What electricity price would make electrofuels cost-competitive?

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"What electricity price would make electrofuels cost-competitive?"

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Electrofuels are fuels produced from water and carbon dioxide, using electricity as the major source of energy. The aim of this study is to calculate the production cost of electro-hydrogen and electro-methanol and find what electricity price would make these fuels cost-competitive to fossil alternatives. Assuming input data of today, we find that electro-hydrogen may be competitive if electricity prices are between 10-20 €/MWh whereas no electricity price would lead to competitive electro-methanol. Both electrofuels, could under a combination of beneficial circumstances, be competitive to fossil alternatives.

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Introduction

One way that could contribute to fossil-free transportation is to utilize renewable electricity for electrolysing water into hydrogen and oxygen. The electro-hydrogen can be used to bind carbon dioxide emissions and via a synthesis process (power-to-fuel) tailor-make methane, methanol, gasoline or other electrofuels, see e.g. refs [1-3]. This study focus on electro-hydrogen and electro-methanol.

Electrofuels are generally far from broad commercial penetration. However, factors such as falling electricity prices and price reduction on electrolyzers, have initiated a number of initiatives in this area. One example is a test facility in Germany showing that it is possible to produce electro-diesel [4]. On Iceland, where electricity prices are relatively low, a commercial facility is producing 4000 metric tons of electro-methanol per year [5].

In Sweden, the fuel producer Preem have announced that they will produce 3 Mm^3 biofuels per year, by 2030 utilizing electro-hydrogen, and the fuel producer Perstorp have indicated that they are interested in producing electro-methanol in order to substitute current fossil methanol used in their biofuel (fatty acid methyl ester, FAME) production.

The aim of this study is to calculate the production cost of electro-hydrogen and electro-methanol and find what electricity price would make these fuels cost-competitive to the fossil alternatives.

Approach

Main components needed to produce electrofuels are illustrated in Figure 1.

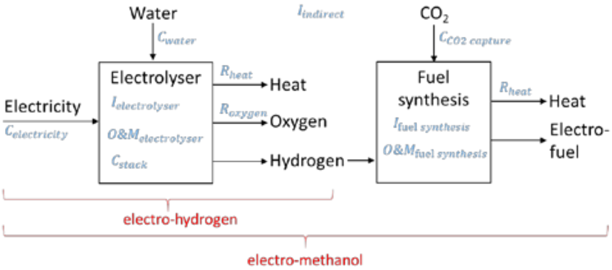

Figure 1. Main components and the cost elements (in blue) building up the total production cost of electrofuels.

The production cost of electrofuels C_{fuel} [€/MWh], is calculated in the following way:

$$C_{fuel} = I_{electrolyser} + O\&M_{electrolyser} + C_{stack} + C_{electricity} + C_{water} + I_{fuelsynthesis} + O\&M_{fuelsynthesis} + C_{CO2capture} + I_{indirect} - R_{heat} - R_{oxygen}$$

where $I_{electrolyser}$ is the annualised direct investment cost of the electrolyser, $O\&M_{electrolyser}$ is the operation and maintenance cost for the electrolyser, C_{stack} is the annualised cost of stack replacements if the electrolyser's assumed system life time exceeds the stack life time, $C_{electricity}$ is the cost of electricity, C_{water} is the cost of water needed for the electrolysis, $I_{fuelsynthesis}$ is the annualised direct investment cost of the methanol synthesis, $O\&M_{fuelsyntheis}$ is the operation and maintenance cost for the methanol synthesis, $C_{CO2capture}$ is the cost to capture CO_2, $I_{indirect}$ represents the annualised indirect investment costs for the facility including for example engineering and construction, equipment and installation costs, fees, and unexpected costs, R_{heat} is the revenue from selling excess heat, and R_{oxygen} is the revenue from selling excess oxygen.

Analyses are made for a base case representing small sale (5MW) production at current costs as well as for a future more optimistic scenario (50MW) and cost reductions based (1) on a continuation of current trend in price reductions on alkaline electrolysers, (2) that research present scenarios on reduced electricity prices [6], (3) that larger synthesis reactors by scale effects reduces the investment cost per MWh$_{fuel}$ (4) that the uncertainty factor can be expected to decline along with that the technology become more used, and (5) CO_2 from high concentrated sources can be captured for a lower cost per ton.

Assumptions and data

Data is collected from interviews with Swedish industry and from the literature [1,7]. Assumptions made in this study are presented in Table 1.

Table 1. Input data for the base case and assumptions made for the future more optimistic case [1,7].

