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Power to Methanol

Seasonal energy carrier – Power-to-X technology

Methanol is a raw material for the chemical industry, but it is also used as a solvent or as an energy source. The reported global methanol capacity in 2023 was around 170 Mio. tonne, and it is expected to grow by >9% until 2028 [1]. The production is facing an environmental challenge, as most methanol is currently produced via steam reforming of natural gas. In recent years, progress has been made in using CO_2 from either direct air capture or exhaust gases from processes, such as biogas production, waste incineration, or wastewater treatment plants.

When CO_2 is combined with hydrogen, it can be converted into methanol. The reaction path is described in the following chemical equation:

$$CO_2 + 3\,H_2 \leftrightarrow 2\,CH_3OH + H_2O$$

Hydrogen is produced through the process of water splitting via electrolysis (see corresponding factsheet). For the Power-to-Methanol (PtMeOH) process, the electrolyser can be powered by excess electricity generated from solar (PV), hydro power, or wind energy.

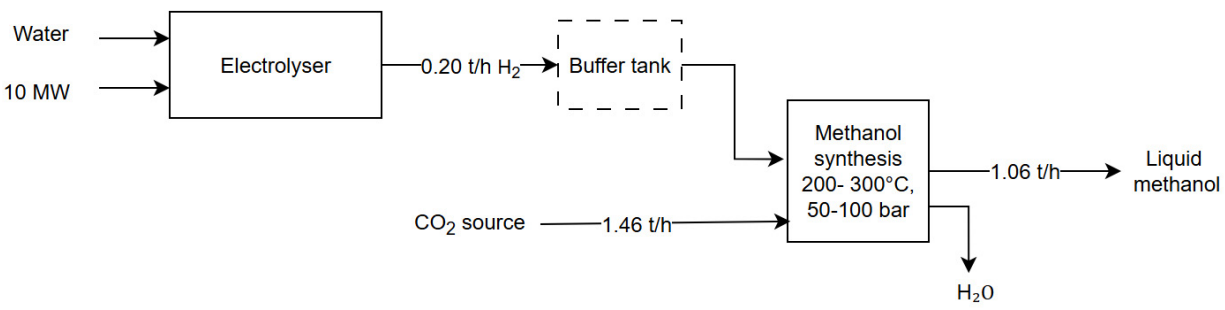
If this methanol is burned, the same amount of CO_2 is released as was used in its production for synthesis. If the used CO_2 is taken from Direct Air Capture (DAC) or from renewable exhaust gases (CO_2 from Biogas), the carbon cycle is thus closed, the process chain is carbon neutral. Methanol from renewable sources cuts CO_2 emissions by up to 95% compared to conventional fuels [2].

The first company that started producing PtMeOH is in Iceland and is still operational with an annual production capacity of 4000 t. Other companies in China, Chile, and India followed with an additional production capacity of around 5400 t/a [2]. In May 2025, a plant in Denmark was inaugurated with a production capacity of 42 kt/a. This Methanol will support the decarbonisation of sectors that are difficult to electrify and will be sold to companies such as Maersk, LEGO, and Novo Nordisk [3].

The biggest plant, which is currently in the engineering phase, is located in the USA and owned by HIF Global and will have a capacity of 1.4 Mio. tonne per year. The announced PtMeOH projects have a projected total capacity of 10.1 Mio. tonne by 2030 [2].

The PtMeOH-to-Storage efficiency is around 56% [4], assuming a hydrogen electrolysis efficiency of 70%, a CO_2 from biogas fermentation (0.43 kWh per kg CO_2, and a MeOH synthesis efficiency of 85%. If CO_2 DAC is used instead, with an estimated energy requirement of 3.44 kWh per kg CO_2, then the PtMeOH-to-Storage efficiency decreases to 35%.

In general, methanol synthesis itself is well established; its integration with electrolysers is relatively new, with the technology readiness level (TRL) estimated at 6–7 [12].



