Hydrogen development in Europe: Estimating metals and water consumption in Net Zero Emissions scenarios

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Overview

Low-carbon hydrogen has already been announced by many governments as one of their priorities for achieving carbon neutrality by 2050. In Europe, particularly, a political momentum for hydrogen use has strengthened in recent years. This potential for massive development of low-carbon hydrogen in the coming decades raises questions about the global impact of the different production technologies. The main risk of such technological change is that it shifts the environmental impacts from greenhouse gas emissions to other environmental burdens, such as mineral resource dependence and water use and scarcity. The aim of this article is to assess the consumption of water and raw materials with hydrogen development in Europe through to 2050. It also provides insights on possible risks related to the supply of these materials. The article also conducts a more in-depth analysis of Iridium (used in PEM electrolyzers) and more generally of platinum group metals (PGMs). It thus presents a broad picture of the current market situation and explore potential geo-economic tensions to be anticipated.

Methods

The methodology adopted for this study is an ex-post evaluation of the material and water requirements for a hydrogen development scenario in Europe. To do so, we rely on the hydrogen evolution pathway obtained in the framework of the Hydrogen for Europe (H24EU) project, led by IFP Energies nouvelles, Deloitte and SINTEF. This project was based on an energy system model that integrates a wide range of existing and future hydrogen technologies, competing with a variety of other technologies to meet the energy demand of all sectors. More precisely, the model used was designed to optimize the evolution of the energy system by following a least cost paradigm, while respecting several constraints including the achievement of carbon neutrality in 2050. This article focuses on the reference scenario of H24EU project, namely the "Technology Diversification pathway". The new installed capacities per decade for each hydrogen production technology, as well as the annual production of H2 by technology, are derived from this baseline scenario. The material and water consumption for each H2 production technology are then estimated through an extensive literature review to build up the necessary data set. At this stage, the material consumption of the hydrogen sector by decade, between 2015 and 2055, can be calculated, as well as the annual water consumption. A sensitivity analysis is also performed on these results, considering a potential technical progress that could reduce the material contents of hydrogen production technologies. Finally, the projected water requirements of the hydrogen sector are compared to the water consumption of the energy sector in Europe, and the projected material requirements to the current annual production. This enables the identification of potential supply tensions to be anticipated. The results are also compared to the existing literature, quantitatively where possible, but also qualitatively on the identification of critical materials. A particular focus is made on Iridium, whose criticality was identified to be the highest in the hydrogen development scenario studied.

Results

Hydrogen production could represent 5 to 7% of water consumption for energy purposes in Europe in 2050 (Table 1). However, it should be kept in mind that the water market is highly regionalized: a more local analysis would be necessary, especially for regions with a high potential for hydrogen production, but with high water stress. Iridium is by far the most critical material, with a projected consumption in Europe alone of about 130-140 tons per year in the decade 2045-2054, while current global consumption is barely 8 tons per year (Table 2). This high demand could seriously threaten the development of PEM electrolysis. Despite the low development of biomass gasification compared to other technologies, the demand for olivine that it generates is substantial. However, no supply tension is to be expected. The demand for nickel generated by hydrogen production is not negligible. This demand comes mainly from the electrodes of alkaline electrolyzers. It could be even higher if the PEM electrolyzers were hampered by their excessive demand for iridium and replaced by alkaline electrolyzers.

Technology	2020	2030	2050
Steam methane reforming	1	356	541
PEM electrolysis	0	2	182
Alkaline electrolysis	0	22	373
Biomass gasification	0	0	36
Water requirement/Water consumption of the European Energy sector in 2017	0.00%	1.87%	5.55%

Table 1 : Water consumption related to hydrogen production in Europe by technology, in billion liters per year.

Material	Production (2019)	2025-2034	2045-2054
Nickel	2610 kt	0.37%	4.18%
Titanium	200 kt	0.27%	5.66%
Iridium	8.02 t	7.73%	164%
Platinum	264 t	0.07%	1.54%
Olivine	8 Mt	1.94%	29.5%

Table 2 : Material requirements for hydrogen production in Europe compared to the current production of each material.

Conclusions

The deployment of low-carbon hydrogen in Europe will certainly put pressure on several resources identified and quantified in this study. The results show that the iridium demand for PEM electrolyzers could cause major supply tensions. These tensions would be exacerbated by the fact that iridium is exclusively a by-product of other platinum-group metals, so an increase in iridium demand would not systematically trigger an increase in mine production. Yet iridium contents for PEM electrolyzers are likely to be greatly reduced in the coming decades, which could alleviate the identified tensions. This study also shows that the nickel demand for alkaline electrolysis could represent a significant proportion of total consumption, which, in the context of a drastic increase in demand for nickel due to the development of electric vehicles, could also hinder the implementation of this type of electrolysis. Finally, this study highlights that the water requirement of the future hydrogen production system is far from negligible. It also underlines the need to investigate more thoroughly the water requirements from the hydrogen sector on a local level, considering the sunniest regions where PV technology coupled with H2 production would be the most profitable to develop are also the driest region.

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