United States of America
Department of the Treasury and Internal Revenue Service
Notice of Proposed Rulemaking on Section 45V Credit for Production of Clean Hydrogen

Comment from the Princeton University Zero-carbon Energy systems Research and Optimization Laboratory (ZERO Lab)[1,2]

The Princeton University ZERO Lab appreciates the opportunity to submit comments in response to the notice of proposed rulemaking (NOPR) by the Department of the Treasury (Treasury Department) and the Internal Revenue Service (IRS) regarding implementation of the Inflation Reduction Act's (IRA) Section 45V Clean Hydrogen Production Tax Credit. Since its inception the ZERO Lab has endeavored to provide timely, unbiased, and robust energy modeling analysis in support of US energy policy design at the state and federal levels. In the past year the lab has conducted peer-reviewed research and analysis to inform decision making on the handling of electrolysis-based hydrogen production pathways under 45V. In this comment we discuss the NOPR proposals relevant to the electrolysis production pathway, including a general discussion of the proposed rules and more targeted responses specific open questions.

Section 1: General Discussion

The Section 45V hydrogen production tax credit is the most generous clean hydrogen subsidy in the world. It is designed to rapidly scale up production of a critical clean energy carrier and feedstock that can help decarbonize hard-to-electrify applications such as steelmaking, fertilizer production, long-distance transportation, and the production of maritime and aviation fuels. The most generous subsidy level offered by 45V – $3/kilogram (kg) – is intended only for processes that produce hydrogen while causing near-zero greenhouse gas emissions (<0.45 kg CO_2-equivalent per kg H_2). Most of the opportunity lies with electrolysis, a technology that can use zero-carbon electricity to produce hydrogen. But hydrogen produced via electrolysis can also be incredibly carbon intensive if it is not supplied almost exclusively with zero-carbon power (Figure 1). Simply plugging electrolyzers into the grid would produce hydrogen with embodied emissions roughly twice as bad as 'grey' hydrogen produced from fossil methane. In fact, even an electrolyzer getting just 2% of its electricity from natural gas plants or less than 1% from coal would violate the strict statutory emissions requirements to claim the $3/kg subsidy.

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[1]This response reflects the views of Prof. Jesse D. Jenkins, principal investigator of ZERO Lab and Wilson Ricks, PhD candidate and research associate at ZERO Lab, and not those of Princeton University, the Department of Mechnical and Aerospace Engineering, or the Andlinger Center for Energy and the Environment.

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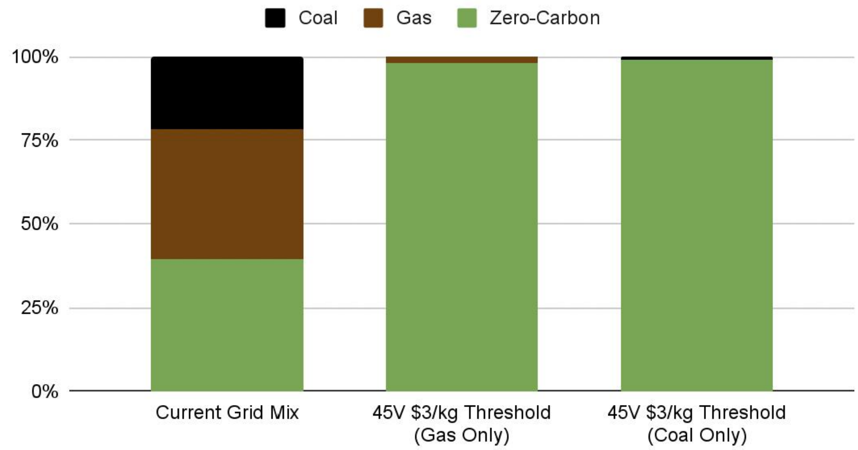

Figure 1: Comparison of the share of fossil resources in the current U.S. average electricity mix with the shares required to reach the 0.45 $kgCO_2/kgH_2$ threshold for the highest tier of 45V. Gas and coal can account for no more than 2% and 0.8% of input power, respectively.

