

# **E-METHANOL — A POSSIBLE SOLUTION FOR DIFFICULT TO DEFOSSILIZE TRANSPORTATION**

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*Within the EU's transportation sector, maritime and aviation accounted for 11% and 13% respectively of greenhouse gas emissions in 2017. The railway transport came at 1.6% because its high degree of electrification (1). Why do we mention these three transport sectors? This is because reducing the fossil carbon footprint in these sectors is not easy at all. We'd like to focus on e-fuels, specifically e-methanol, in this brief analysis because they may be able to help defossilize these modes of transportation. It is difficult to reduce the fossil carbon footprint of these transportation sectors.*

Electrofuels, often known as e-fuels (synthetic fuels) are gaseous and liquid fuels such as e-methanol, e-petrol, e-diesel, e-methane, e-kerosene etc. fuels generated exclusively from renewable electricity.

## **E-fuels - carbon-neutral energy carriers**

E-fuels are made of hydrogen produced through the electrolysis of water and combined with carbon dioxide or nitrogen. "They are an alternative to biofuels!"

E-fuels and biofuels are very significant for reducing fossil CO<sub>2</sub>-emissions in the transport sectors that are difficult to defossilize. The main advantage of these fuels is the possibility of using existing infrastructures (distribution, filling stations). It is clear that global biofuel resources would be limited in the near future. Expansion of biofuel production in the EU has increased prices for food grains, oilseeds and vegetable oils. Almost all biodiesel is produced from refined vegetable oil and bioethanol is made from corn. If biofuels are produced from feedstocks that would have been used for food, then biofuels directly reduce potential food supplies. The production of food-based biofuels reduces the land devoted to food production.

That is why e-fuels are considered the only option for providing large volumes of carbon-neutral liquid fuels in the future.

## **Description of methanol properties**

Methanol, also known as methyl alcohol, is the simplest alcohol, with the formula CH<sub>3</sub>OH (Figure 1).

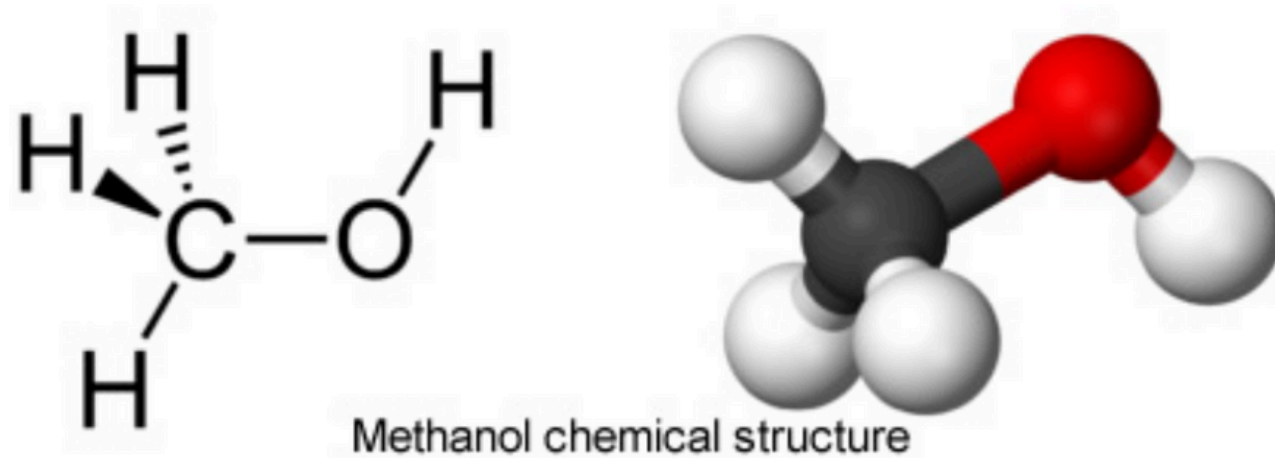


Image Credit: biologycorner

Figure 1. Methanol chemical structure

Methanol is a light, colorless, volatile, flammable liquid with a distinctive alcoholic odour. It's a liquid at room temperature, unlike LNG, pure hydrogen or ammonia, which makes handling much easier. It's water-soluble, which means that any leaks are quickly diluted and broken down in natural processes. Its use results in very low pollutant emissions: no SO<sub>x</sub>, no soot (PM), very low NO<sub>x</sub>. It is toxic but easy to control, especially in industrial applications.

