Electric Hydrogen's mission to produce renewable hydrogen at fossil-parity

Electric Hydrogen (EH2)

White Paper

March 2022

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After a deep dive into low-carbon hydrogen technologies and markets at Breakthrough Energy Ventures, Dave Eaglesham – former Bell Labs device physicist and early CTO of First Solar – had only one goal in mind: to make the lowest cost renewable-based electrolytic hydrogen at a scale big enough to help industry decarbonize quickly.

Dave and his co-founders went to work building a team of world-class engineers and scientists from some of today's most inspirational deep-tech companies – SpaceX, Tesla, First Solar and others. They tasked their team to rethink electrolysis entirely from a clean slate with one guiding light – to minimize the Levelized Cost of renewable Hydrogen (LCOH). The team eagerly went to the drawing board armed with the latest tools, methods, and lateral thinking, bringing novel ideas from other industries and disciplines. At every single design decision, manufacturability and constructability were at the forefront. They overhauled status quo designs, optimized system tradeoffs, redesigned critical components, and pushed the frontiers of electrochemistry. The goal was to create an electrolysis plant capable of producing fossil-free H2 at fossil-parity costs. An obsession for cost reduction was born within Electric Hydrogen (EH2) and it became the company's north star.

As the product underwent cycles of designs, builds, and tests, the team at EH2 developed a set of performance and cost models to inform electrolysis plant design decisions. Among those is a comprehensive techno-economic model for renewable-based electrolysis used daily by EH2 and its partners to steer key engineering and commercial decisions.

There is a significant level of hype today around hydrogen, which has re-energized the industrial decarbonization movement, but also has created a lot of noise and may have blurred the real economic drivers. EH2 is committed to fostering transparency and openness within the hydrogen industry. This is why EH2 is also sharing a simplified version of the tool, made publicly available for all (https://eh2.app/lcoh) to provide insights on the economics of electrolytic hydrogen production; a way to help filter out a bit of the noise, stay focused on the real and useful "signal", and understand the reality of fossil-free renewable hydrogen.

Figure 1. View of EH2 LCOH model, made publicly available

EH2 LCOH+, the advanced and more detailed version, is available upon request to EH2's partners. On top of the simplified LCOH model, it incorporates a comprehensive set of plant and operational parameters like hybrid solar and wind power supply, renewables capacity over-sizing, water supply cost, support mechanisms (grants and tax credits), and perhaps most uniquely, hydrogen storage modeling. Storage is an important aspect of future electrolysis plants to help reduce the intermittency of the hydrogen supplied, matching production to end-user needs within plant uptime and availability targets; EH2 LCOH+ includes these robust storage sizing and costing features.

Throughout the rest of this article, we will share key insights into the future of electrolysis and demonstrate the functionality of EH2's LCOH toolkit.

The economics of renewable-based electrolytic hydrogen

In 2021, the US Department of Energy announced ambitious targets to reach a milestone of \$2/kg of hydrogen produced using renewable electricity by 2026. Here, we will look at the conditions needed to achieve this target without support mechanisms (e.g., tax credits). We will use Texas as a case study, a location with good conditions for utility-scale electrolysis.

\$2/kg refers to the total cost of H_2 production achieving \$2 per kilogram of H_2 generated, incorporating plant installation costs and operational factors. Through this target, DOE intends to align industry efforts toward a total cost of production mindset – one that will simultaneously optimize CapEx as well as the operational costs, process inputs and overall plant efficiency.

Renewable electricity is needed to produce renewable hydrogen, and wind and solar resources in Texas are some of the most attractive in the country. If existing renewables tax credits are extended beyond 2023 (the date at which those reduce from 26% to 10% credit), EH2 estimates the LCOE (levelized cost of energy) from onshore wind and solar PV in Texas to be around \$28/MWh and \$23/MWh, respectively, by mid-decade. The good availability of wind and solar in the state makes these LCOEs possible, with capacity factors around 48% and 32% for wind and solar, respectively.

Water is another key input for electrolysis and is the source molecule for the hydrogen produced. In highly water-stressed regions like Texas, a sustainable approach might be to use recycled water or desalinated water. Based on a survey of the literature, including a recent study on brackish water desalination by Pearson et al in 2021 [1], we can use a conservative estimate of \$2 per cubic meter (m^3) of desalinated water.

The core of the green hydrogen production remains the electrolysis plant. Today, all-in installed capital costs for electrolysis plants vary in the 800-1200 \$/kW range – alkaline tends towards the lower part of the range while PEM sits at the higher end of the range.

