Widespread adoption of hydrogen as an energy carrier is widely believed to require continued advances in Power-to-Gas (PtG) technologies. Here we provide a comprehensive assessment of the dynamics of system prices and conversion efficiency for three currently prevalent PtG technologies: alkaline, polymer electrolyte membrane, and solid oxide cell electrolysis. We analyze global data points for system prices, energy consumption, and the cumulative installed capacity for each technology. Our regression results establish that, over the past two decades, every doubling of cumulative installed capacity resulted in system prices coming down by 14-17%, while the energy required for electrolysis was reduced by 2%. Incorporating multiple forecasts of future deployment growth, our calculations project that, in the coming decade, all three technologies will become substantially cheaper and more energy-efficient. Specifically, the life-cycle cost of electrolytic hydrogen production is projected to fall in the range of $1.6-1.9/kg by 2030, thereby approaching but not reaching the $1.0/kg cost target set by the U.S. Department of Energy.
three PtG technologies by tracking global observations on investment expenditures and energy consumption. This information is linked to capacity installations at facilities commissioned worldwide between 2000–2020. Our estimates return significant and robust learning curves for system prices in the range of 83–86% (Figure 1). Thus, system prices declined by 14–17% compared to the price levels prior to the doubling of cumulative installments. The relatively young SOC technology is projected to show the sharpest price decline at a 17% learning rate. PEM electrolyzers, in contrast, have experienced high capacity growth and a rapid price decline between 2003 and 2020. Here, our estimates yield a relatively slow learning rate of 14%. For conversion efficiency, we estimate that every doubling of cumulative installed capacity reduces the required kilowatt-hours (kWh) per kilogram (kg) of hydrogen produced by approximately 2% across all three technologies.

Our regression results can be extrapolated to yield forecasts for the system prices and conversion efficiencies of the three PtG technologies in question by the year 2030. Even for divergent growth forecasts issued by different industry and policy sources, the extrapolated values fall into a relatively narrow range. These calculations, in turn, lead us to conclude that the Hydrogen Shot target by the U.S. Department of Energy of producing clean hydrogen at a cost of $1.0/kg by 2030 is ambitious but not unrealistic. Because electricity prices will become the dominant component of the lifecycle cost of hydrogen by 2030, the attainment of the Hydrogen Shot target via electrolytic hydrogen ultimately hinges on the availability of inexpensive and clean electricity.

Figure 1: Estimates of learning curves.

This figure plots the global system prices in 2020 $US against the global cumulative installed capacity together with our estimates of the corresponding learning curves for (a) alkaline, (b) PEM, and (c) SOC electrolyzers. The figure also plots the energy consumption against the global cumulative installed capacity together with our estimates of the corresponding learning curves for (d) alkaline, (e) PEM, and (f) SOC electrolyzers. Areas shaded in red represent 95% confidence intervals.
References


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