BW Ingenieuretag, Stuttgart, 28/06/2023

Karlsruhe Institute of Technology

Das Energiesystem der Zukunft
Neueste Forschungen am KIT

KIT Energy Center

Dr. Th. Walter Tromm, Dr. Wolfgang Breh

Karlsruhe Institute of Technology
The Research University in the Helmholtz Association

Karlsruhe Institute of Technology

Karlsruhe Institute of Technology (KIT)

Core tasks: Research, Teaching, Innovation

22,275 Students, 21% international

5,556 Researchers, 25% international

Researchers and students from 120 countries

Annual budget of € 1 090,7 million

KIT – Research and Innovation at 6 Locations

Campus North

Campus South

Campus East

Campus West

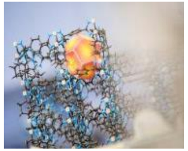
Campus Alpine

Helmholtz Institute Ulm

KIT Science Profiling – Discipline Diversity

Division I

Biology



Chemistry

Process Engineering

Division II

Informatics

Economics

Society

Division III

Mechanical Engineering

Electrical Engineering

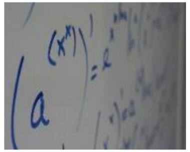
Division IV

Civil Engineering, Geo- and Environmental Sciences

Architecture

Division V

Physics



Mathematics

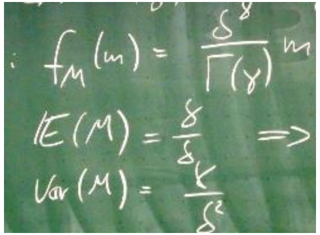
8 KIT Centers Link Discipline Diversity

Karlsruhe Institute of Technology

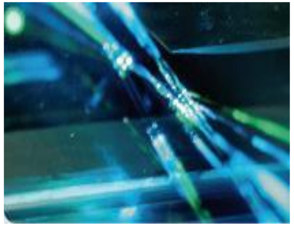
Energy

Mobility Systems

Information Systems Technologies



Mathematics in Sciences, Engineering, and Economics



Materials

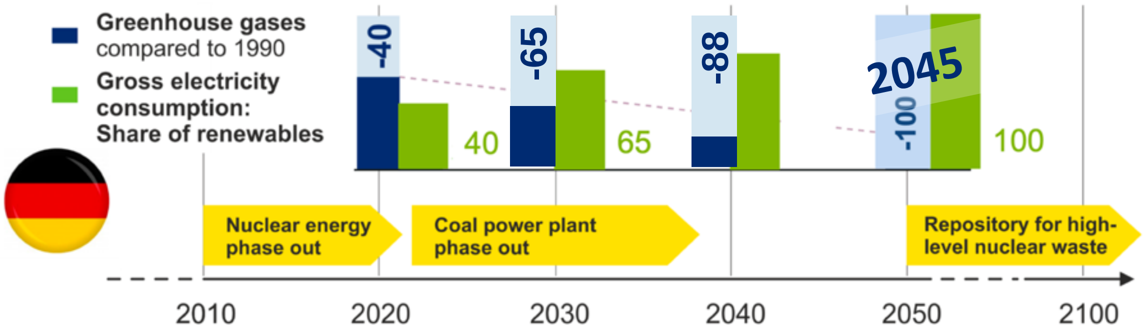
Climate and Environment

Elementary Particle and Astroparticle Physics

Humans and Technology

Grand Challenges in Energy Research and Beyond

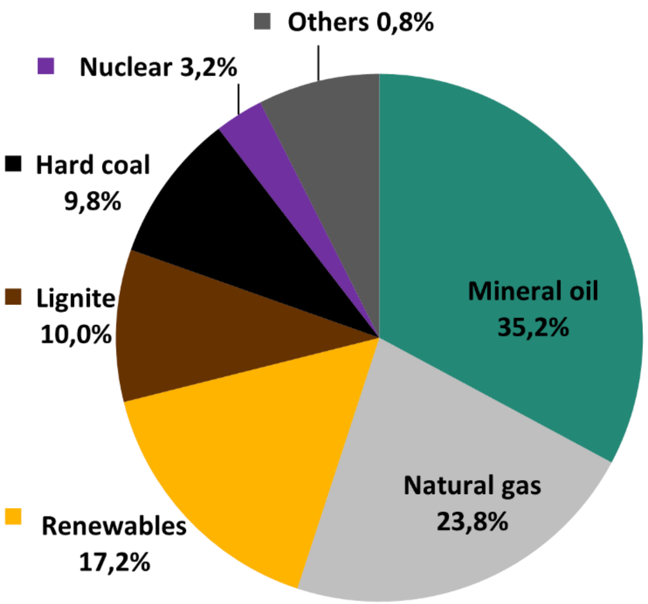
- Nuclear energy **phase out** in 2022
- Coal power plant **phase out** in 2038
- Reduction of greenhouse gases to **zero** in **2045**
- Share of renewables up to **100%** in 2050
- Feasibility of commercial **nuclear fusion**
- **NEW: Independence from Russian fossil fuels and raw materials**



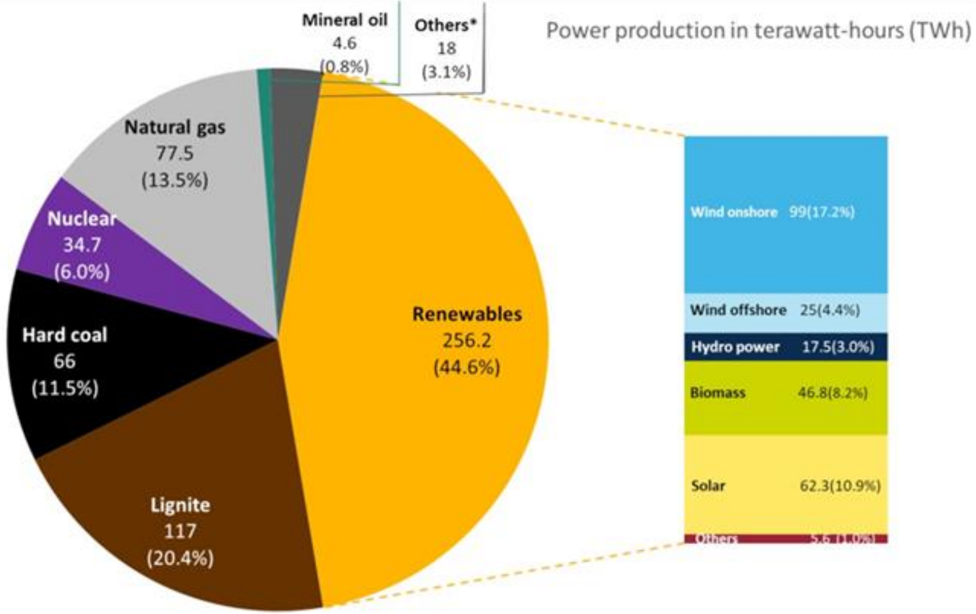
European Green Deal: "Net Zero" Greenhouse gas emissions by 2050