In January of 2023, researchers at the ZERO Lab published a peer-reviewed academic paper exploring the impact of multiple potential implementations of 45V on the effective carbon intensity of electrolytic hydrogen production in the United States.[3] This work concluded that three requirements for qualifying energy attribute certificates (EACs) – incrementality, temporal matching, and deliverability – were necessary in order to minimize the emissions impact of subsidized hydrogen electrolysis and achieve effective carbon intensities below the legal threshold for 45V qualification. We further found that imposing these requirements would not significantly increase the cost of qualifying hydrogen production compared to a hypothetical scenario with no clean power procurement requirements.

We call these requirements the 'Three Pillars' because all three are structurally critical: remove any one and the whole "clean" hydrogen house comes tumbling down. Our research demonstrated that individually waiving requirements for incrementality, temporal matching *or* deliverability resulted in direct and indirect emissions of approximately 10-40 kg CO_2/kg H_2 across different locations in the Western United States, even while maintaining the two remaining requirements. Subsidizing hydrogen production that fails to meet *all Three Pillars* would not only result in lifecycle emissions that are unlawful under IRA statute but could drive hundreds of millions of tons of additional CO_2 emissions through 2030, pushing the United States' climate goals out of reach. This scenario could also see substantially higher consumer electricity prices, as the cost of meeting new electricity demand from hydrogen production is socialized among all electricity consumers rather than being borne primarily by hydrogen developers. For example, our peer-reviewed modeling found that the deployment of 5 GW of electrolysis capacity in California would cause local wholesale electricity prices to rise by 8% if

[3] Ricks, W., Xu, Q., and Jenkins, J.D. "Minimizing emissions from grid-based hydrogen production in the United States." *Environmental Research Letters* Vol. 18 No. 1, 2023. https://iopscience.iop.org/article/10.1088/1748-9326/acacb5

the Three Pillars were not put in place, while this impact on electricity prices is avoided under the Three Pillars.

It is important to stress that the 45V statute requires consideration of both direct and significant indirect emissions impacts from the hydrogen fuel cycle.[4] To capture both direct and significant indirect emissions impacts associated with adding new hydrogen demand to the grid with various electricity procurement decisions is to consider the impact of these changes on both operations *and* installed capacity on the grid: aka operational and structural changes. Capacity expansion planning models are necessary to estimate this impact, and it is notable that every subsequent study employing a capacity expansion planning framework to consider the implications of different 45V implementation decisions confirmed our study's findings that all Three Pillars of incrementality, temporal matching, and deliverability are necessary to avoid significant indirect emissions impacts. This includes peer-reviewed publications from our group and researchers at the MIT Energy Initiative[5] as well as public reports from the Electric Power Research Institute[6] and Evolved Energy Research.[7] The only studies published that purport to show acceptable emissions outcomes under less stringent clean electricity purchasing requirements are based on methods that are incapable of capturing the impacts of hydrogen electrolysis on generation and storage investment and retirement decisions and thus should be disregarded in the evidentiary basis for Treasury's rulemaking on this matter.[8,9]

Furthermore, there is every reason to expect the U.S. clean hydrogen industry will grow and thrive under the Three Pillars framework proposed by Treasury. A ZERO Lab report published in May 2023 compared the projected costs of Three Pillars compliant hydrogen production across a number of recent studies and found that proper utilization of both wind and solar power can enable high electrolyzer utilization rates and consistently competitive hydrogen production costs, even with fairly expensive electrolyzer systems.[10] Studies by EPRI and Evolved Energy also found that the Three Pillars would not impede the growth of a truly clean hydrogen electrolysis sector.[11] A group of hydrogen project developers collectively representing about 50

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[4] 42 U.S.C. 7545(o)(1)(H)

