INTEGRATED ENERGY

Power-to-X as Key Enabling Technology & Industrial Implementation Aspects

Rüdiger-A. Eichel

IEK-9: Fundamental Electrochemistry
Institute of Energy and Climate Research
Forschungszentrum Jülich
Germany

Chair of Energy Conversion & Storage
Institute of Physical Chemistry
RWTH Aachen University

11. Göttinger Energietagung | Paulinerkirche, 8. 5. 2019

Mitglied der Helmholtz-Gemeinschaft

JÜLICH
Forschungszentrum

KOPERNIKUS FLAGSHIP-PROJECT

“Power-to-X: Exploration, Validation and Implementation of P2X Concepts”

Coordination:

JÜLICH FORSCHUNGSZENTRUM

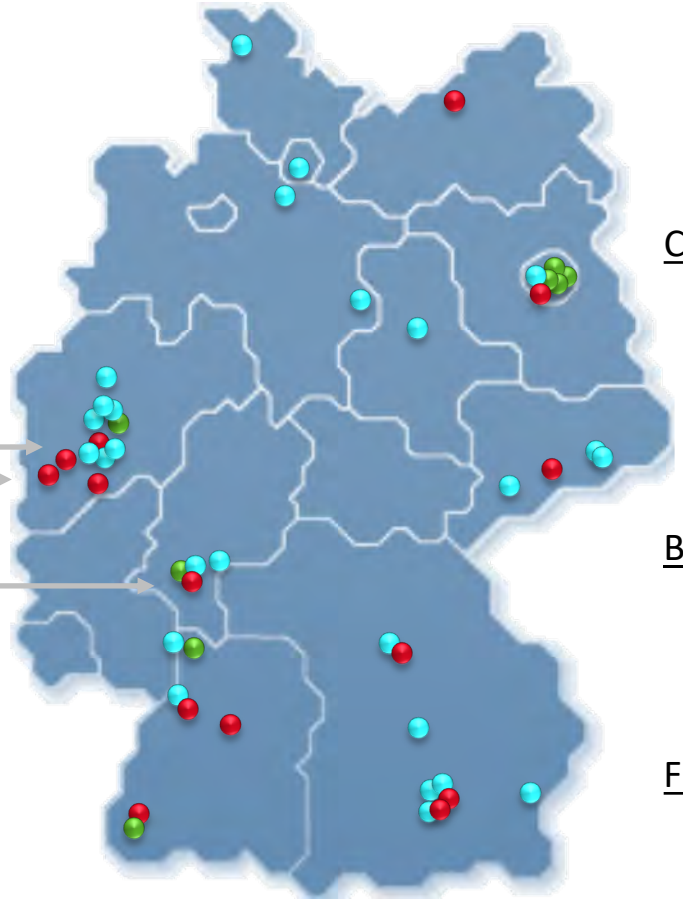
Rüdiger-A. Eichel, IEK-9

RWTH AACHEN UNIVERSITY

Walter Leitner, ITMC

DECHEMA

Kurt Wagemann



- Academia
- Industry
- Socio-economics

KOPERNIKUS P2X PROJEKTE
Die Zukunft unserer Energie

Consortium:

17	Research Institutes
26	Partners from Industry
3	Civil Society Organizations
→ **64**	**Working Groups**

Budget:

38.3 M€	(1st funding period of 3 years)
8.3 M€	(contribution from Industry)

Funding term:

10 y	in total (of three periods)

funding:

Bundesministerium für Bildung und Forschung

EXCELLENCE INITIATIVE OF THE GERMAN FEDERAL AND STATE GOVERNMENTS

Cluster of Excellence (2012 – 2018)

Tailor-Made Fuels from Biomass (TMFB)

Cluster of Excellence (2019 – 2025)

The Fuel Science Center (FSC)

Adaptive Conversion Systems for Renewable Energy and Carbon Sources

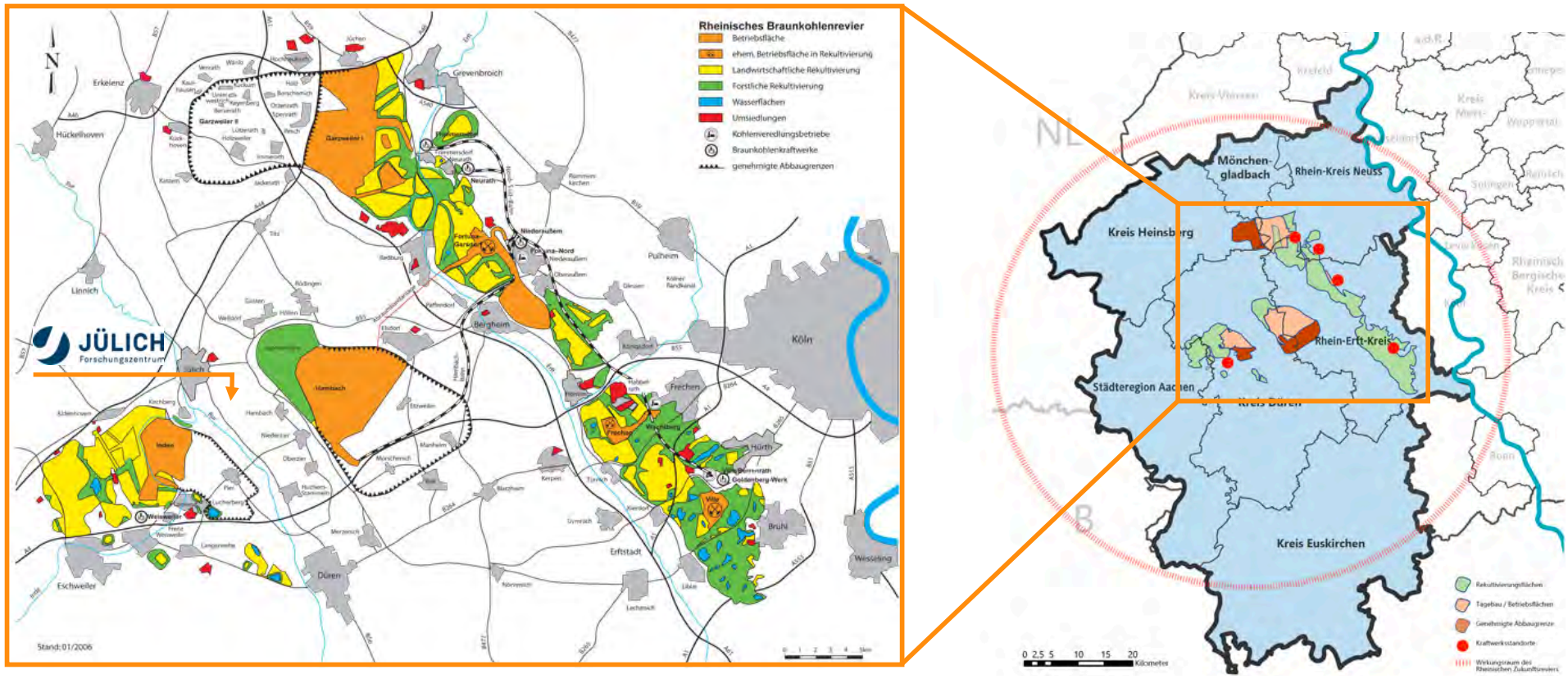
funding:

