



Synthetische Brenn- und Treibstoffe

Christian Bach

Abteilungsleiter Chemische Energieträger und Fahrzeugsysteme
Co-Koordinator SWEET-Konsortium reFuel.ch

Empa – Eine Forschungsanstalt im ETH-Bereich

für Materialwissenschaften und Technologie

Eidgenössisches Departement für Wirtschaft,
Bildung und Forschung WBF

ETH-Rat

ETHZ

EPFL

PSI

Empa

Eawag

WSL

Technische
Universitäten

Forschungsanstalten



Guy Parmelin
Bundesrat



Prof. Dr. Michael O. Hengartner
Präsident ETH-Rat



Prof. Dr. Tanja Zimmermann
Direktorin Empa

Abt. Chemische Energieträger und Fahrzeugsysteme

Intelligente, vernetzte und klimafreundliche Mobilität

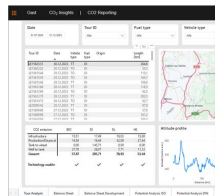
Research Group Vehicle Systems

Vehicle Operations & Fleet transformation

- Machine learning for vehicle clustering
- Real-world energy consumption
- Fleet transformation approach

Sensors for autonomous driving

- Sensor selection model and sensors on

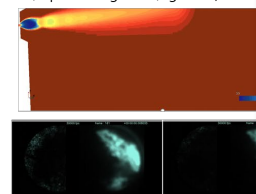


Niroomand et al. (2021): Vehicle Dimensions Based Fuzzy and Non-Fuzzy Clustering Methods, Transportation Research Part D
 Elser et al. (under Review): Trends in Swiss Passenger Vehicle Learning Classification, Transportation Research Part D

Research Group Powertrain Systems

Diffusion-Controlled Hydrogen Combustion for Efficiency Increase

instead of classical premixed approach (CFD, optical diagnostic, ignition)



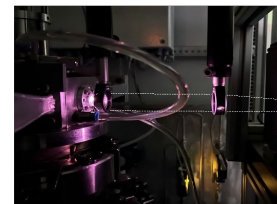
Balmelli et al. (2024): Optical and thermodynamic investigation of jet-guided combustion, International Journal of Hydrogen Energy
 Merotto, Balmelli, Sollic (2024): Hydrogen direct injection: Optical investigation guided combustion modes, International Journal of Hydrogen Energy
 Balmelli et al. (2024): Zero-Dimensional Modeling of a Nanosecond Pulsed

Air Supply

Research Group Hydrogen Systems

Plasma based CH₄ decomposition

Plasma Spectroscopy and simulation, carbon analysis and processing



Cooperation with Empa Lab 402 towards «CO₂-free» carbon Mining the Atmosphere projects

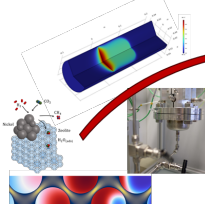
Heat transfer at high pressure H₂ refueling

Numerical simulations assisted by selected

Research Group Reactor and Processes for Power-to-X

Reaction engineering

Sorption-enhanced catalysis, membrane load-flexibility & electrification



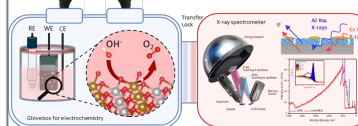
Kiefer et al., Chem. Eng. J. 499 (2022) 137872
 Nikolic et al., PCCP 2024 (under review)

Process design

Research Group Hydrogen Spectroscopy

Hydrogen Catalysis

Renewable fuels rely on the efficient conversion of hydrogen containing molecules.



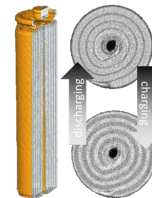
High-end characterization and performance of rationally designed (electro-) catalysts for water splitting, hydrogenation and oligomerization reactions.

F. Longo, et al., ACS Appl. Mater. Interfaces in press (2024)
 S. Kazaz, et al., Adv. Sci. 11, 2304603 (2024)
 A. Cesarini, et al., to be published (2024)

Hydrogen Analysis

Operando visualization of hydrogen at the surface as well as in the bulk is needed to understand the materials - device - performance relationship in hydrogen devices.

E.g., to follow the H-distribution during charging of a Ni-MH battery, and in hydrogenation reactors by neutron imaging.

