

Exploring Investment Strategies in the Green Hydrogen Industry: An Agent-Based Modeling Approach

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Abstract

Green hydrogen is a promising substitute for fossil fuels, as its production via renewable electricity releases no CO₂ emissions. However, existing production capacities for electrolyzers and green hydrogen do not meet national political targets. In addition, enough excess electricity from renewables is missing to operate electrolyzers economically. Therefore, investment in renewables, electrolyzers, and production capacities for electrolyzers is necessary. Typically, investments are based on profitability; however, in emerging markets, like the green hydrogen and electrolyzer market, strategic investments are initially made where profitability is less important. Today, it is unclear how the scale-up of the green hydrogen industry might look and how the three markets might synchronize to deliver the desired, rapid scale-up. We want to understand if investments will be made and, if so, when. Additionally, we want to assess expected profitability for companies. Lastly, we want to investigate what effect strategic investments have on the overall development.

We created an agent-based model that includes the electricity, green hydrogen, and electrolyzer markets, both with companies and production capacities. Our model shows that in the reference case without strategic investment, investments are initially solely made in new renewables and rapidly expanded. The expansion can be divided into two phases. The first phase is primarily due to the general demand for electricity. While the general demand is not primarily covered by renewables, new investments in renewables are profitable. The second phase is defined by additional demand for electricity due to electrolyzers. As long as the installed electrolyzer capacity grows, investments in renewables remain lucrative. The share of renewables in electricity production reaches up to around 90%. Hydrogen producers start to invest in new electrolyzers only if sufficient excess electricity exists. Furthermore, the model shows that early electrolyzers usually run either at full load or not at all; however, the share of hours with partial load increases significantly due to growing competition from additional electrolyzer capacities. Initially, the market for green hydrogen and electrolyzers grows exponentially as the size of new capacities increases and new companies enter the market. This leads to a surplus of electrolyzers, which results in installed capacities first leveling off and then decreasing when companies go bankrupt. Similar behavior can be seen in the electricity market, where the surplus of installed electrolyzers leads to a surplus of renewables, resulting in unprofitability and thus bankruptcies. In general, profitability is low, particularly in the green hydrogen sector, even though the cost for electrolyzers falls by around an order of magnitude due to learning effects. In the case that hydrogen and electrolyzer producers are allowed to make strategic decisions, i.e., initial investments do not have to be profitable, the market scale-up of green hydrogen and electrolyzers starts earlier than in the reference case. However, this option is riskier, and not all companies can survive.

Our work shows how the green hydrogen industry might develop in a fully liberalized market and what effect strategic investments could have on this development. The work contributes to a better understanding of the factors influencing the scale-up and its timeframe.