	Base case	Future case
Data connected to the electrolysis		
Investment cost electrolyser (alkaline) [€/kW$_{el}$]	500	300
O&M factor [share of investment cost]	0.04	
Stack replacement factor [share of investment cost]	0.5	
Conversion efficiency [$H_{2,LHV}$/electricity input]	65%	
Electrolyser's stack life time [h]	75,000	
Demand for water (assuming 2X stoichiometric demand) [ton/MWh$_{H2}$]	0.54	
Cost for water [€/ton$_{water}$]	1	
Excess heat produced in the electrolyser [MWh$_{th}$/MWh$_{H2}$]	0.46	
Oxygen produced in the electrolyser [ton$_{O2}$/MWh$_{H2}$]	0.24	
Heat revenue [€/MWh$_{heat}$]	0	30
Oxygen revenue [€/ton$_{O2}$]	0	50
Data connected to the synthesis		
Investment cost methanol synthesis reactor (base: 5 MW, future: 50 MW)[€/kW$_{meoh}$]	1000	500
O&M factor [share of investment cost]	0.04	
Conversion efficiency methanol synthesis [Methanol$_{LHV}$/H_2 input]	0.79	
Demand H_2 [MWh$_{H2(LHV)}$/MWh$_{meoh}$]	1.27	
Demand CO_2 [ton$_{CO2}$/MWh$_{meoh}$]	0.28	
Excess heat (electrolyser+ synthesis) [MWh$_{th}$/MWh$_{meoh}$]	0.73	
Cost for CO_2 capture (10–50% concentration) [€/ton$_{CO2}$]	30	5
Other data		
Electricity price [€/MWh$_{el}$]	30	20
Interest rate	0.08	
System life time [yr]	25	
Capacity factor [share of max capacity over a year]	0.95	
Experience factor for indirect investment costs	3.14	2
Market price natural gas based hydrogen, excl taxes [€/MWh]	50	
Market price natural gas based methanol, excl taxes [€/MWh]	63 (400 $/ton)	

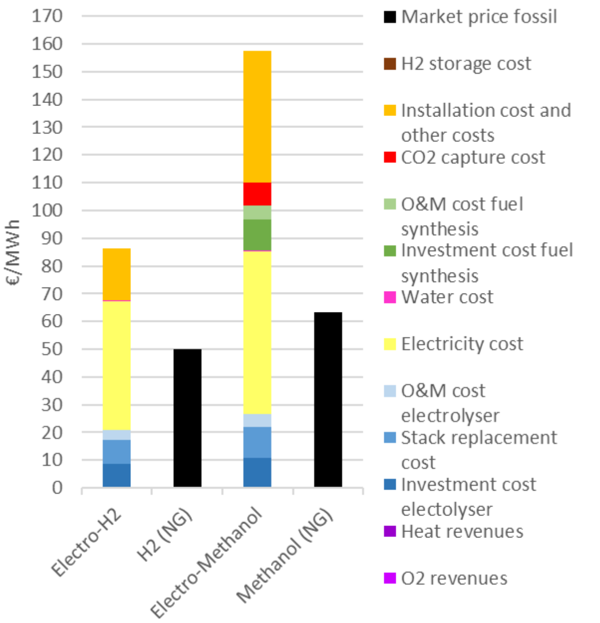

Figure 2. Base case production cost for electro-hydrogen (86 €/MWh) and electro-methanol (158 €/MWh), compared to market prices for fossil alternatives.

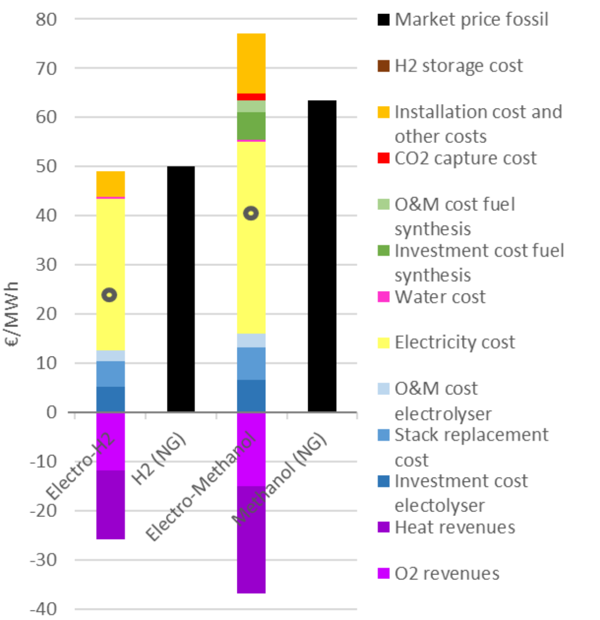

Figure 3. Production cost in the future more optimistic scenario, for electro-hydrogen (23 €/MWh) and electro-methanol (40 €/MWh), compared to market prices for fossil natural gas-based alternatives.