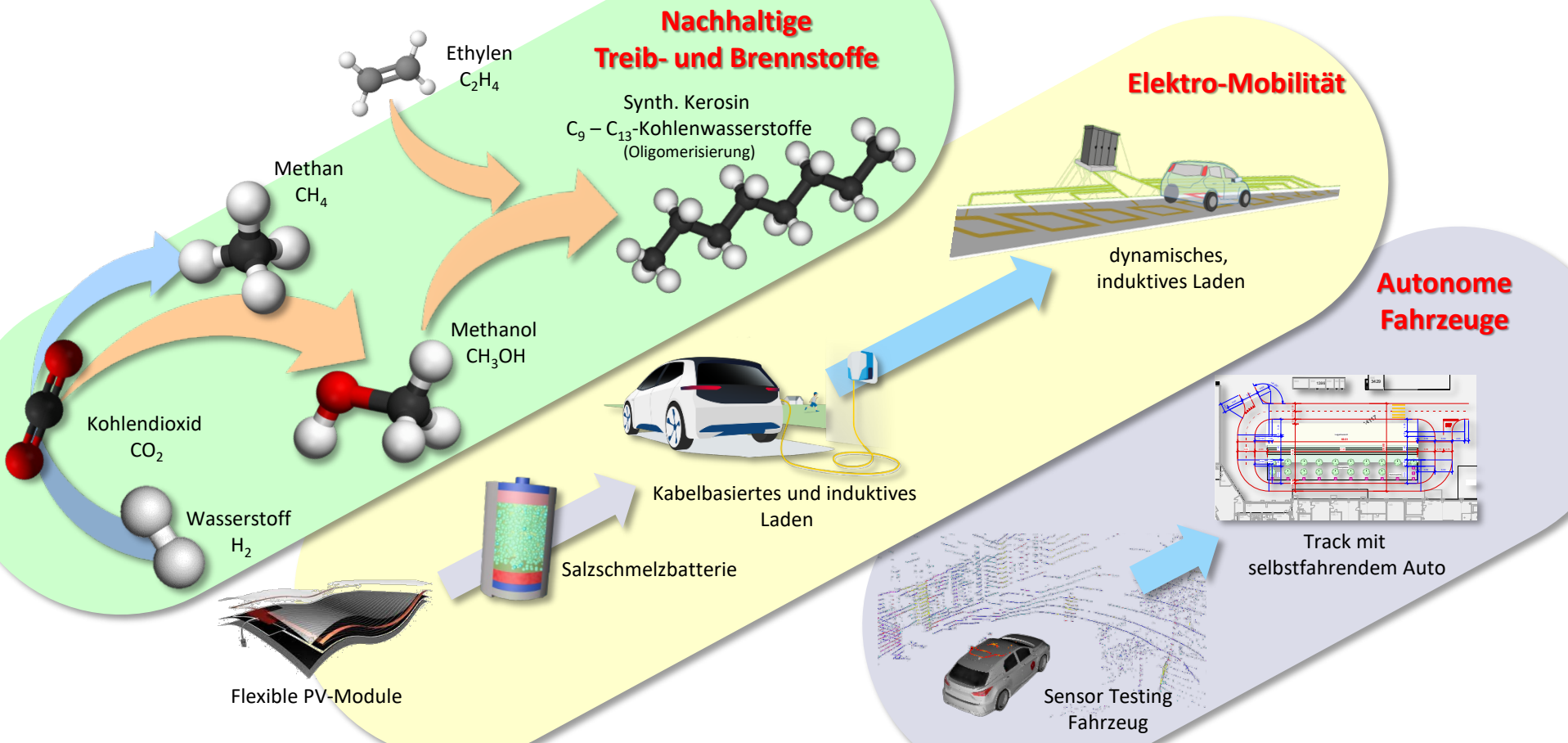


M. Nikolic, et al., Angew. Chem. Int. Ed., e202307367 (2023)
 M. Nikolic, et al., Phys. Chem. Chem. Phys., 24, 27394 (2022)

Umsetzung
 Demonstratoren,
 Industrie-/Marktkooperationen

Der Future Mobility Demonstrator «move»

Nachhaltige Treib- und Brennstoffe, Elektromobilität und autonome Fahrzeuge



erneuerbare anstelle von fossiler Energie

Netto Null CO₂
Negative CO₂-Emissionen

bis 2050

*Nutzung bestehender Handelsmechanismen
und Infrastrukturen*

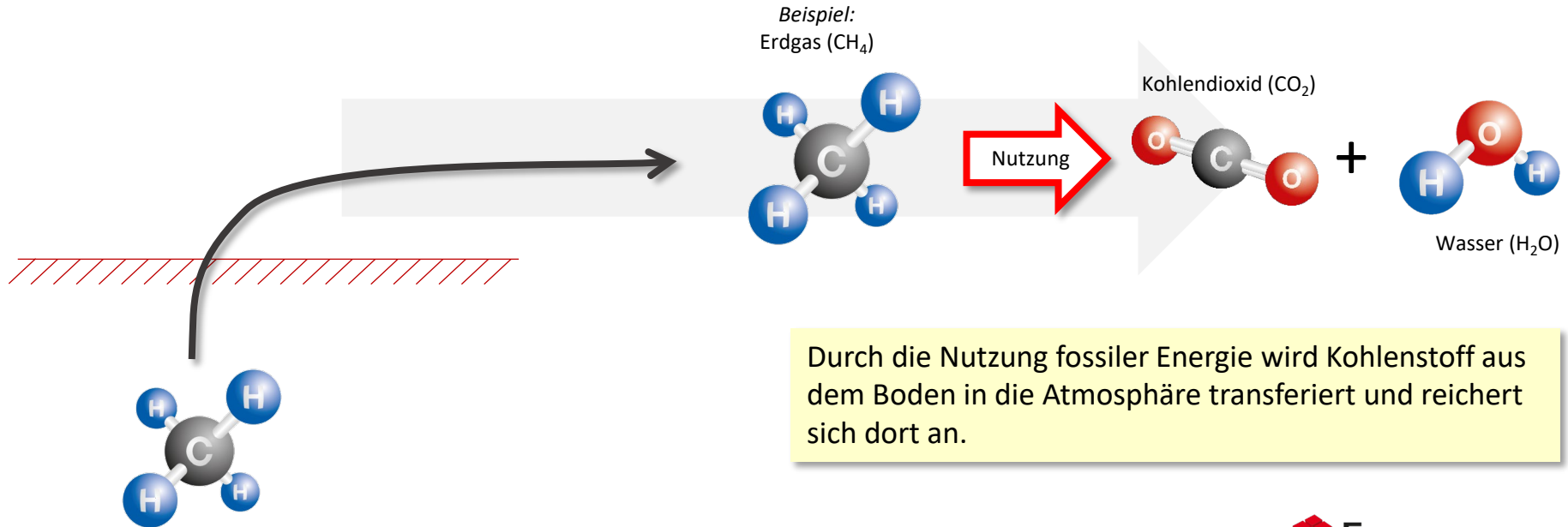
Bundesrat, 28.08.2019

Inhalt

- 1. Was sind synthetische (künstliche) Brenn- und Treibstoffe?**
2. Skalierungsprojekt in Oman
3. Möglichkeit zur Erzielung negativer Emissionen
4. Zusammenfassung

Was sind fossile Energieträger?

