**From biogas to low-cost green methanol**

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After 4500 million years running an optimization algorithm, nature chose to produce hydrogen from the water splitting – photosynthesis – but not to store it or use it as such; Nature decided to produce and transform hydrogen into energy-carrying biomolecules and biomolecules used to build biological structures. Hydrogen, under ambient conditions, has a low energy density and must be compressed or liquefied to be used as an energy vector, that is, as a substrate for energy transport and storage. At 700 bar, hydrogen exhibits an energy density of 1.3 kWh/L. The compression process requires the equivalent ca. 13 % of the energy of compressed hydrogen (thermodynamic energy is 6.7 %, assuming isothermal compression, and 10.5 % for adiabatic compression); Liquefied hydrogen has an energy density of 2.3 kWh/L, and the liquefaction process requires the equivalent of 36 % of the energy of liquefied hydrogen. Hydrogen is then a bad energy vector, however, it is a very relevant intermediate reagent. Hydrogen should preferentially be produced and consumed locally, as Nature realized millions of years ago. The methane splitting reaction, CH4 ⇌ C (s) + 2H2, ∆*H*0 = 75.3 kJ/mol, produces decarbonized hydrogen and carbon when green electricity is used to balance the reaction enthalpy. The intermediate temperature catalytic methane splitting (IT-CMS), running between 750 °C and 850 °C, is one of the most efficient and low-cost emerging processes for conducting this reaction; it produces decarbonized hydrogen and high-added-value nanofilament graphite carbon particles. When biomethane is used, this process produces renewable graphitic carbon, CO2 emission licenses, and hydrogen; the balance cost of this hydrogen is very low due to the high value of the produced graphitic carbon. However, the production of hydrogen at the biogas production sites is not attractive due to the high storage and transport costs of hydrogen. However, it can be made to react with the CO2 present in the biogas to produce high-value green methanol. Assuming that biomethane cost is 150 €/MWh (very high price) [1], the renewable electricity is 70 €/MWh, the CO2 permits is 70 €/t, and the graphitic carbon is 0.77 €/kg, the balance cost of hydrogen is *ca*. -2.4 €/kg. When reacted with the biogas CO2, it can produce green methanol at ca. 211 €/t[[1]](#footnote-1), which compares very favorably with the present cost of methanol, 625 €/t + CO2 emissions = 721 €/t [2]. The expected EU capacity to produce biogas by 2030 is 35 bcm/year (342 TWh/year) [3], suitable to produce 47 Mt of methanol, preventing the emission of 79.3 Mt/year of CO2 and originating a net profit of 47 x (721 - 211) ≈ 24 000 M€/year.

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**References:**

[1] <https://www.europeanbiogas.eu/benefits/affordable-energy/>, assessed in May 2025.

[2] <https://www.methanex.com/about-methanol/pricing/>, assessed in May 2025.

[3] <https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/biomethane_en>, assessed in May 2025.

1. It is assumed that the CO2 capture and purification from biogas costs ca. 10 €/t. [↑](#footnote-ref-1)