DFG Deutsche Forschungsgemeinschaft

Institute of Energy and Climate Research
IEK-9: Fundamental Electrochemistry

RWTH AACHEN UNIVERSITY | JÜLICH Forschungszentrum

DAS RHEINISCHE ZUKUNFTSREVIER

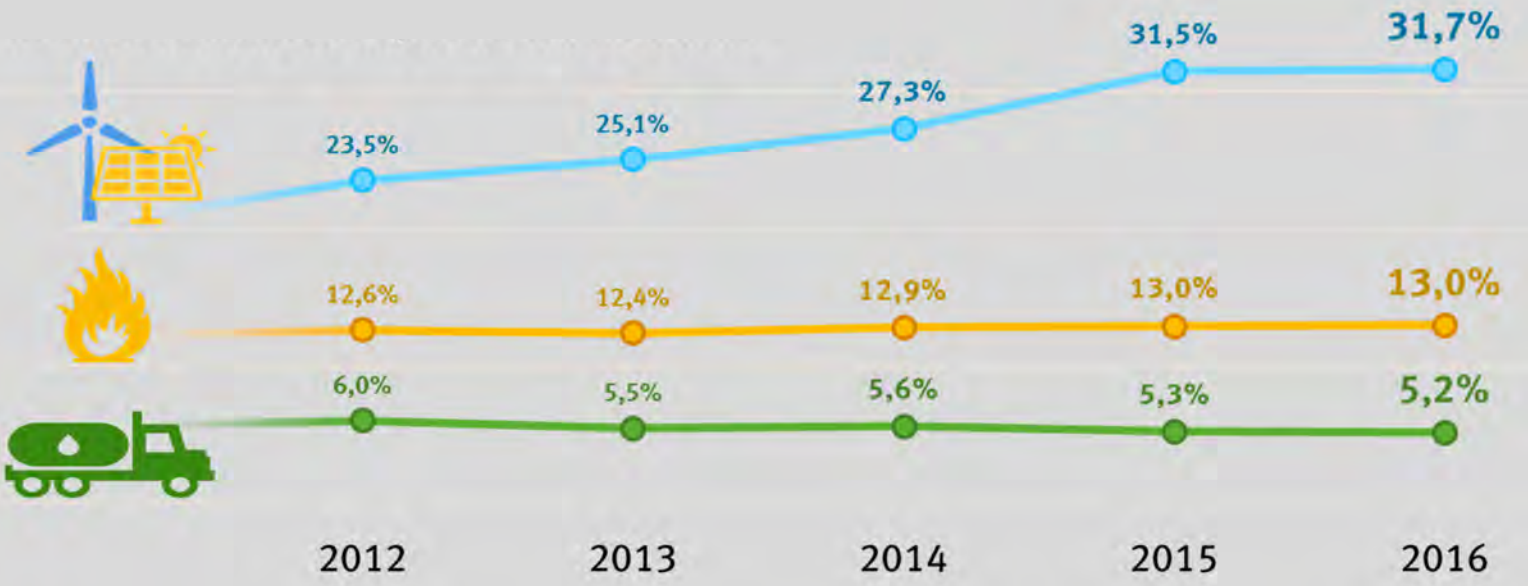


RWTH AACHEN UNIVERSITY | JÜLICH Forschungszentrum

TRANSFORMATION TOWARDS SUSTAINABILITY

Status-Quo – ‚Energiewende' is mainly a Transformation of the Energy Sector

Proportion of Renewable Energies in Germany
in the sectors: Electricity, Heat and Transport

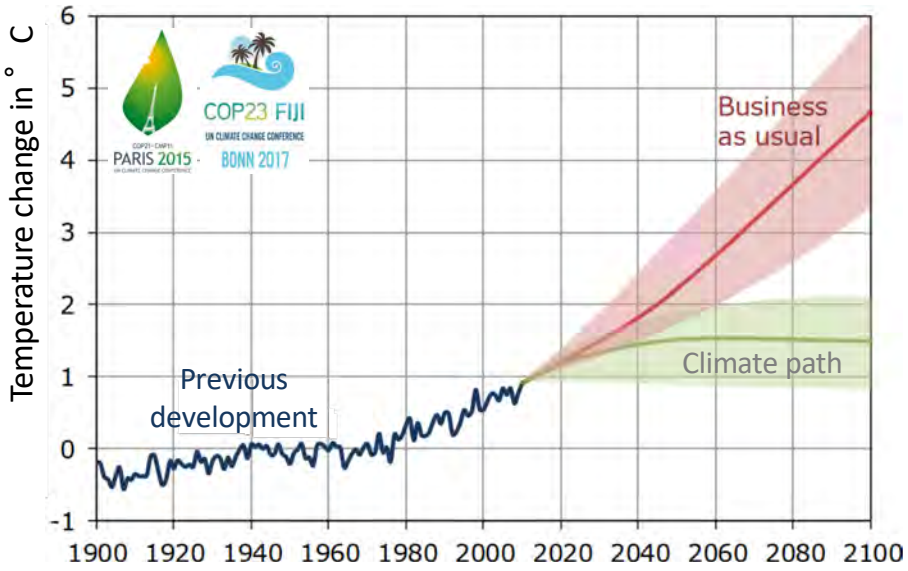


AGEE-Stat 2017

TRANSFORMATION TOWARDS SUSTAINABILITY

Global Warming and Greenhouse-Gas Emissions

Temperature Change [°C]

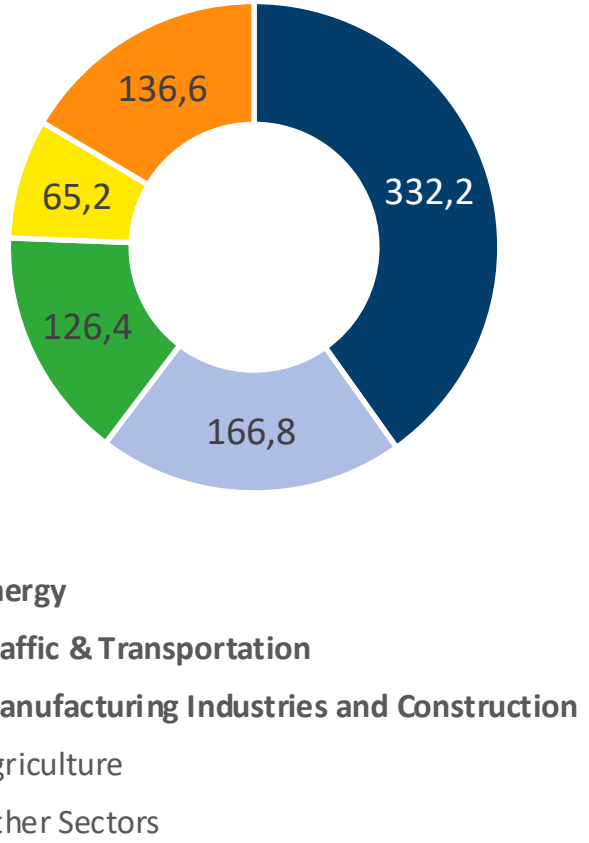


Global warming by Anthropogenic Greenhouse Gases:

- Up to 5° in 2100 without Mitigation Measures

Source: Dezentrale Solarstromspeicher für die Energiewende, Berliner Wissenschafts-Verlag, (2015)