The essential advantage of e-methanol is its high compatibility with existing infrastructure like tanks, pipelines, and fueling stations as well as existing propulsion technologies.

Some properties of methanol:

The specific density 791 kg/m<sup>3</sup> at 20°C

The specific gravimetric energy density 6.2 kWh/kg

The specific volumetric energy density 4900 kWh/m<sup>3</sup>

## E-methanol versus other alternative fuels

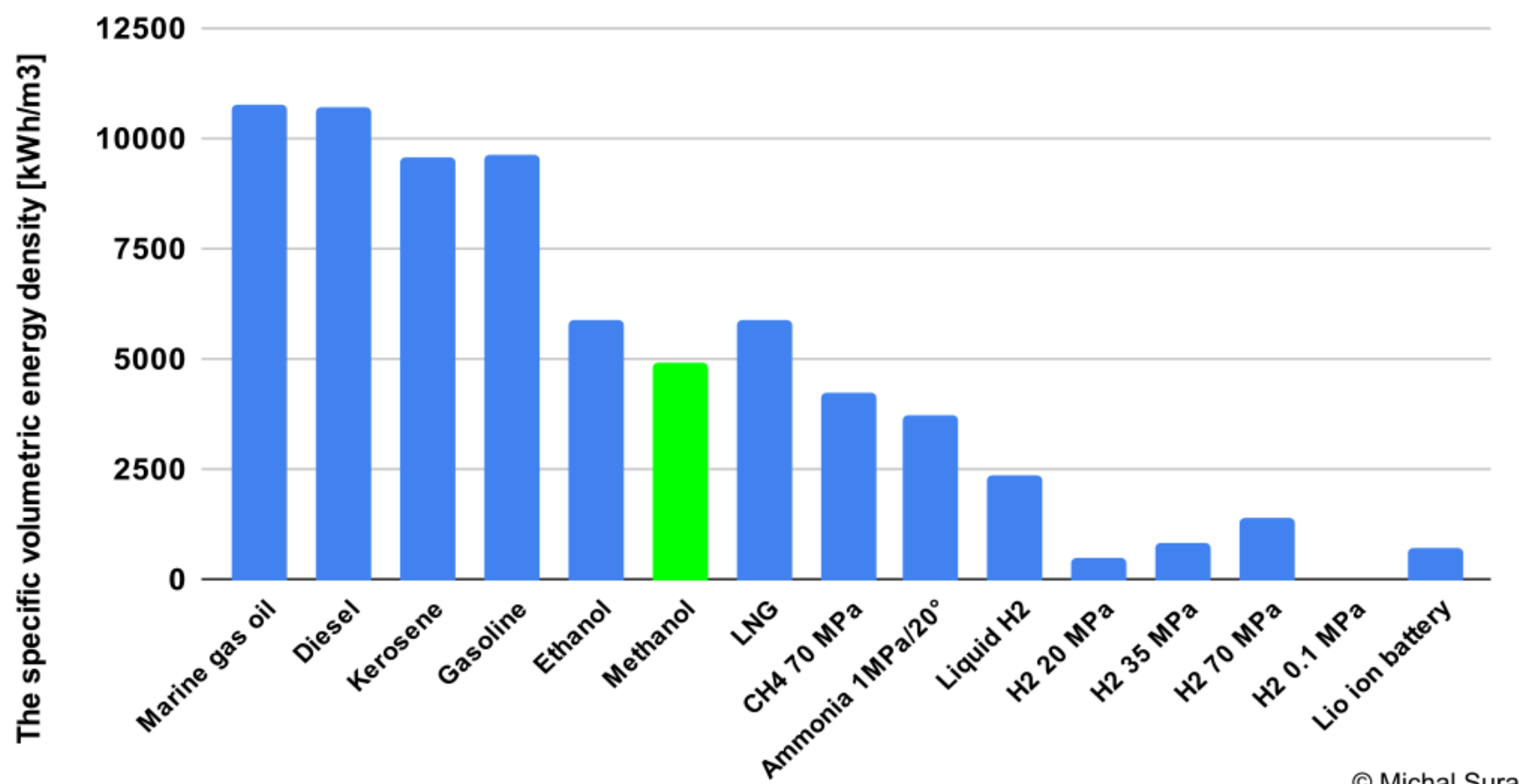
Methanol has several advantages over other proposed renewable energy carriers such as hydrogen, CNG/LNG, ammonia (see Table 1 and Figure 2). Hydrogen has been proposed as an energy storage medium, and when combusted, there is produced only water. But in practice, hydrogen storage is very difficult and energy-intensive due to its low volumetric density. There is necessary to compress it to high pressures (35-70 MPa) or liquefy it at very low temperatures (-253°C). It's also extremely flammable and explosive, and it can easily pass through a variety of metals and materials. The infrastructure needed to transport, store and distribute hydrogen safely would be very expensive for the reasons mentioned above. LNG too requires cryogenic temperatures for its storage (-162°C). Liquid ammonia has either to be cooled down to -34°C or kept under moderate pressure. Methanol, on the contrary, does not need any refrigeration or pressurisation because it is a liquid under ambient conditions.