Assuming a median \$1,000 per installed kW for today's electrolyzer plant costs, as well as the above LCOE estimates in Texas for solar and wind power, \$2/m^3 for desalinated water and using an average 7.5% weighted average cost of capital, our LCOH+ model estimates the LCOH to be at **\$3.7/kg for solar powered electrolysis** and **\$3.3/kg for wind-powered electrolysis**. These are 85% and 70% higher than the DOE cost target of \$2/kg as shown in Figure 2. **Based on where electrolysis stands today, the industry would miss the DOE \$2/kg target by a significant margin.** It will be unable to economically compete with hydrogen from natural gas, expected in the \$1-1.5/kg for gray hydrogen (hydrogen from natural gas without GHG abatement).

Note: the reader can reproduce these economics using our publicly available LCOH model within a few cents of accuracy as our LCOH model is a simplified version of the detailed LCOH+ tool.

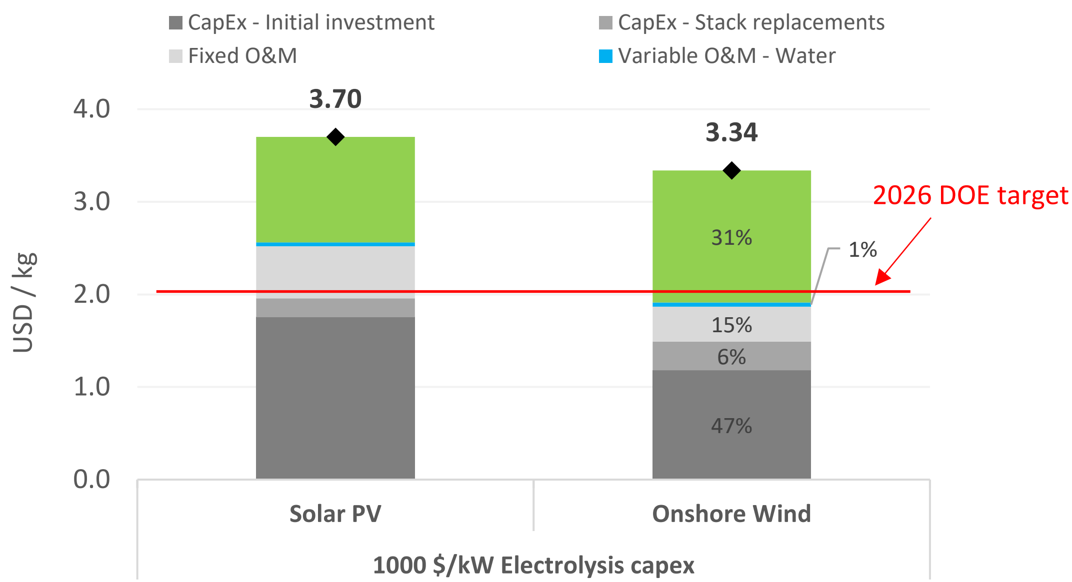

Figure 2. LCOH with today's electrolyzer technology in Texas

Figure 2 shows that the CapEx component is a significant portion of the LCOH, varying between 35% and 47%. This is directly related to utilization levels or Capacity Factor (CF) of the system as well as the total installed costs of the systems (here, it is assumed that the utilization rate of the electrolyzer matches the capacity factors of the renewable power supply). With the assumed LCOE, capacity factors and water costs expected in 2026, it is clear what cost driver needs to give: electrolyzer plant costs. **Industry needs to see major cost reductions from electrolyzer companies to achieve DOE targets.**

Fortunately, the electrolysis industry is aligned on the need to provide cheaper electrolyzers. However, from EH2's analysis and survey of the industry, the approach by current players is largely focused on scaling up legacy designs stemming from the early days of the industry. These designs were created for the kW scale and are at odds with today's gigawatt scale aspirations. This tracks with the fact that most of industry is targeting cost reductions down to the $500-$600/kW. **But is that enough?**

Meeting 2026 US DOE Target

In order to reach the $2/kg mark without financial incentives, a significant CapEx reduction is needed, as noted above. Using our LCOH+ model, and as shown in figure 3, installed electrolysis plants will need to cost between **$285/kW and $325/kW by 2026**, about 3x-4x decline in the next 4 years. **Is this achievable?** At Electric Hydrogen we believe it is, but under one condition: a complete system re-design that pushes electrochemistry and system performance beyond current limits— the thesis behind the company's existence.