➢ Full replacement of fossil energy carriers by renewables

Overview: Current Energy Situation in Germany



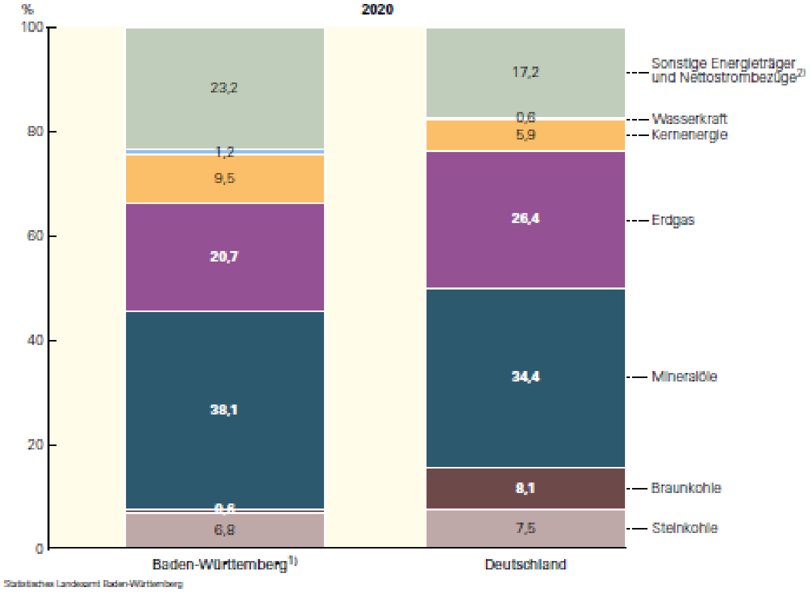
primary energy consumption
in Germany by energy source 2022*



gross electricity production
in Germany by energy source 2022*

Source: BDEW, Destatis, Statista, EEX, VGB, ZSW; 12/2022 *preliminary

Primärenergieverbrauch in Baden-Württemberg und Deutschland 2020 nach Energieträgern



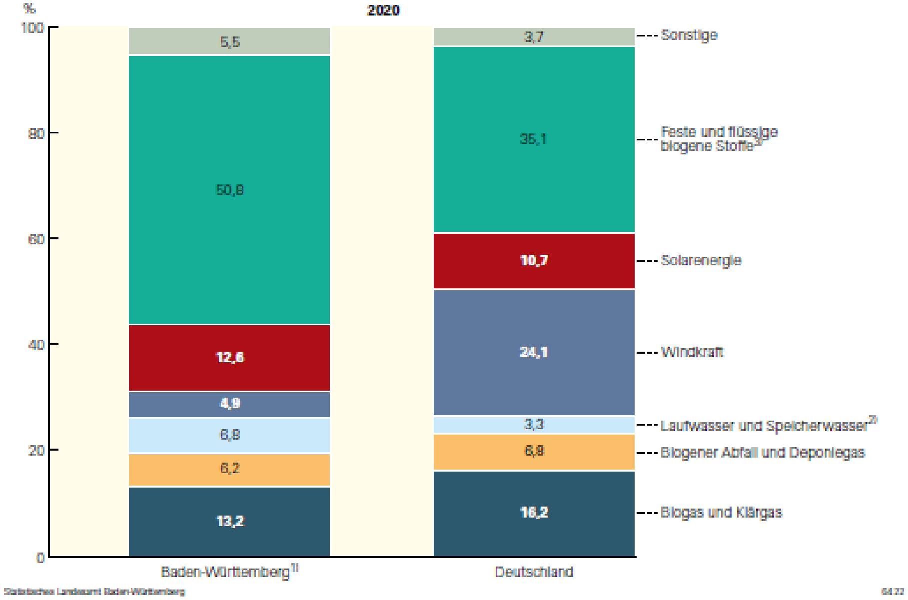
Statistisches Landesamt Baden-Württemberg

1) Energieverbrauchswerte enthalten teilweise Schätzungen, insbesondere bei den Energieträgern Mineralöle und Mineralölprodukte. 2020 vorläufige Ergebnisse. – 2) Grubengas, Windkraft, Solarenergie, Klärgas, Deponiegas, Biomasse und Sonstige.

Datenquellen: Energiebilanzen für Baden-Württemberg. Für Deutschland: Arbeitsgemeinschaft Energiebilanzen e.V.; Daten für 2019 Stand: 25.02.2021, Daten für 2020 Stand: 11.02.2022.

Primärenergieverbrauch erneuerbarer Energieträger in Baden-Württemberg und Deutschland 2020

Karlsruhe Institute of Technology



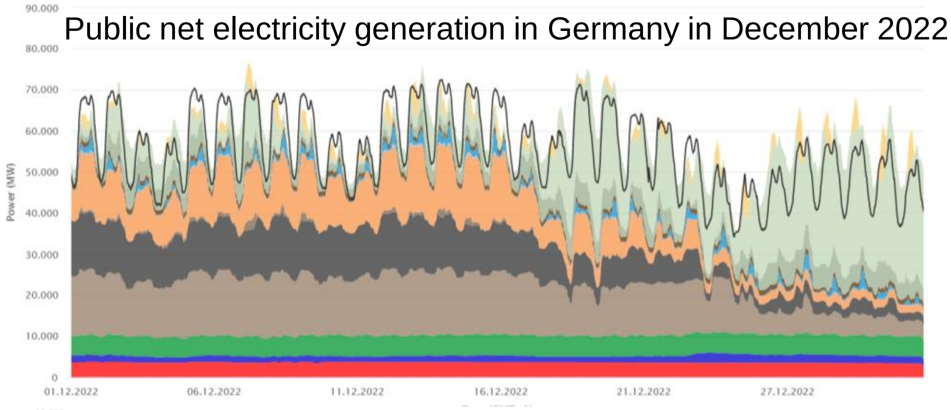
Statistisches Landesamt Baden-Württemberg 64 22

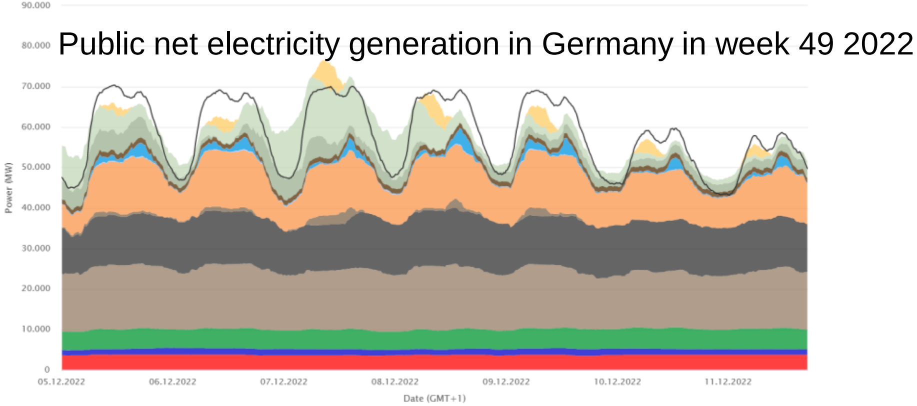
1) Energieverbrauchswerte enthalten teilweise Schätzungen, insbesondere bei den Energieträgern Mineralöle und Mineralölprodukte. 2020 vorläufige Ergebnisse. – 2) Einschließlich Pumpspeicherwasser mit natürlichem Zufluss. – 3) Einschließlich Biotreibstoffe. Für Deutschland einschließlich Klärschlamm. Für Baden-Württemberg ist dieser bei biogenem Abfall und Deponiegas enthalten.

Datenquellen: Energiebilanzen für Baden-Württemberg. Für Deutschland: Arbeitsgemeinschaft Energiebilanzen e.V., Daten für 2019 Stand: 25.02.2021, Daten für 2020 Stand: 11.02.2022.

