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Water Availability for Electrolysis in Germany: Evidence from 2030 Scenarios and Perspectives for 2045

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Germany has set ambitious goals for the expansion of hydrogen production based on water electrolysis. While current debates predominantly focus on the necessary renewable electricity supply and hydrogen infrastructure to achieve this, the availability of water for electrolysis has received limited attention so far. This study builds on a model-based assessment of the German energy system for the year 2030 and evaluates the implications of water availability, water pricing, and hydrogen transport infrastructure for the regional deployment of electrolysis capacity in the year 2045.

Using a spatially disaggregated energy system model of the federal states in Germany, the analysis for 2030 integrates regional renewable energy potentials, hydrogen demand, water charges, and assumptions on freshwater availability under different water stress scenarios. We find that the total water demand of electrolysis remains small in comparison to overall national water withdrawals. Water costs make up a negligible share of total electrolysis costs and therefore only have limited influence on investment decisions. However, regional constraints in freshwater availability can affect the optimal electrolyzer locations, particularly under scenarios of limited hydrogen transport capacity. Our 2030 results further show that the expansion of the hydrogen transport network is the dominant factor shaping the spatial distribution of electrolysis. When hydrogen transport is unconstrained, electrolysis capacity concentrates in regions with high renewable electricity potential, especially in northern Germany with strong offshore wind resources. Conversely, under scenarios with restricted hydrogen transport, electrolysis deployment becomes more demand-oriented and shifts toward industrial regions, thereby increasing the relevance of local water availability. In scenarios with limited freshwater availability, the model indicates spatial relocation of electrolysis capacity away from potentially water-stressed regions and a partial substitution of freshwater by alternative sources such as desalinated seawater in coastal regions.

Although these findings suggest that water availability is not a binding constraint for hydrogen deployment in Germany by 2030, these results may change when looking ahead to 2045, when Germany wants to achieve greenhouse gas neutrality. Domestic hydrogen demand could quadruple from 2030 to 2045 according to the National Hydrogen Strategy, which would require a significant uptake in hydrogen production. Thus, water availability, particularly in the light of more severe droughts due to climate change, might play a larger role for electrolyzer locations in the future. Building on the insights from the 2030 analysis, we propose an extension of the modeling framework to 2045 to capture the seasonal availability of ground water. Scenarios regarding water availability are derived from a hydrological model that captures climate-driven changes in hydrological conditions. Additionally, different scenarios for the hydrogen demand are explored. Furthermore, we account for the relevance of offshore electrolysis versus onshore electrolysis in coastal regions.

Overall, the study demonstrates that water availability plays a limited role in shaping electrolysis deployment by 2030. However, this may change with an increasing hydrogen economy in Germany. The analysis of 2045 scenarios aims to identify potential tipping points at which water availability could shift from a secondary consideration to a strategic constraint. By linking energy system modeling with hydrological models, the study contributes to a more integrated understanding of the water–energy nexus and provides evidence-based guidance for the sustainable development of Germany's hydrogen strategy.

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