Karlsruhe Institute of Technology

ENERGY LAB 2.0

Synthetic fuels from CO_2 and renewable electricity can make a significant contribution to achieve CO_2-neutral mobility.

The Three-Phase Methanation (Power-to-Gas)

Methanation is a promising process for storing volatile renewable energies in form of chemical energy carriers. The three-phase methanation (3PM) is a unique catalytic process with highly dynamic operability.
In the bubble column reactor of the 3PM a mix of hydrogen and carbon dioxide or carbon monoxide disperses into a suspension of solid catalyst particles and inert liquid – the three phases. At the surface of the catalyst, the educt gases react to methane.
Excellent selectivity and educt conversion rate guarantee high yields, a methane synthesis with hardly any byproducts and a methane output of about 10 m³/h in the shown pilot plant.
The efficient heat absorption of the liquid phase allows dynamic load changes from 0 to 100 % within a few minutes, grants an optimal control of the reaction and allows heat extraction for further purposes.
By feeding the methane into the omnipresent gas grid, storage capacities and all established applications for natural gas can be used.

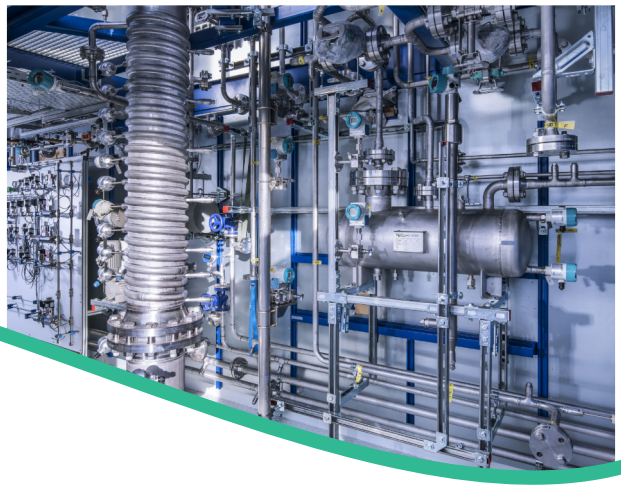
Key data:

- Feed gas: Syngas with H_2 and CO_2 (and/or CO)
- Product: CH_4
- Nominal power: 100 kW (CH_4 output)
- Pressure: 1 - 20 bar
- Temperature: 250 - 330 °C
- Bubble column reactor: $Ø_i$ = 250 mm, l = 2.500 mm
- Modified 40’ shipping container

Facts:

- **Scale**:
  Pilot plant at KIT can supply around 50 households with CH_4
- **Methane-Yield**:
  CH_4 yield > 95 % possible
- **Dynamic Operation**:
  Load changes from 0 to 100 % within one minute
- **Efficiency**:
  Methanation efficiency of 80 %. Can be increased further by utilization of reaction heat (T > 250 °C).

The picture of the process room shows several main components:
gas mixing rack, reactor, condensate vessel (f.l.t.r)
Photo: A. Bramsiepe, KIT