Public net electricity generation in Germany, 2022

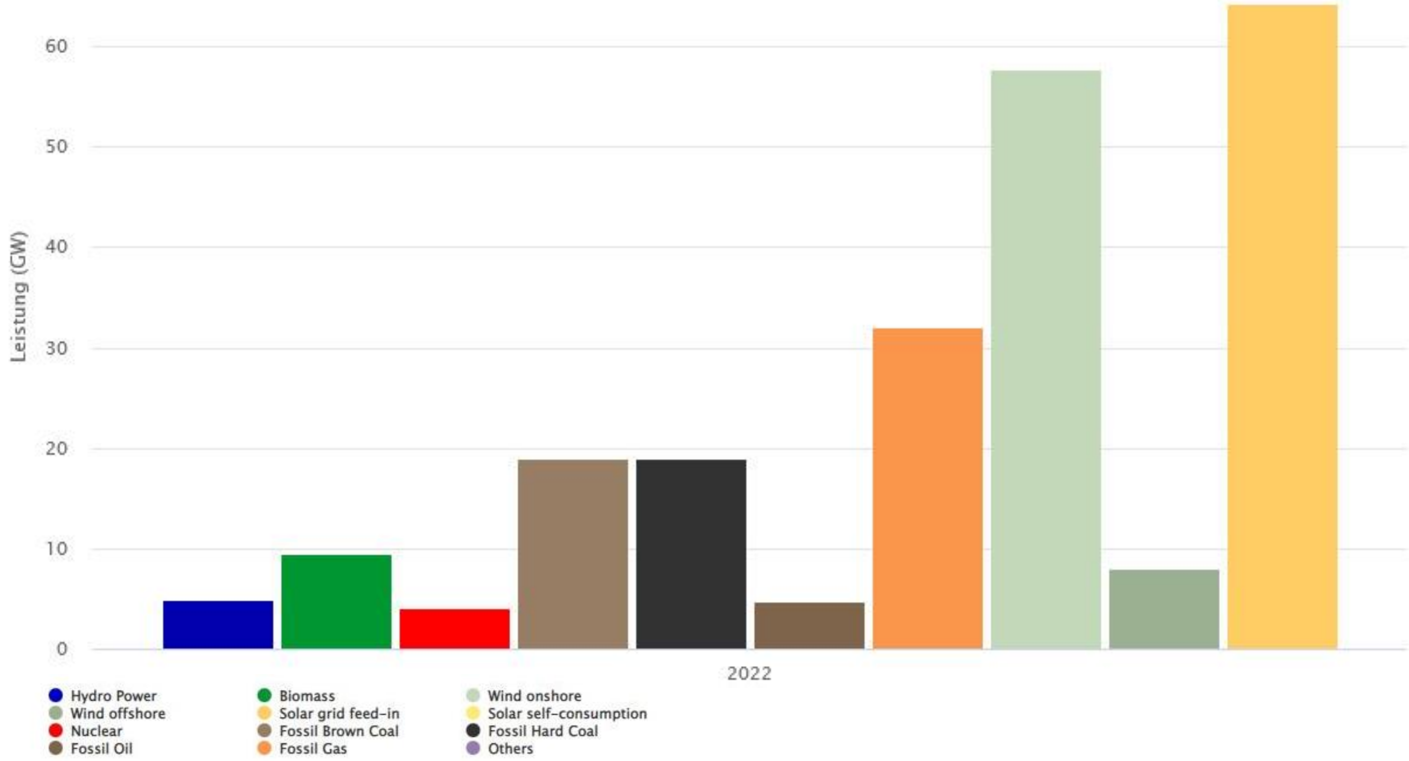
- Hydro pumped storage consumption
- Hydro Run–of–River
- Fossil hard coal
- Geothermal
- Others
- Wind onshore
- Biomass
- Fossil oil
- Hydro water reservoir
- Waste
- Solar
- Renewable share of generation
- Nuclear
- Fossil brown coal / lignite
- Fossil gas
- Hydro pumped storage
- Wind offshore
- Load





Source: Energy-Charts; 2023

Net installed capacity for power generation in Germany in 2022



Source: Energy-Charts; 2023

The Helmholtz Association of German Research Centres

Karlsruhe Institute of Technology

- KIT is one of 18 Helmholtz Centers in Germany
- Helmholtz is Germany's largest scientific organisation
  - > 43.000 employees
  - annual budget of > € 5 billion
- Mission of Helmholtz: address the grand global challenges
- Helmholtz is promoting research in six research fields; KIT contributes to four of them:

ENERGY	EARTH and ENVIRONMENT	HEALTH
AERONAUTICS, SPACE AND TRANSPORT	MATTER	INFORMATION

Research Field Energy
Programs in POF IV at KIT 2021 – 2027

Helmholtz Energy Transition Roadmap (HETR)
- Science driven
- Research-strategy tool
- Advice to politics and society

Energy System Design
- Energy System Transformation
- Digitalization and System Technology

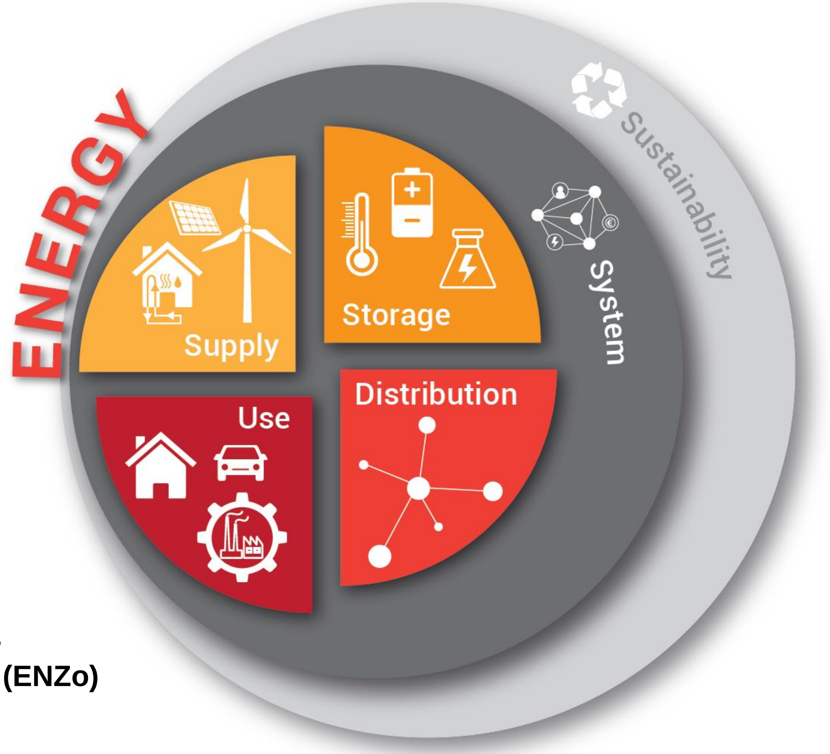
Fusion
- Stellerator Research
- Tokamak Physics
- Fusion Technologies and Materials
- Plasma-Wall Interactions

Materials and Technologies for the Energy Transition
- Photovoltaics and Wind Energy
- Electrochemical Energy Storage
- Chemical Energy Carriers
- High-Temperature Thermal Technologies
- Resource and Energy Efficiency

Nuclear Waste Management, Safety and Radiation Research
- Nuclear Waste Management
- Reactor Safety

KIT Energy Center

Karlsruhe Institute of Technology



60 Institutes

67 Professors

Education
Graduate School –
Enabling Net-Zero (ENZo)

250 Mio.€
Annual Budget

1800 Scientists / Tech Staff

International
Research
Cooperation

Large-Scale Research Infrastructures at KIT (Selection)


Cryogenic Material Test Karlsruhe (CryoMAK)


KALLA Laboratory


Biomass to Liquid (bioliq®)

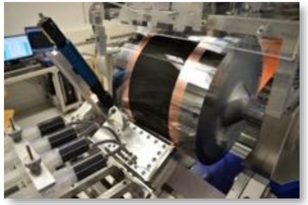

Modular Low Temperature Cycle Karlsruhe (MoNiKa)


PtL-Plant with Direct Air Capture (Kopernikus Project)


INE Laboratories


Energy Lab 2.0


3-Phase-Methanation Plant


Energy Materials Foundary (HEMF)