[5] Giovanniello, M.A., Cybulsky, A.N., Schittekatte, T., and Mallapragada, D.S. "The influence of additionality and time-matching requirements on the emissions from grid-connected hydrogen production." *Nature Energy* 9, 197-207, 2024. https://www.nature.com/articles/s41560-023-01435-0

[6] "Impacts of IRA's 45V Clean Hydrogen Production Tax Credit." White Paper by the Electric Power Research Institute, 2023. https://www.epri.com/research/products/000000003002028407

[7] Haley, B. and Hargreaves, J. "45V Hydrogen Production Tax Credits: Three-Pillars Accounting Impact Analysis." White Paper by Evolved Energy Research, 2023. https://www.evolved.energy/post/45v-three-pillars-impact-analysis

[8] "Green hydrogen: what the Inflation Reduction Act means for production economics and carbon intensity." Wood Mackenzie, 2023. https://www.woodmac.com/news/opinion/green-hydrogen-IRA-production-economics/

[9] "Analysis of Hourly & Annual Emissions Accounting for Hydrogen Production." E3, 2023. https://acore.org/wp-content/uploads/2023/04/ACORE-E3-Analysis-of-Hourly-and-Annual-GHG-Emissions-Accounting-for-Hydrogen-Production.pdf

[10] Ricks, W. and Jenkins, J.D. "The Cost of Clean Hydrogen with Robust Emissions Standards: A Comparison Across Studies." Princeton ZERO Lab Policy Memo, 2023. https://doi.org/10.5281/zenodo.7948769

[11] "Impacts of IRA's 45V Clean Hydrogen Production Tax Credit." White Paper by the Electric Power Research Institute, 2023. https://www.epri.com/research/products/000000003002028407; Haley, B. and Hargreaves, J. "45V

gigawatts (GW) of planning electrolysis deployment, have written Treasury to support the Three Pillars framework. Using an experience curve analysis, which relates reductions in cost to cumulative deployment, ZERO Lab estimates that the completion of 50 GW of electrolysis in the United States is likely to reduce the installed cost of electrolysis systems from approximately $2,000/kilowatt (kW) today to approximately $500-650/kW. By that point, we estimate that Three Pillars compliant projects will be capable of producing hydrogen for less than $1.00/kg at the facility gate nearly everywhere the United States.[10] We also note that after the European Union finalized clean hydrogen rules based on the Three Pillars in early 2023, the number of electrolysis projects planning to be online in Europe by 2030 *increased* by 30% to 813 Three Pillars-compliant projects.[12]

In light of this strong evidentiary basis, we are pleased that Treasury has proposed adopting requirements for incrementality, temporal matching after December 31, 2027, and deliverability for all electrolytic hydrogen projects receiving 45V. This will ensure that all subsidized hydrogen produced after the phase-in date for temporal matching induces the minimum possible direct and indirect greenhouse gas emissions, and has the minimum possible impact on power prices for other electricity consumers.[13]

Additionally, the fact that the incrementality, temporal matching, and deliverability requirements explicitly capture the regional and temporal availability of clean power will appropriately align the incentives of hydrogen producers in the near term with the anticipated needs of a decarbonized economy. U.S. technology policy goals must extend beyond simply deploying electrolyzers at any cost. Rather, the objective is to build up a complete clean hydrogen industry that can thrive in a post-45V environment. That means an industry that can operate flexibly to consume clean, cheap renewable energy when it is physically available using flexible electrolyzer systems, contracting procedures, optimized project designs, offtake arrangements, etc. that are necessary to achieve this. Lax rules that deviate from the Three Pillars would artificially incentivize round-the-clock hydrogen production using inflexible Alkaline electrolyzers. These projects would be little more than ‘subsidy farms’ that become completely uneconomic once 45V ends, and artificially advantaging these projects would crowd out legitimately clean hydrogen producers and eliminate the competitive advantage of American companies focused on manufacturing advanced flexible PEM electrolyzers in the United States. The incentive to align hydrogen production with the availability of clean power will also encourage innovating firming solutions like long-duration hydrogen storage and flexible industrial processes, which will be needed if clean hydrogen is to play its hoped-for role in economy-wide decarbonization.

