"Electrofuels: a review of pathways and production costs"

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Electrofuels are produced from carbon dioxide (CO_2) and water using electricity as the primary source of energy. Production costs for the fuel options methane, methanol, dimethyl ether, Fischer-Tropsch (FT) diesel are estimated based on different assumptions. The production costs of these electrofuels, for a best, average and worst case, was found to be in the range of 120-135, 200-230 and 650-770 $€_{2015}$/MWh fuel respectively where methane had the lowest and FT diesel the highest costs within each range.

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Introduction

Tailor-made synthetic fuels produced by utilising hydrogen and carbon dioxide (CO_2), here called electrofuels, can be made from renewable sources and thereby contribute to reduce the climate impact from transport. The aim of this study is to assess the production costs of electrofuels to get a better understanding of the cost-competitiveness of electrofuels.

Literature review production costs

The main posts within the production of electrofuels are connected to the hydrogen production, the CO_2 capture, the fuel synthesis, and the electricity price. In this study it is assumed that hydrogen is produced from electrolysis of water. The most discussed types of electrolysers are alkaline, proton exchange membrane (PEM) and solid oxide electrolyse cells (SOEC), where the latter is not yet large scale available. The costs for commercial alkaline electrolyser systems varies in the literature from 600 up to 2600 €/kW_{elec} depending on production capacity and efficiency with most estimates around 1100 €/kW_{elec} [1-4]. Future costs for alkaline electrolysers are estimated to 400-900 €/kW_{elec}. PEM electrolysers are more expensive mainly due to the use of membrane and noble metals [5]. The investment cost is in the range of 1900-3700 €/kW_{elec}, and are expected to be reduced to 300-1300 €/kW_{elec} by 2030 [2,3,6]. The cost of SOEC is estimated in the range of 400-1000 €/kW_{elec} for 2030 [7-9]. In this study only alkaline cells have been considered.

CO_2 can be captured from various, e.g. biofuel production, natural gas processing, flue gases from fossil and biomass combustion plants, industrial plants such as cement, oil refineries, iron and steel, pulp and paper, geothermal activity, air and seawater. The cost depends on the CO_2 sources (i.e. concentration of CO_2) and the capture method. Most biofuel production plants have high concentration of CO_2, and capturing costs are in the range of 5-9 €/tCO_2 [10]. For CO_2 separation in flue gases, and industrial processes, the capture cost has been estimated to be in the range of 20-65 €/tCO_2. [11-12]. Strong bases such as NaOH, KOH and $Ca(OH)_2$ can scrub CO_2 out of the atmosphere [13], but the regeneration of the bases is an energy intensive process, and other alternative materials that might be more energy efficient are under development. The cost estimations for capturing CO_2 from air fall in the range of 150-1250 €/t CO_2. A CO_2 capture cost of 30 €/ton has been chosen in this study.

Hydrogen and CO_2 can form different energy carriers in fuel synthesis processes. The investment cost for methane synthesis is 30-900 €/kW_{fuel} for different plant sizes and technological maturity [4,14-17]. The investment cost for methanol and DME synthesis is 200-1200 €/kW_{fuel} [15-16,18-19] and 300-1200 €/kW_{fuel} [15,18] respectively, whereas the investment cost for Fischer-Tropsch liquids have a slightly higher range of 300-2100 €/kW_{fuel} for different plant sizes [15,18,20-22].

In many studies calculating production costs of electrofuels, the average electricity price of 50 €/MWh has been used, which also is the chosen electricity price in this study.

Results

Production costs are calculated using data found in literature for six different cases (the best case, the worst case, and the average case) based on current available technologies in a small-scale plant of 5 MW_{fuel} as well as based on technologies assumed available in 2030 in a medium-sized 50 MW_{fuel} plant. All costs and prices are expressed in $€_{2015}$. Fuel options assessed are methane, methanol, dimethyl ether, and Fischer-Tropsch (FT) diesel. Results for the six cases are presented in Figure 1.

In Figure 1a it can be seen that the production costs of assessed electrofuel options, using current technologies, for a best, average and worst case, were found to be in the range of 120-135, 200-230 and 650-770 $€_{2015}$/MWh_{fuel} respectively where methane has the lowest and FT liquids the highest costs within each range. Figure 1b shows that the production costs can be significantly reduced by 2030, where results for the best, average and worst case, were found to be in the range of 100-110, 155-180 and 265-340 $€_{2015}$/MWh_{fuel} respectively where methanol has the lowest and again FT liquids the highest costs within each range.

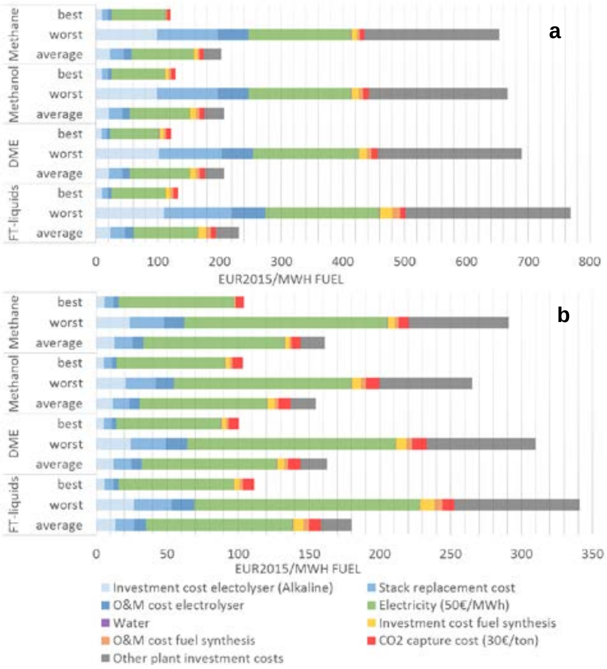

Fig. 1: Production costs of electrofuels based on (a) current technology in a 5 MW plant and (b) technology assumed available in 2030 in a 50 MW plant. Note the different scales on the x-axes.

Productions costs of other fuel options

To get a better understanding if electrofuels can be cost-competitive, production costs of other fuel options are listed in Table 1.

Table. 1: Comparison of production cost for fossil, biogenic and synthetic fuels.

Fuel options	2020–2030 (€/MWh)
Fossil oil-based fuels	39-140 [23], 72 [24]
Ethanol (maize)	188-247 [23]
Ethanol (wheat)	260-345 [23]
Biodiesel (rapeseed)	151-210 [23]
Biodiesel (palm oil)	72-129 [23]
HVO (palm oil)	134-185 [23]
BTL (wood)	451-655 [23]
Electrofuel-methane	110 [24]
Electrofuel-methanol	120 [24]

From Table 1 it can be seen that the production costs for electrofuels, assuming best case up to average case, are in the same magnitude as some of the most expensive biofuels, i.e., having the potential to become cost-competitive.

Discussion and Conclusions

One reason behind that results presented as worst case are significantly higher than the other cases are the uncertainties connected to the additional costs that may come when investing in new equipment. The specific investment cost for each process unit is generally multiplied with an installation factor to generate a direct investment cost and thereafter multiplied with a factor representing indirect costs. In the reviewed publications it is not fully transparent if these factors are included or not.

Results in this study show that there is no significant difference between the fuel options assessed, but indicate that methane is the least costly electrofuel to produce.

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