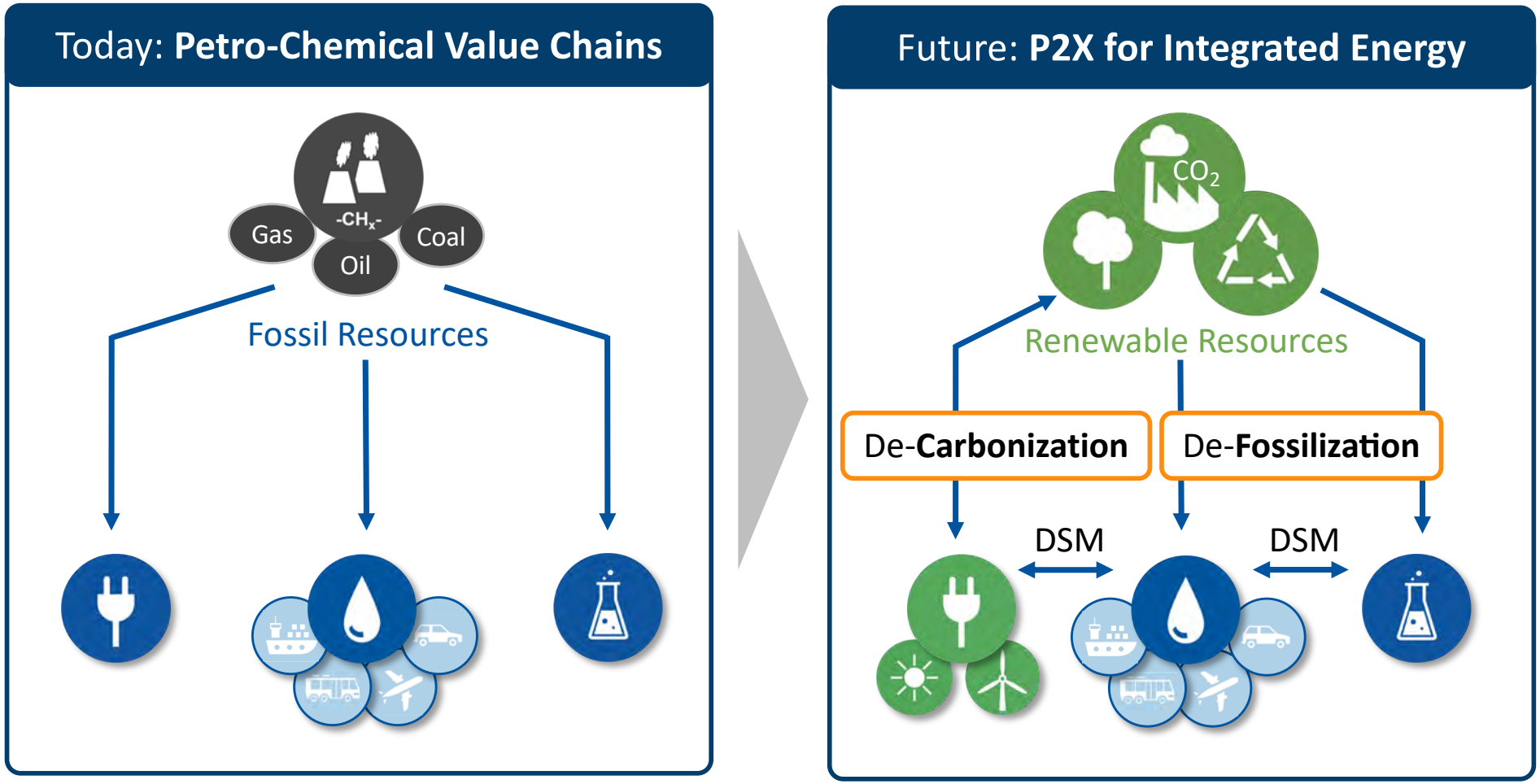
CO_2-Emissions [Mt CO_2-equiv.]