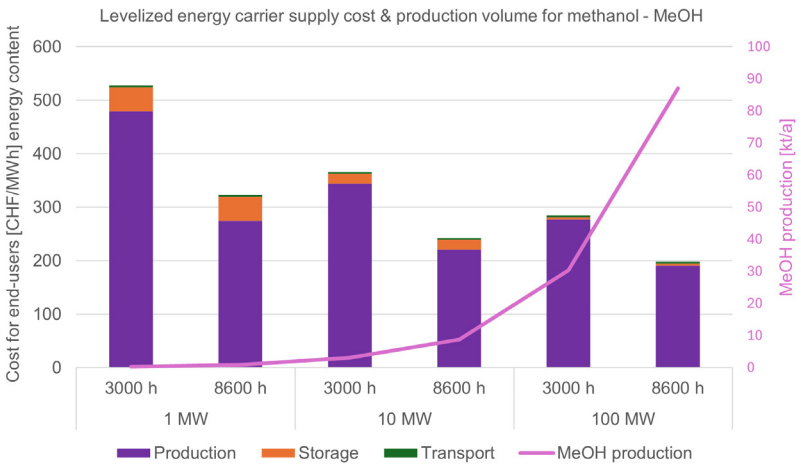
Availability & ressources

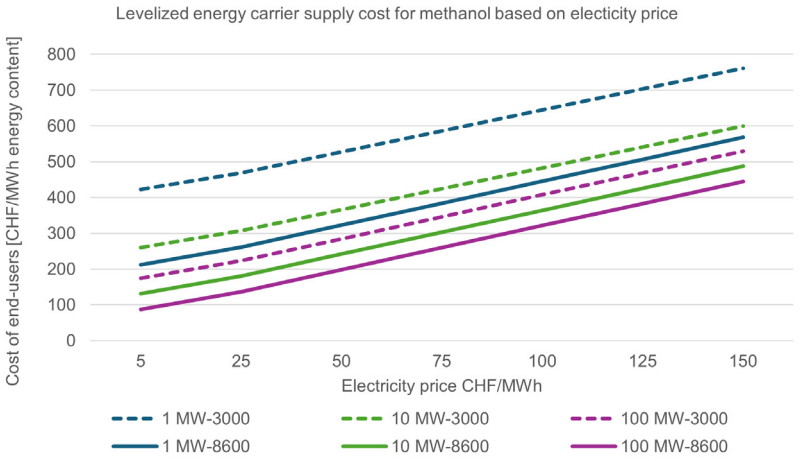
Global production of methanol in 2023	170 Mio tonne [1]
Global production of PtMeOH	38 000 tonne [2]
CH production of PtMeOH in 2024	0
CO_2 source	Wastewater treatment plant, biogas, Direct air capture (DAC)

Chemical properties & Safety

Volumetric energy density (LHV): Net calorific value	4380 kWh/m3 [5] @ standard conditions: 273.15 K, 1.013 bar
Gravimetric energy density	5.53 kWh/kg [5]
Melting point / boiling point	-98 / 65 °C
Flash point / Auto ignition	11 / 464 °C
Explosive / flammability limits in air	Highly flammable (6.7-36.5%)
Health safety	Toxic if swallowed, inhaled or skin contact. May cause cancer
Safety (hazard based on EU Regulation)	H225, H301, H311, H331, H370
Safety (precaution based on EU Regulation)	P210, P233, P240, P241, P242, P243, P260, P280, P301+P310, P303+P361+P353, P304+P340, P305+P351+P338, P307+P311, P403+P235, P501

Cost analysis





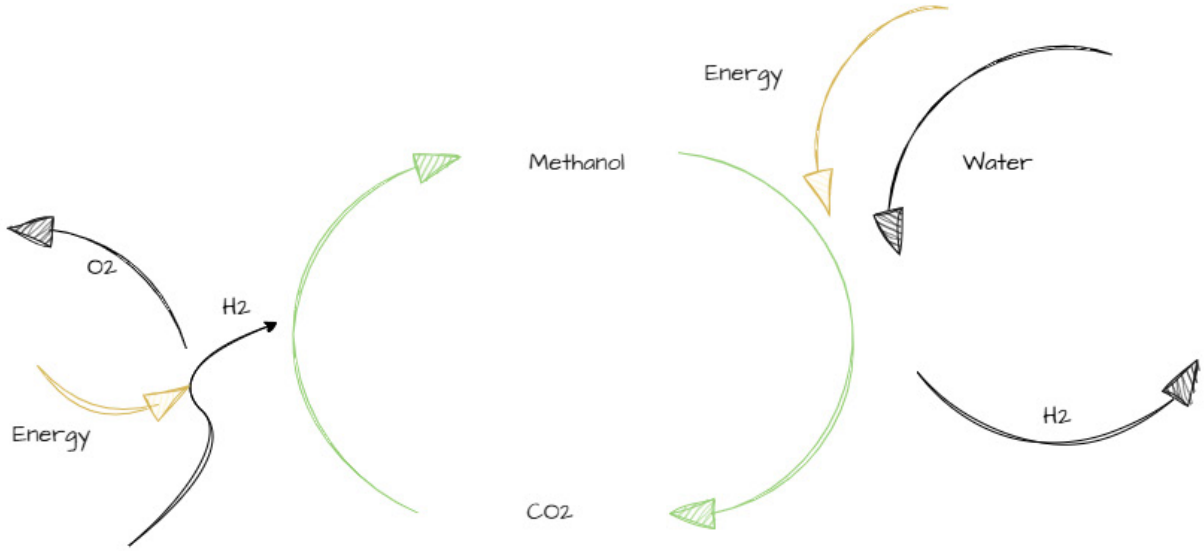
The upper left graph presents the cost distribution for installed MeOH capacities of 1 MW, 10 MW, and 100 MW under two operational modes (3000 and 8600 h). A fixed cost on CO_2 with 0.05 CHF/kg has been applied, taking the average unit cost for different CO_2 sources and technologies. Larger installed capacities result in lower carrier supply cost, while the pink line indicates the corresponding annual production volume in kilotons.

The lower left graph shows how the overall MeOH carrier price depends on the electricity price, with an increase of about 100 CHF/MWh-MeOH for every 25 CHF/MWh rise in electricity cost.

Production cost is the main cost driver, while transport and storage account for a small portion of the cost [6]. The calculation on the transport cost is based on a transport distance of 50 km by truck for 0.64 CHF/tkm [10]. The cost drivers in production are the hydrogen electrolysers and the MeOH synthesis plant. [7,8]. With higher installation capacity and more annual operating hours, the cost per unit of the energy carrier decreases. The cost of fuel (OPEX) ranges between 100 and 600 CHF/MWh, depending on plant size and electricity cost. Transport and logistics add between 3 and 10 CHF/MWh for truck deliveries over distances of 50 to 150 km.

For detailed cost information on hydrogen, refer to the corresponding Power-to-Hydrogen factsheet.

Simplified MeOH concept



Above a simplyfied concept of PtMeOH production. Water serves as an input and is split into hydrogen and oxygen. The hydrogen is then combined with CO_2 to produce methanol.

To retrieve hydrogen, a reforming process of methanol is required, releasing hydrogen and CO2. The hydrogen is then introduced into a fuel cell to generate energy, while the CO_2 is reused for methanol production.

Sources / additional information

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