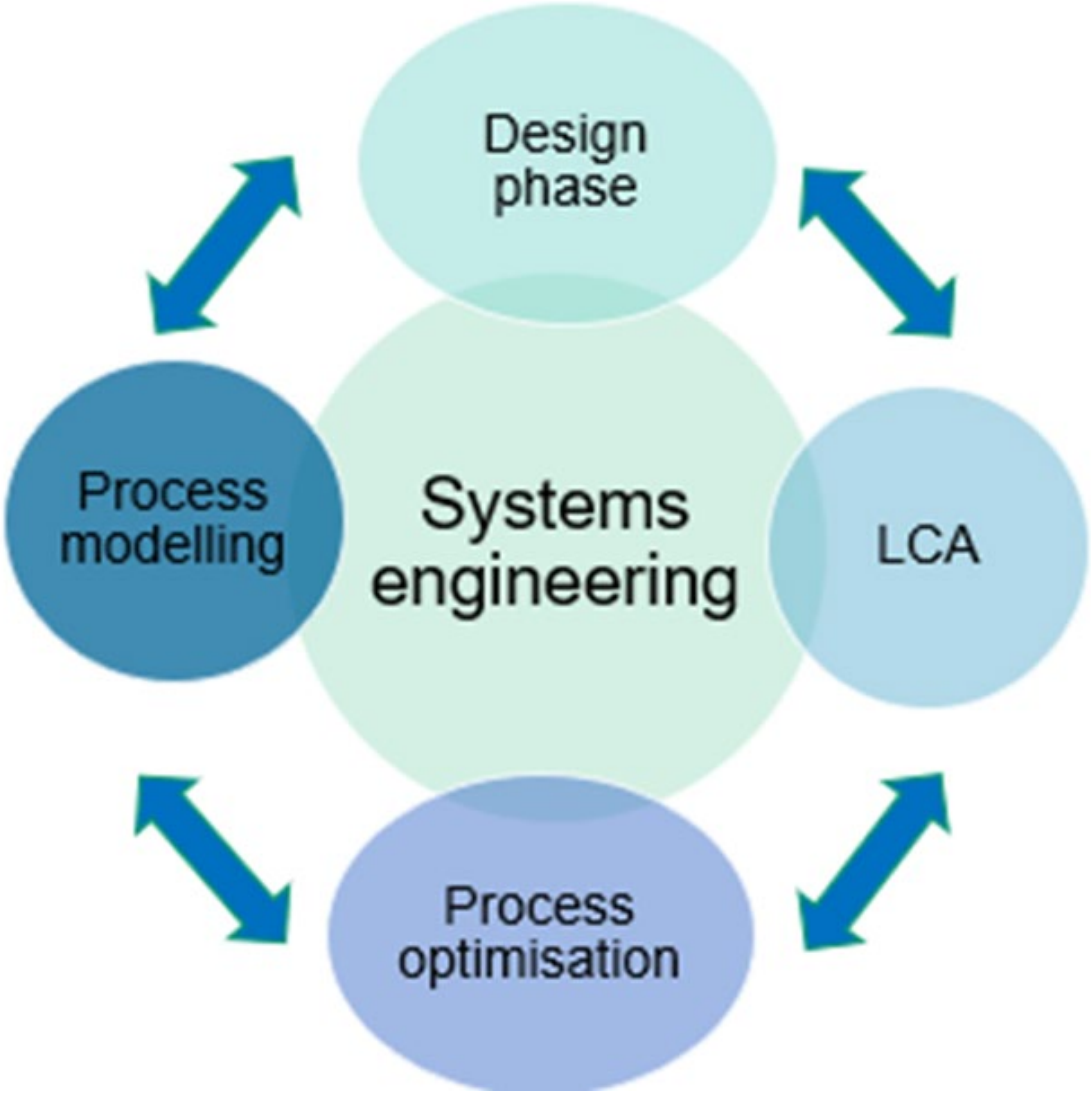




Systems Engineering and Life Cycle Assessment (LCA)