CAT-ACT Beamline at Karlsruhe Research Accelerator KARA

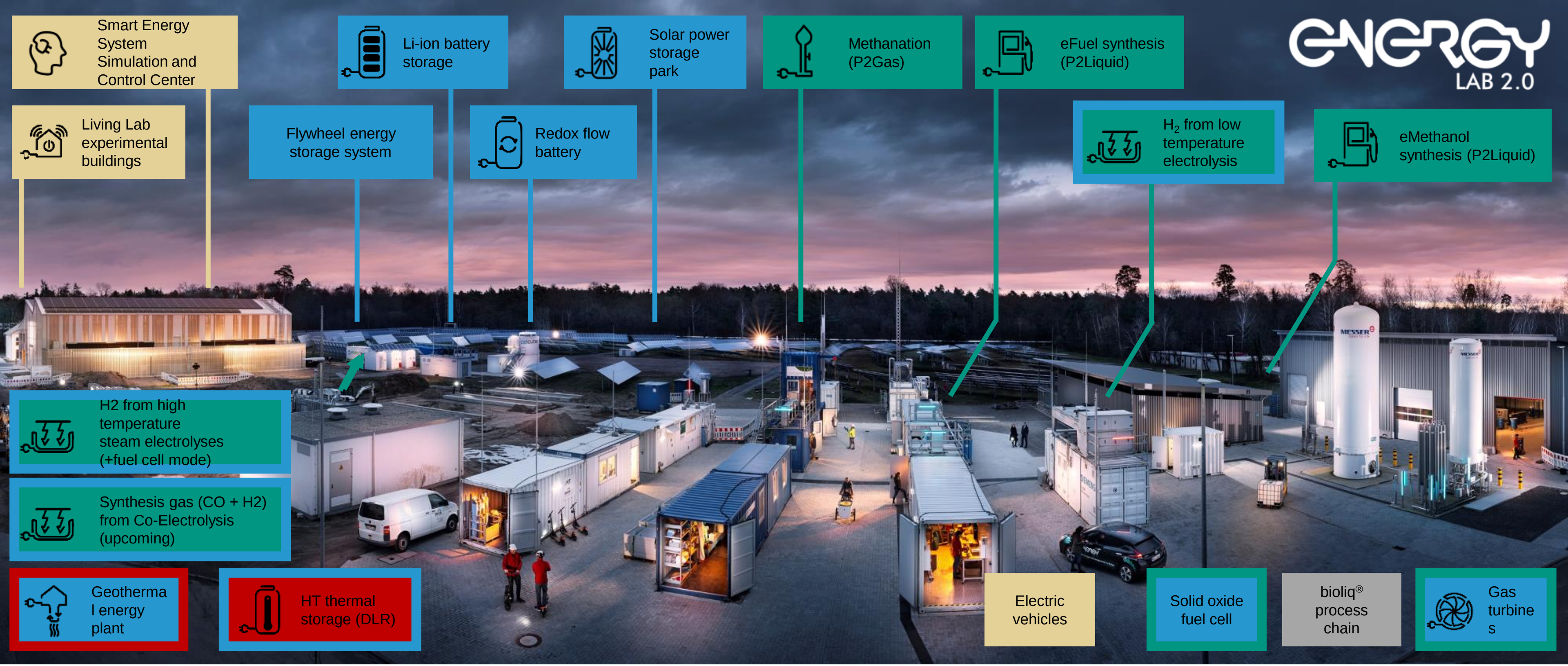

SEnSSiCC Laboratory


CHF on Smooth and Modified Surfaces (COSMOS)


Engine Test Benches (IFKM)

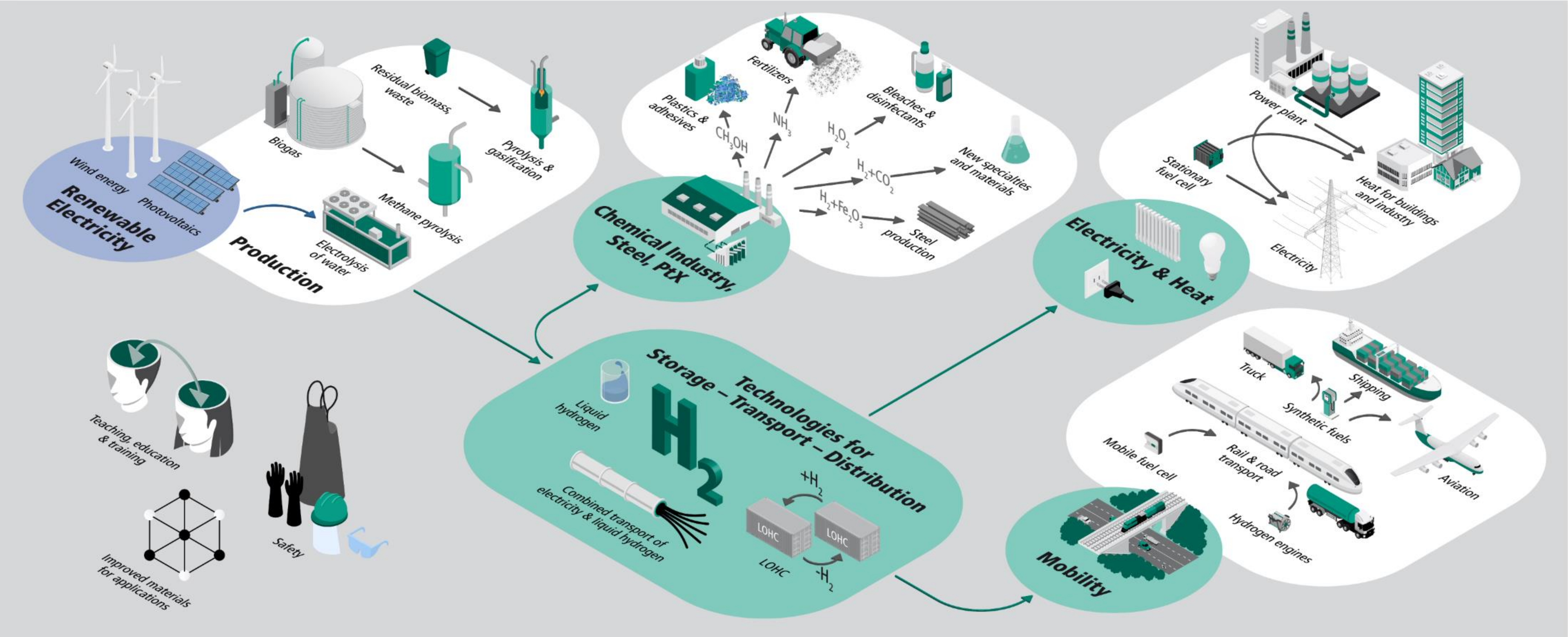

Fusion Materials Laboratory (FML)


Power Hardware in the Loop (PHIL)



The Energy Lab 2.0 is a Large-scale research infrastructure to investigate future energy systems and technologies based on renewable energies. Our mission is to develop technological solutions for the overall energy system in 2050 in order to successfully integrate the renewable energies into the power grid, especially by conducting technology-oriented research on a demonstrator scale and complementing it with comprehensive energy systems analysis.

Hydrogen Research at KIT



R&D Flagships:
New Technology Platforms

Hydrogen Flagship Projects
Green. Great. Global.

Bundesministerium für Bildung und Forschung

KIT Karlsruhe Institute of Technology

H_2Giga
Industrialization of electrolysis
112 Partners
Coordination: DECHEMA e.V.

