RESOURCES
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45V Hydrogen Tax Credit in the Inflation Reduction Act: Incorporating the Demand for Hydrogen

Issue Brief 23-03 by **Aaron Bergman** — August 2023

1. Introduction

The potential trade-off between the deployment of electrolyzers and changes in greenhouse gas emissions is a central part of the debate surrounding the 45V hydrogen production tax credit. In the **previous installment** of this series (**click here for the first**), I examine studies from the **Princeton ZERO Lab** and the **MIT Energy Initiative (MITEI)**. While some differences in the details do exist, at the highest level these studies both fixed the demand for hydrogen and let the model determine the emissions and cost impacts of the different approaches for matching hydrogen production to clean electricity generation. Importantly, the models were not able to adjust the size of the electrolyzers in response to the supply and demand for hydrogen.

In this issue brief, I'll look at a **study from Evolved Energy Research**. In this study, both the supply and demand of hydrogen are modeled, which enables the assessment of the effects of the different policy choices on the deployment of hydrogen. This is important, because one of the **central questions in this debate** is whether more complicated rules for the tax credit could increase costs to electrolyzers to the extent that the green hydrogen industry never gets off the ground.

The Evolved Energy Research study results show that the choice of policy for 45V does in fact make a difference on electrolyzer deployment, particularly in the short term. As the costs for electrolyzers decline, however, the levels of deployment under the different policy approaches converge by 2030. As with all modeling, significant uncertainty exists in technology price trajectories. The results show that the choice of policy can reduce the emissions rate from hydrogen production, even as, in most of the scenarios examined, the emissions rates are higher than the thresholds under which an electrolyzer must remain to qualify for the 45V tax credit. The cost increases from the more stringent requirements range from \$0.10/kg H_2 to \$0.40/kg H_2. For comparison, the highest value of the 45V tax credit is \$3/kg H_2. However, important differences in the policy options for 45V that are being modeled are central to understanding this result. I'll get into these differences in the following sections.

2. What Does Evolved Energy Research Model?

Before getting to the results, a brief review: an electrolyzer—a device that makes hydrogen and oxygen from water—uses a lot of electricity. Even as the electrolyzer doesn't emit any direct greenhouse gases, if that electricity is made from fossil fuels, the overall emissions, including those from the production of electricity, can be quite high. These are called the life-cycle emissions. In fact, these life-cycle emissions from electrolytic hydrogen production can be higher than the emissions from making hydrogen from natural gas. Since the value of the 45V tax credit **depends on these lifecycle emissions**, electrolyzers need a way to claim that they are using clean electricity, not just ordinary electricity from the grid. The main approach that is being considered for this claim relies on the purchase of energy attribute credits (EACs). In annual matching, a purchased EAC can be used by an electrolyzer to claim the consumption of clean electricity at any time of the year. In hourly matching, on the other hand, the EAC must be used in the same hour that it is generated.