Source: Umweltbundesamt; Nationales Treibhausgasinventar 04/2018

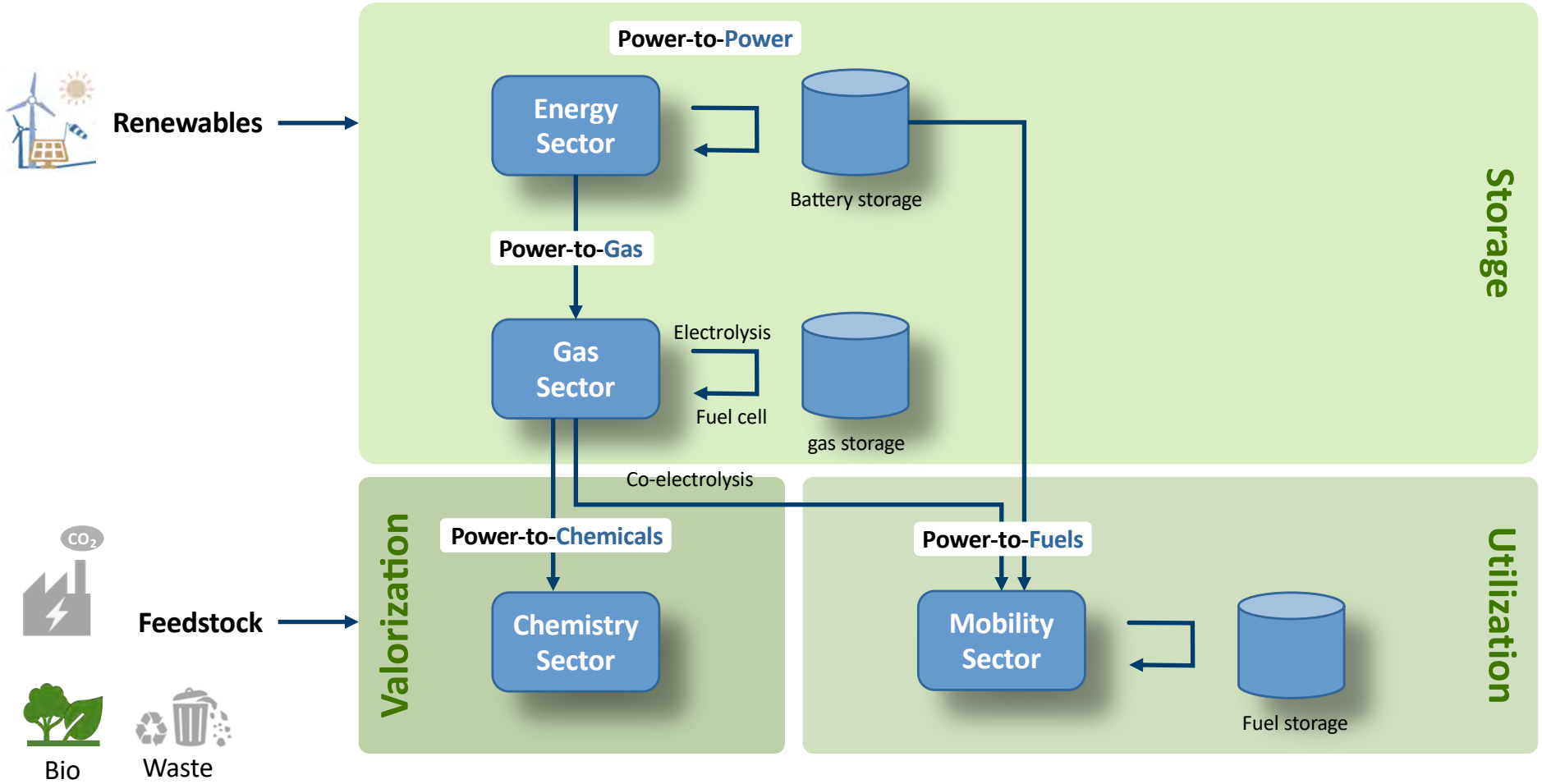
POWER-TO-X & INTEGRATED ENERGY

Transition of Key Sectors towards Sustainability



‘INTEGRATED ENERGY’ SCENARIO

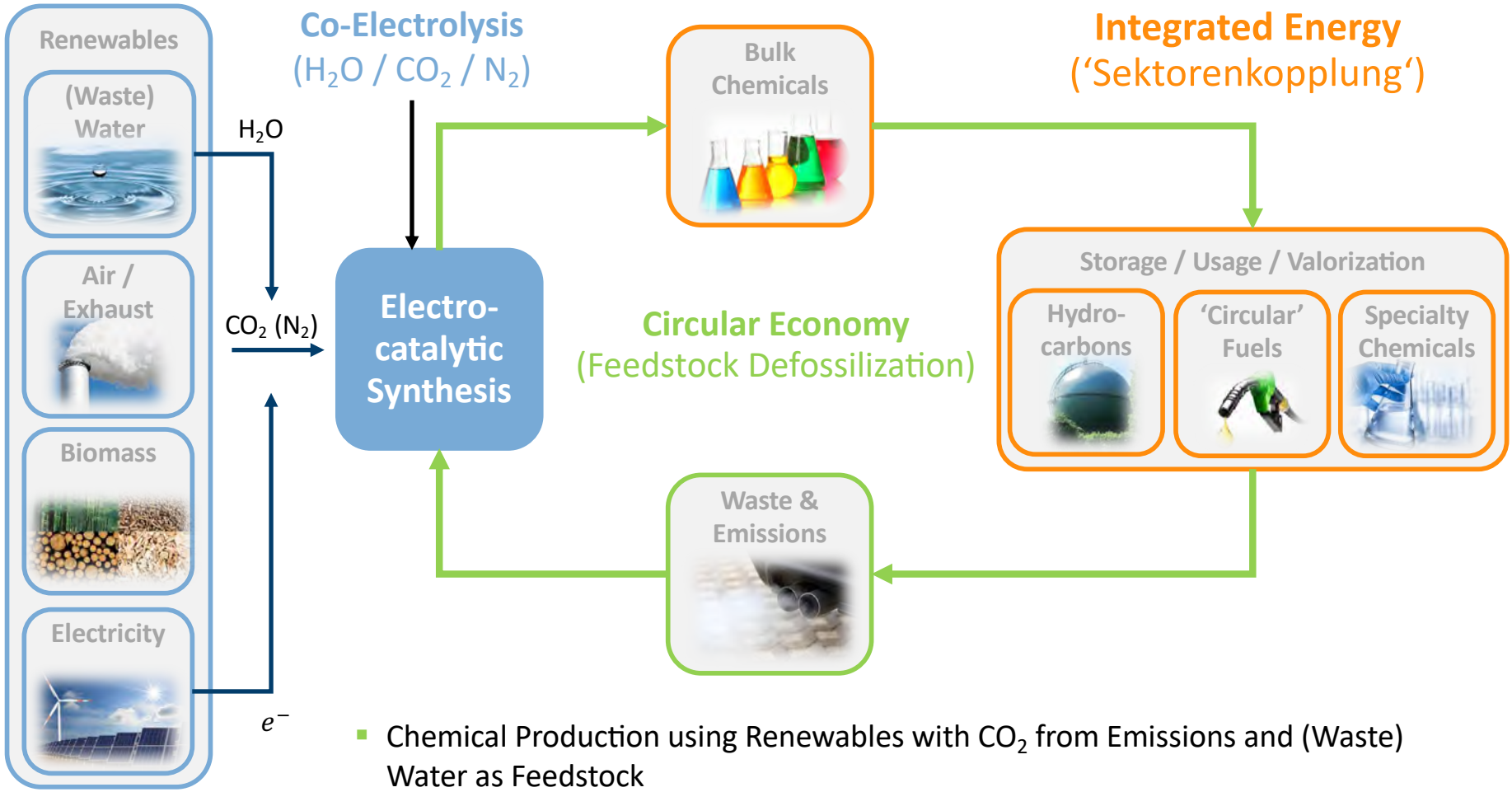
Power-to-X as Key enabling Technology



- Reduction of **Industrial Carbon Footprint**
- Sustainable **Value Generation**

CIRCULAR-ECONOMY SCENARIO

Power-to-X as Key Enabling Technology



- Chemical Production using Renewables with CO_2 from Emissions and (Waste) Water as Feedstock
- Closed Carbon Loops

‘POWER-TO-GAS‘

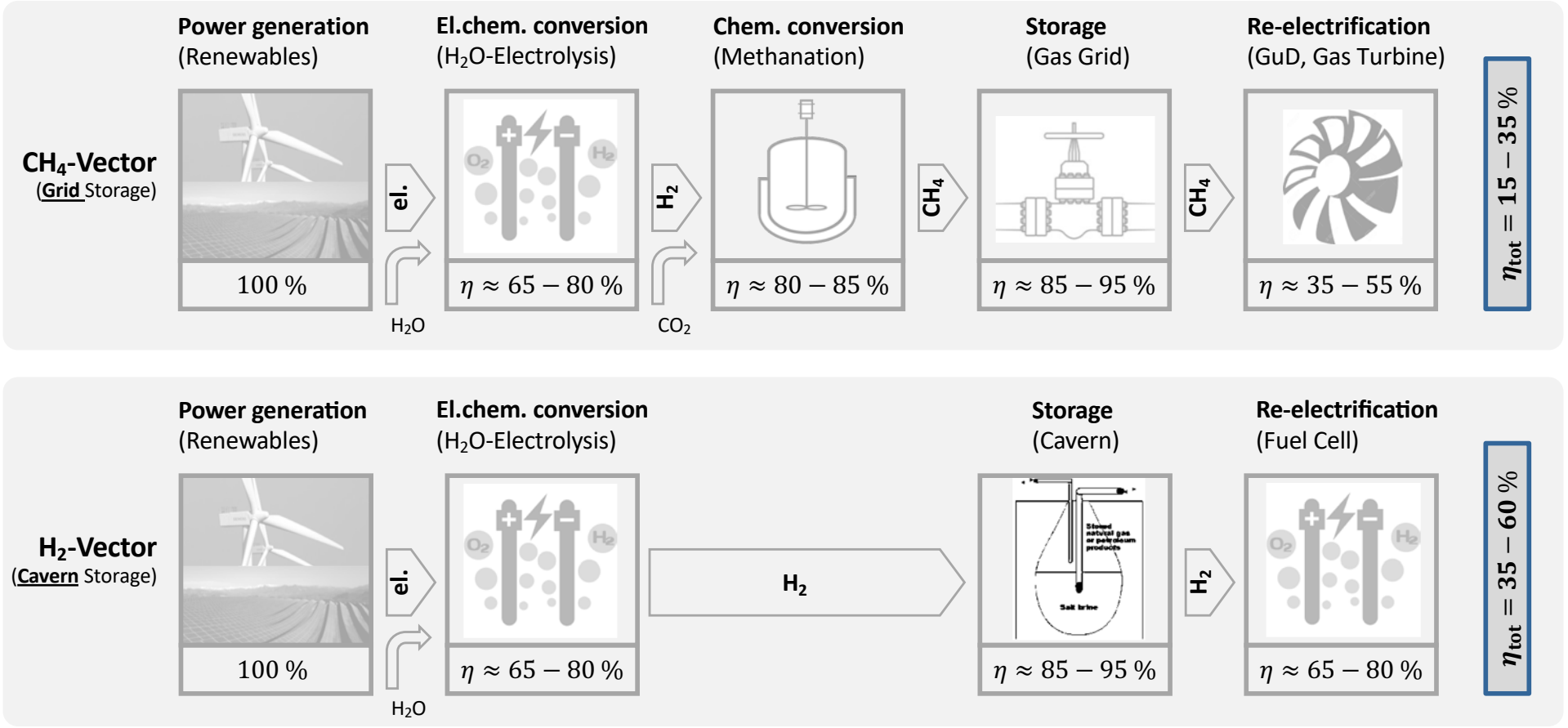
Transition of the Energy Sector (‘Energiewende’)