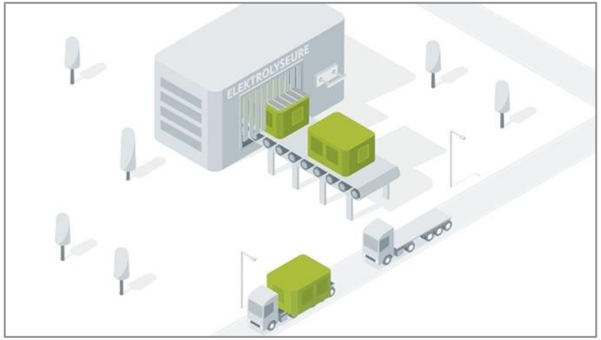
KIT: Ulrike Krewer, Bettina Frohnapfel and others

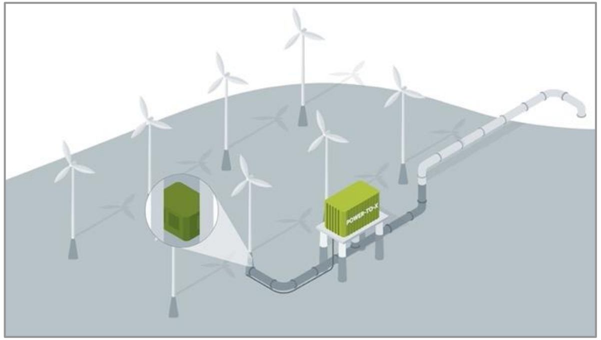
H_2Mare
Offshore electrolysis & PtX
33 Partners
Coordination: Siemens Energy
Total budget ~ 100 Mio €

KIT: Roland Dittmeyer, Harald Horn, Thomas Kolb and others

TransHyDE
Hydrogen transport
89 Partners
Coordination: MPI CEC, Fraunhofer IEG, RWE Renewables

KIT: Tabea Arndt, Thomas Jordan and others



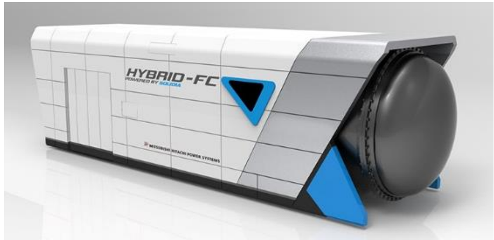


https://www.wasserstoff-leitprojekte.de/leitprojekte

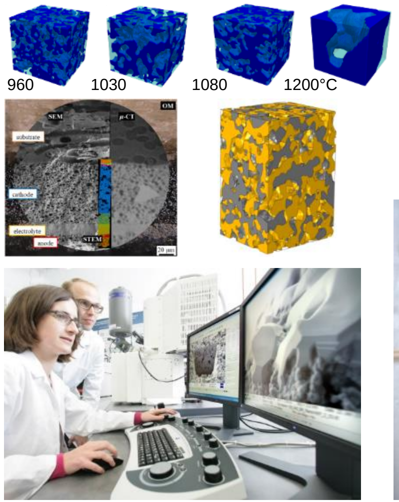
H_2 Giga:

To cover Germany’s demand for green hydrogen, large capacities of efficient and cost-effective electrolysers are needed

Fuel Cells and Electrolysis
High Temperature
Solid Oxide Cells
(500-900°C)

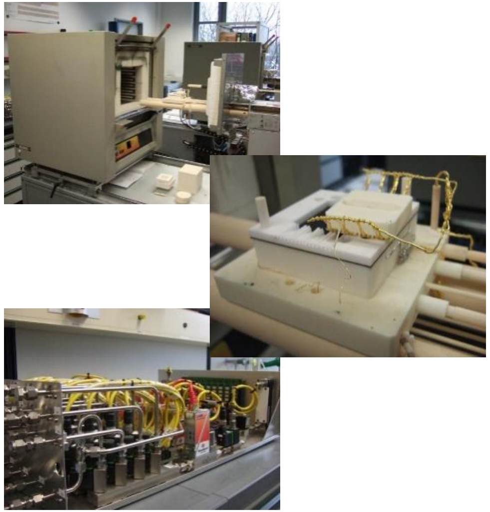


tomography (FIB-SEM, µCT)



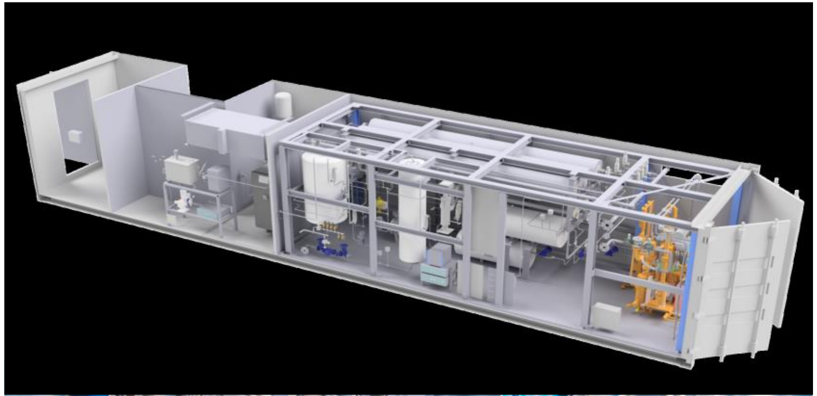
dynamic characterization

cell testing – performance and durability



H_2 Mare Transforming Volatile Power from Renewable Resources to CH_4 by Honeycomb Methanation

- At sea, the conditions are ideal for generating renewable electricity.
- The direct production of green hydrogen from wind power in offshore facilities without grid integration can significantly reduce costs compared to onshore production.
- The H2Mare flagship project will therefore explore the offshore production of green hydrogen and other power-to-X products.



The HCM plant

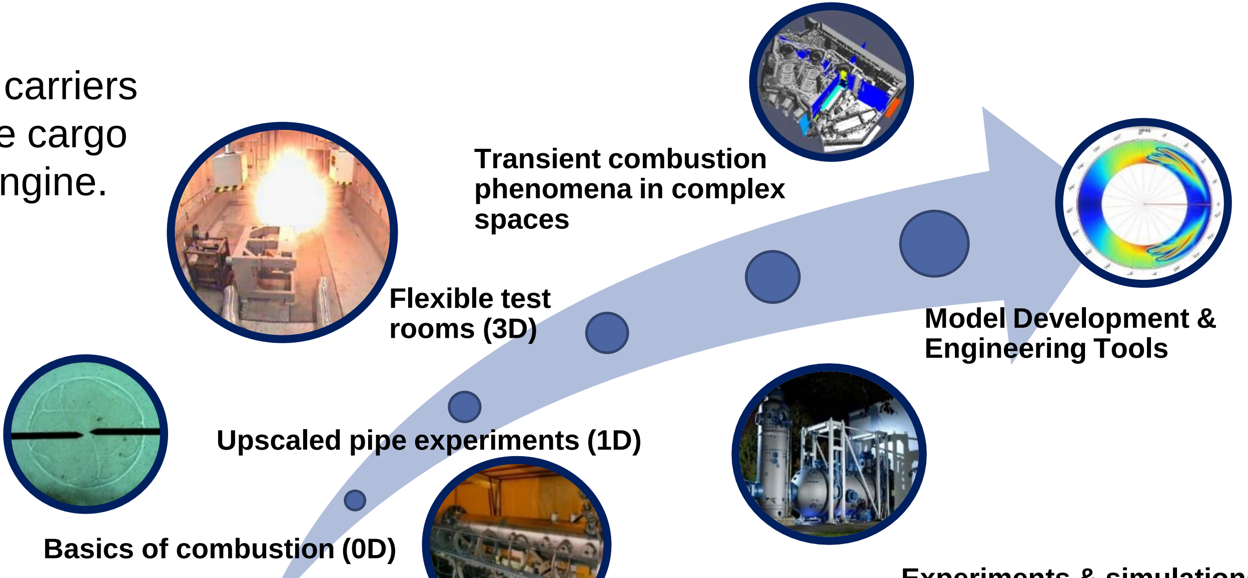
- The HCM plant will create research results for the production of renewable gaseous (CNG) and liquefied (LNG) methane.
- The operation of the interconnected plants will demonstrate the feasibility of the overall process on a technical scale.
- The innovative modular reactor system will speed up the evolution of optimized, large-scale methanation reactors for PtG and BtG processes.

Hydrogen Safety Research

TransHyDE: Without a suitable transport infrastructure, the hydrogen economy cannot function.