Hydrogen Production Tax Credits: Three-Pillars Accounting Impact Analysis.” White Paper by Evolved Energy Research, 2023. https://www.evolved.energy/post/45v-three-pillars-impact-analysis

[12] “Clean Hydrogen Monitor 2023.” Hydrogen Europe, 2023. https://hydrogeneurope.eu/wp-content/uploads/2023/10/Clean_Hydrogen_Monitor_11-2023_DIGITAL.pdf

[13] Ricks, W. and Jenkins, J.D. “Consumer Electricity Price Impacts of the 45V Hydrogen Production Tax Credit.” ZERO Lab Research Addendum, 2023. https://doi.org/10.5281/zenodo.10689836

Finally, the proposed rules will align US clean hydrogen production standards with those put in place by the European Union,[14] ensuring the credibility and competitiveness of American clean hydrogen and in both domestic and overseas markets. This alignment will be important not just for hydrogen itself, but also to derived products like fertilizer, steel, and sustainable aviation fuel. With excellent solar and wind resources, more abundant land, and the world's most generous hydrogen production subsidy, American hydrogen producers are positioned to meet a burgeoning global market for clean hydrogen and all forms of hydrogen-derived products. All that remains is for Treasury to finalize a credible set of emissions rules aligned with EU standards.

The remainder of these comments respond to specific topics and questions raised in the NOPR.

Section 2: Targeted Responses

Incrementality

Treasury proposes to require that EACs used for 45V qualification be sourced from generators built within 36 months of the electrolysis facilities that they supply. The need for new 'incremental' supply to avoid increases in emissions is consistent with the findings of our research and with basic reason: if electrolysis facilities pull power from existing non-incremental clean generators, the customers previously served by these generators will back-fill the lost supply and do so with no clean power procurement requirements of their own, likely inducing significant additional emissions. In the 45V NOPR, Treasury requests comment on several possible circumstances under which the incrementality exemption could be relaxed. Specifically, Treasury correctly notes that existing clean generators that would have retired had it not been for additional revenue from EAC sales to hydrogen producers could be considered incremental, as could power from existing generators that would have been curtailed due to a lack of demand had a hydrogen producer not been able to consume it. In the following subsections we discuss several approaches suggested by Treasury as potential means of allowing existing clean generators to participate in 45V.

A. A Blanket 5-10% Incrementality Exemption for Existing Clean Generators

The Treasury Department and IRS recognize that some amount of existing clean generation is curtailed due to lack of demand, and that some percentage of existing clean generators may be at risk of retirement due to unfavorable economics. To address both of these issues, which are estimated to account for roughly 5% of existing clean generation, Treasury suggests that 5-10% of the hourly power output from all existing clean generators could be considered incremental for the purpose of 45V qualification.

A blanket exemption for 5-10% of existing clean generation from incrementality requirements is arbitrary, disconnected from any specific evidence basis, and would result in significant emissions impacts that are not permissible by 45V statutory requirements. New ZERO Lab

[14] https://energy.ec.europa.eu/news/renewable-hydrogen-production-new-rules-formally-adopted-2023-06-20_en