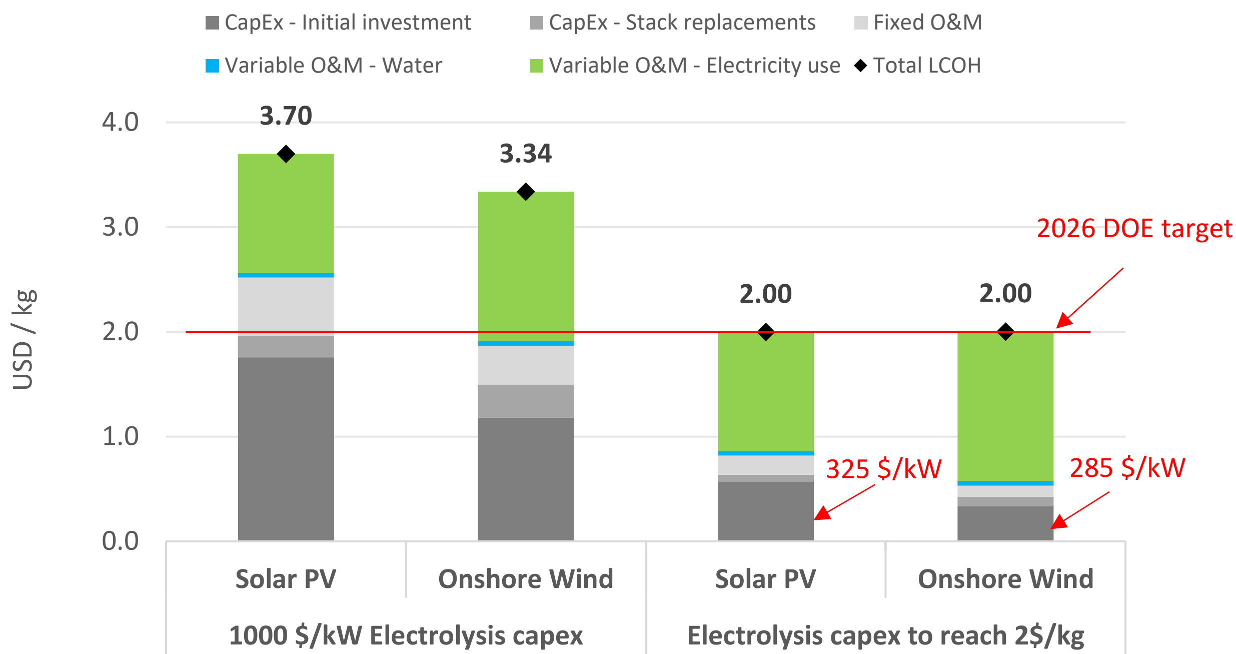

Figure 3. Capex needed to reach LCOH of 2$/kg, *using the same LCOE, CF and water assumptions as above, expected to adequately reflect those inputs in 2026 in Texas*

EH2 firmly believes that merely scaling up existing legacy solutions designed initially for the kW-scale will not be sufficient. It will certainly achieve some cost reductions — most likely around 2x — but not enough to reach DOE targets and would remain far from cost-parity with gray hydrogen.

Equipped with numerous patent applications and innovations across the spectrum of technical opportunities from the cell electrochemistry and stack to the balance of plant and EPC—all targeting the lowest possible LCOH by balancing capital cost reduction, performance, and efficiency— EH2 is determined to provide fully integrated electrolysis plants capable of reaching the 2026 US DOE target and competing with fossil-based hydrogen.

"It is an ambitious plan and a difficult task, but we would not be doing this if it was easy. We have an obligation towards our planet and our industrial partners, and targets cannot be achieved without fossil-free hydrogen at cost-parity with incumbent hydrogen" says Soufien Taamallah, Senior Engineering Product Manager at EH2, and former Director of Energy Technologies and Hydrogen Research at IHS Markit.

How about green hydrogen production intermittency?

Intermittent renewable power invariably produces intermittent hydrogen. Today, it is rare for the "quality" of the hydrogen production to be mentioned, but industrial customers of hydrogen will need a more continuous supply to run their processes. Until a hydrogen grid and geologic storage infrastructure is built to compare to what exists today for natural gas, a form of storage (electricity or hydrogen) or enhanced design of the renewable power and electrolysis plants (for instance, hybridizing solar and wind, and/or electrolyzer supply top-up using the grid) will likely be needed. **Electric Hydrogen does not shy away from this: EH2's advanced LCOH+ model includes a storage sizing and costing feature that estimates different storage options.** Intermittent hydrogen might be sufficient in many instances when supplementing another hydrogen source, but for renewables-based electrolytic hydrogen as the primary H2 source, storage is vital.