Objectives for Chemical Energy Storage:

- Intermittent Energy Supply & Consumption
- Long-term (seasonal) Energy Storage by Chemicals
- Reliable Energy Supply with Renewables

POWER-TO-GAS-TO-POWER

Round Trip Efficiency



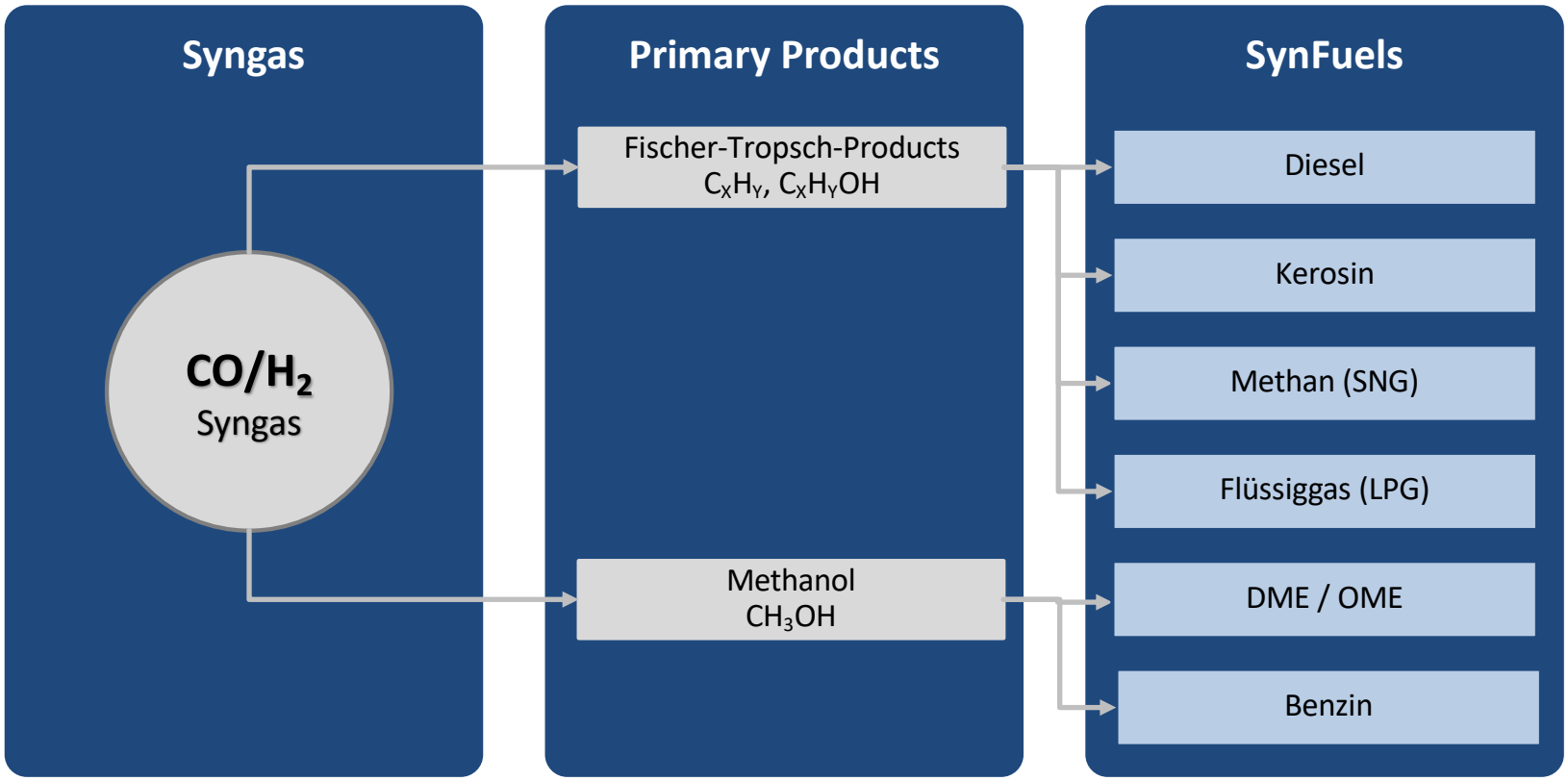
‘POWER-TO-FUELS’

Transition of the Traffic & Transportation Sector (‘Verkehrswende’)

Objectives for Synfuels:

- Reduced CO_2- & NO_x-emissions

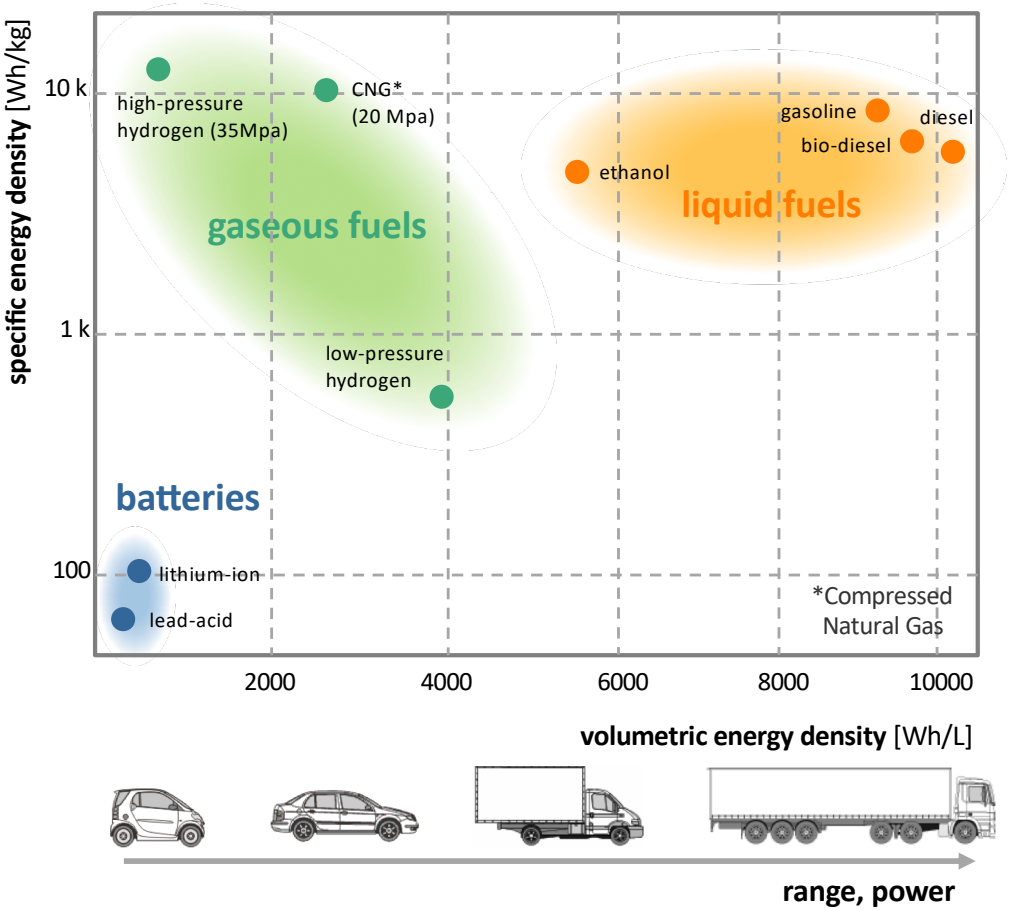
SYNFUELS



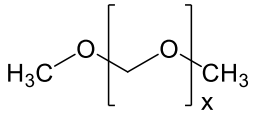
Herstellung flüssiger Kraftstoffe:
– Synthetisches Kerosin und Diesel über das Fischer-Tropsch-Verfahren
– Ottobenzin über die Produktion von synthetisches Methanol mit anschließendem Methanol-to-Gasoline (MTG)-Verfahren
– Oxymethylenether (OMEx) als Dieselersatz

ENERGY DENSITY OF SYNFUELS

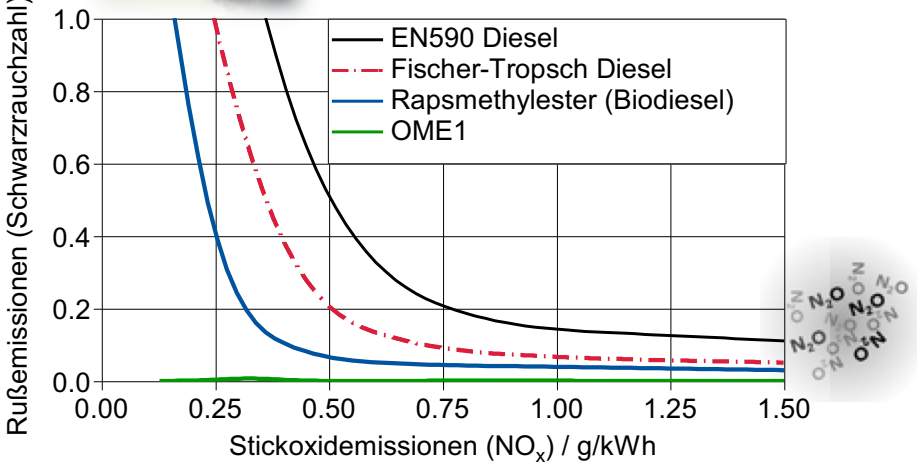
Energy Storage Capacities



Synfuel Emissions (Oxymethylene ether, OME)



OME_x (1; 3 < x < 6)



D. Deutsch, D. Oestreich, L. Lautenschütz, P. Haltenort, U. Arnold, J. Sauer
Chemie Ingenieur Technik **2017**, *89*, 486–489.

FILLING STATION INFRASTRUCTURE (GERMANY)

Petrol Filling Station Infrastructure (existing)

www.aral.de

Existing infrastructure:

- 14.510 petrol filling stations (2017)
- Capital cost per station: ≈ 2.5 M€

Hydrogen Filling Station Infrastructure (future)

www.linde.com

Existing infrastructure:

- 17 hydrogen filling stations (2014)
- Capital cost per station: ≈ 1.0 – 2.5 M€

planned infrastructure (2023):

- 400 hydrogen filling stations (invest ≈ 400 – 1000 M€)

RWTH AACHEN UNIVERSITY | JÜLICH Forschungszentrum

‘POWER-TO-CHEMICALS’

CO_2 as Chemical Feedstock (‘Chemiewende’)

Objectives for CO_2 as Chemical Feedstock:

- Chemical Production using CO_2, Water and Renewables
- CO_2 (and Biomass) as sole Carbon Source for Chemical Industry

