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Electro-methane: integration aspects and cost estimates.

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1. Introduction

One way to decrease the emissions of greenhouse gases from the transport sector is to use renewable fuels such as biogas either produced from anaerobic digestion of e.g. household waste or via gasification of woody biomass. Both processes give raise to excess biogenic CO2, which can be utilized to produce electro-methane. If renewable electricity is used to produce the hydrogen needed, to form electro-methane, the electro-methane is entirely renewable and fully blendable with biogas. The concept potentially provides an opportunity for biogas producers to increase the yield from the same amount of feedstock if the excess CO2 is used to produce electro-methane, see e.g. [1,2]. Several demonstration scale facilities of electro-methane, have been developed in Europe during the last decade, e.g., a 6 MW plant in Germany, which uses electricity from wind power and CO2 from a biogas plant to produce electro-methane [3]. There are, however, aspects that need to be clarified in order to understand the potential role of electro-methane in a future low-emitting transport sector. One such aspect is the cost-competitiveness. The aim of this study is to calculate the production cost and assess if there are conditions under which electro-methane are cost-competitive to fossil natural gas or biogas.

2. Method

Main components needed to produce electro-methane are illustrated in Fig 1.

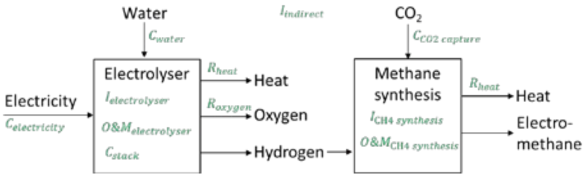

Figure 1. Main components and the cost elements, in green, building up the total production cost of electro-methane.

The production cost of electro-methane C_{CH4} [€/MWh], is calculated in the following way:

$$C_{CH4} = I_{electrolyser} + O\&M_{electrolyser} + C_{stack} + C_{electricity} + C_{water} + I_{CH4\ synthesis} + O\&M_{CH4\ synthesis} + C_{CO2\ capture} + I_{indirect} - R_{heat} - R_{oxygen}$$

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, $I_{CH4synthesis}$ is the annualised direct investment cost of the methane synthesis, $O\&M_{CH4syntheis}$ is the operation and maintenance cost for the methane synthesis, $C_{CO2\ capture}$ 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.

3. Assumptions and data

Data is collected from interviews with Swedish industry and from the literature see refs [2,4]. Assumptions made in this study are presented in Table 1.

Table 1. Input data for the base case and assumptions made for a future optimistic case [2,4].

	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 methane synthesis reactor (base:5 MW, future: 50 MW)[€/kW$_{CH4}$]	600	300
O&M factor [share of investment cost]	0.04	
Conversion efficiency methane synthesis [Methane$_{LHV}$/H_2 input]	0.77	
Demand H_2 [MWh$_{H2(LHV)}$/MWh$_{CH4}$]	1.30	
Demand CO_2 [ton$_{CO2}$/MWh$_{CH4}$]	0.21	
Excess heat (electrolyser+synthesis) [MWh$_{th}$/MWh$_{CH4}$]	0.78	
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, excl taxes [€/MWh]	25	
Market price Swedish biogas excl VAT (anaerobic digestion) [€/MWh]	56	

4. Results

The production cost for electro-methane has been calculated for a base case scenario and a future optimistic scenario and compared to market price of Swedish biogas and fossil natural gas.

Base case

Results using assumptions presented in the column "Base case" in Table 1 can be found in Figure 2.

