Transforming Volatile Power from Renewable Resources to CH_4 by Catalytic Three-phase Methanation.

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

Key data:

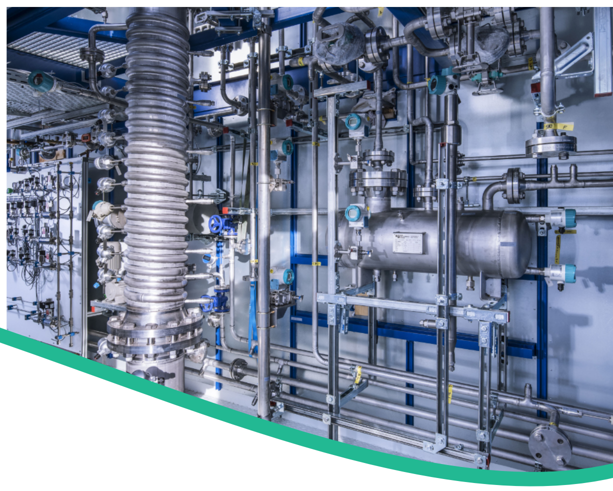
- Feed gas: Syngas with H_2 and CO_2 (and/or CO)
- Product: CH_4
- Nominal power: 100 kW (CH_4 output)
- Pressure: 1 - 20 bar
- Temperature: 250 - 330 °C
- Bubble column reactor: $Ø_i$ = 250 mm, l = 2.500 mm
- Modified 40' shipping container

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).

Methanation is a promising process for storing volatile renewable energies in the form of chemical energy carriers. Three-phase methanation (3PM) is a unique catalytic process of 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.
At the surface of the catalyst, the educt gases react to methane.
An 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 pilot plant at KIT.
The efficient heat absorption of the liquid phase allows dynamic load changes from 0 to 100 % within a few minutes, ensures an optimal control of the reaction, and allows heat extraction for further purposes.
Feeding the methane into the omnipresent gas grid, storage capacities and all applications established for natural gas can be used.

Picture of the process room with several main components:
Gas mixing rack, reactor, condensate vessel (f.l.t.r)



Photos: A. Bramsiepe, KIT

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ENERGY LAB

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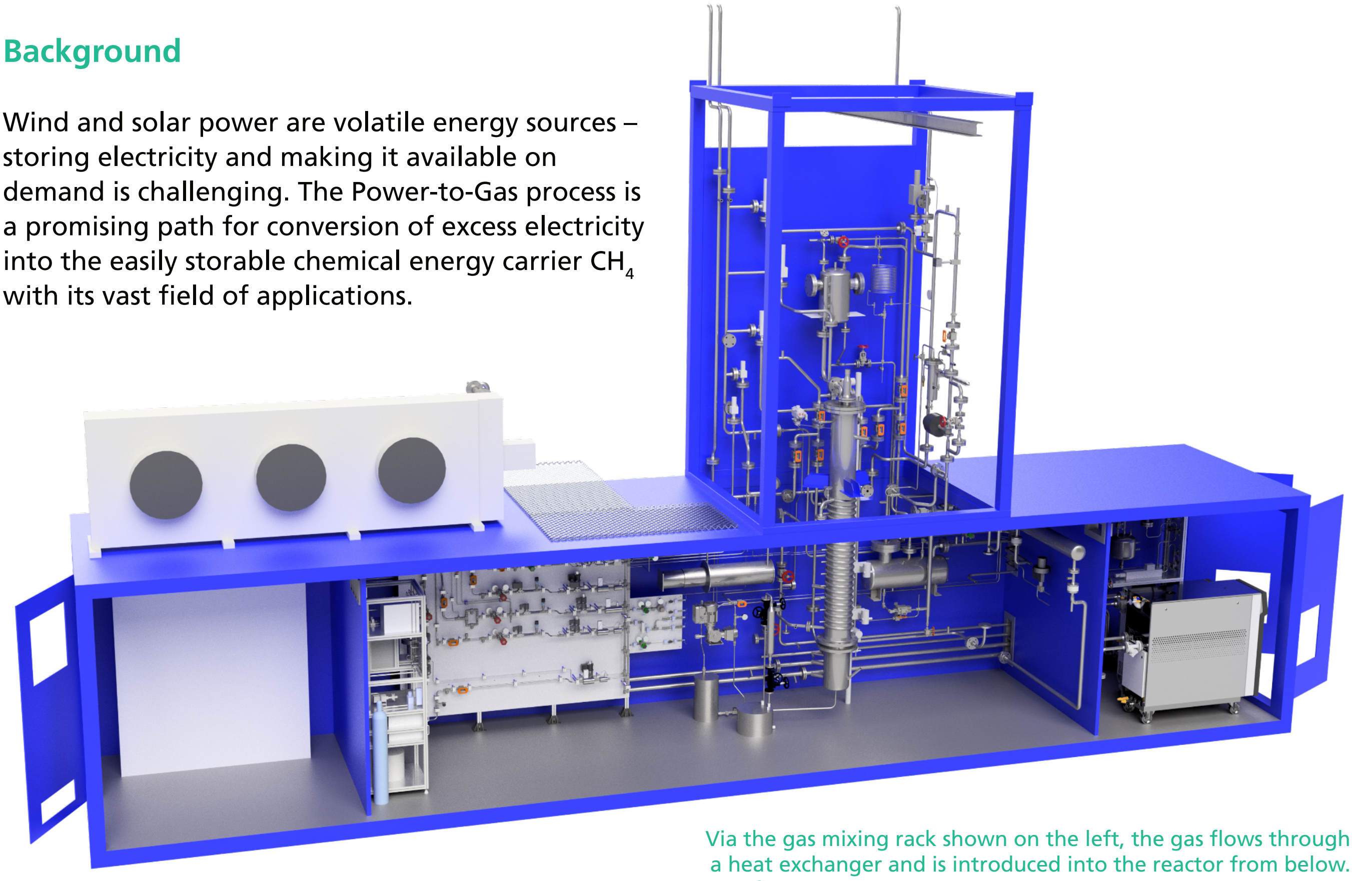
Background

Wind and solar power are volatile energy sources – 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 shown 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 shown on the right of the drawing control the temperature of the reactor and the heat exchangers 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, which is a decisive advantage as compared to the laboratory scale. The 3PM enables the conversion of hydrogen and carbon dioxide and/or monoxide into methane according to the following equations:

$$4\,H_2 + CO_2 \rightleftharpoons CH_4 + 2\,H_2O$$

$$3\,H_2 + CO \rightleftharpoons CH_4 + H_2O$$

Vision

Sustainably produced methane fed into the well-established gas infrastructure with its vast storage capacity supplies multitudes of systems throughout the country and mobility applications in form of renewable LNG or CNG. The use 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.

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