Economic analysis of increased renewable methane output through CO_2 utilization

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Natural gas is an important energy carrier in the EU [1] and is used for various applications like electricity production, synthesis of chemicals, transport, etc. However, the consumption of fossil fuels like natural gas leads to increasing CO_2 concentrations in the atmosphere and the rise of global average temperatures. Biomass can be used to produce substitutes for fossil fuels, but it is a limited resource due to land conflicts [5]. Furthermore, there exists a competing use in different industries [6]. By the current biomass-to-energy conversion plants, only around 30-40 % of the carbon can be utilized and converted to a fuel product. The integration of an electrolyzer offers the opportunity to increase the production of energy carriers based on biogenic carbon [7], [8] and to reduce emissions compared to conventional fuels.

The core objective of this paper is to calculate the production costs for synthetic natural gas (SNG) and biomethane by adding hydrogen to the process chain and to derive scenarios for cost reduction by 2050.

Methodology

Two types of technology were chosen for the calculation of renewable methane production. The first is biomethane production, which is a market-proven, available technology and the second is biomass gasification, for which only a few pilot plants could be established until now. The production costs (c_fuel) for SNG and biomethane were calculated with the formula (1). The investment costs (I_0) for biomethane plants vary depending on the type of feedstock, for example, organic waste, energy crops, etc. However, woody biomass is the main source of SNG plants.

$$c_{fuel} = \frac{CRF * I_0 + C_{OF} + C_{misc}}{FLH} + \frac{P_f}{LHV * \eta} + c_{var} \quad (1)$$

CRF = capital recovery factor, n = plant lifetime, r = depreciation rate, c_{fuel} = levelized cost of fuel production C_{OF} = fixed operating cost [EUR/ kW], C_{misc} = other capacity related cost, P_f = feedstock price, LHV = lower heating value, η = energy efficiency, c_{var} = variable cost [EUR/ kWh].

In the case of carbon capture and utilization, additional hydrogen is required to convert CO_2 into CH_4. The hydrogen costs were calculated additionally (2) with electrolyzer investment costs from literature [6] and renewable electricity sources such as wind and solar (c_{ele}). The usage of grid electricity serves as a benchmark for the comparison of economic performance. The hydrogen costs are then evenly distributed among the whole amount of CH_4 produced and therefore considered within c_{var} (1).

$$c_{H_2} = \frac{CRF * I_0 + C_{om}}{FLH} + \frac{c_{ele}}{\eta} \quad (2)$$

c_{H_2}= levelized cost of hydrogen production, c_{ele}= energy costs for electricity, I_0 = investment cost, C_{om}= operating and maintenance costs.

Scenarios considering the cost reductions of electrolyzers and renewable electricity were conducted to show production cost developments by 2050.

Results and Discussion

The hydrogen production costs are shown in figure 1. The highest costs are currently caused by solar based production because of low full load hours. However, cost reductions will occur until 2050. The biomethane production strongly costs depend on the feedstock type in the base case (turquoise). This relationship is still existing for the second process chain, but less significant. The production costs are currently at least two times higher compared to the base case.

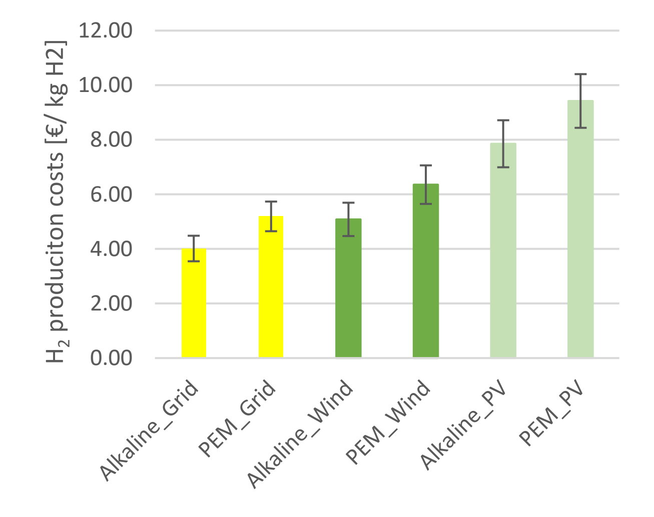

Fig. 1. Hydrogen production costs for 2020 of an alkaline and proton exchange membrane (PEM) electrolysis using grid electricity, onshore wind (W) or photovoltaics (PV).

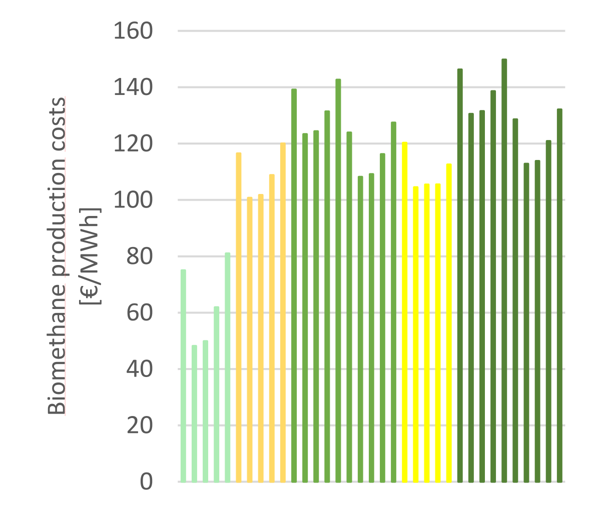

Fig. 2. Production costs of enhanced biomethane output through the integration of an electrolyzer into the process chain. The base cases are on the left side (turquoise), followed by alkaline and PEM integration with different electricity sources.

Conclusions

- The integration of an electrolyzer can increase the production of biomethane and SNG based on biogenic carbon.
- Production costs will strongly decline until 2050 due to cost reductions for electrolyzers and renewable electricity.

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