Fuel type	Specific density [kg/m <sup>3</sup> ]	Gravimetric energy density [kWh/kg]	Volumetric energy density [kWh/m <sup>3</sup> ]	Storage pressure [MPa]	Storage temperature [°C]
Marine gas oil	900 kg/m <sup>3</sup>	12 kWh/kg	10800 kWh/m <sup>3</sup>	0.1	20
Diesel	850 kg/m <sup>3</sup>	12.6 kWh/kg	10710 kWh/m <sup>3</sup>	0.1	20
Kerosene	800 kg/m <sup>3</sup>	12 kWh/kg	9600 kWh/m <sup>3</sup>	0.1	20
Ethanol	790 kg/m <sup>3</sup>	7.5 kWh/kg	5900 kWh/m <sup>3</sup>	0.1	20
Gasoline	740 kg/m <sup>3</sup>	13 kWh/kg	9620 kWh/m <sup>3</sup>	0.1	20
Methanol	790 kg/m <sup>3</sup>	6.2 kWh/kg	4900 kWh/m <sup>3</sup>	0.1	20
LNG	424 kg/m <sup>3</sup>	13.9 kWh/kg	5900 kWh/m <sup>3</sup>	0.1	-162
CH <sub>4</sub> 70 MPa	305 kg/m <sup>3</sup>	13.9 kWh/kg	4240 kWh/m <sup>3</sup>	70	20
LNH <sub>3</sub>	717 kg/m <sup>3</sup>	5.2 kWh/kg	3730 kWh/m <sup>3</sup>	1	-20
Liquid H <sub>2</sub>	70 kg/m <sup>3</sup>	33.6 kWh/kg	2350 kWh/m <sup>3</sup>	0.1	-253
H <sub>2</sub> 20 MPa	14.5 kg/m <sup>3</sup>	33.6 kWh/kg	487 kWh/m <sup>3</sup>	20	20
H <sub>2</sub> 35 MPa	24 kg/m <sup>3</sup>	33.6 kWh/kg	806 kWh/m <sup>3</sup>	35	20
H <sub>2</sub> 70 MPa	42 kg/m <sup>3</sup>	33.6 kWh/kg	1411 kWh/m <sup>3</sup>	70	20
H <sub>2</sub> 0.1 MPa	0.089 kg/m <sup>3</sup>	33.6 kWh/kg	3 kWh/m <sup>3</sup>	0.1	20

Table 1. Comparison of various fuel properties

### The specific volumetric energy density of various fuels



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Figure 2.

There are a number of ways to produce e-methanol through electrochemical processes. The simplest and most mature method is to make hydrogen through the electrolysis of water using renewable electricity, followed by catalytic reaction with CO<sub>2</sub> to form e-methanol (Figure 3).