Example: Next-generation LH2 carriers may use the boil-off gas from the cargo tanks as additional fuel for the engine.

https://global.kawasaki.com/en/corp/newsroom/news/images/news_210506-2.jpg

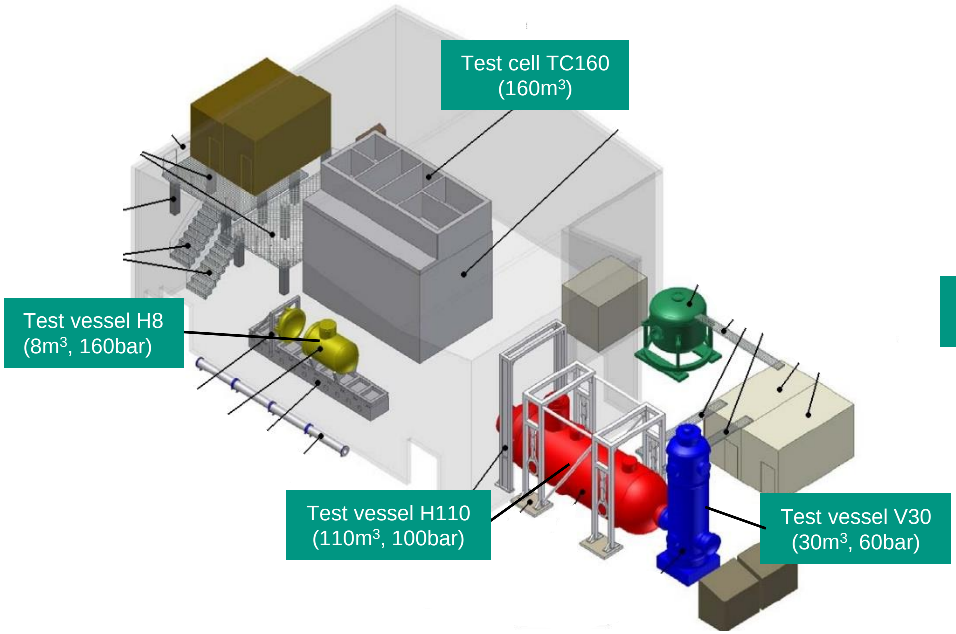


Experiments & simulations
→ Safety studies on industry relevant scales

hySafe FCH ISO iea hydrogen IPHE

Hydrogen Safety Research Test Infrastructure:

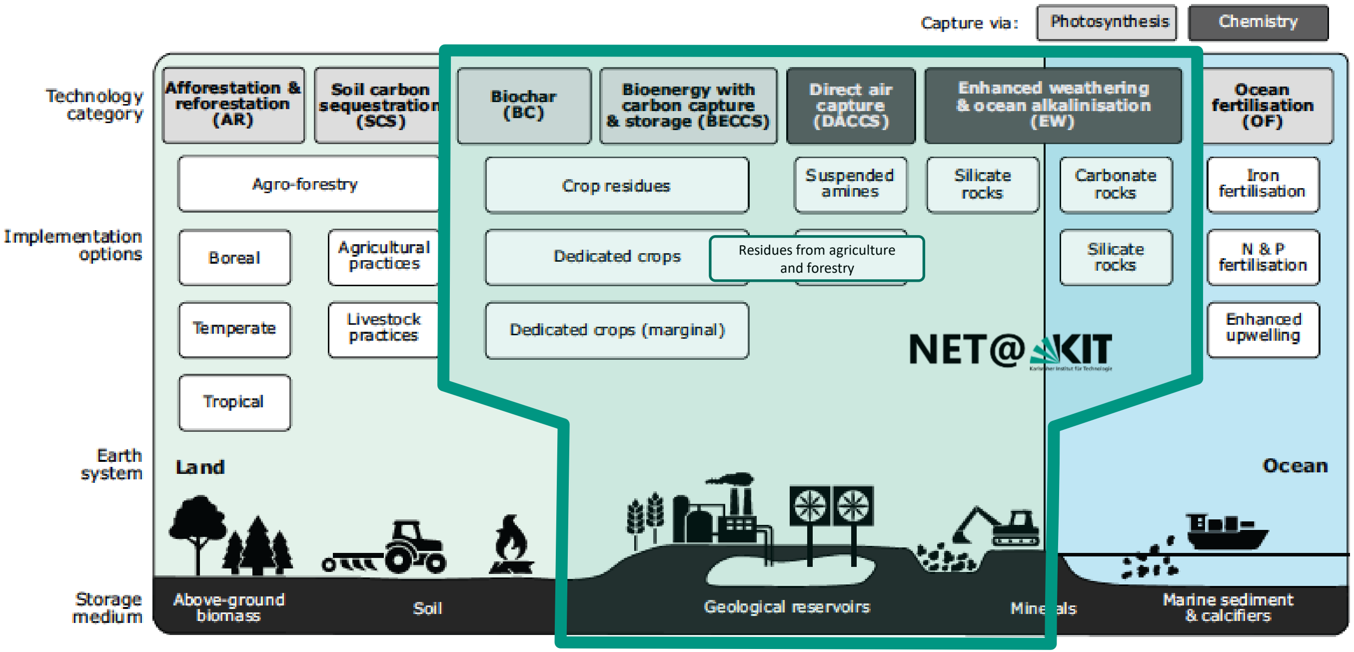
Hydrogen Test Center HYKA



NET@KIT Karlsruher Institut für Technologie

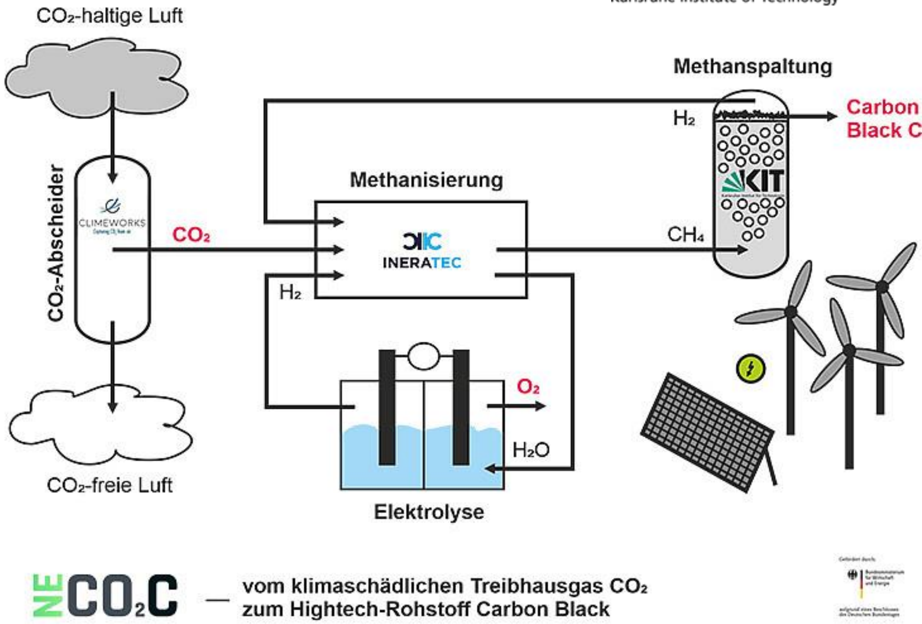
KIT Karlsruhe Institute of Technology

The positive turn for carbon dioxide: How greenhouse gas becomes a raw material



- **At KIT we have all the necessary competencies to do this.**
- **Unique selling point within the national and international research landscape.**

- In the joint project NECOC, a pilot plant for the conversion of climate-damaging carbon dioxide (CO2) from ambient air into solid carbon as a usable raw material for industrial applications is built at KIT.
- Climeworks, INERATEC and KIT bring their know-how together to realize negative greenhouse gas emissions.



