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Renewable methanol

Methanol is the simplest form of alcohol and it is mainly produced via synthesis gas (H_2 and CO) derived from fossil feedstocks, such as natural gas and coal. Approximately 70% of the global methanol demand is currently used in the chemical industry, but the fuel and energy markets are increasing steadily and represent around 30% of the global use. Renewable methanol can be produced as a biofuel or an electrofuel, and can be used blended with petrol, as marine fuel, or in fuel cells. Renewable methanol is currently produced at small scale compared to conventional fossil-based production.

Properties

Chemical formula: CH3OH Molecular mass: 32.04 g/mol C (%wt) 37.5 H (%wt) 12.5 O (%wt) 50 Density at 20°C: 791 kg/m³ Viscosity at 20°C: 0.59 mPa s Heating value: 19.9 MJ/kg	Methanol is a colorless and water-soluble liquid that burns with an invisible flame. It has a faint smell and boiling point of 65°C. It is more corrosive than petrol. Methanol is highly toxic to humans, but less toxic than petrol and not carcinogenic. An important benefit is that in case of spills, methanol is biodegradable.

Primary area of use

Renewable and fossil methanol are chemically the same molecule, and therefore identical from a usage perspective. Approximately 70% of the global methanol supply is used in the chemical sector. Out of this, roughly 20%-points is used for olefins production using the so-called MTO-process, while 50 %-points is used to produce other chemicals such as formaldehyde and acetic acid. Chemicals produced from methanol are used in the production of many common products, such as paints, antifreeze agents, plastics, and propellants. (Methanex 2025)

About 30% of the global methanol supply is used in various fuel applications, either directly as a fuel (commonly in blends with gasoline) or indirectly as a precursor to other fuels or additives, including biodiesel and the gasoline additive MTBE.

Methanol has a high octane number making it a good alternative to fossil petrol, which has been demonstrated for e.g. M15, M85 and M100. The EU allows low blending up to 3 vol-% in petrol, but the market norm is for gasoline with no more than trace amounts of methanol (S&P Global 2022). While older cars had a limited ability to handle high oxygen content and therefore couldn't use gasoline blends with more than 3-5 vol-% methanol, modern cars have been shown to handle blend rates as high as 15 vol-% successfully (Methanol Institute 2016).

When the blend rate exceeds 15 vol-%, modifications are required. Examples include higher fuel injection to compensate for the lower energy density, modification to the ECU (Engine Control Unit), and material modifications to endure the corrosiveness of methanol. Emissions in the form of carbon monoxide, nitrogen oxides and hydrocarbons are lower from methanol compared to petrol, and methanol contains very low levels of impurities of sulphur or metals. The energy content (Lower heating value, LHV) is 15.8 MJ/litre (or 19.9 MJ/kg), slightly less than half of that of petrol.

Methanol producers expect significant growth in the demand for renewable (or low-carbon) methanol in the coming decade, but primarily from new applications. In particular, there is significant interest in methanol as a marine bunker fuel, due to international regulatory changes (e.g., the FuelEU Maritime regulation), low non-CO_2 emissions and cost advantages relative to other alternative fuels. (Methanex 2025)

Although not commercially significant today, jet fuel production from methanol is possible using so-called methanol-to-jet (MtJ) technology. MtJ using sustainable methanol as feedstock is one of many potential pathways to produce sustainable aviation fuels (SAF), and the technology is being licensed by, e.g., Topsoe. (Topsoe 2026)

Feedstock and production

Conventional (fossil) methanol is produced in two steps. First, the feedstock (currently mainly fossil fuels like natural gas and coal) is converted into a synthesis gas consisting of CO, H_2 and smaller amounts of CO_2 through catalytic reforming or partial oxidation. In the second step methanol is synthesised catalytically from the synthesis gas. Each of these steps can be carried out in a number of ways using different technologies. The methanol process has a high selectivity leading to high production efficiency. The total global nameplate capacity was estimated at 158 million tonnes per year by methanol producer Methanex in 2025. (Methanex 2025, Topsoe n.d.)

Renewable methanol can be produced either as a biofuel or an electrofuel and both tracks are being pursued by many companies and projects. However, the combined capacity of bio- and electro-methanol plants worldwide is less than 1 million tonnes per year, i.e., less than 1% of the total production capacity.