### Electrolysis of water to hydrogen followed by catalytic methanol synthesis

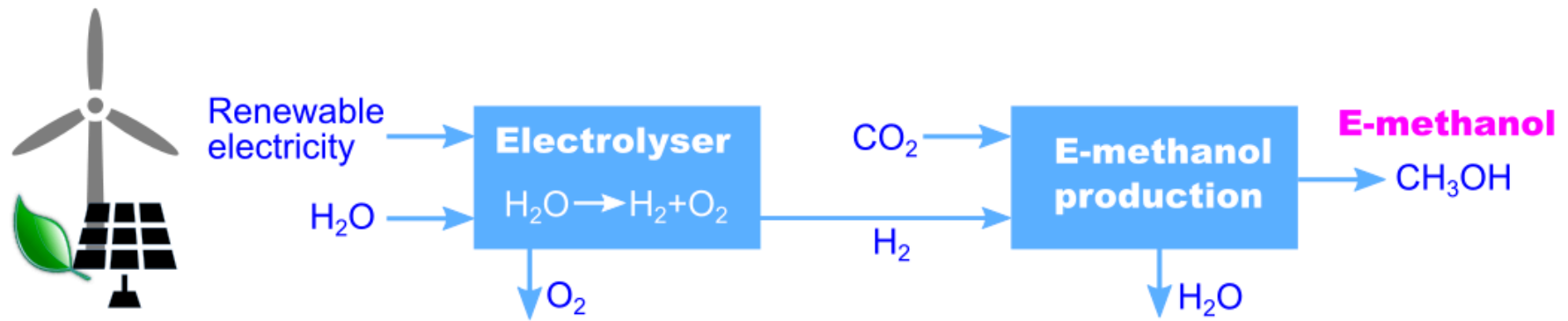


Figure 3.

E-methanol is produced through the catalytic hydrogenation of captured CO<sub>2</sub>. In the presence of catalysts (Cu/ZnO/Al<sub>2</sub>O<sub>3</sub>), CO<sub>2</sub> reacts with H<sub>2</sub> to form methanol at a pressure of 5-10 MPa and temperature of 210–270°C (2)(3)(4)(5)(6). Produced methanol is separated from water and residual gases and purified through distillation (Figure 4).