Example of a commercial Direct Air Capture & Storage plant "Orca" by Climeworks in Iceland. Orca captures carbon dioxide directly from the ambient air and separates it using an adsorption-desorption process. At its core is a special filter material that acts as a membrane. (Image: Climeworks GmbH)

Reliability of Energy Supply („Zeitenwende-Project“)

Geotechnologies for future climate-neutral energy supply

* **Current energy mix**
  * ≈75% of German primary energy from the geosphere (oil, gas, coal, nuclear fuels).
  * ≈75% of German heat from fossile geo-resources.
* **State of development GeoEnergy**
  * **Hydrothermal state-of-the-art technology**: Roadmap Deep Geothermal Energy for Germany (7-9, depending on regional conditions)
  * Enhanced Geothermal Systems (EGS) technology: towards site-independence
  * Storage: towards large-volume storage (MTET-goal: TRL5-6 in 2027)

*“Market potential of **hydrothermal resources** ≈25 % of total heat demand in GER”*

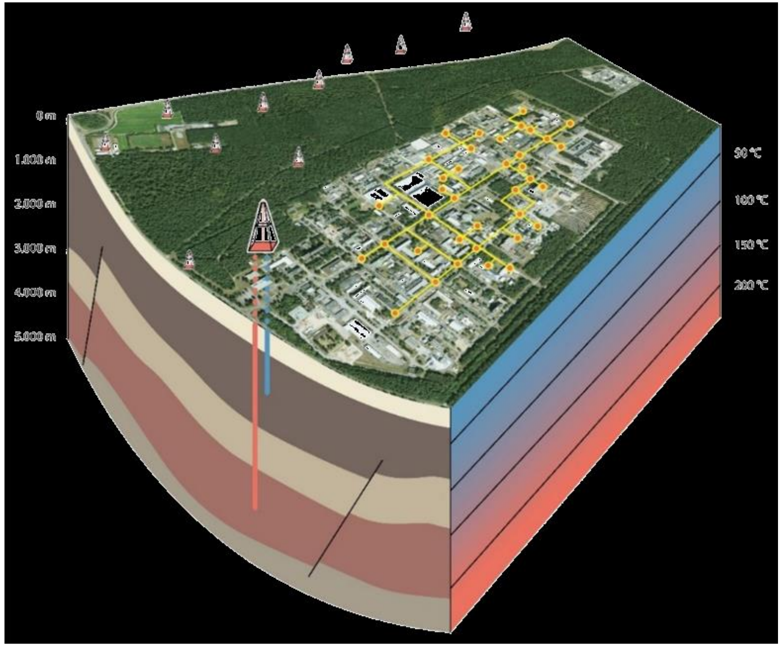
***“Exploration drilling program** to reduce the exploration risk”*

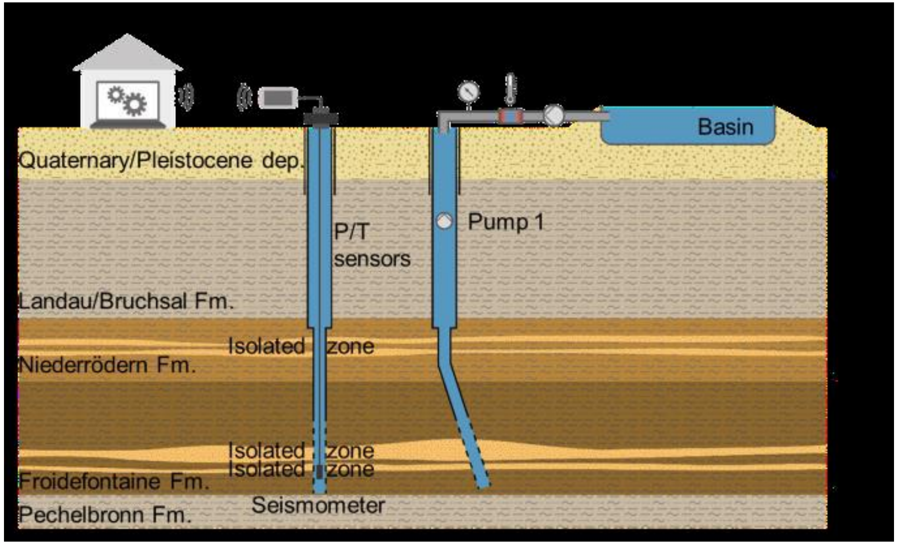
*“Demonstration and pilot plants **with close scientific support”***

DeepStor

High-temperature heat storage in the deep underground

DeepStor is a scientific infrastructure demonstrating the HT-ATES (High Temperature Aquifer Thermal Energy Storage) concept.



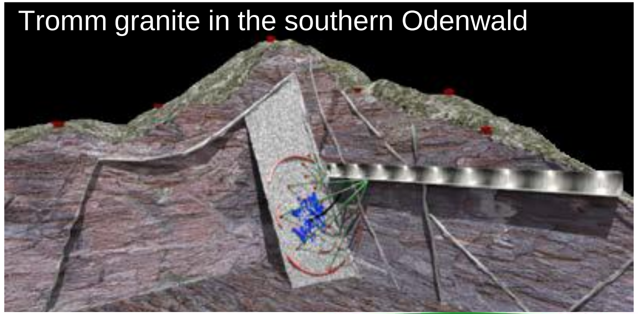


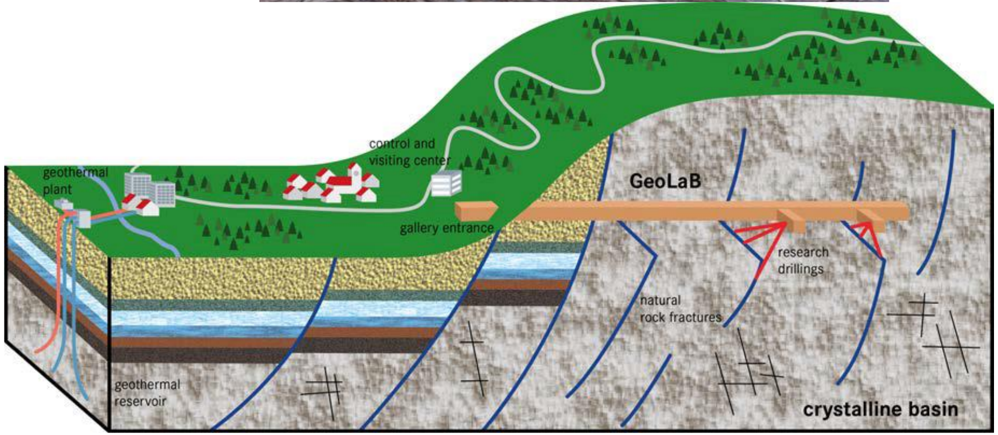
Largest known heat anomaly in Germany with about 170°C in 3 km

GeoLaB - A geoscientific underground laboratory

First large-scale geo-infrastructure in Helmholtz

- Approval of GeoLaB – Geothermal Laboratory in the crystalline Basin
- First generic geothermal reservoir simulator
- Largest geoscientific infrastructure for 35 years
- Addressing basic to applied research
- Cooperative project
  With (Inter-)national partners