Bio-methanol can be produced in a process identical to that for fossil methanol production from natural gas, if the natural gas is replaced for biomethane (upgraded biogas). Alternatively, bio-methanol can be produced in a two-step process wherein biomass feedstock is first gasified to produce a raw gas that is conditioned to the requirements of conventional methanol synthesis. The synthesis gas is then fed to a catalytic synthesis step that is identical to that for conventional production. The gasification step is feedstock flexible and a wide range of solid biomasses can be used, including agricultural waste, municipal solid waste, and other lignocellulosic resources. Finally, small bio-methanol volumes are produced from black liquor by kraft pulp mills. (Danish Energy Agency 2025)

Electro-methanol is produced from hydrogen (that is produced by water electrolysis, hence the "electro"-prefix) and captured carbon dioxide using either a one-step or a two-step ("indirect") process. In the one-step process, hydrogen and CO_2 are fed directly into a catalytic synthesis reactor that is similar to that used in the second step of the conventional process. Compared to the synthesis gas used in the conventional process (that mostly contains H_2 and CO), an H_2/CO_2 mixture contains extra oxygen, which means that more water will be formed in the methanol reactor. In a two-step process, the H2/CO_2 mixture (with excess of H_2) is first sent to a reverse water-gas-shift reactor where H_2 and CO_2 are "shifted" to CO and H2O (water). After removal of the formed H2O, this gives a synthesis gas matching the gas produced in the first step of the "conventional" process, which can be sent to a conventional methanol reactor. (Danish Energy Agency 2025)

The bio-based process generates an excess of CO_2 that is separated from the process before the methanol synthesis. Alternatively, renewable hydrogen can be added to balance the excess CO_2, combining the bio- and electro processes into one hybrid process.

Distribution and storage systems

The technology for distributing and storing methanol is very similar to the current systems used for petrol and diesel, including pipelines, barges, chemical tankers, rail tankers and trucks. Material components must however be replaced to endure the corrosiveness of methanol. In Sweden, some distribution systems are adapted to alcohols, and systems adapted for E85 can also store M85 or GEM fuels (gasoline-ethanol-methanol).

Some risks are associated with the transportation and distribution of methanol. Methanol is highly toxic to humans and can cause blindness or even death on ingestion. Methanol is classified like petrol or diesel regarding toxicity but is non-mutagenic and methanol vapour does not involve any health risks under practical conditions. Methanol biodegrades very rapidly in aerobic as well as anaerobic conditions and it will not persist in the environment. The half-life in groundwater is several hundred days shorter for methanol in comparison to petrol components.

Renewable methanol production plants

Gena Solutions tracks renewable methanol globally; this section is based on the Gena's December 2025 status update and its underlying database (Gena Solutions 2025). At the end of 2025, the global production capacity for renewable methanol was just below 1 million tonnes per year, mostly in the form of bio-methanol. The least technically and economically challenging production pathway for renewable methanol is to use biomethane in a conventional, natural gas-based process, either in a dedicated plant (using only biomethane) or mixed in the natural gas feedstock of a fossil plant. This production pathway accounts for about 60% of the renewable capacity, with large plants (> 100 ktpa) being operated by Methanex in the USA and by Shanghai Huayi Group in China. The second largest group of operational plants are based on gasification of biomass, with China accounting for the lion's share of installed capacity. (Gena Solutions 2025)

Electro-methanol accounted for about 10% of the installed capacity at the end of 2025, i.e., roughly 100 kilo tonnes per year. The oldest operational plant is CRI's 4 ktpa George Olah-plant in Iceland, constructed in

[1] In principle, the biomethane input can also be produced via biomass gasification. However, if gasification is used, methanol can be produced directly from the gasification products without taking the route via biomethane.

2010-2012 (Carbon Recycling International n.d.). One new plant was commissioned in Europe during 2025: European Energy's 42 ktpa Kassø-plant. Chinese plants account for most of the remaining capacity.

About 45 Mtpa of methanol capacity with start-up dates before the end of 2030 was under development at the end of 2025. The project pipeline is split almost 50/50 between electro- and biobased production indicating that there is (currently) no clear winner between the two pathways. Among bio-methanol projects, the gasification pathway accounts for most of the capacity under development. China is poised to be the global leader in renewable methanol production with ca 80% and 40% of the bio- and electro-methanol project pipelines, respectively. Although biomethane-plants account for most of the installed capacity, this pathway is limited by the availability of biomethane (and ultimately by the availability of biogas produced from anaerob digestion) and represents only 4% of the project pipeline. However, it should be noted that the conversion of a natural gas-plant to biomethane is straightforward compared to other renewable methanol production pathways and may not be communicated ahead of time, possibly explaining its low share of the project pipeline. (Gena Solutions 2025)

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f3 Innovation Cluster for Renewable Transport Fuels is a network organisation with a long history of stakeholder collaboration in system-related research on renewable fuels.

Industry, universities, institutes, and authorities participate in f3. Together, the members create new collaborations, increase knowledge, and identify barriers and opportunities and possible solutions for actual and rapid transition to renewable fuels in the transport sector.

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