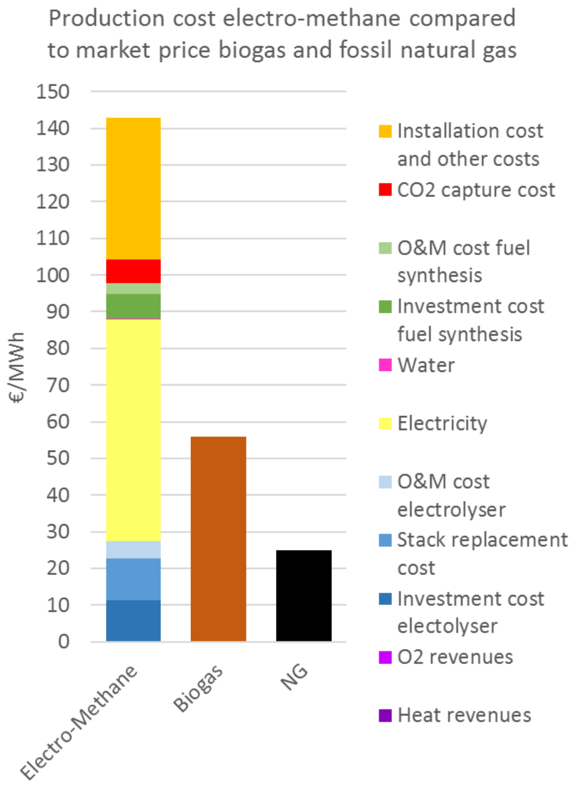

Figure 2. Base case production cost electro-methane (143 €/MWh) compared to market price for biogas (56 €/MWh) and fossil natural gas (25 €/MWh).

From Figure 2, it can be seen that the dominating posts are the cost for electricity (yellow), the three posts that build up the cost for electrolyser (blue) and the experience factor representing installation cost and unexpected costs (orange). The cost for water, CO2 capture and methane synthesis are minor (compared to the larger posts). The production cost for electro-methane (143 €/MWh) is roughly 2.5 times higher compared to the Swedish market price for biogas (56 €/MWh excluding VAT) and almost 6 times higher than the market price for fossil natural gas (25 €/MWh without taxes). It is difficult to see any business opportunities for electro-methane unless the fossil alternative becomes more expensive, biogas has reached its upper supply potential or the production cost for electro-methane is reduced. The latter scenario is analysed in the following section.

Future optimistic case

Since there currently is a strong trend for price reductions on alkaline electrolysers and future research scenarios point at reductions on electricity prices [4] it is of interest to explore production costs in a future optimistic scenario. Also the uncertainty factor can be expected to be reduced along with that the technology become more used. In a future scenario it can further be expected that the methane synthesis reactor becomes larger and thereby scale effects will reduce the investment cost in €/MW_{CH4}. In base case the CO2 capture cost is representing a CO2 concentration between 10-50% but when integrating the electro-methane production with biogas production from either anaerobic digestion or from gasification the concentration may be higher than 50% and in this optimistic case it is assumed that CO2 can be utilized at a cost of 5 €/t_{CO2}. Changing the assumptions on input data as presented in column “Future case”, in Table 1, will reduce the production cost of electro-methane down to 34 €/MWh, and thereby become cost-competitive to biogas, see Figure 3. Note that the revenue from selling excess heat and oxygen need to be withdrawn from the bar presented in the figure.

