Estimating PEM Electrolyzer Costs for Hydrogen Production Through 2050

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Background & Motivation

Hydrogen has been one of the technologies to receive the most recent attention as of late, specifically within the U.S. Inflation Reduction Act (IRA) production tax credit. The hope is that hydrogen can provide great support in goals of decarbonization. The prevalent questions are relating to what role the technology will play, and how hydrogen will reach regions of cost-competitiveness when compared to other green technologies. Hydrogen, if produced with clean electricity, can be considered a clean technology and is often referred to as "green hydrogen." This analysis focuses specifically on Polymer Electrolyte Membrane (PEM) electrolyzers, as there is early evidence to suggest these will be the most cost effective electrolyzers, with support from government, industry, and academia in this claim.

Variations of measurement for the cost of hydrogen are important to consider. The focus of this analysis will be CAPEX. The units for CAPEX are measured as the amount of upfront capital cost necessary to produce one unit of electricity, typically reported in $/kW or $/MW. This specific cost unit is especially applicable when considering the capacities of different electrolyzers being installed, as well as infrastructure that would be necessary outside of primary production.

Methodology

The paper analyzed 45 scenarios for hydrogen adoption, and thus provide potential outcomes for electrolysis to meet feasible cost levels through a scale up to meet worldwide expectations for hydrogen production capacity.

- To determine future scenarios for decreasing the costs of PEM electrolyzers, learning rates are estimated through the principles of Wright's Law.
- Wright's Law best fits the nature of the analysis as it determines a decrease in cost of production based upon a doubling in installed capacity.
- Given that most available electrolyzer data contained either a price or expected capacity, Wright's Law was the best fit to determine a learning rate for specific scenarios.
- The general Wright's Law formula for a decreasing cost reads as:

$$Y = aX^{-b}$$

Where: Y = the cost per unit ($/kW), X = the cumulative number of units produced (GW), a = cost to produce the first unit ($/kW), and b = slope of the function[1,2].

Results

Key Results of the Analysis:

- Starting price is less important in the long-term, as the learning rate is a larger factor.
- Upfront capital costs could play a significant role in determining future competitive cost options for electrolyzers over the next 2-3 decades.
- Projects with larger capacities can have the benefit of a noticeably decreased CAPEX.[3]
- Cost differences between most expensive and least expensive scenarios will converge to smaller intervals as time progresses towards 2050.
- CAPEX is expected to decrease the most between 2022 and 2030, with a smaller decreases projected between 2030 and 2050.
- Based on the CAPEX ranges of 2050, PEM electrolyzer costs are likely to decrease by a noticeable margin, even if not to the same learning rates as described in the more aggressive scenarios.

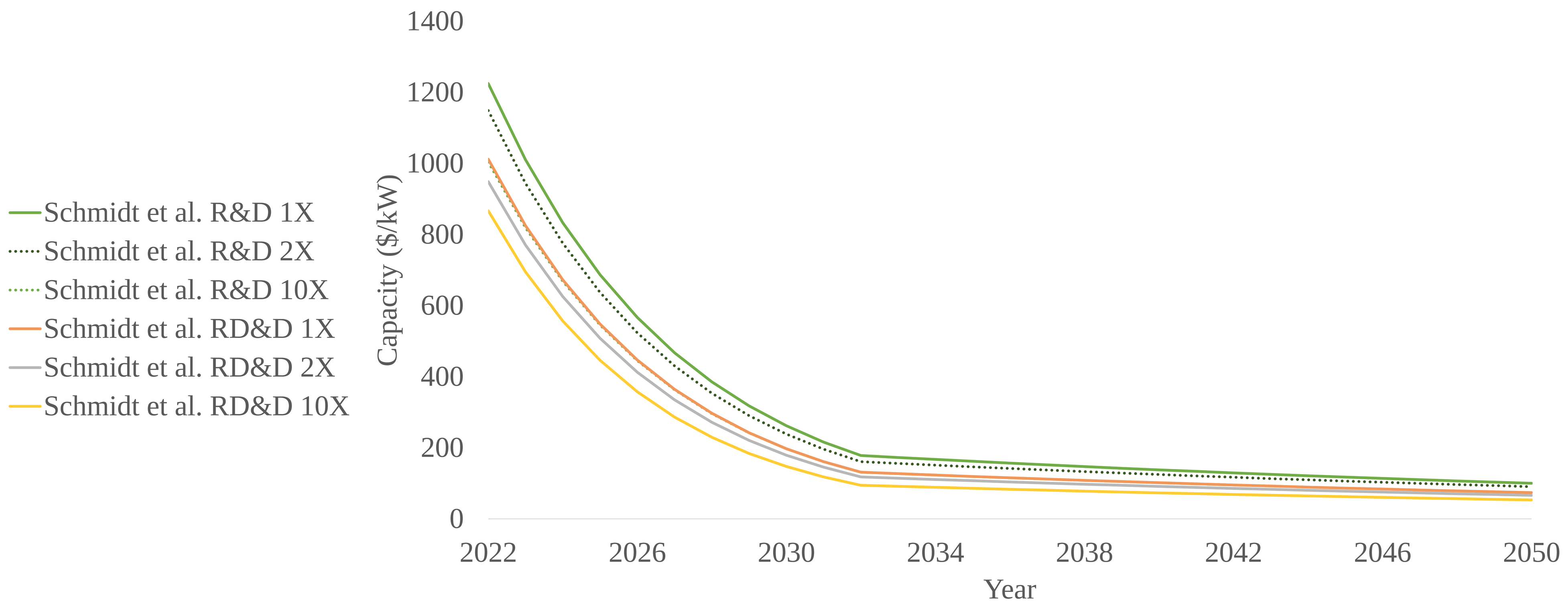

Figure: Trends of CAPEX ($/kW) decreases from 2022 through 2050 from original Schmidt et al. scenarios[4]. Extrapolated the change in costs predicted for each Research and Development type between 2020 and 2030 to the year 2032. Next, used IEA hydrogen database to predict a doubling time for a new learning rate between 2032 and 2050. This time to double was then applied to a general learning rate of 25%. Scenario with RD&D 10X starts and ends as the lowest CAPEX scenario as this prediction is the most aggressive scenario and there are lower starting costs.

