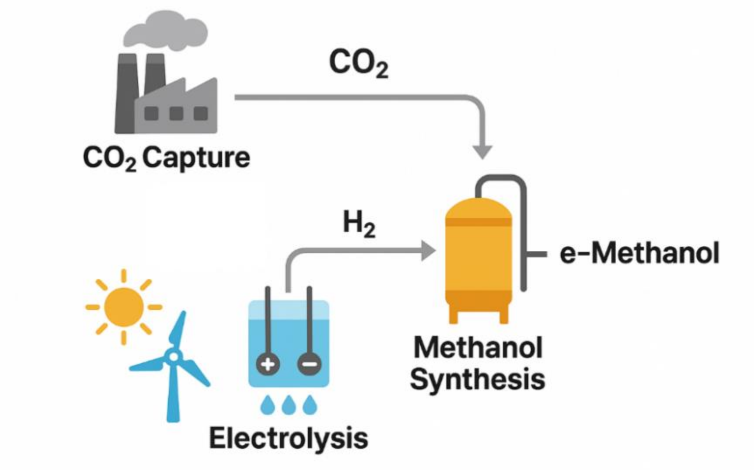
Executive summary – e-fuels

Whereas there are many technologies capable of producing e-fuels, the most mature technology involves the capture of CO_2 from a point source, the production of hydrogen (H_2) via water electrolysis, and the conversion of CO_2 and H_2 into the target product in one or more thermocatalytical synthesis units. This general approach applies to both methanol (see illustration) and methane, although operating conditions and catalyst material in the synthesis steps are evidently different. In the case of aviation fuels (e-kerosene), methanol can be used as feedstock in the methanol to jet route, or alternatively CO_2 needs first to be converted into CO, such that it can be fed together with H_2 into the well-known Fischer-Tropsch process. From a technical point of view, these processes are relatively mature although upscaling risks remain when going to very large plants, since not much experience has been gained at that level yet.



Among the most likely applications for e-fuels are longer-distance transport modes where direct electrification is not feasible or cost effective. For example, methanol is often seen as an important solution for maritime shipping, and the same goes for e-kerosene in aviation. Methane could play a role as fuel for long distance trucking as well as heat or power generation, however the future role of this molecule is somewhat more uncertain. It should be noted that these e-fuels are in direct competition with other e-fuels, some of which are not based on CO_2 (e.g. H_2 itself or NH_3), and the success of each will depend on the trade-off between production cost, convenience of storage and distribution, and efficiency in the use phase. As e-fuels are generally more expensive than fossil fuels as well as biofuels, their penetration will depend strongly on policy mandates. These mandates in the EU are low in the short term, but specifically for aviation fuels a growth path until 2050 has been set[1]. Apart from use as fuel, methanol production may also grow significantly due to organic growth in its current application as chemical feedstock, and due to the possibility to use it as precursor to produce more sustainable plastics.

As electricity use is often a dominant cost factor in an e-fuels value chain, it is preferable to establish a plant in a location that has access either directly to affordable renewable electricity (e.g. solar energy in the South of Europe) or can draw low-cost, decarbonized electricity from the grid (e.g. hydropower dominated grids in certain Scandinavian countries). Since under EU policy imports from non-EU countries can contribute to e-fuel mandates, there will also be competition with many regions that have excellent endowments of renewable energy sources. Apart from energy cost, also CAPEX has an important share in cost structure of e-fuels. This is primarily driven by the electrolysis unit, but also the fuel synthesis and CO_2 capture units contribute significantly. The fuel synthesis units often involve high temperature and pressure processes, sometimes with a large sequence of unit operations (e.g.

[1] From 2030, 1.2% of aviation fuels must be e-fuels, rising to 35% in 2050. For transport sector in general, at least 1% of all energy in 2030 will need to be met by e-fuels, and specifically for maritime transport the minimum share is 2% by 2034.

methanol to jet) as well as extensive heat integrations, and a sufficient process scale is essential to keep capital cost of such process under control. Based on a review of planned projects (see background report), many e-fuels plant are in the range of 50-100 kton/yr scale. To further optimize the business case, also the valorisation of waste heat (e.g. district heating) and the oxygen produced during electrolysis as well as participation in grid services markets can be considered.

While technically all CO_2 sources can be used for e-fuels production, regulatory and economical constraints will determine which sources will be used. First, the Renewable Energy Directive stipulates that fuels produced from fossil CO_2 will no longer qualify as e-fuel from 2035 (in case CO_2 was generated from power generation) or 2040 (other sectors) onwards. Since this leaves a too short period to recover investment costs, this means that biogenic CO_2 and CO_2 captured directly from the air will be preferred for any project starting now. From economic point of view, as indicated above, a scale of > 50 kton/yr of CO_2 is preferred[2]. Currently e-fuels projects generally seem to rely on a single point source, although a clustering of different sources is evidently possible, but this will carry an extra logistics cost. Therefore, large scale sources with biogenic CO_2 (whose amounts in the EU are relatively low compared to what may be needed for e-fuels in the longer term) will be of particular interest for e-fuels applications.

To lower the high cost of e-fuels, which is a significant obstacle today, several pathways are being pursued. The use of solid oxide electrolysis (SOEC) technology, which is nearing commercialization, can be an important aspect since it allows to use exothermal heat from processes such as methanation, Fischer-Tropsch or methanol synthesis directly, significantly lowering energy cost of H_2 production as compared to conventional PEM and alkaline technologies. Among emerging technologies are plasma and electrochemical technologies, which each have their own value proposition but in general have the advantage that they can produce CO_2 based products such as CO without the need for intermediate production of H_2, which can simplify e-fuel processes.

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[2] E-fuels plants with a product capacity in the range of 50-100 kton/yr require a CO_2 supply that is higher but in the same range (the exact amount depends on the target product and process carbon efficiency).