Fossile Energieträger mit linearem Kohlenstoff-Transfer in die Atmosphäre



Durch die Nutzung fossiler Energie wird Kohlenstoff aus dem Boden in die Atmosphäre transferiert und reichert sich dort an.

Was sind «synthetische» Energieträger?

Biofuels

Konventionelle Biotreibstoffe

Nahrung & Futtermittel (Annex IX B)

Advanced Biofuels

Nicht-Nahrungsmittel (Annex IX A)

Biomethane / Bio-LNG

Vergärung od. Vergasung biogener Rohstoffe

Bio-based fuels (HVO etc.)

Hydrierung pflanzl./tier. Öle & Fette

Ausgangsstoff: Biomasse
THG-Einsparung: $\geq 65\%$ vs. fossil
Annex V/VI RED III

■ Biogener Ursprung

RFNBO

Renewable Fuels of Non-Biological Origin

Grüner Wasserstoff (H_2)

Elektrolyse mit ern. Strom (PtG)

e-Methan (CH_4)

$H_2 + CO_2$ (PtG)

e-Methanol / e-DME

$H_2 + CO_2$ (PtL)

e-Kerosin / e-Diesel

$EE\text{-Strom} + H_2O + CO_2$
Additionalität + zeitl/geogr. Korrelation
THG-Einsparung: $\geq 70\%$
Del. VO 2023/1184

■ Erneuerbare Elektrizität

RCF

Recycled Carbon Fuels

Flüssige RCF

Pyrolyse/Vergasung nicht-rezykl. Abfälle & Reststoffe

Gasförmige RCF

Synthesegas aus fossilen Abgasströmen (CCU)

e-Fuels aus fossil- CO_2

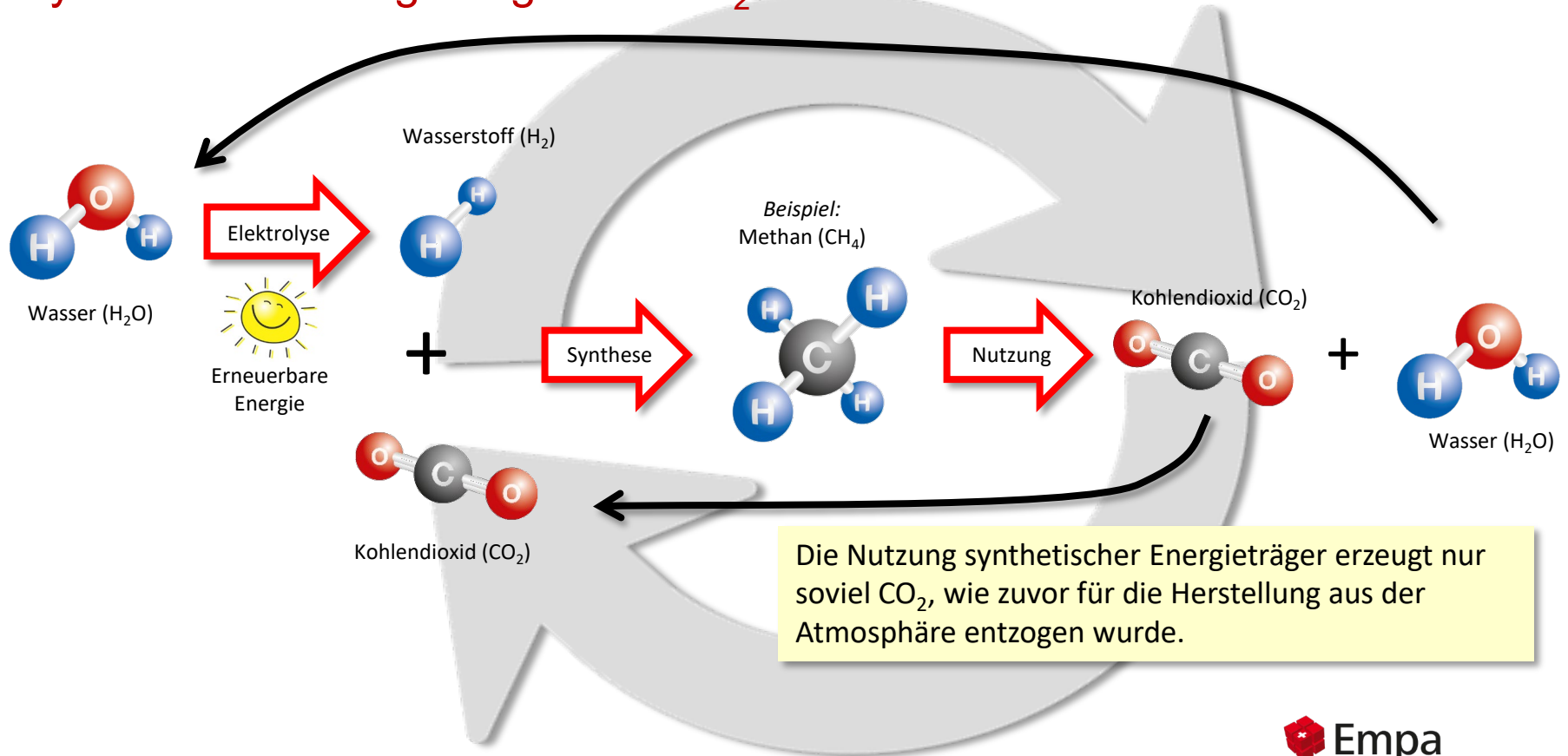
PtL/PtG mit CO_2 aus fossilen Industriequellen