"Our tool helps our partners design the hydrogen plant while optimizing for intermittent renewable H2 LCOH or optimizing for continuous green H2 LCOH. These do not always lead to the same parameters. In both cases, our core electrolysis technology will help reach the lowest cost of hydrogen possible," says Alex Panchula, VP of Product Management at Electric Hydrogen.

Accelerants to the adoption of renewable based electrolysis

The US Build Back Better plan (BBB) proposes support mechanisms for low-carbon hydrogen in the United States. Its future is currently uncertain (as of March 2022), but the latest plans provide a good initial framework to test their impact on the LCOH. Europe and other countries like Australia have been leading the charge to support the scaling up of the low carbon hydrogen value chain; in these countries, hydrogen strategies have been released (mostly in 2020) and significant funding made available mainly in the form of grants to cover part of the capital expenditures (most notably under the IPCEI, Important Projects of Common European Interest). Our EH2 LCOH+ tool allows the user to include such support mechanisms and test their impact.

Besides grants to support pilots and manufacturing of electrolyzers, the production tax credit (PTC-H2) remains the most impactful proposal to date. The proposal is color-agnostic to hydrogen production methods and is based on the well-to-gate carbon-equivalent intensity of the produced hydrogen. This means that one must include the greenhouse gas intensity of all emissions including those of process inputs like natural gas, which have upstream fugitive emissions that are often overlooked.

To date, it is still unclear if the emissions scope delineation for electrolytic hydrogen includes the emissions due to electrolyzer manufacturing (steel required, metals mining, etc.) and the renewable power generation supply chain (wind turbines, solar wafers manufacturing, etc.). As a baseline, other regulatory bodies like the California Air Resources Board (CARB) do not consider those embedded emissions in the hydrogen life cycle assessment). However, it is worth mentioning that Electric Hydrogen is prioritizing sustainability of plant equipment and cell stacks in its design and procurement strategy. Here we will assume that those are limited.

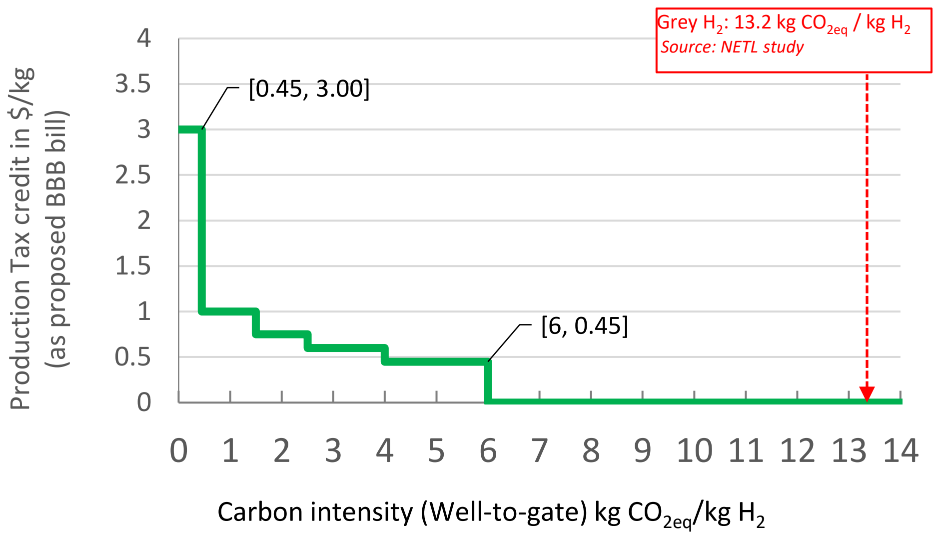

Figure 4. PTC-H2 levels as a function of the well-to-gate carbon intensity

as proposed by the Build Back Better plan

As shown in Figure 4, a full $3/kg tax credit would be received by a hydrogen producer who can keep its well-to-gate carbon intensity below 0.45 kg CO_{2eq}/kg H_2. Notably, the proposed production tax credits are for a 10-year time span, not for the full length of the plant lifetime (usually between 20-30 years for similar types of infrastructure). This means that the impact of the PTC on the LCOH is not a simple subtraction of the full $3/kg but rather a lower figure that depends on the weighted average cost of capital (it is the present value of the $3/kg received over the first 10 years of the economic lifetime of the plant). Based on EH2 assumptions consistent with the analysis throughout this article — with a tax rate of 21%, a 5-year MACRS depreciation schedule and a WACC of 7.5% — the PTC impact on the LCOH amounts to $2.4/kg for H_2 produced with less than 0.45 kg CO_{2eq}/kg H_2.