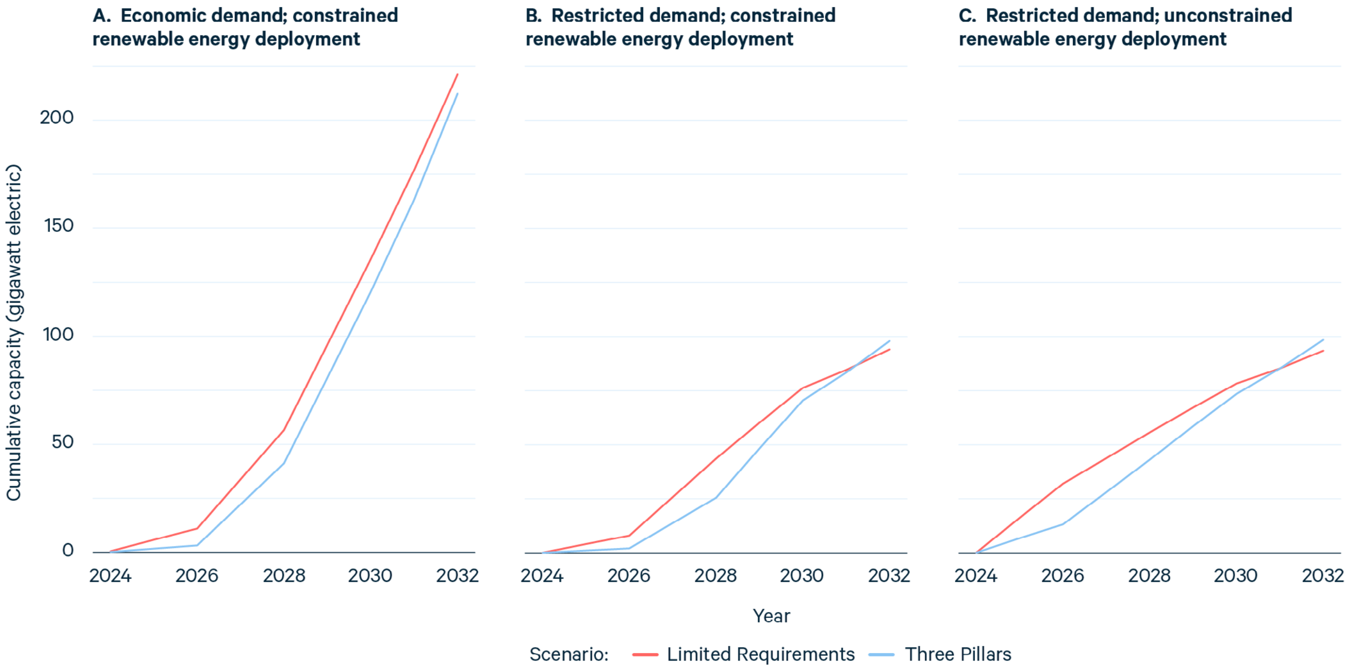
With respect to the 45V policy, Evolved Energy Research looks at two different scenarios. The first, which is referred to as “Limited Requirements,” only requires annual matching for the EACs. The second, referred to as “Three Pillars,” has three requirements: (a) hourly matching; (b) that the EACs cannot come from existing clean electricity generators; and (c) that the EACs must originate in the same model region (see Figure 2 of **the Evolved Energy Research study**) in which they are used. The Three Pillars scenario also requires that clean generators supplying EACs cannot sell more power than the electrolyzer purchasing the EAC consumes. In other words, if an electrolyzer purchases at least one EAC from a generator, then for any hour in which that generator cannot sell an EAC, it must shut down or curtail generation, forgoing any potential revenues from the sale of electricity. I’ll talk more about this unusual requirement in the section on building new clean electricity generation.

Evolved Energy Research assesses each of the scenarios for matching EACs against two different scenarios for hydrogen demand. In the Restricted Demand scenario, hydrogen demand mainly comes from existing demands for hydrogen in chemicals and refining and from the transportation sector. In the Economic Demand scenario, demand also can come from synthetic fuel producers, power generators, and industrial steam operators. Finally, this study also looks at scenarios with constraints on renewable energy deployment to represent siting and permitting restrictions.

3. Costs and Deployment

The novel feature of this study is that it models both the supply and demand for hydrogen, so I will start with its results for electrolyzer deployment, which are shown in Figure 1. Across all scenarios, fewer electrolyzers exist in the early years of the Three Pillars scenarios than in the early years of the Limited Requirement scenarios. As the prices of electrolyzers decline, the total deployment in the two scenarios converges, with more total deployment in Three Pillars scenarios with restricted hydrogen demand.