Nicht-recyclebare fossile/ind. CO_2 -Quellen
Kein RFNBO-Status möglich (fossiles CO_2)
THG-Einsparung: $\geq 70\%$
Del. VO 2023/1185

■ Fossiler C-Kreislauf (Übergangslösung)

Was sind nachhaltige Energieträger?

Synthetische Energieträger mit CO₂-Kreislauf



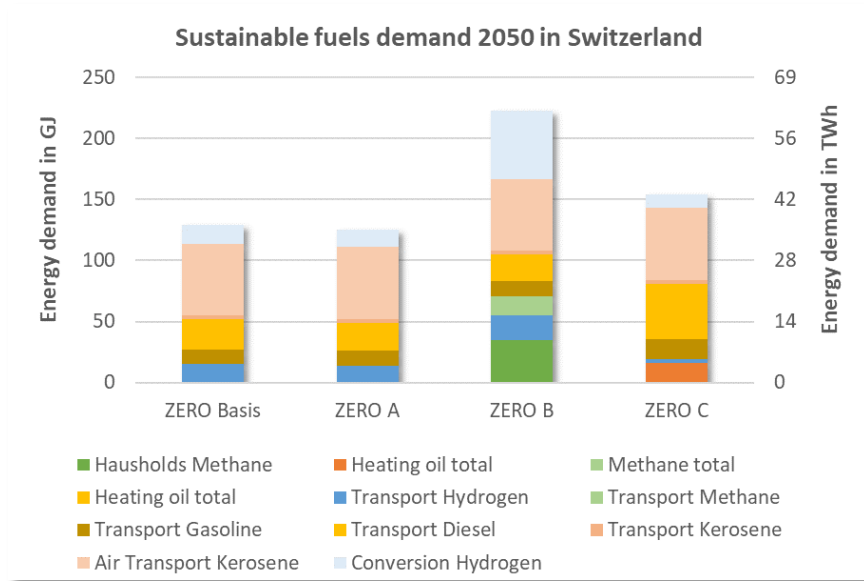
Die Nutzung synthetischer Energieträger erzeugt nur soviel CO₂, wie zuvor für die Herstellung aus der Atmosphäre entzogen wurde.

Bedarf an nachhaltigen Brenn- und Treibstoffen

Der Bedarf an nachhaltigen Brenn- und Treibstoffen wird in den Energieperspektiven 2050+ des Bundesamtes für Energie (BFE) bis 2050 je nach Szenario auf 110 bis 220 GJ bzw. **30 bis 60 TWh/Jahr** geschätzt.

- ZERO Basis: intensive Elektrifizierung
- ZERO A: intensive Elektrifizierung
- ZERO B: inkl. erneuerbare Gase (PtH₂/PtG)
- ZERO C: inkl. erneuerbare flüssige Brenn-/Treibstoffe (PtL)

Es wird davon ausgegangen, dass **>90 % davon importiert** werden müssen.



Inhalt

1. Was sind synthetische (künstliche) Brenn- und Treibstoffe?
- 2. Skalierungsprojekt in Oman**
3. Möglichkeit zur Erzielung negativer Emissionen
4. Zusammenfassung

Oman Projektinitiative: Policy support

Memorandum of Understanding

Unterzeichnet im November 2023

Collaboration letter

Unterzeichnet im November 2023

Implementation programme

Unterzeichnet im Mai 2025

Letter of Intent

Unterzeichnet im Dezember 2025

MEMORANDUM OF UNDERSTANDING
BETWEEN
THE FEDERAL OFFICE OF ENERGY OF THE SWISS CONFEDERATION
AND
THE MINISTRY OF ENERGY AND MINERALS
OF THE SULTANATE OF OMAN
IN THE FIELDS OF SUSTAINABLE AND RENEWABLE ENERGY AND
RENEWABLE ENERGY TECHNOLOGIES

Stemming from the distinguished relations between the Swiss Confederation and the Sultanate of Oman, and the desire of both countries to continue promoting and developing cooperation between Oman, and the fields of sustainable and renewable energy, and sustainable and renewable energy technologies, based on the reciprocal benefits and in light of the discussions held between Swiss and Omani sides, the Federal Office of Energy of the Swiss Confederation and the Ministry of Energy and Minerals of the Sultanate of Oman, (hereinafter referred to jointly as the "Partners") have agreed to the following:

Paragraph 1

This Memorandum aims to develop a bilateral cooperation in the fields of sustainable and renewable energy and sustainable and renewable energy technologies for the purpose of achieving the following objectives:

1. Promote autonomous interaction between the private sector of both countries in the fields of energy, scientific and technical assistance and joint research, storage and distribution of energy.
2. Facilitating the interaction for the implementation of knowledge and best practices in the fields of sustainable and renewable energy, efficiency, and decarbonization.