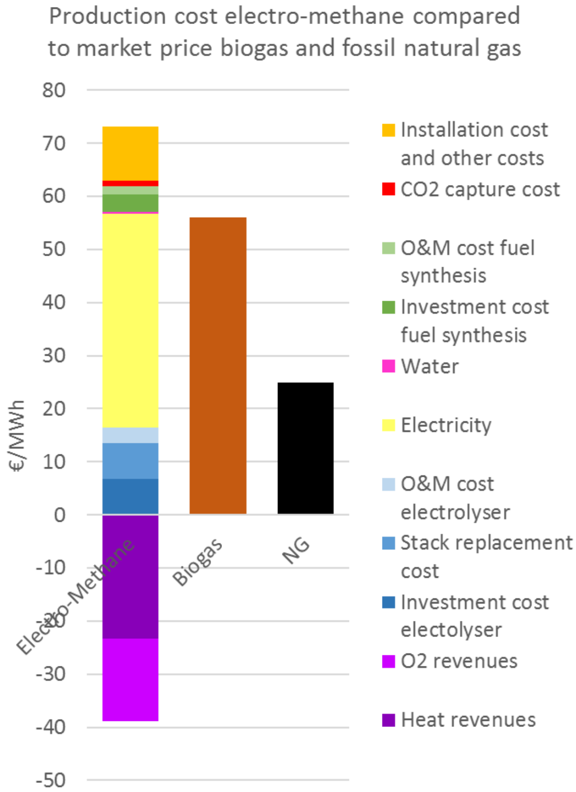

Figure 3. Production cost electro-methane in a future optimistic case (34 €/MWh) compared to market price for biogas (56 €/MWh) and fossil natural gas (25 €/MWh).

What electricity price and electrolyser investment cost would be needed to compete with biogas or natural gas?

Since the production cost of electro-methane to a large extent depend on the electricity price and the investment cost of electrolysers, where 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) that the facility can be run on the 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 SE02-area, in 2030, presents almost zero electricity prices up to 10% of 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 [5]. This scenario has been used in order to adjust the capacity factor when systematically calculating the production cost of electro-methane depending on electricity prices between zero and 50 €/MWh and the electrolyser's investment cost in the range of 100-500 €/kW_{el}. Results are presented in Figure 4.

a)

Electro-methane. Productions cost. Base case.

Electrolyser €/kW_{el}						
500	614	188	117	138	158	178
400	537	166	107	127	147	167
300	460	144	97	117	137	157
200	384	122	86	107	127	147
100	307	101	76	96	116	136
CF:	10%	40%	95%	95%	95%	95%
	0	10	20	30	40	50

Electricity price €/MWh

b)

Electro-methane. Productions cost. Optimistic case.

Electrolyser €/kW_{el}						
500	301	81	50	70	90	110
400	249	65	42	62	82	102
300	197	49	34	54	74	95
200	145	34	26	47	67	87
100	93	18	19	39	59	79
CF:	10%	40%	95%	95%	95%	95%
	0	10	20	30	40	50

Electricity price €/MWh

Figure 4. Production cost of electro-methane, 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 fossil natural gas, yellow-marked results indicate a production cost that is equal or below the market price of biogas, and red-marked results indicate a production cost that higher than the market price for biogas, i.e. difficult to see business opportunities.

5. Conclusions

We find that there are circumstances when electro-methane can be produced at lower cost compared to the market price of natural gas as well as biogas, however not in the base case. In a future optimistic scenario, a production cost lower than the market price of natural gas can be found for electricity prices of 10-20 €/MWh combined with an investment cost of 100 €/kW_{el} for the electrolyser, where the latter must be judged as an extremely optimistic assumption. Production costs equal or lower than the market price for biogas can in the future scenario be found for electricity prices between 10-30 €/MWh also for current electrolyser investment cost (500 €/kW_{el}). We judge these circumstances realistic.

6. References

[1] Mignard D, Pritchard C. On the use of electrolytic hydrogen from variable renewable energies for the enhanced conversion of biomass to fuels. Chemical Engineering Research and Design 86:473-87. (2008).

[2] Brynolf S, Taljegård M, Grahn M, Hansson J. Electrofuels for the transport sector: a review of production costs. Renewable & Sustainable Energy Reviews 81 (2) 1887-1905. (2018).

[3] ETOGAS GmbH. Audi e-gas plant Wertle, Germany: Accessed: 16 March, 2018. europeanpowertogas.com/blog/623

[4] Grahn, M. & Jannasch, A-K. Electrolysis and electro-fuels in the Swedish chemical and biofuel industry: a comparison of costs and climate benefits. f3 The Swedish Knowledge Centre for Renewable Transportation Fuels, Sweden. In Press. (2018).

[5] Taljegård, M. Electricity price scenarios for Europe 2030: Results from the energy systems model ELIN/EPOD. Work in progress (2018).