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Editorial

The Merit and the Context of Hydrogen Production from Water and Its Effect on Global CO_2 Emission

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For a green economy to be possible in the near future, hydrogen production from water is a sought-after alternative to fossil fuels. It is, however, important to put things into context with respect to global CO_2 emission and the role of hydrogen in curbing it. The present world annual production of hydrogen is about 70 million metric tons, of which almost 50% is used to make ammonia, NH_3 (that is mostly used for fertilizers), and about 15% is used for other chemicals [1]. The hydrogen produced worldwide is largely made by steam CH_4 reforming (SMR), which is one of the most energy-intensive processes in the chemical industry [2]. It releases, based on reaction stoichiometry, 5.5 kg of CO_2 per 1 kg of H_2 (CH_4+ 2 H_2O → CO_2 + 4 H_2). When the process itself is taken into account, in addition, the production [3] becomes about 9 kg of CO_2 per kg of H_2 and, this ratio can be as high as 12 [4]. This results in the production of about one billion tons/year of CO_2. The world annual CO_2 emission from fossil fuels is, however, much larger: it is about 36 billion tons, of which roughly 25% is emitted while generating electricity and heat, 20% due to transport activity and 20% from other industrial processes. Because of the link between global warming and CO_2 emissions, there is an increasing move towards finding alternative approaches for energy vectors and their applications.

The amount of CO_2 released while producing hydrogen from fossil fuel represents 3–4% of its total emission. Making hydrogen from renewables to replace the present hydrogen production from natural gas, while very difficult, will not decrease CO_2 emission. Moreover, all chemicals (not fuel) consumed worldwide, once burnt, release about 3% of CO_2 globally. In other words, the present numbers indicate that transforming CO_2 to chemicals, using H_2 from water, as well as replacing SMR by electrolyzers (for example) will have a minor effect on curbing global CO_2 emission. The power of hydrogen and its important effect on cleaning the environment can be seen when it is used as fuel for transport, heat and other energy applications, as these applications represent over 70% of CO_2 emissions worldwide. This poses a much bigger problem for R&D; hydrogen needs to be made at an unprecedented scale, much larger than the present one, and from water, not from methane [5]. This is a daunting task that is probably not fully appreciated nor given its level of importance.

The present cost of hydrogen made via SMR with CO_2 sequestration is between USD 1.3 and USD 2.8 per kg [6]. The cost of hydrogen from H_2O using energy from the sun will need to compete with this, or more realistically, it will need to be largely subsidized for a few years. At present, the numbers for the levelized cost of hydrogen production (the minimum selling price of hydrogen without loss, after 20 years of production) from water are about USD 5/kg [7]. The destructive effect on the environment of the carbon-based economy, affecting life on land and in the sea, is increasingly observed and will ultimately force the continuous displacement of humans and other living species, with many negative consequences, most of which are probably unforeseen. Due to this, global efforts to make hydrogen from water at the highest possible efficiency, safety and process reliability is needed. The photo-catalytic production of hydrogen from water as well as the thermal route

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(termed thermochemical water splitting) are still at the research level, and therefore, electrocatalysis, which is an available technology, and probably photo-electrocatalysis, which has an overall higher efficiency than PV-electrolysis, are the most promising options at present. However, both need to be at the TW scale. A detailed set of different scenarios to replace fossil fuel by renewables was made over a decade ago by the late David MacKay, who ended by indicating that in order to replace fossil fuels at the present state of technology, the numbers show that only nuclear stands as an option, from which he coined the sentence "I am not pro-nuclear, I am pro-arithmetic" [8].

The gigantic effort for making hydrogen from water cannot be left to companies because they rely solely on profit. It is also important to indicate that targeted research on renewable energies needs to be put in context, and a certain type of research might be unnecessarily diverting funds, efforts and talents towards ill-conceived solutions to techno-chemical problems. One cannot overemphasize the fact that transforming CO_2 to chemicals, such as methanol, and using hydrogen from water, while important locally, is relevant globally when these chemicals are used as an energy vector, not for commodity use.

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References

1. Birol, F. *The Future of Hydrogen: Seizing Today's Opportunities*; Report Prepared by the IEA for the G20, Japan; International Energy Agency: Paris, France, 2019.
2. Worrell, E.; Phylipsen, D.; Einstein, D.; Martin, N. *Energy Use and Energy Intensity of the U.S. Chemical Industry*; Energy Analysis Department, Environmental Energy Technologies Division, Ernest Orlando Lawrence Berkeley National Laboratory: Berkeley, CA, USA, 2000.
3. Sun, P.; Elgowainy, A. *Updates of Hydrogen Production from SMR Process in GREET*; Systems Assessment Center, Energy Systems Division, Argonne National Laboratory: Argonne, IL, USA, 2019. Available online: https://greet.es.anl.gov/publication-smr_h2_2019 (accessed on 8 February 2022).
4. Koch Blank, T.; Molly, P. Hydrogen's Decarbonization Impact for Industry. In *Near-Term Challenges and Long-Term Potential*; Rocky Mountain Institute: Basalt, CO, USA, 2020. Available online: https://rmi.org/wp-content/uploads/2020/01/hydrogen_insight_brief.pdf (accessed on 8 February 2022).
5. Idriss, H. Towards large scale hydrogen production from water, what have we learned and what are the main hurdles to cross for commercialization? *Energy Technol.* **2021**, *9*, 2000843. [CrossRef]
6. Parkinson, B.; Balcombe, P.; Speirs, J.F.; Hawkes, A.D.; Hellgardt, K. Levelized cost of CO_2 mitigation from hydrogen production routes. *Energy Environ. Sci.* **2019**, *12*, 19–40. [CrossRef]
7. Khan, M.A.; Al-Shankiti, I.; Ziani, A.; Idriss, H. Demonstration of 28% solar to hydrogen efficiency and evaluation of its economic importance. *Sustain. Energy Fuels* **2021**, *5*, 1085–1094. [CrossRef]
8. MacKay, D. *Sustainable Energy-Without the Hot Air*; UIT Cambridge Ltd.: Cambridge, UK, 2008; p. 169.