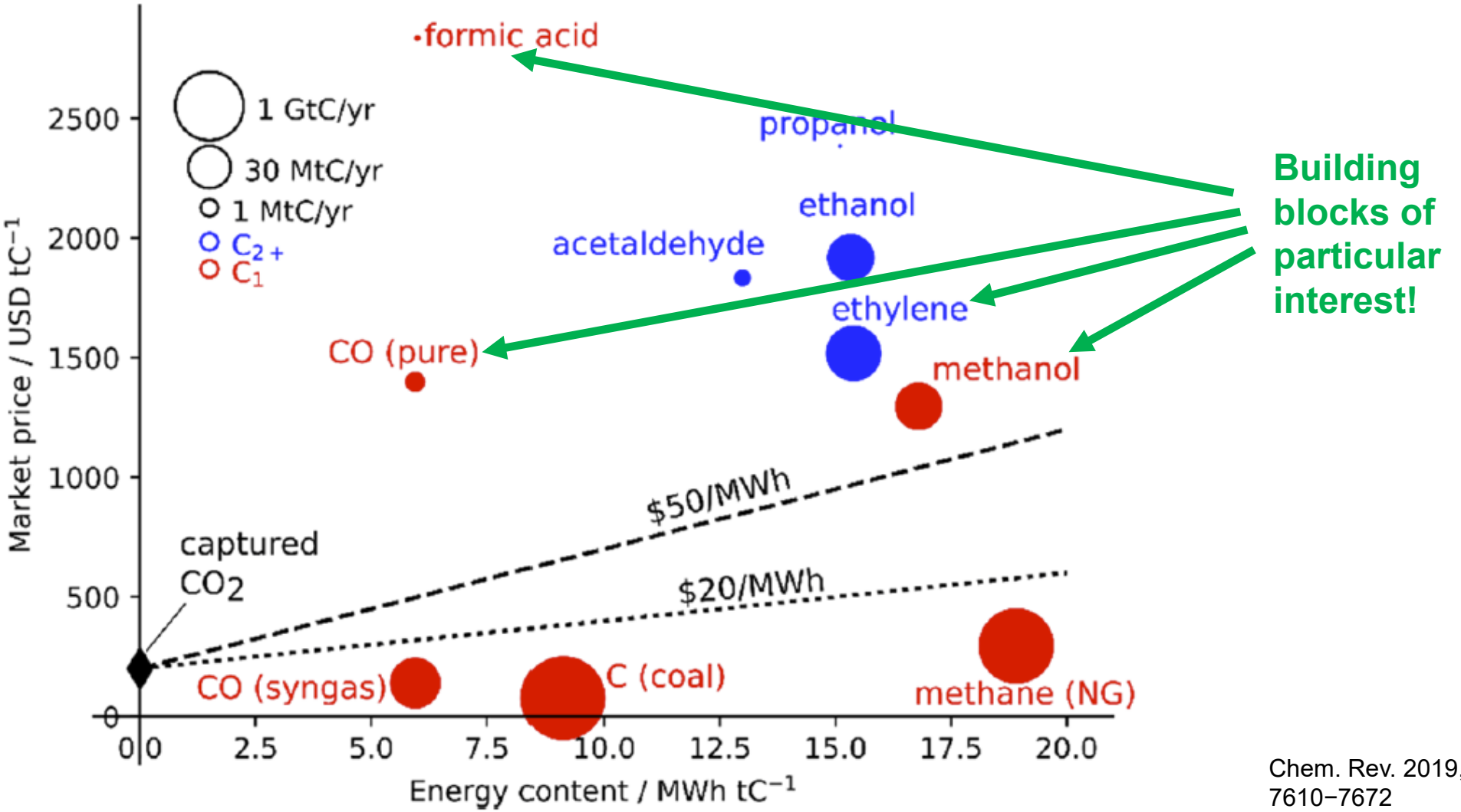
Motivation and Goals

- Develop a **process framework** to activate and upgrade CO_2 to valuable products – a CO_2 refinery
- Use **CO_2, reducing agents, energy and/or biomass** as feedstock for the **production of fine chemicals, biomaterials and fuels/energy carriers** – thus reducing fossil dependence AND emissions to the environment
- **Benchmark** by combined process simulation and LCA