IMPLEMENTATION PROGRAMME OF THE MEMORANDUM OF UNDERSTANDING BETWEEN THE MINISTRY OF ENERGY AND MINERALS OF THE SULTANATE OF OMAN AND THE FEDERAL OFFICE OF ENERGY OF THE SWISS CONFEDERATION IN THE FIELDS OF SUSTAINABLE ENERGY AND SUSTAINABLE ENERGY TECHNOLOGIES

Driven by the desire to strengthen the friendly relations, promote cooperation in the fields of sustainable and renewable energy, as well as its technologies, and in pursuance of the Memorandum of Understanding between the Government of the Sultanate of Oman and the Federal Office of Energy of the Swiss Confederation, signed in Muscat on 30 November 2023, the Ministry of Energy and Minerals of the Sultanate of Oman (hereinafter referred to as the "Omani Party") and the Federal Office of Energy of the Swiss Confederation (hereinafter referred to as the "Swiss Party"), hereinafter referred to together as the "Partners", have agreed to facilitate the following Implementation Programme (the "Programme") by Omani and Swiss Implementing Partners (the "Partners"). Partners can be government entities, state-owned companies, private sector companies, business associations, academia & research institutions.

ARTICLE (1) OBJECTIVE

The objective of this Programme is to activate the bilateral MoU in the fields of sustainable energy and sustainable energy technologies of 30 November 2023 for the coming two years, and to support the concretization of activities between the Partners of the Parties.

ARTICLE (2) PROGRAMM SCOPE OF WORK

As part of fulfilling the Objectives, Parties agree to facilitate the implementation of the following points:

1. **FX-synthesis processes (e.g. methanation)**
 - Share experience and knowledge in methanation process, research and pilot studies conducted by;
 - Share local experiences and efforts to realize methanation projects locally.
2. Conduct joint academic research in the field of methanation by organizing at least once a year academic workshop
3. Organize at least two knowledge sharing sessions

Embassy of
The Sultanate of Oman
Bern

Mr. Christian Bach
Head of Automotive Powertrain
Technologies Laboratory
EMPA
Lindenstrasse 129
8600 Dübendorf, Switzerland
Bern, 6th of November, 2023

Subject: **Agreement for collaboration**

Dear Mr. Bach,

Further to my last visit, along with Dr. Anika Kastner from the Oman-Swiss Friendship Association (OSFA), on last April, to your Federal Laboratory for Materials Science and Technology (EMPA), for discussing possible cooperation, the Embassy is delighted to kindly inform you that the Ministry of Energy and Minerals of the Sultanate of Oman has given officially its approval to collaborate with your Laboratory in the field of information exchange.

The focal point person responsible of the cooperation in this field is:
Mrs. Sultana Bina HANADOO AL NASRANI, Engineer in charge of electrical energy at the Department of Renewable Energy and Hydrogen Studies.
Email: sultana.b.alnasrani@mem.gov.om

The Embassy hopes that this will lead to open the perspectives of promising fruitful cooperation and will be pleased to bring any assistance in the future in this regard.

Please, accept Dear Mr. Bach, the expression of our best consideration.

The Ambassador
rahmadood AL HASANI



LETTER OF INTENT

Sulphur Port and Freezone
Port and Freezone
Sulphur 127 (Oman)
(hereinafter referred to as "Sulphur Port and Freezone")

and

Empa
Head of refuel.ch Consortium and coordinator Switzerland-Oman Cooperation
Chemical Energy Carriers and Vehicles Systems Laboratory
Lindenstrasse 137
8600 Dübendorf (Switzerland)
(hereinafter referred to as "Empa")

In the following, the above-mentioned signatures may be referred to individually as "Party" or collectively as "Parties".

1. **Preamble**

Port of Sulphur and Freezone is a fully integrated industrial along global trade routes between Europe and Asia. Operated by the ADNOC Group and the Port of Rotterdam, it is a long-term partnership, designed to stimulate investment in key technologies, hosted by Empa, the Swiss Federal Institute of Technology and a member of the ETH Campus, alongside the research institutions across Switzerland, along with the research institutions across Switzerland, along with the research institutions across Switzerland, along with the research institutions across Switzerland.

Within the refuel.ch consortium, an initiative was born to develop a synthetic drop-in fuels, such as methane, a gas with Swiss regulatory frameworks for CO₂ reduction obligations.