As shown in Figure 5, a pre-PTC green hydrogen LCOH of $3.5/kg would be sufficient to have cost-parity with grey hydrogen (at $1.06/kg - *Source: NETL study*) with the support mechanism. Grey hydrogen would not receive any PTC (see figure 4). Renewables-based hydrogen costs in Texas achieved using today's electrolyzer costs are already close to this LCOH, as seen in figure 1.

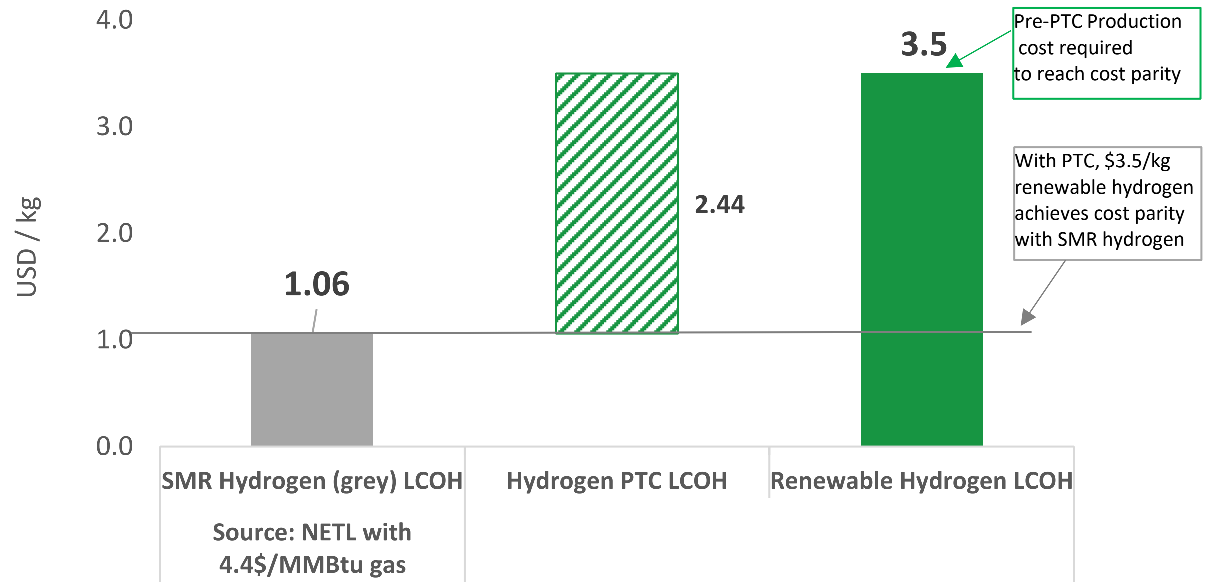

Figure 5. Back calculated renewables based LCOH required for fossil-parity

EH2's advanced LCOH+ has a support mechanism feature that factors in CapEx grants or tax credits like those proposed in BBB. The tool helps discern how effective the PTC can be in leveling the playing field for different hydrogen technologies based on their carbon intensity. **A support mechanism guided by carbon intensity is critical to spur industry to invest in and scale up the infrastructure around low and no carbon hydrogen.**

Concluding remarks

Around 30% of global emissions come from the industrial sector. To decarbonize the industrial segments that cannot be directly electrified, we must unlock cost-competitive renewable hydrogen. A rigorous LCOH-focused approach is essential to this.

While today's electrolyzer costs are on track to decline 2x by mid to end of this decade, this is far from the cost reductions required to achieve fossil parity hydrogen. The industry must be clear-eyed about the electrolyzer cost targets needed to achieve the US DOE's HydrogenShot's $1/kg in 1 decade with intermediate target of $2/kg in 2026; a 2x cost decline is not sufficient— we will need a 4x decline. EH2 was built to achieve this goal.

Our eyes are wide open to the electrolyzer cost targets we must hit, and we are persistently pioneering the uncharted path of cost declines unseen in electrolysis. Armed with decades of lessons from the solar and electric vehicles industries, we are applying new concepts to electrolysis to deliver fossil-parity hydrogen at industrial scale for the hardest to abate sectors.

With our LCOH models, industry stakeholders and our committed partners can better understand the cost targets required to achieve fossil-parity green hydrogen for a net zero future.

Want to contact us? Get in touch with us here or email info@eh2.com

[1] Jeffrey L. Pearson, Peter R. Michael , Noreddine Ghaffour and Thomas M. Missimer. "Economics and Energy Consumption of Brackish Water Reverse Osmosis Desalination: Innovations and Impacts of Feedwater Quality", Membranes 2021.