Results production cost

Results for the production cost of electro-hydrogen and electro-methanol, using assumptions presented in Table 1, can be found in Figures 2–3, where also market prices for the natural gas based alternatives (50 €/MWh and 63 €/MWh, respectively), i.e. the cost that the industries would have to pay if not investing in the electrofuel option. Note that the revenue from selling excess heat and oxygen need to be withdrawn from the bars in Fig 3, where the total production costs are marked with circles.

In Fig 2, the dominating posts are the cost for electricity, the three posts that build up the cost for the electrolyser and the experience factor representing installation and unexpected costs. The costs for water, CO_2 capture and methanol synthesis are minor (compared to the larger posts). The production costs for electro-hydrogen and electro-methanol are roughly 1.7 and 2.5 times higher than the fossil alternatives, respectively. It is difficult to see any business opportunities for electrofuels unless the fossil alternatives become more expensive, or the production cost for electrofuels are reduced. The latter scenario is represented in our more optimistic scenario, see Figure 3. The most dominating positive effect comes from introducing the possibility of selling excess heat and oxygen. Both electro-hydrogen (23 €/MWh) and electro-methanol (40 €/MWh) may in future have the potential of being produced at lower production costs than current market prices of fossil alternatives.

Impact from different electricity prices

Since two large posts when producing electrofuels are electricity price and investment cost of electrolysers, and both posts show potential for price reductions, it is of interest to explore the effect of reducing these costs.

When assuming a lower electricity price, it is important to understand at what capacity factor (the share of max capacity over a year) the facility can be run on assumed electricity price. The European energy systems model ELIN/EPOD, generates future electricity price-scenarios for all different price areas in Europe. Results for the Swedish SE2-area, in 2030, presents almost zero electricity prices up to 10% of the year, an average electricity price of 10 €/MWh for the 40% cheapest hours and an average electricity price of 20 €/MWh for the entire year [11]. This scenario has been used to adjust the capacity factor when systematically calculating the production cost assuming various electricity prices and electrolyser's investment cost Results are presented in Figure 4.

a) **Electro-methanol. Productions cost. Base case.**

Electrolyser €/kW$_{el}$						
500	762	230	138	158	177	197
400	688	208	128	147	167	187
300	613	187	118	137	157	177
200	539	166	108	127	147	166
100	465	144	98	117	137	156
CF:	10%	40%	95%	95%	95%	95%
	0	10	20	30	40	50
	Electricity price €/MWh					

b) **Electro-methanol. Productions cost. Optimistic case.**

Electrolyser €/kW$_{el}$						
500	348	93	55	75	94	114
400	297	78	48	67	87	106
300	247	63	40	60	79	99
200	196	47	33	52	72	91
100	145	32	25	45	64	84
CF:	10%	40%	95%	95%	95%	95%
	0	10	20	30	40	50
	Electricity price €/MWh					

Figure 4. Production cost of electro-methanol, for different electricity prices and different electrolyser investment cost, in the (a) base case and in a (b) future optimistic scenario, where green-marked results indicate a production cost that is equal or below current price on fossil methanol, yellow-marked results indicate a production cost that is equal or below double the fossil price (indicate possible business opportunities), and red-marked results indicate a production cost that is higher than double the market price, i.e. difficult to see business opportunities.

In the future case electro-methanol is shown to have a lower production cost, compared to fossil methanol, if the electricity price is around 20 €/MWh. Also if electricity prices are between 10-30 €/MWh and the cost for electrolyzers around or lower than 300 €/kW$_{el}$. Further, for electricity prices 10-50 €/MWh, electro-methanol may be produced at a cost lower than double that of fossil methanol (indicated from the industry that they are willing to pay for renewable methanol) (Fig 4b). Base case results show, however, no combinations where electro-methanol can be produced at lower cost than current price of fossil methanol (Fig 4a).

For electro-hydrogen, base case assumptions, results indicate a lower production cost, compared to fossil hydrogen, if electricity prices are between 10-20 €/MWh and the cost for electrolyzers is around, or lower than, 200 €/kW$_{el}$. In the future more optimistic scenario, electro-hydrogen show possible business opportunities (below double the fossil price) for all analyzed combinations except for zero electricity price combined with an electrolyzers cost of 400 €/kW$_{el}$ or more.

Main insights

Main insights from this study is that electrofuels, under a combination of beneficial circumstances, can be cost-competitive to natural gas based alternatives, however not in the base case.

Acknowlegdement

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