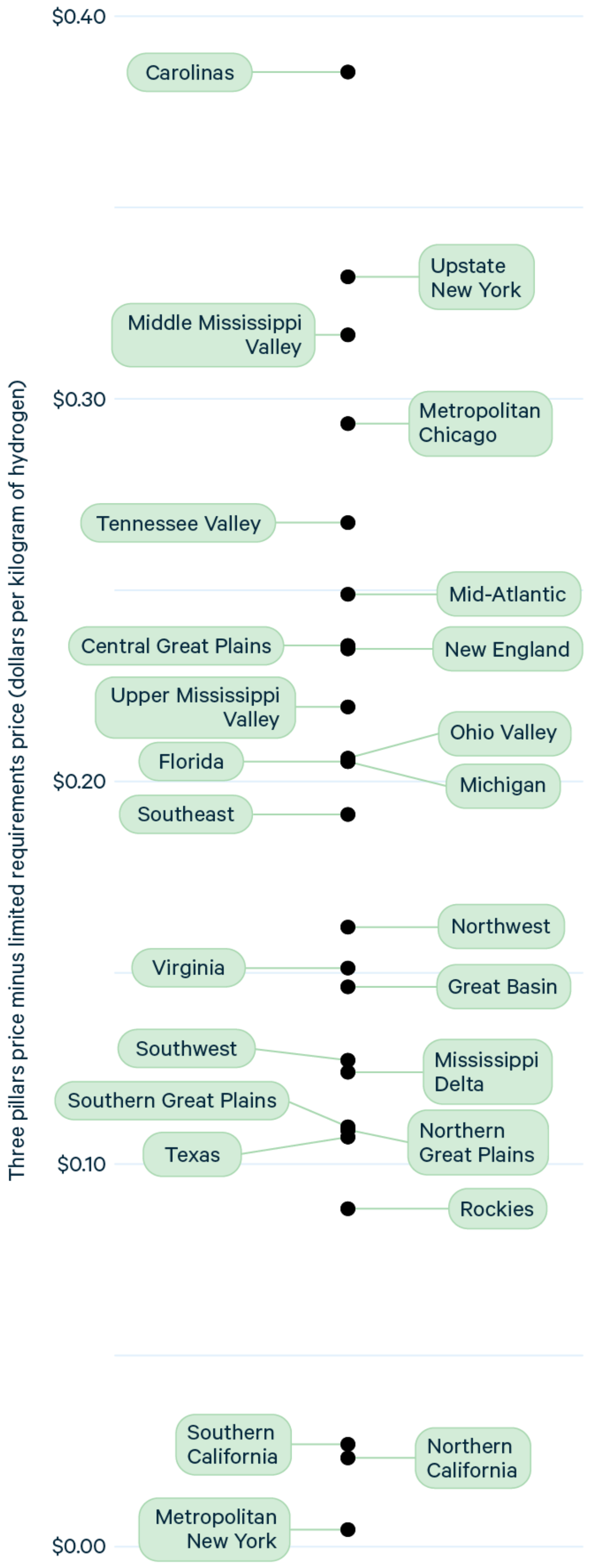
Figure 1. Cumulative Deployment of Electrolyzers in All Scenarios



In this modeling, the costs of electrolyzers decline over time irrespective of how many electrolyzers are built. In reality, one expects cost declines to be driven by the amount of deployment, as people learn how to better construct electrolyzers. This assumption raises the question of whether the level of deployment that is projected reflects the cost declines that are assumed by the model. To test the cost reductions in the Evolved Energy Research scenarios, I used the deployment and cost data to calculate implied learning rates[1] of less than 8 percent in the early years and less than 18 percent in the later years. For context, the International Renewable Energy Agency used a learning rate of 18 percent in its **study on green hydrogen**. Considering that the global deployment of hydrogen also will drive cost declines through learning, these modeled costs don't seem unreasonable. Even so, technology cost declines from learning are never guaranteed, and the decreased deployment in the Three Pillars scenario does represent a risk to achieving those declines.

Figure 2 shows the difference in the levelized cost of hydrogen—the price at which an electrolyzer must be able to sell its hydrogen to recover all of its costs—between the Three Pillars and the Limited Requirements scenarios for the various regions. With a few outliers, the cost differences are between $0.10 and $0.50, which are in line with the differences in **other studies**. These prices are for the year 2030 in the Restricted Demand scenario with no annual constraint on the deployment of renewables. As was the case in the prior studies, the cost increases are driven by the EAC price and the capacity factors of the electrolyzers, which are lower in the Three Pillars scenario. (These capacity factors are shown in Figure 9 of the **Evolved Energy Research study**).