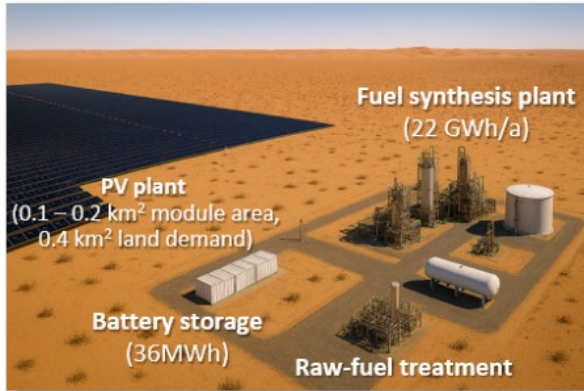


Oman Projektinitiative – Review/Diskussionspartner

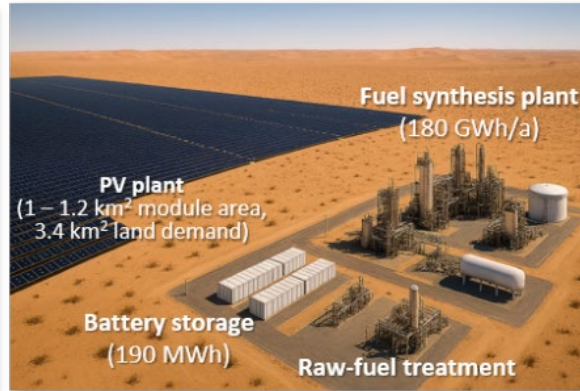


Skalierungsansatz

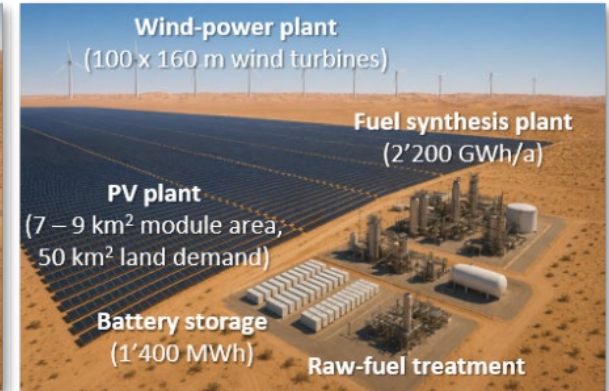
Stufe 1 (25 MW_{el})
Port of Sohar and Freezone



Stufe 2 (200 MW_{el})
Duqm (Hydrom auction)



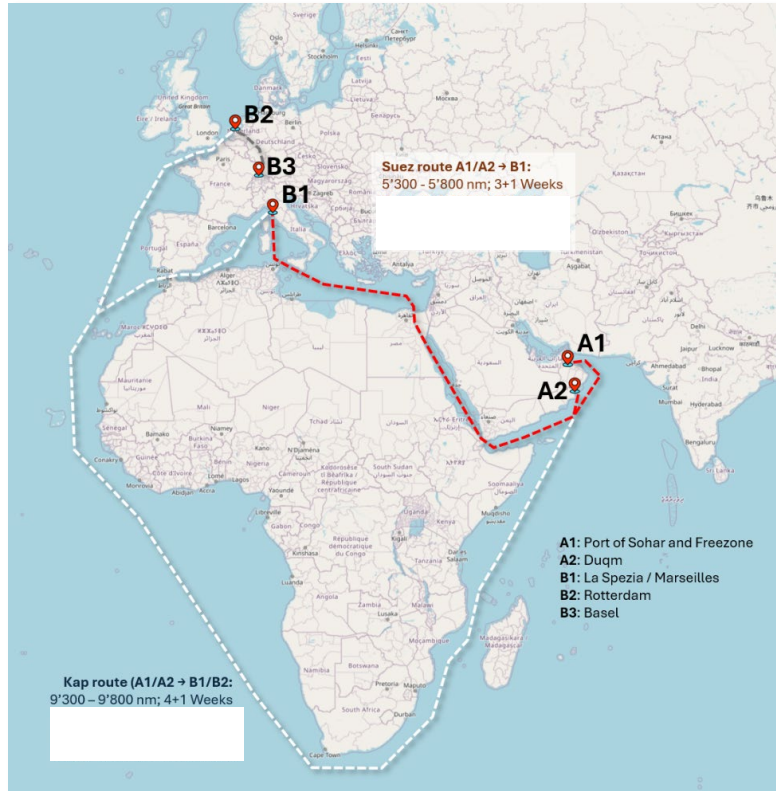
Stufe 3 (2'000 MW_{el})
Duqm (Hydrom auction)



- Herstellung von erneuerbaren Kraftstoffen nicht-biogenen Ursprungs (RFNBO)
- Zertifiziert nach der ISCC-EU-Richtlinie für erneuerbare Energien III (RED-III)
- Massensilanzierter Transport nach Europa/Schweiz

Transport nach Europa/Schweiz

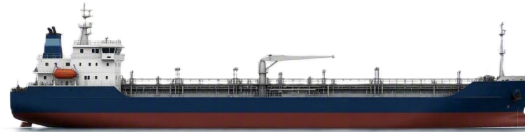
preliminary results



Stufe 1-Anlage: 1 x monatlich 20 ISO-Container nach Basel



Stufe 2-Anlage: 1 x monatlich 4'000 m³ Produkttanker nach Rotterdam mit Umladen auf Rheinschiff und Transport nach Basel



