

I01-1735 - (Invited) Techno-Economic Aspects of Hydrogen Production from Water Electrolysis



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Abstract

Hydrogen production today

Today, hydrogen is still mainly being used as a specialty chemical, including the synthesis of ammonia and methanol, and during steel and glass manufacturing where it is the preferred reducing gas during annealing and forming processes. The great majority of all these H_2 is being produced by 2 large-scale chemical processes : steam methane reforming (SMR) and coal gasification. Both of these processes are heavily CO_2 intensive, SMR emitting up to 8 tons of CO_2 per ton of H_2 produced. Therefore, with the objective of reaching the CO_2 emission targets already in today's fossil-based H_2 production, the part of electrolytic hydrogen produced from renewable electricity should significantly increase. However, in order to meet the current global H_2 demand of around 80 Mton/year, a total of 300 GW installed electrolyser capacity would already be needed today. Such instantaneous massive electrolyser deployment is not very realistic. Alternatively, a selection of technologically feasible market penetrations for electrolytic H_2 needs to be made. In the ideal case, such a selection also implies that today's local H_2 consumers, besides becoming local (on-site) producers of renewable electricity, also need to become local (on-site) producers of electrolytic H_2 , at a production scale which still allows to meet the stringent requirement of fossil parity.

The cost of electrochemical hydrogen production

As compared to an individual large-scale SMR production unit, typically corresponding to an electrolyser power equivalent well above 100 MW, the basic units of a water electrolyser are rather small-scale : both the geometrical area of the electrodes (a few m^2 at most) and the number of electrodes that can be compiled in series in a single stack is relatively limited. As a result, the unit size of water electrolyzers has long been limited to the kW-range, a typical on-site containerized production unit being a few 100 kW at most. However, in order to be able to realize the coupling to renewables, the power scale of water electrolyzers needs to become at least of the same order of magnitude as the renewable electricity source itself, i.e. multi-MW. Such an electrolyser scale-up is typically being realised by increasing the number of cells per stack. However, from the state-of-the-art data that we recently collected from a number of electrolyser manufacturers, such a "keep-on-stacking" approach seems to have a practical limit at around 200 cells/stack [2]. Beyond that number, other balance-of-plant issues come into play. Therefore, for multi-MW applications, multi-stack electrolyser systems are typically being used.

While it is technically feasible to produce electrolytic hydrogen with such multi-stack systems at the multi-MW scale (even >100MW), as was already demonstrated several decades ago, the critical question still remains at what price/cost this can be done today. In this respect, the 3 major parameters affecting the electrolytic H_2 production

cost are the operational time of the electrolyser, the cost of renewable electricity, and the electrolyser CAPEX. Hence, before becoming a realistic alternative production technology, there is a need for cheap(er) renewable electricity (well below 70 €/MWh) and the investment cost of electrolyzers needs to be brought down (to about 500 €/kW). Luckily, with respect to all these requirements, significant progress has been made over the past years, as we will highlight in our presentation using the most recent data from both the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA).

The scale of fossil parity for electrolytic hydrogen

An important techno-economic aspect then relates to the production scale required for obtaining fossil parity with electrolytic H₂. Indeed, one might wrongly conclude that reaching the required reduction in electrolyser CAPEX down to about 500 €/kW would require very large-scale electrolytic H₂ production units around 100 MW or above, on the same order of today's SMR units. However, our own recent data suggest that there might be a much smaller production scale for reaching such low CAPEX values. Indeed based on an extrapolation of the currently available CAPEX data for single-stack alkaline electrolyzers, the level of 500 €/kW could already be reached at less than 10 MW [3]. Such a significant reduction in the scale required for fossil parity is directly related to the much steeper reduction in CAPEX that can be realised for single-stack as compared to multi-stack water electrolysis systems. Some promising implications of such small-scale fossil parity will be discussed during our presentation as well.

[1] Global Hydrogen Review 2023, International Energy Agency, <https://www.iea.org/reports/global-hydrogen-review-2023>

[2] J. Proost, International Journal of Hydrogen Energy, 44, 4406-4413 (2019)

[3] J. Proost, International Journal of Hydrogen Energy, 45, 17067-17075 (2020)

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