SCENARIO TYPE:	NUMBER OF SCENARIOS:	LEARNING RATE RANGE (%):	MEDIAN LEARNING RATE (%):	2022 CAPEX RANGE ($/KW):	2050 CAPEX RANGE ($/KW):
SCHMIDT	6	31.93-27.8	29.39	1225-867	100.39-53.35
IEA NET ZERO	6	73.55-5.9	8.81	1225-867	172.95-71.46
IEA CONSERVATIVE	12	29.56-5.09	25	1225-867	283.49-132.42
NREL	9	31.93-25	25	1503	339.04-100.3
INDUSTRY	12	25	25	1225-867	500.92-241.65

Table: Summary of various scenarios used in analysis. Includes the number of scenarios used for each type, as specified in the methodologies; the minimum and maximum of the used learning rates for each type; the median learning rate for further clarity on the true middle of the learning rates used; the CAPEX starting points in 2022 for each type of scenario; and the CAPEX ending points in 2050 for each type. Plug Power were the scenarios with the largest possible ending CAPEX but also had the most consistent learning rate, as 25% was used for all years.

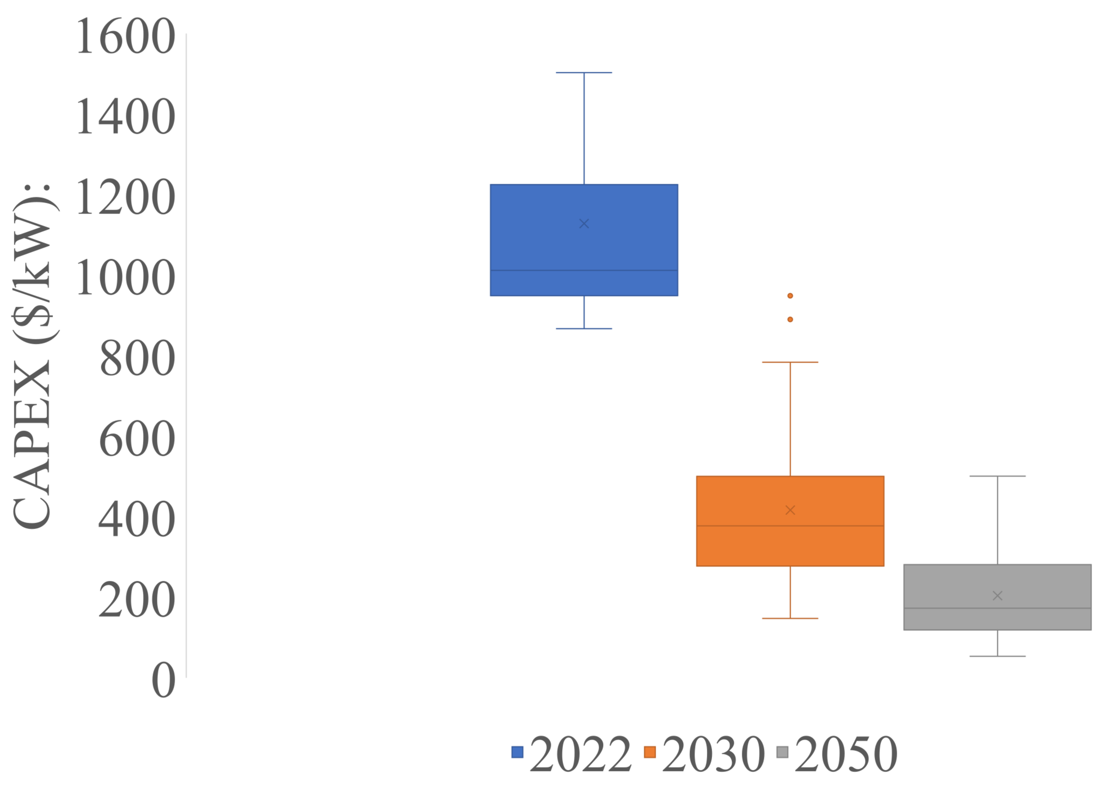

Figure: CAPEX distributions across all scenarios in analysis for the years 2022, 2030, and 2050. Using a box and whisker plot to display inter-quartile ranges for the years 2022, 2030, and 2050 are displayed. Outside of two outliers in 2030, no other year has outliers present, displaying a relatively continual decrease in CAPEX between the years.

Discussion

In order for the most aggressive learning rates to come to fruition the following are recommendations:

- Continued support for policies like the IRA, allowing the production of new technologies at a much lower cost.
- Along with research and development, deployment is essential to the process of furthering the learning curve.
- The biases associated with CAPEX as a metric should be further discussed to help with research accuracy.
- More open and transparent access to data regarding electrolyzers would increase the accuracy of analysis and allow for more efficient learning processes.

References

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