Headerphoto: A. Bramsiepe, KIT

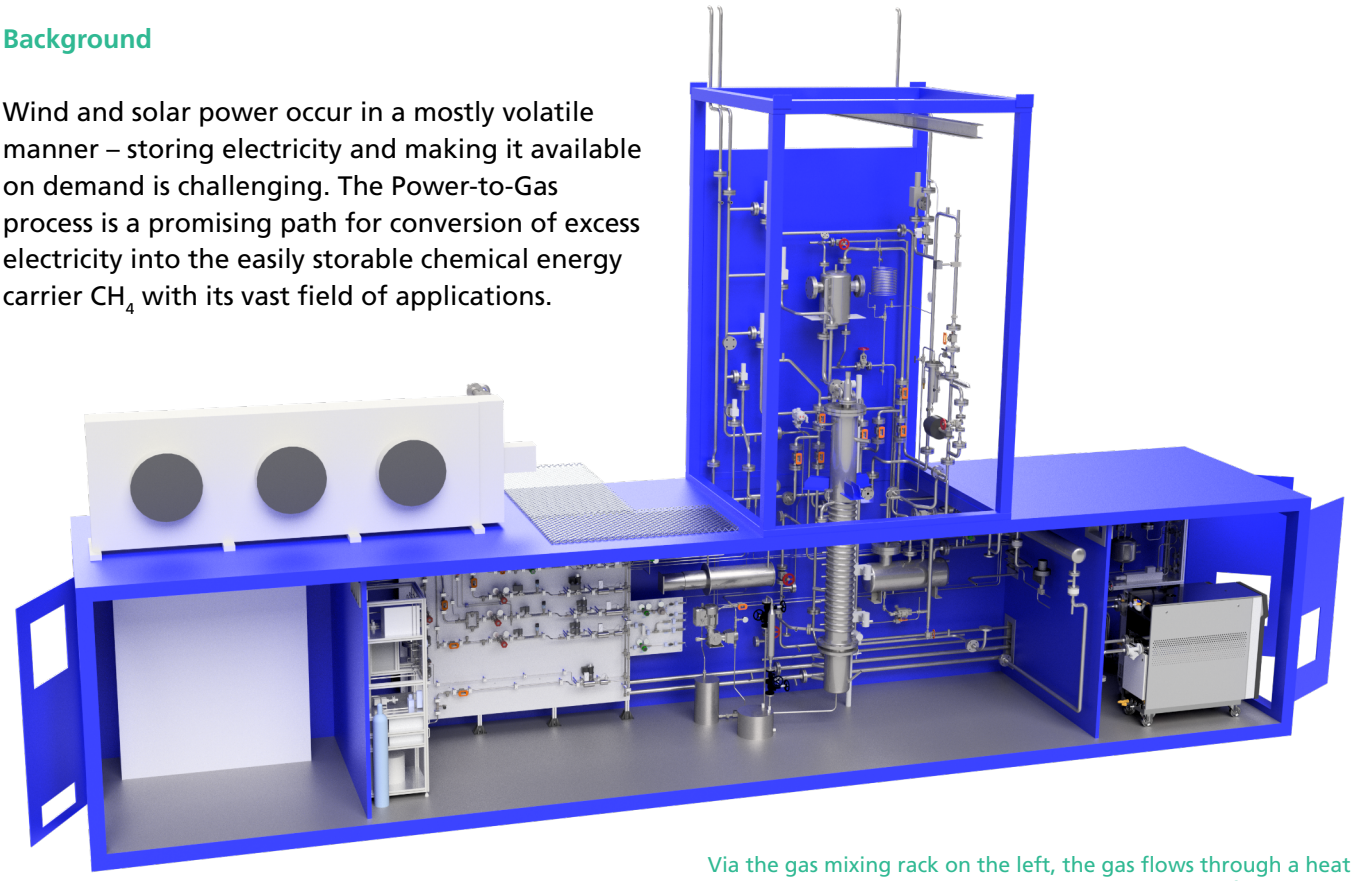
Karlsruhe Institute of Technology

ENERGY LAB 2.0

The Three-Phase Methanation (Power-to-Gas)

Background

Wind and solar power occur in a mostly volatile manner – storing electricity and making it available on demand is challenging. The Power-to-Gas process is a promising path for conversion of excess electricity into the easily storable chemical energy carrier CH_4 with its vast field of applications.



Via the gas mixing rack on the left, the gas flows through a heat exchanger and is introduced into the reactor from below. Afterwards, the product gas is cooled and dried and available for utilization. Two thermostats on the right of the drawing control the temperature of the reactor and the heat ex-changers and can be coupled with heat utilization processes.
Picture: Raphael Küchlin

The 3PM plant

KIT operates a pilot scale 3PM plant to create research results and process knowledge. The focus lies on a more profound understanding of reaction kinetics, hydrodynamics and mass transfer in dynamically operated bubble column reactors for catalytic reactions like methanation. The larger scale eliminates wall effects, a decisive advantage compared to laboratory scale.
The 3PM enables the conversion of hydrogen and carbon dioxide and/or monoxide to methane according to following equations:

$$4\ H_2+CO_2 \rightleftharpoons CH_4+2\ H_2O$$
$$3\ H_2+CO \rightleftharpoons CH_4+H_2O$$

Vision

Feeding sustainably produced methane into the well-established gas infrastructure with its vast storage capacity fuels multitudes of applications throughout the country and mobility applications in form of renewable LNG or CNG.
The utilization of carbon dioxide from renewable sources and its subsequent reuse in the form of methane is CO_2-neutral and therefore does not increase greenhouse gas emissions. Apart from the high load flexibility, the excellent heat extraction capabilities of the 3PM process offers opportunities for further increases in process chain efficiency due to intensive heat integration.

Dr. Siegfried Bajohr
Engler-Bunte-Institut (KIT)

Engler-Bunte-Ring 1
Gebäude 40.51

siegfried.bajohr@kit.edu

Federal Ministry of Education and Research
Federal Ministry for Economic Affairs and Energy
Baden-Württemberg
MINISTERIUM FÜR WISSENSCHAFT, FORSCHUNG UND KUNST