VALORIZATION ... VALUE CHAINS

Short History of Time – towards Power-to-Chemicals

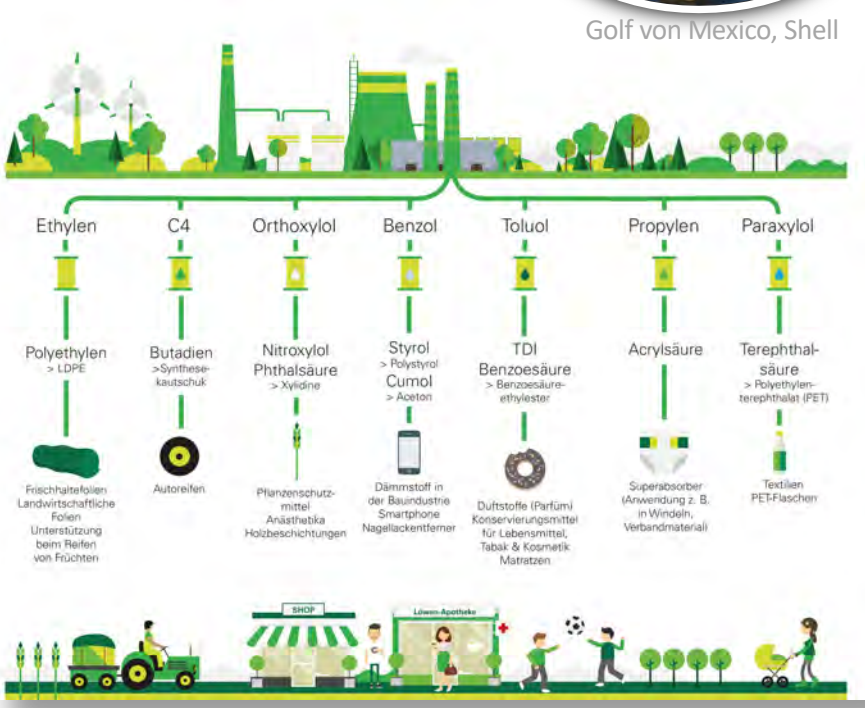
Tagebau Hambach, RWE

Kohlechemie

Leuna Chemie

Petrochemie

Golf von Mexico, Shell

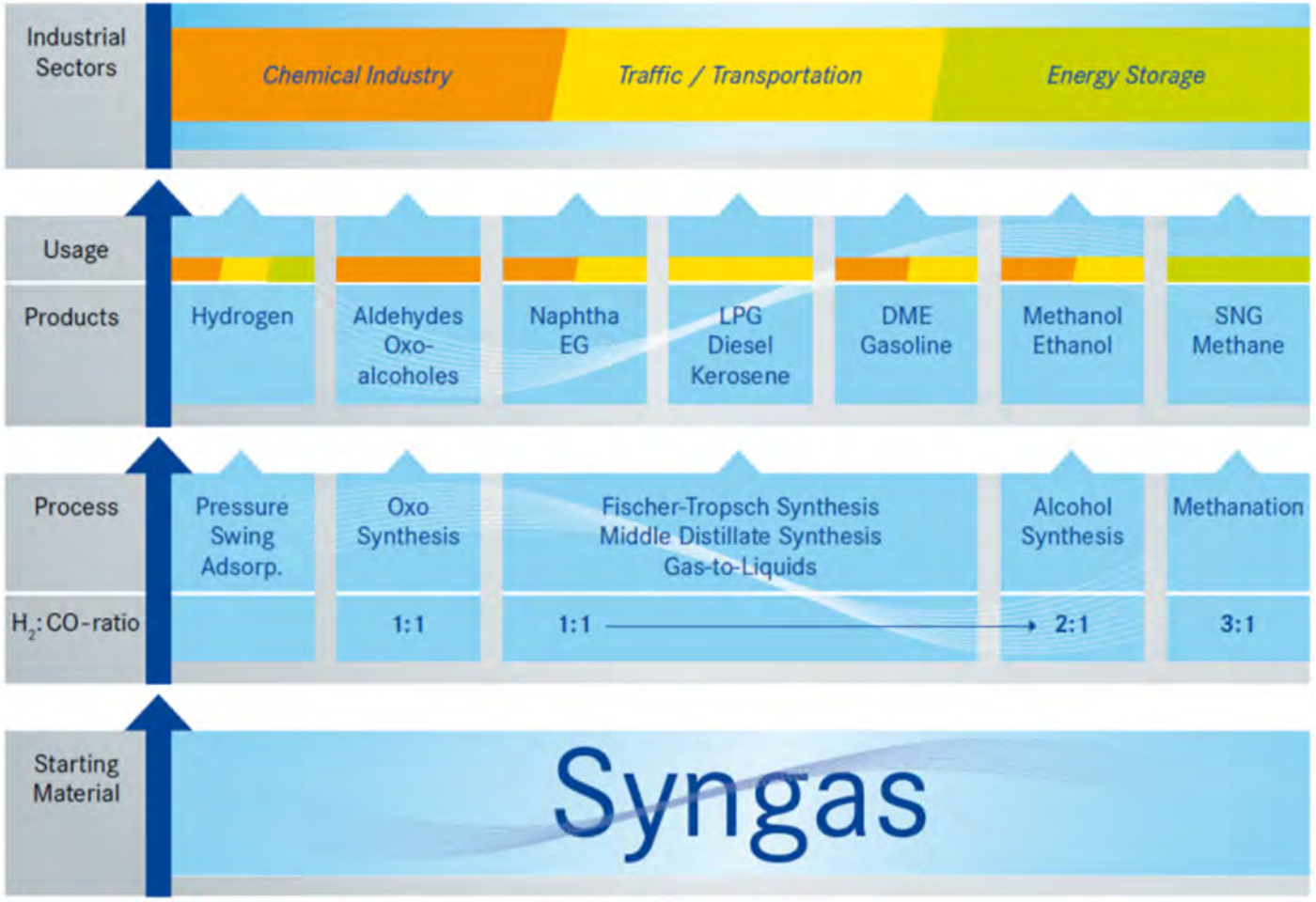


BP

RWTH AACHEN UNIVERSITY | JÜLICH Forschungszentrum

POWER-TO-CHEMICALS

Sustainable Value Chain – ‚green' syngas chemistry



S. Foit, I.C. Vinke, L.G.J. de Haart, R.-A. Eichel, Angew. Chem. Int. Ed. **56** (2017) 5402 – 5411

‘INTEGRATED ENERGY’ SCENARIOS

Power-to-X as Key enabling Technology

Objectives for ‘Integrated Energy’ Scenarios (‘Sektorkopplung’):

- Reduction of GHG emissions by input of renewables into the sectors Chemical Industry, Heat, Traffic & Transportation
- CO_2-conversion as chemical Storage Option

‘INTEGRATED ENERGY’ SCENARIO

Availability of Renewables – Case Study ‚Synfuels‘

‚Worldscale‘-Facility **Topaz Solar Farm**
(California, USA)

Foto: NASA

1 TWh (@ 550 MW rated power)

➞ ca. 40.000 t annual synfuel production

‚Worldscale‘-Facility **Alpha Ventus**
(45 km north Borkum)

Foto: Deutsche Offshore-Testfeld und Infrastruktur GmbH & Co. KG Oldenburg

0.242 TWh (@ 60 MW rated power)

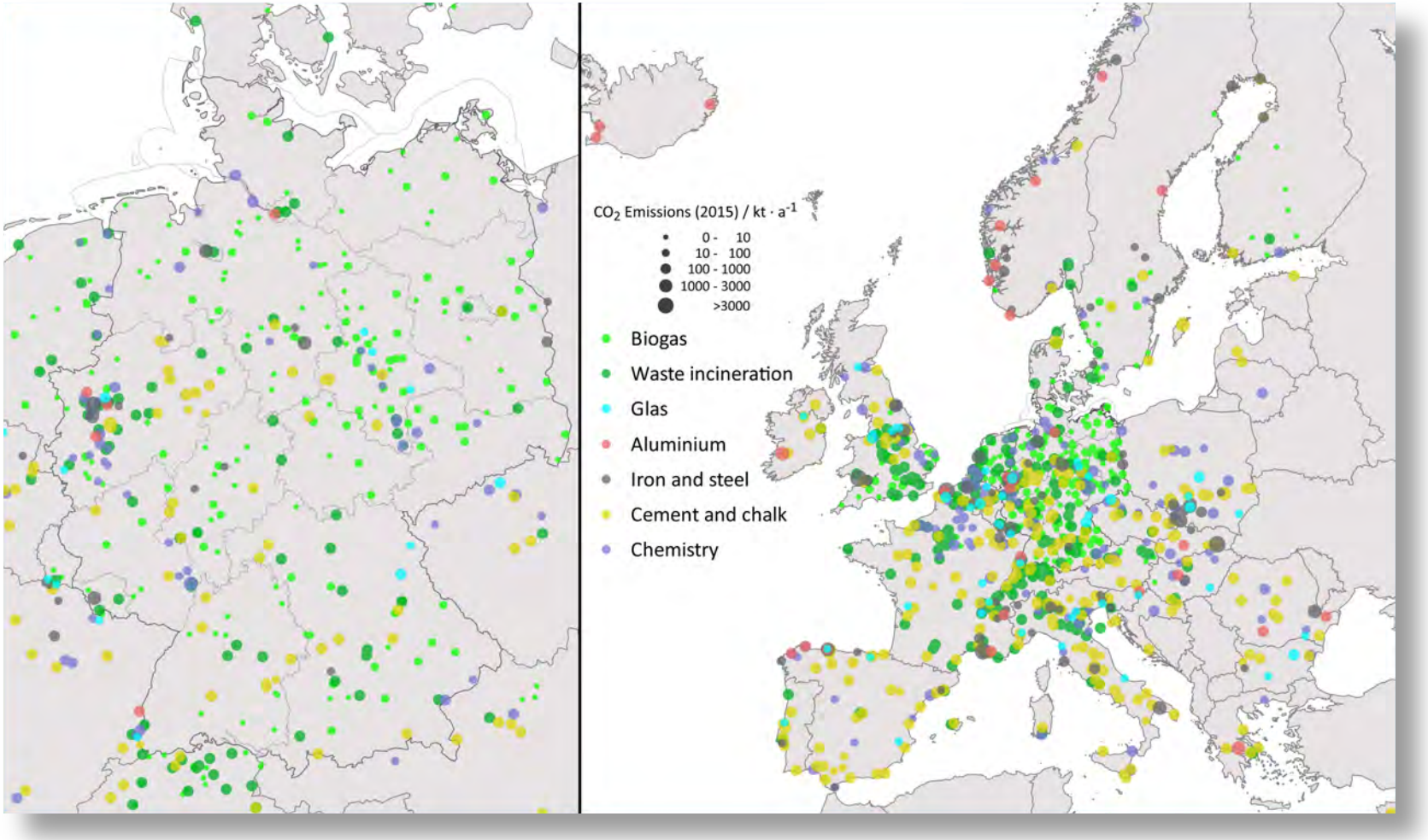
➞ ca. 10.000 t annual synfuel production