### Raw materials needed to produce e-methanol

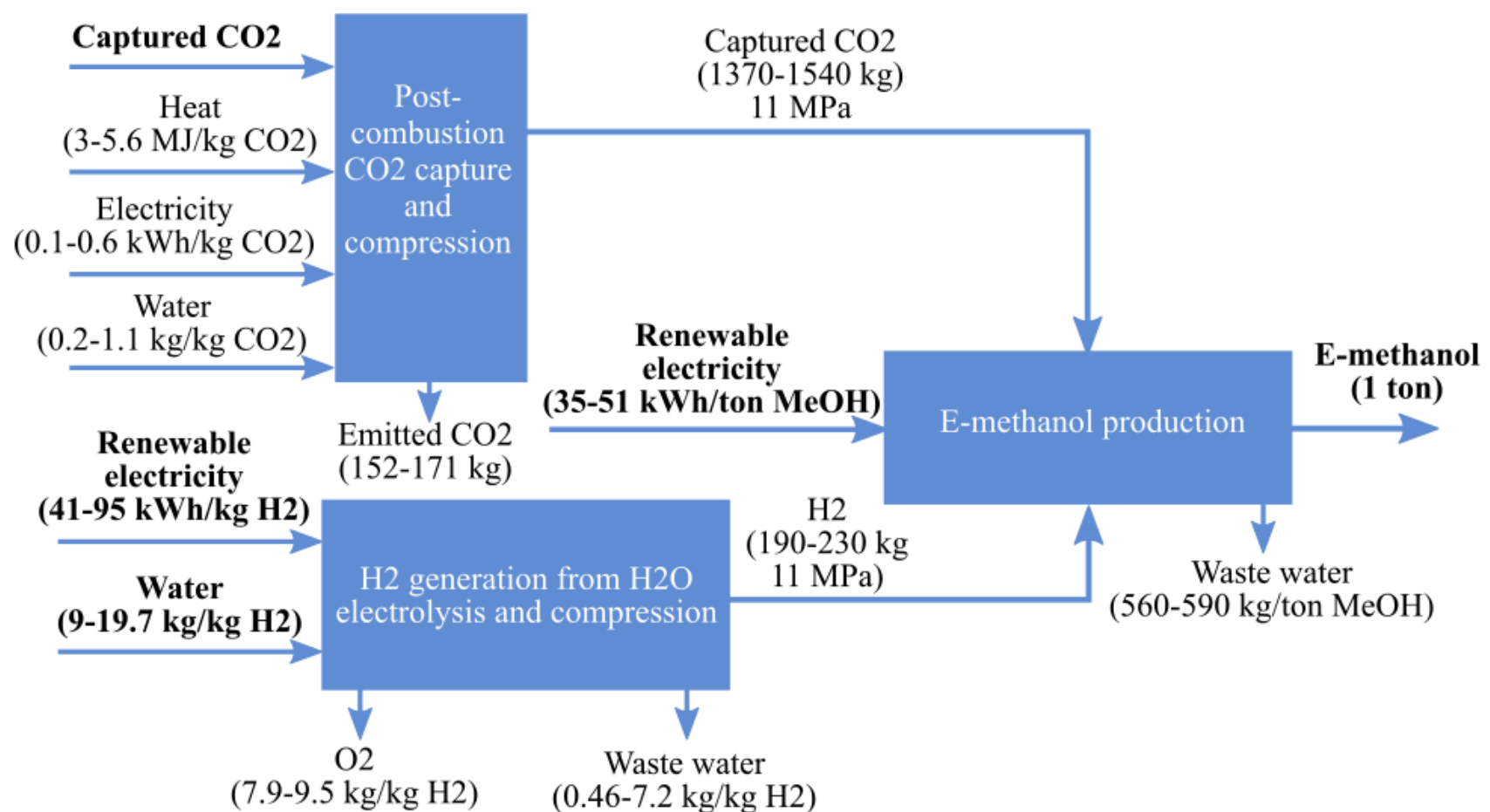


Figure 4.

To produce 1000 kg of e-methanol, about 1400 kg of CO<sub>2</sub>, ~200 kg of hydrogen and ~1700 kg of water are needed. Around 10-11 MWh of renewable electricity is required to produce 1000 kg of e-methanol, a predominant part of it is used for the electrolysis of water.

Methanol has a specific gravimetric energy density of 6.2 kWh/kg. When 10-11 kWh of renewable electric energy is required to produce 1 kg of e-methanol, the production of e-methanol is 56-62 percent efficient.

It is not true that methanol is a low-emission fuel, as we frequently hear (see Table 2). When 1 kg of methanol is burned, it emits 0.25 kg CO<sub>2</sub>, the same as diesel or kerosene (7). E-methanol and bio-methanol should be regarded as emission-neutral fuels rather than low-carbon or low-emission fuels.



Fuel	Specific CO2 emission	
	kg CO2/kg Fuel	kg CO2/kWh
Diesel	3.15	0.25
Kerosene (Jet)	3	0.25
<b>Methanol</b>	<b>1.37</b>	<b>0.25</b>
Ethanol	1.91	0.23
Gasoline	3.3	0.26
Heavy fuel oil	3.11	0.27

Table 2. Specific CO2 emissions of various fuels

## CO2 sources to produce e-methanol

In terms of chemistry, any CO2 source can be used to produce e-methanol. The molecule remains the same whether CO2 is emitted from a coal-fired power plant or biomass combustion. E-methanol is considered green and sustainable as long as the energy required for processing is renewable. CO2 derived from biomass and direct air capture (DAC) are clearly preferred for producing e-methanol because they lead directly to a closed CO2 cycle. There is some debate about whether CO2 from various industrial sources, such as power plants, cement, steel, and so on, can be used to produce green e-methanol. Because the production of steel or cement without the use of fossil CO2 is not yet feasible. Environmental institutions should evaluate the use of this CO2 on a case-by-case basis.

Although conventional and e-methanol are chemically identical, their CO2 footprints are vastly different. E-methanol is a carbon-neutral fuel, whereas conventional methanol is typically produced using fossil fuels such as natural gas or coal.

CO2 emitted by transportation and industry is not currently used in the production of e-fuel; the two sectors are separated from each other (Figure 5).