Figure 2. Difference in Levelized Cost of Hydrogen between Scenarios in Modeled Regions



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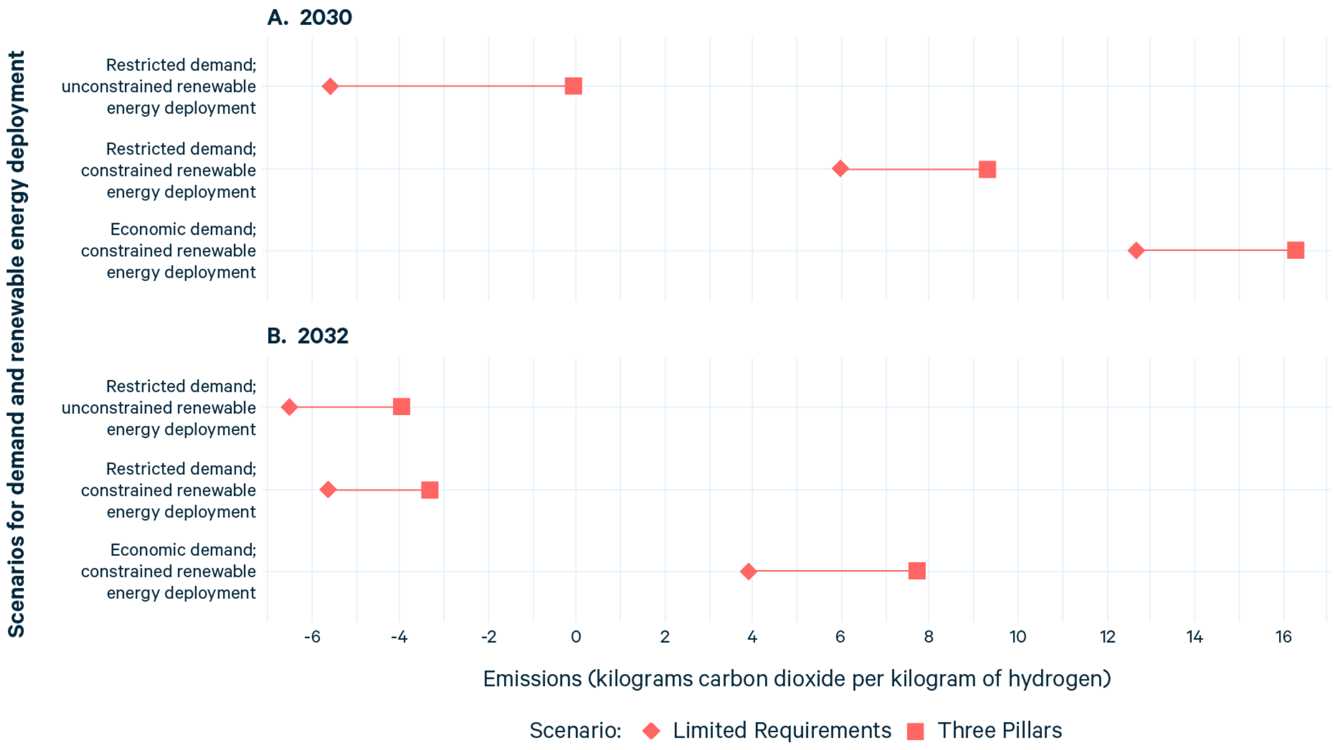
[1] Implied learning rates are the decline in costs for each doubling in the total amount of electrolyzers deployed.

4. Emissions

Figure 3 shows the emissions per kilogram of hydrogen produced across the scenarios that are modeled in the Evolved Energy Research study, as compared to a scenario without the 45V tax credit in which almost no hydrogen is produced. These are the emissions from the economy as a whole and not just the electric sector. In particular, these emissions rates are not comparable to the emissions rates that are projected in the Princeton ZERO Lab and MITEI studies, because those studies do not include the emissions from the industrial sector. As a consequence, the emissions rates in the Evolved Energy Research study are lower, because they also include the emissions reductions resulting from hydrogen's displacement of the use of fossil fuels in industrial applications. To precisely map one type of emissions onto the other is hard, but the two biggest uses for hydrogen in the Evolved Energy Research scenarios are refining and ammonia production. In those cases, the electrolytic hydrogen is displacing hydrogen that is produced with natural gas via steam methane reforming[2], which Evolved Energy Research assumes to have an emissions rate of around 9.5 kg CO_2/kg H_2. So, a reasonable approximation is to add 9.5 to the numbers in the figure for the purposes of comparing them with the Princeton ZERO Lab and MITEI studies.