Assumption: 25 TWh ≡ 1 Mio. t trad. fuel

RWTH AACHEN UNIVERSITY | JÜLICH Forschungszentrum

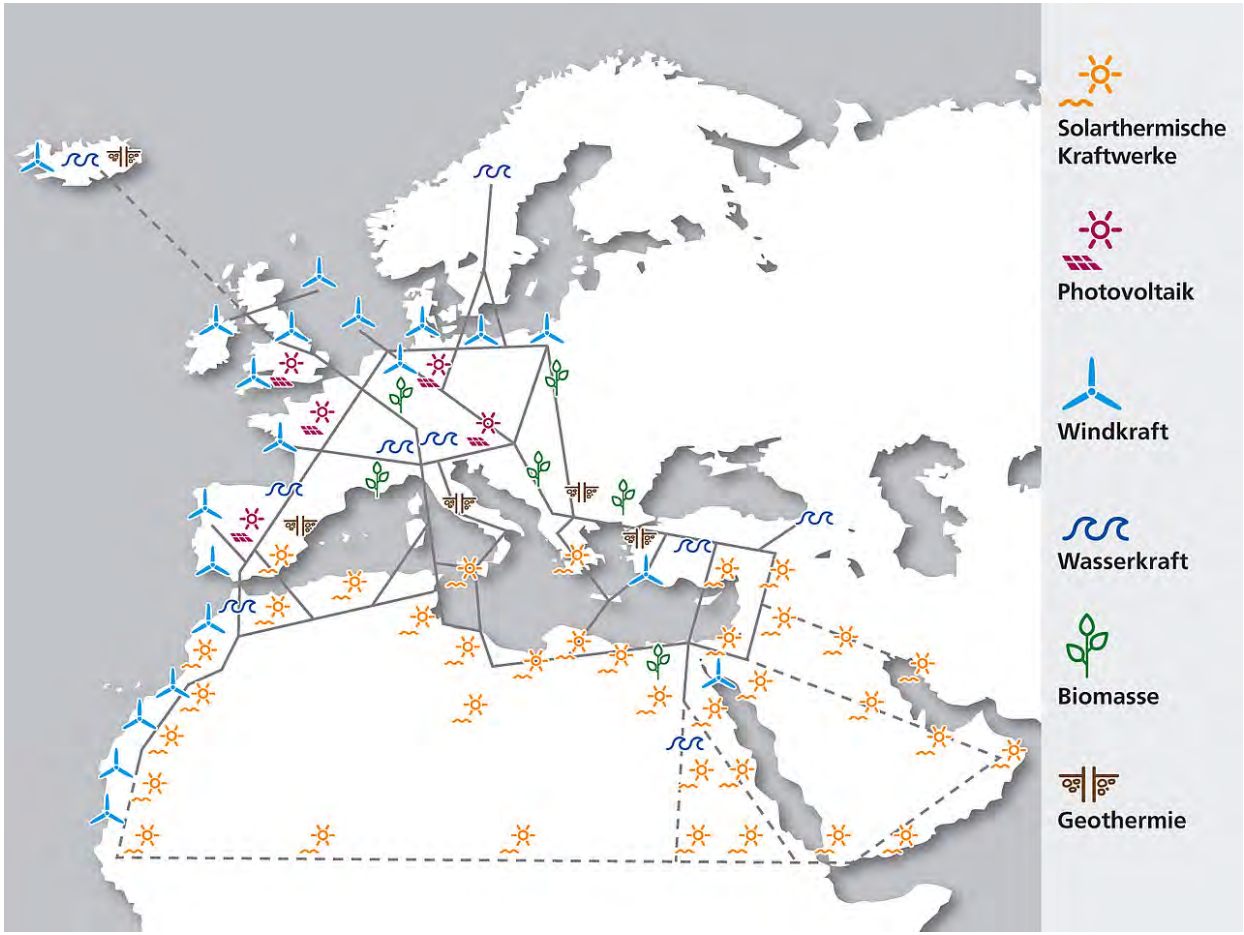
‘INTEGRATED ENERGY’ SCENARIO

Availability of CO_2 as Feedstock



‘INTEGRATED ENERGY’ SCENARIO

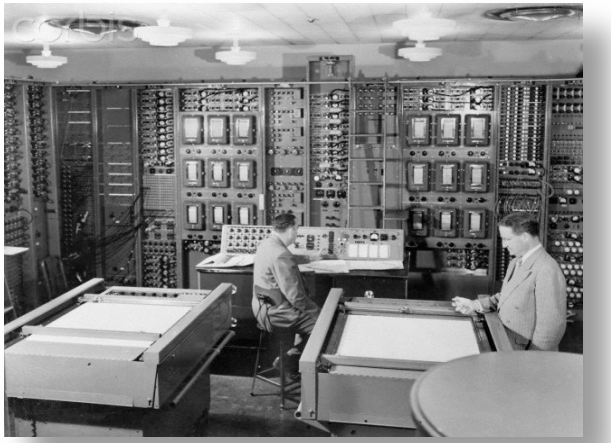
Availability of Renewable Power



Courtesy of DLR

OFF-GRID SCENARIOS

Decentralized or Autonomous Technologies



→ Scalability (‘Terawatt Challenge’)

→ Versatility (Fuels, Chemicals, …)

ACKNOWLEDGEMENTS

Team **Low-Temperature P2X**:

- Prof. Josef Granwehr
- Dr. Hans Kungl
- Dr. Hermann Tempel
- Dr. Peter Jakes
- Dr. Steffen Merz
- Dr. Peter P.M. Schleker
- M.Sc. Jörg Ackermann
- M.Sc. Sven Jovanovic
- M.Sc. Ansgar Kretzschmar
- M.Sc. Emmanouil Veroutis
- M.Sc. Heeyong Park
- et al.

Team **High-Temperature P2X**:

- Dr. Lambertus G.J. de Haart
- Dr. Isaak C. Vinke
- Dr. Kevin Schiemann
- Dr. Vibhu Vaibhav
- M.Sc. Severin Foit
- M.Sc. Lucy Dittrich
- M.Sc. Markus Nohl
- M.Sc. Kevin Schiemann
- M.Sc. Trutz Theuer
- et al.

funding:

KOPERNIKUS PROJEKTE
Die Zukunft unserer Energie

Bundesministerium für Bildung und Forschung

Bundesministerium für Wirtschaft und Energie

Ministerium für Kultur und Wissenschaft des Landes Nordrhein-Westfalen

Ministerium für Wirtschaft, Innovation, Digitalisierung und Energie des Landes Nordrhein-Westfalen

CEF.NRW
Cluster EnergieForschung

KlimaExpo.NRW
Motor für den Fortschritt

Bayerisches Staatsministerium für Wirtschaft, Energie und Technologie

DFG

SEVENTH FRAMEWORK PROGRAMME