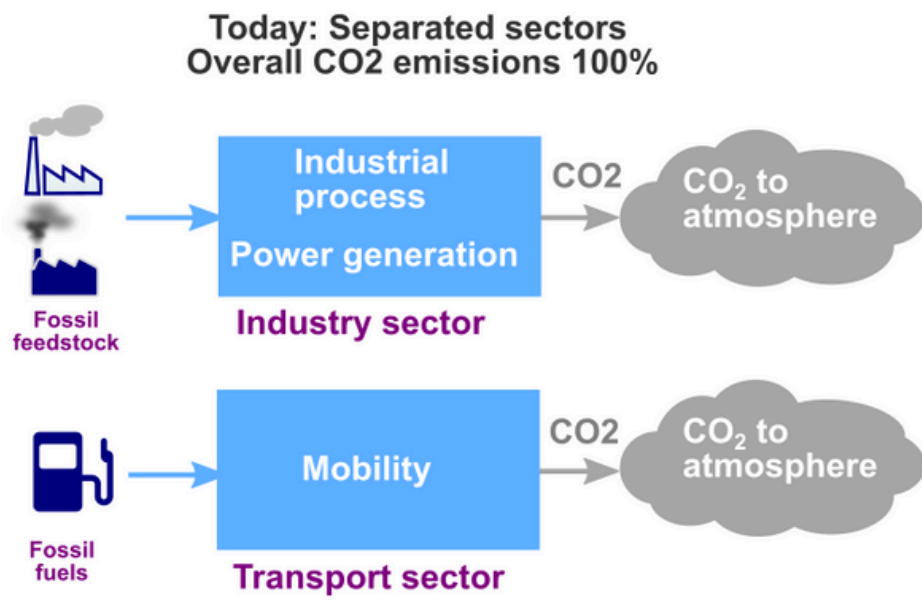


Figure 5.

In the near future, CO<sub>2</sub> captured from industry production/power generation processes, as well as CO<sub>2</sub> captured from the air (via direct air capture), will be used to produce e-methanol (Figure 6).

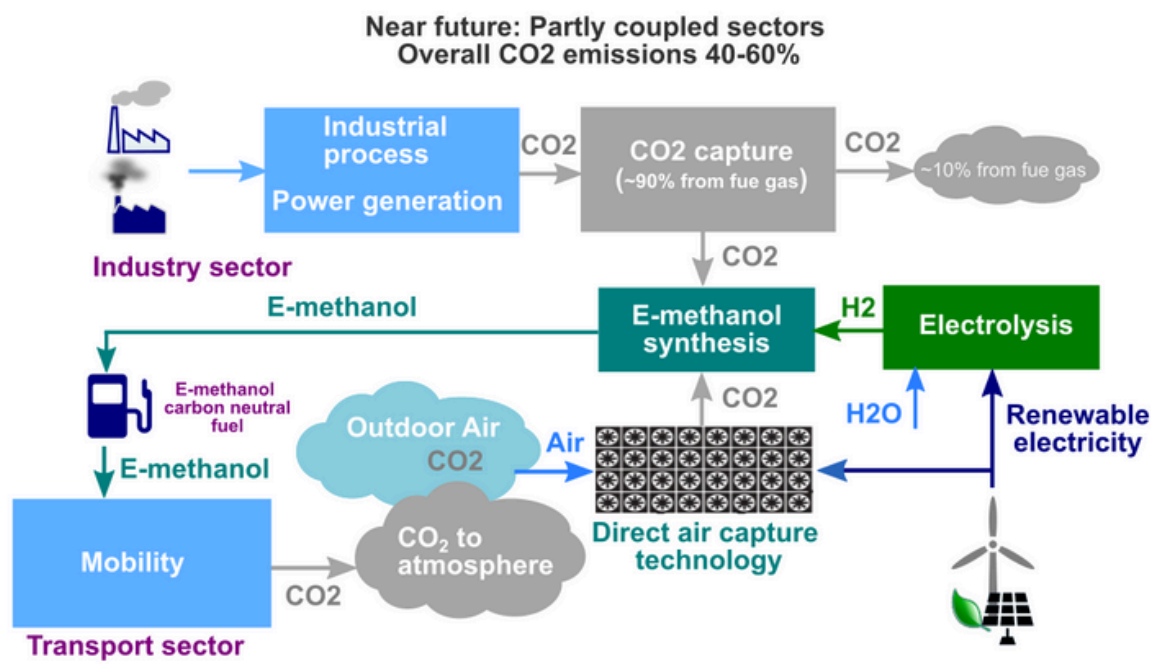


Figure 6.

In the distant future, it is planned that only CO<sub>2</sub> obtained through direct air capture (DAC) will be used to produce e-methanol (Figure 7).