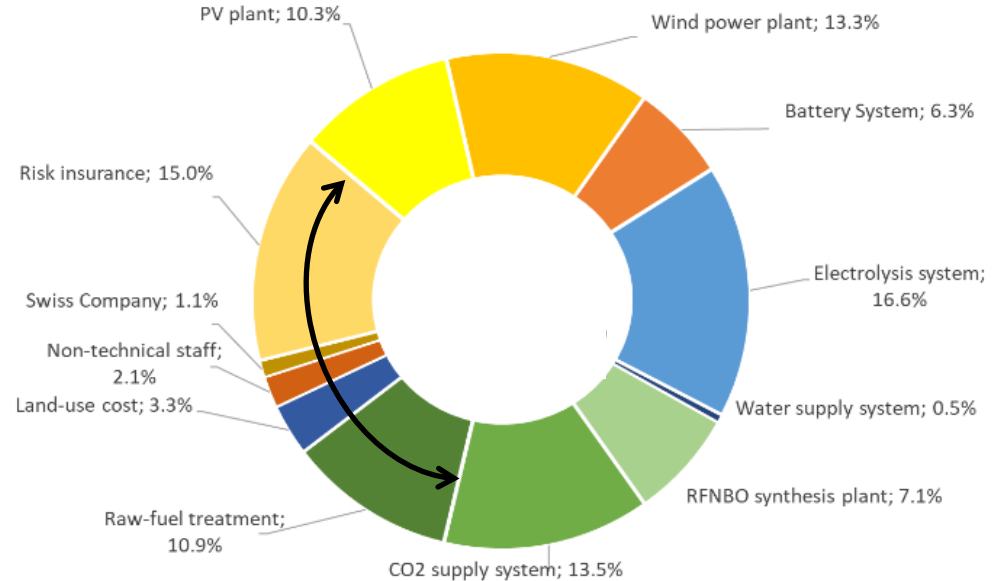
Stufe 3-Anlage: 1 x monatlich 50'000 m³ Tanker nach Marseille/Fos-sur-Mer und Einspeisung in Pipeline



Gestehungskosten

preliminary results

Die Gestehungskosten strombasierter nachhaltiger Brenn- und Treibstoffe setzen sich aus verschiedenen Positionen zusammen, die im Rahmen der Pre-Feasibility Studie analysiert wurden. Zusätzlich zu den Kostenpositionen des Global PtX Atlas (Fraunhofer Institut IEE) wurden weitere Kostenpositionen berücksichtigt (schwarzer Pfeil).

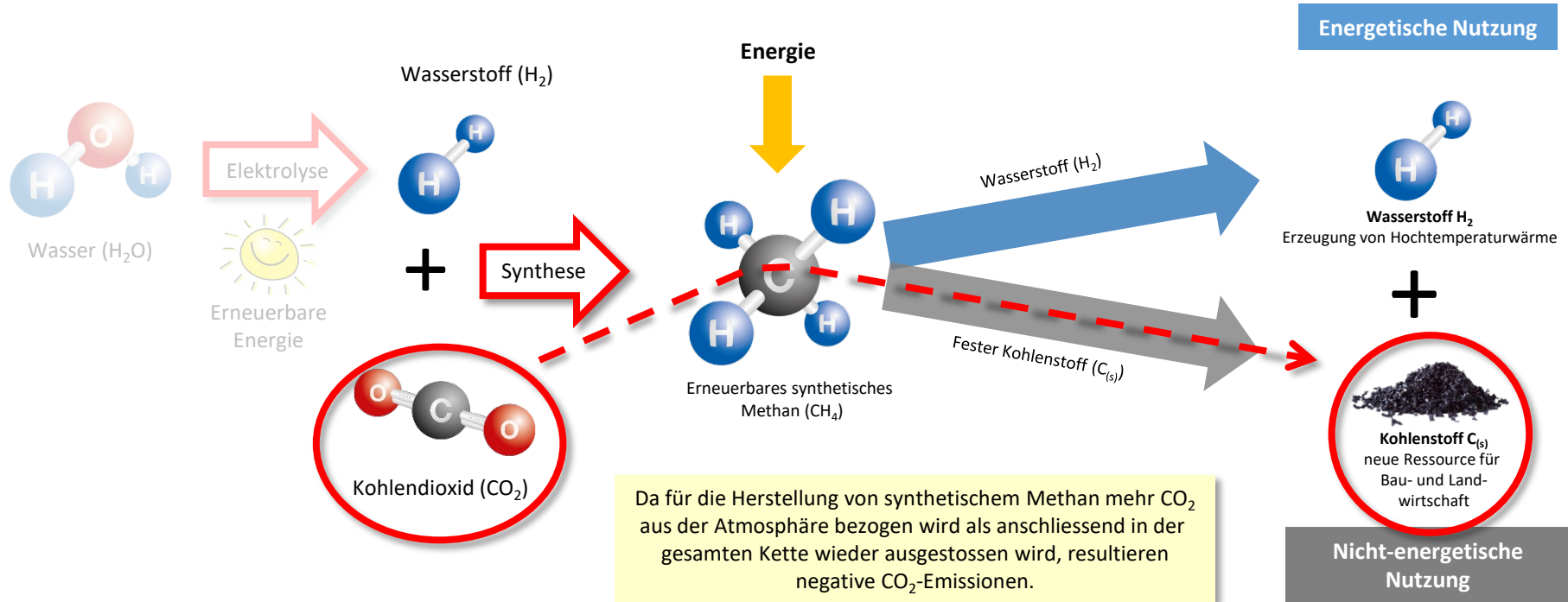


Inhalt

1. Was sind synthetische (künstliche) Brenn- und Treibstoffe?
2. Skalierungsprojekt in Oman
- 3. Möglichkeit zur Erzielung negativer Emissionen**
4. Zusammenfassung

Methan-Pyrolyse

Abspaltung von Kohlenstoff vor energetischer Nutzung



Ein Projekt des Vereins zur Dekarbonisierung der Industrie (VzDI)

Tech Cluster Zug AG, V-ZUG AG, Metall Zug AG, AVAG AG, Partners Group, Accelleron Industrial, SHL Medical AG, VZ Depotbank AG, WWZ AG, Sika AG, Amag Group AG, Siemens AG, Holcim, Empa