In all cases, the Three Pillars scenario projects lower emissions than the Limited Requirements scenario. In addition, the Restricted Demand scenarios have lower emissions than the Economic Demand scenarios. Looking at the economy-wide emissions, the emissions intensities in many scenarios are below the thresholds for the 45V tax credit. However, if we only look at the upstream emissions (by adding in the displaced emissions from hydrogen consumption at approximately 9.5 kg CO_2/kg H_2), the emissions still are significantly greater than the thresholds for 45V.

Figure 3. Economy-Wide Emissions per Unit of Hydrogen Production



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[2] Steam methane reforming takes methane, the primary component of natural gas, and heats it in the presence of steam to create a mixture of carbon monoxide and hydrogen.

In all scenarios with restricted demand, most of the new electricity generation that is built is clean (Figure 14 of the **Evolved Energy Research study**), as is reflected in the negative emissions rates in 2032. More clean electricity is built in the Three Pillars scenario. In 2030, the annual constraint on the deployment of renewables likely is a significant driver of emissions in these scenarios, making it challenging for electrolyzers to procure sufficient clean energy at a reasonable cost and leading to increased electricity generation from fossil fuels. Even in the scenarios with restricted hydrogen demand and no constraint on the deployment of renewables, electricity generation from fossil fuels increases as compared to the no credit scenario.

5. Building New Clean Electricity Generation

One point that I emphasized in the **previous issue brief** is the role of EAC prices in driving the construction of new clean electricity generation. As in the Princeton ZERO Lab and MITEI studies with annual matching, the EAC price in the Limited Requirements scenario is zero. However, in the Three Pillars scenarios in the Evolved Energy Research study, a shortage of EACs exists in most regions, which drives the construction of new electricity generation. In contrast to the Princeton ZERO Lab study, in over half the hours in every region the EAC price is greater than zero in the Evolved Energy Research study.

Another novel feature of the Evolved Energy Research study is that some of the EAC prices are negative. This is because of the additional restriction that is placed on clean electricity generators, where generators have to shut down when they're not able to sell EACs. In those hours, the generator is forgoing the ability to earn money by selling its power, and so it is willing to pay the electrolyzer to generate more hydrogen in that hour to be able to earn additional money. This willingness to pay is the source of the negative prices. On the other hand, in the hours where the electrolyzer is consuming power, the EAC prices must be high enough to compensate the clean electricity generator for shutting down during the other hours. Similarly, more hours with positive EAC prices exist because of all the curtailed generation that is due to this restriction.

If excess sales are allowed, one possibility is that the electrolyzer will purchase the clean electricity that is available at a zero EAC price and only run when that clean electricity is available. This would mean that no additional clean electricity generation would occur in hourly matching scenarios, and the emissions impact of the Three Pillars scenario as compared to the Limited Requirements scenario would be small or zero. With excess sales disallowed, the electrolyzer would have to pay clean electricity generators to curtail generation when electricity isn't being used by the electrolyzer, making those EACs no longer zero-price. However, that the end result will be decreased emissions is not guaranteed, particularly since the curtailed generation is clean electricity that is then not available to the grid. Princeton ZERO Lab analyzed scenarios with and without excess sales allowed and saw some scenarios where the difference in emissions between hourly and annual matching increased and some scenarios where it decreased. I am told by Evolved Energy Research that, in their modeling that allowed excess sales, both the deployment of electrolyzers and the overall level of emissions increased, reducing the gap between the Three Pillars and Limited Requirements Scenarios.

6. Conclusion

The emissions benefits of hourly matching are driven by the quantity of zero-price EACs and the amount of hydrogen that is demanded. The case of the different electrolyzers in the Wyoming/Colorado region in the Princeton ZERO Lab study in the previous issue brief was a good demonstration of this relationship. When the size of the electrolyzer is part of the modeling, as in the Evolved Energy Research study, the size of the electrolyzer can and will adjust to the incentives, which can mitigate the impact on emissions of a given policy. Not allowing excess sales can reduce the quantity of zero-price EACs, although such a policy requirement would likely be met with strong resistance.

In the final installment of this series, we will look at two studies in which the new electricity generation is assumed to be clean and discuss what that assumption means and whether it may be justified.

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