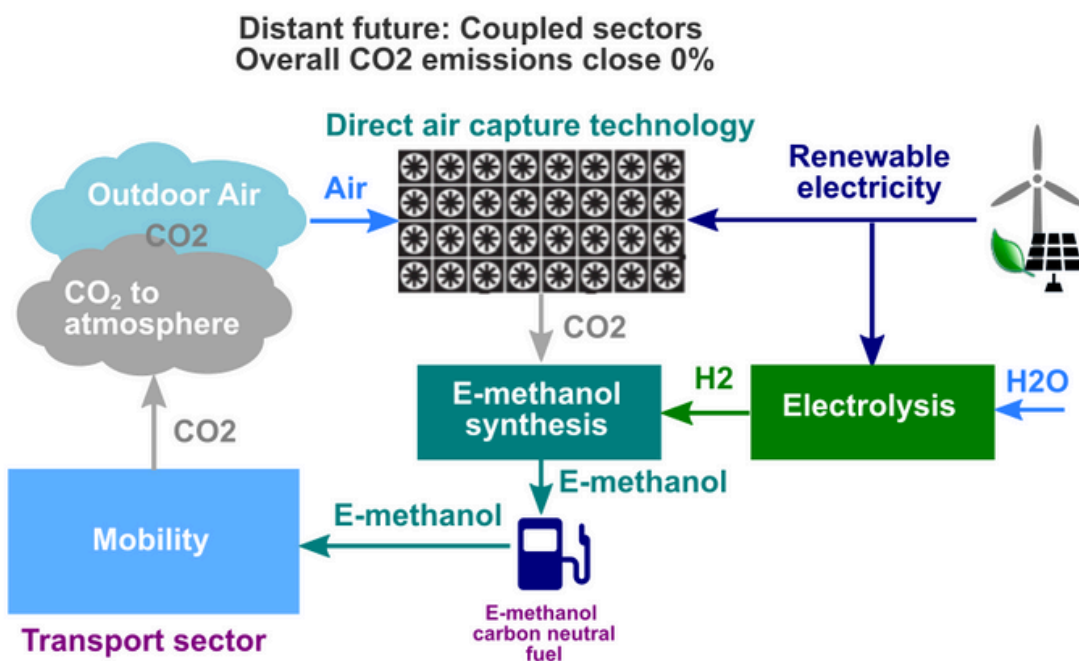


Figure 7.

## Example of commercial production e- methanol

The first commercial CO<sub>2</sub>-to-methanol recycling plant using local cheap geothermal energy has been operated in Iceland by Carbon Recycling International (CRI) since 2011. This commercial plant has annual capacity of 4 000 t of e-methanol.



Figure 8. Carbon Recycling International methanol plant

## Examples of practical using of methanol

Methanol as a fuel, can be used itself or in a blend with gasoline. Methanol, because of its high octane rating, can be used as an additive or substitute for gasoline in internal combustion engines. Methanol, in particular, has about half the volumetric energy density of gasoline and diesel. If pure methanol is used as a fuel, tank size must be adjusted if a similar range is to be achieved. Methanol is toxic, but it is easy to control, particularly in industrial applications, as previously stated.



Figure 9.



Figure 10.

Finnish technology company Wärtsilä, Swedish ferry company Stena Line, and Canadian supplier of methanol Methanex Corporation have marked five years of the successful operation of the methanol-fuelled ferry Stena Germanica.

Stena Germanica was converted to be capable of running on methanol fuel at Remontowa Shipyard in Poland in early 2015. The 240-metre long ferry, with a capacity for 1,500 passengers and 300 cars, was retrofitted with a first-of-its-kind fuel-flexible Wärtsilä 4-stroke engine that can run on methanol or traditional marine fuels.



Figure 11. Stena Germanica

E-methanol should be used as fuel only in vehicles where there are no alternatives to propulsion systems that use fossil fuels. That is, aviation, maritime transportation, and rail transportation. The production of e-methanol is relatively expensive, and we are unlikely to be able to produce enough of it to power ICE vehicles. We have already developed emission-free propulsion systems in this case.

We demonstrated that e-methanol is neither carbon-free nor low-emission fuel; rather, it is carbon-neutral.

E-methanol, in our opinion, is just a temporary solution until emission-free propulsion systems for the mentioned transport sectors are not developed.

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