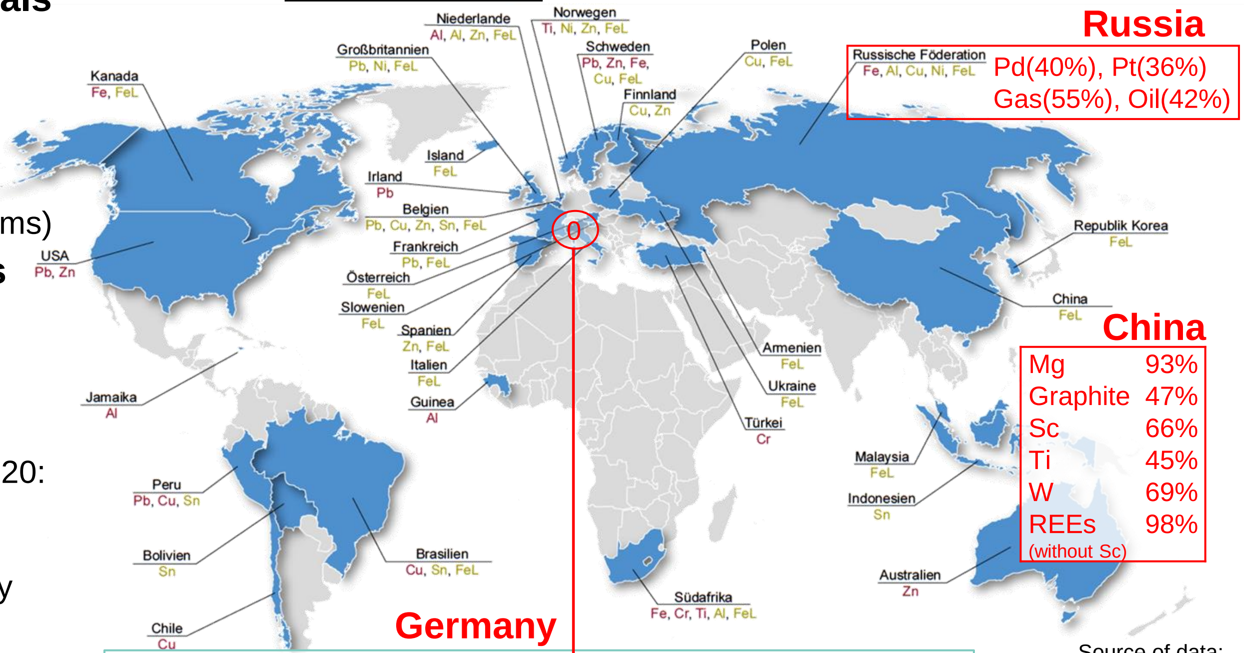




Security of raw materials supply for the energy transition

* **Renewable energies require much more mineral & metal raw materials than fossile energy,** e.g.:
  * Ni, Ti, Pt, Ir (electrolyzers)
  * Co, Li, Graphite (batteries)
  * Rare Earths (wind turbines)
  * Cu (digitalization, power based systems)
* **Oil and gas dominant feedstocks for chemicals production**
* **Supply strongly dependent on Russia (and China!)**
  * Germany imported from Russia in 2020: Ni 44%, Ti 41%, Pt 36%, carbon as material > 50%
  * China controls > 40% of most primary raw materials

Bulk Commodities   Critical Raw Materials



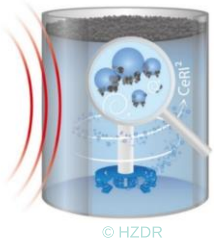
* No relevant domestic mining sector
* Recycling contributes < 10% of metal and carbon demand

Source of data: BGR (2021), EU (2020), Statista (2022)

Security of raw materials supply for the energy transition

Karlsruhe Institute of Technology

* **Goal:**
  * Independent supply through **closing of material cycles**
* **Contribution:**
  * Raw materials supply for the energy transition
  * Higher domestic carbon recovery
  * Energy demand reduction through recycling
* **Proposal:**
  * **Intensification** of technology transfer and industrial cooperation on recycling and recovery technologies
  * **Accelerating** realization of Helmholtz infrastructures FlexiPlant, CeRI^2 and CC-Lab for advanced processing and recycling research



CeRI²

Center for Resource Process Intensification and Interface Studies

FlexiPlant

Flexible Processing Plant Demonstrator Platform

C-Lab

Research & Development Platform for the Future Carbon Cycle

Graduate School – Enabling Net-Zero (ENZo)

- Shaping future technologies
- Lectures
- Real-World projects

Graduate School „ENZo“ - Enabling Net Zero
Management Team: **Scientific Spokesperson: Jörg Sauer**, Coordinator: Heike Kull

Future of Energy Systems and Technologies
Focus: Sector Coupling and Circular Economy

Renewable Energies
(E. Schill, A. Colsmann)

- Geothermal Energy: Heat, Power, Underground Heat Storage
- Photovoltaics: Materials & Modules
- PV Integration / Electrical and Chemical Storage

Topic SCI: Sector Coupling Industrie –
Electricity, Heat, Chemical Energy (Sources)
(R. Dittmeyer, B. Ladewig)

- Coupling of Release, Storage, Application
- Decentralized Concepts

Topic SCC: Sector Coupling Construction -
Integral Building and Quarter Concepts
(A. Wagner, V. Hagenmeyer)

- Integrated Building and Energy Concepts
- Nearly Zero Emission Buildings
- Energy Management at Quarter Level

Topic CE: Circular Economy –
Use of Raw Materials and Energy
(D. Stapf, R. Volk)

- Anthropogenic Carbon Cycle
- Metals
- Construction materials

Topic HES:
Humankind in the Energy System
(W.-R. Poganietz, A. Ardone)

- Techno-economic Assessment
- Interaction Technology - Society
- Acceptance of Technological and Social Developments

Topic ML:
Machine Learning and digital Tools
(R. Mikut, R. Markovic)

- Time Series Modeling
- Generative Modeling
- Modeling Integration

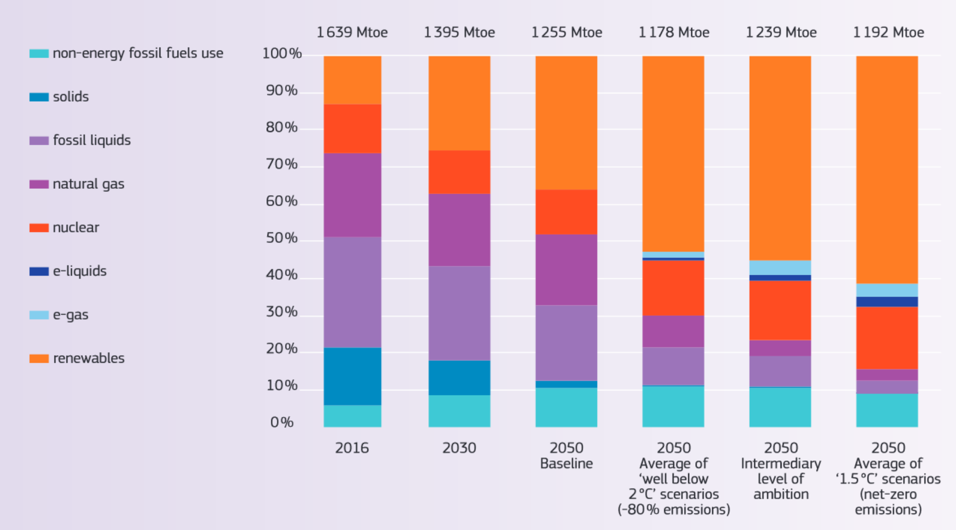
KIT Energy Center

The European Commission's vision outlines seven main strategic building blocks:

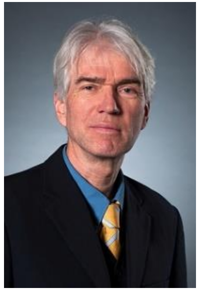
- maximise the benefits of energy efficiency, including zero emission buildings;
- maximise the deployment of renewables and the use of electricity to fully decarbonise Europe's energy supply;
- embrace clean, safe and connected mobility;
- a competitive EU industry and the circular economy as a key enabler to reduce GHG emissions;
- develop an adequate smart network infrastructure and interconnections;
- reap the full benefits of bioeconomy and create essential carbon sinks;
- tackle remaining CO2 emissions with Carbon Capture and Storage (CCS)

Framework is required to:

- Spur research and innvoation
- Scale up private investments
- Provide the right signals to market
- Ensure social cohesion so no one is left behind



Contact



Dr. Walter Tromm
Scientific Spokesperson

Dr. Wolfgang Breh
Managing Director

Alexander Hertenstein
Executive Assistant

Sabrina Meo Colombo
Assistant

For further information please go to: www.energy.kit.edu