PhD #9: Diana Dimande

Associated topics: Electrochemical CO_2 reduction

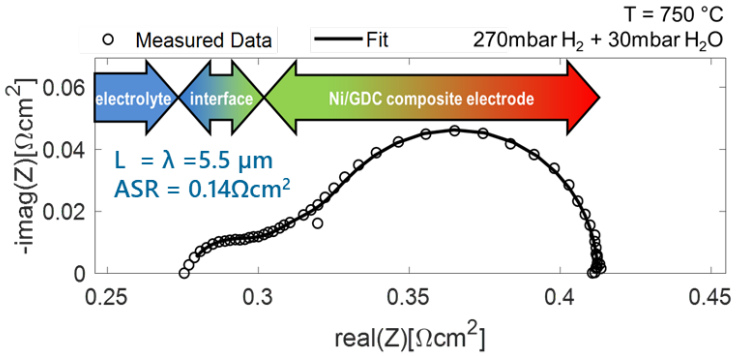


Building blocks of particular interest!

Chem. Rev. 2019, 119, 7610−7672

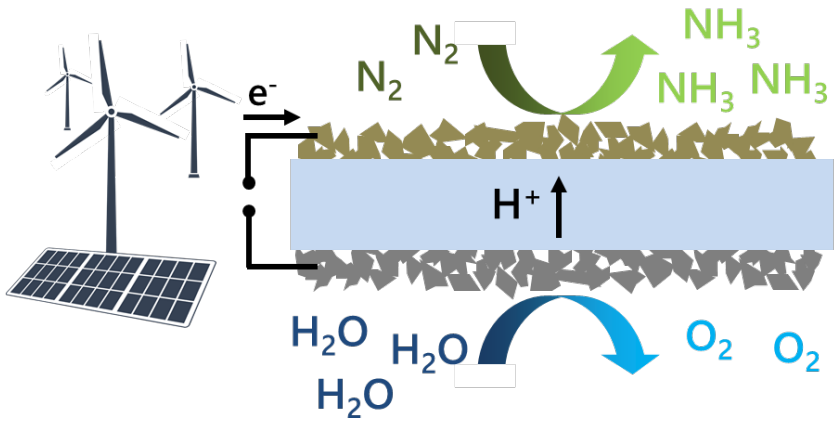
Associated topics: Electrochemical processes

- **High temperature electrolysis of H_2O and CO_2 in solid oxide cells**
- Model system supported performance optimization and in-situ surface chemical analysis of electrodes
- Electrochemical hydrogenation reactions – e.g. for decentralized ammonia synthesis



cathode: $N_2 + 6\,H^+ + 6\,e^- \rightarrow 2\,NH_3$

equivalent to high $p(H_2)_{cath}$



anode: $2\,H_2O \rightarrow 4\,H^+ + O_2 + 4\,e^-$

equivalent to low $p(H_2)_{an}$

Alexander Opitz
FG Electrochemical Energy Conversion

Empfehlungen für zukünftige F&E Aktivitäten in Österreich

- **Unterstützung der experimentellen Forschung auf mehreren TRL-Ebenen:**
  - Neue disruptive Konversionskonzepte (Grundlagenforschung)
  - Labor- und Pilotstudien
  - Demonstrationsprojekte (=> gesamte integrierte Prozesskette (!))
- **Fokus bei Demonstrationsprojekten auf wissenschaftliche Begleitung (Modellierung / Simulation / LCA / ökonomische Bewertung)**
- **Technologische Empfehlungen:**
  - Integrierte Prozessketten (Abscheidung – Konversion – Wiedereinschleusung in Nutzungskreisläufe), also inklusive Upstream, Downstream, Konzepte für Nebenprodukte und Kreislaufschließung
  - Elektrifizierung in der Prozesstechnik auf allen Ebenen & elektrochemische Aktivierungs- und Konversionstechnologien (Wasserelektrolyse versus CO_2-Elektrolyse)
  - Nachweis der Skalierbarkeit (!)
  - C1 Plattformmoleküle: Methan, Methanol, Formaldehyd, Ameisensäure
  - Biotechnologische Prozesse (Gasfermentation (!))

(Michael Harasek)

CO2 REFINERY

TU WIEN

Visit us here: www.tuwien.at/co2refinery