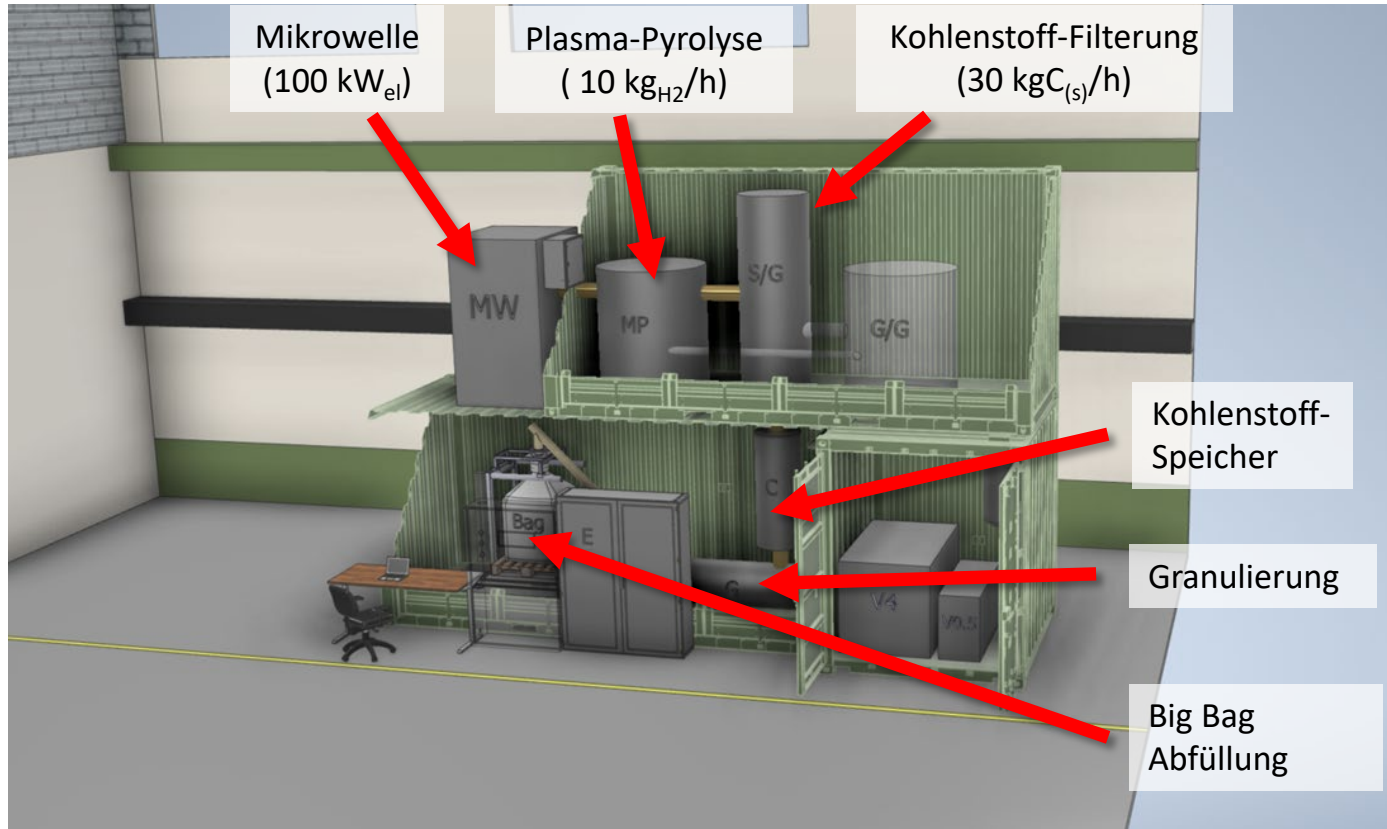
Umsetzung in Demonstratorprojekt in Zug

Verein zur Dekarbonisierung der Industrie (VzDI)



Visualisierung des Demonstrators

H₂ für den Emaillierungs-Ofen der V-ZUG und C_(s) mit Integration in Beton



Installation:
ab Oktober 2025

Inbetriebnahme:
Q1 2026

Phase 1
(Betriebskonzept)
Jan. 2026 – Okt. 2026

Phase 2
(H₂/C_(s)-Produktion)
Nov. 2026 – Nov. 2029

Inhalt

1. Was sind synthetische (künstliche) Brenn- und Treibstoffe?
2. Skalierungsprojekt in Oman
3. Möglichkeit zur Erzielung negativer Emissionen
- 4. Zusammenfassung**

Zusammenfassung

- Synthetische Brenn- und Treibstoffe sind künstlich auf erneuerbarer Basis hergestellte chemische Energieträger die fossilen Brenn- und Treibstoffen typischerweise beliebig beigemischt werden können.
- Im Rahmen des vom BFE finanzierten SWEET-Konsortiums reFuel.ch wird in Zusammenarbeit mit der Industrie ein Skalierungsprojekt in Oman initiiert. Das Ziel ist die jährliche Produktion von 2 TWh (200 Mio Liter Diesel-Äquivalent) in einer Grossanlage (2 GW_{el}).
- Synthetisches Methan kann zur Erzeugung negativer CO₂-Emissionen genutzt werden, indem der Kohlenstoff vor der energetischen Nutzung mittels Methan-Pyrolyse abgetrennt wird.

Vielen Dank für die Aufmerksamkeit

Verdankung: Dr. Patrik Soltic
Dr. Nikolaus Thumm

Kontakt:
christian.bach@empa.ch