modeling using the analytical tools developed for our peer-reviewed publication investigates the efficacy of this approach directly. We find that any blanket exemption of existing clean generators from incrementality requirements would result in significant additional carbon emissions from all electrolyzers taking advantage of the exempted EACs.[15] In the California case examined in our Research Addendum (attached alongside these comments), the effective carbon intensity of hydrogen produced using exempted EACs from existing clean generators is on the order of 20 $kgCO_2e/kgH_2$, more than 40 times the legal threshold for the top 45V credit. Because the exempted EACs are spread evenly across all hours and all existing clean generators, they are neither effective at reducing curtailment (which is concentrated in specific hours and locations) nor at preventing retirement (of which only specific generators are truly at risk). While the aggregate carbon impact of this exemption can be reduced by limiting the percentage of qualifying existing generation, the unavoidable truth is that every unit of exempted generation is still non-incremental, and any hydrogen electrolysis produced using EACs from such exempted generation would induce significant emissions. We stress that there is no statutory basis for Treasury to grant such a blanket incrementality exemption to hydrogen produced in a manner that demonstrably results in lifecycle emissions that exceed the statutory thresholds in the law.

B. Targeted Approaches to Capturing Retirement Risk

The NOPR invites comments on other more targeted approaches that could potentially be used to identify existing clean generators at risk of retirement and redefine these as incremental for the purpose of 45V qualification. We believe that such an approach, while potentially difficult to administrate and subject to uncertainty, would be more aligned with the goal of avoiding retirements than any form of blanket exemption. Still, because the question being investigated is a hypothetical – "would the plant in question have retired had it not been able to sell 45V-qualifying EACs?" – the framework used to answer this question must be rigorous and the burden of proof must be high.

Specifically, we propose a framework to waive incrementality requirements for certain existing nuclear generators submitting an avoided retirement application to Treasury demonstrating that they meet the following criteria:

i. *Relicensing decision:* to limit eligibility to facilities facing potentially significant upcoming capital expenditures associated with relicensing and extended lifetime operations, the facility must have submitted an application to the Nuclear Regulatory Commission to extend its operating license with a license renewal date no later than five years after the date the avoided retirement application is submitted to Treasury.

ii. *Economic test:* to demonstrate facilities are at economic risk of retirement, the facility must meet one of the two following economic tests:

[15] Ricks, W. and Jenkins, J.D. "Examination of Proposed Exemptions to Incrementality Requirements for Section 45V." ZERO Lab Research Addendum, 2024. https://doi.org/10.5281/zenodo.10689836

1. A facility is qualified for the Civilian Nuclear Credit Program (CNCP), as determined by the Department of Energy, at any point within 36 months prior to the date the avoided retirement application is submitted to Treasury; *or*

2. For two out of the three years prior to the date the avoided retirement application is submitted to Treasury, a plant must have qualified for a nonzero payment under the formula for determining the Section 45U zero-emission nuclear power production credit.[16] Nuclear facilities with at least 50% of ownership held by utilities subject to cost-of-service regulation or public ownership should not qualify for this economic test unless a public determination is also made by an appropriate state regulatory commission or board of a publicly owned utility that the facility is not economic to continue operating without additional revenues.

iii. *Co-location or long-term purchase agreements:* to ensure that revenues from hydrogen production are an integral component of the decision to extend operations of the existing facility and not an incidental factor, EACs from the nuclear facility should only be eligible for use by electrolysis facilities co-located with the nuclear facility behind a common point of grid connection, or electrolysis facilities signing a purchase agreement for EACs with the nuclear facility of at least 10 years in length.

While the above proposal is designed for existing nuclear plants specifically, which are likely the facilities most at risk of retirement, it could theoretically be generalized to cover other forms of existing clean generation.

C. **Targeted Approaches to Capturing Curtailment**

Curtailment typically occurs when the available supply of power that can be generated at an equal or lower marginal cost than a given generator exceeds current local demand, forcing the generator in question to produce less power than it otherwise could. As noted in the NOPR, curtailment of minimal-emitting resources is closely associated with low or negative electricity prices. For this reason, locational marginal electricity prices (LMPs) can provide a good proxy metric for curtailment where they are available. However, it is important to note that a large portion of total curtailment occurs due to local grid constraints that prevent transmission of power to nearby demand centers, rather than due to system-wide overabundance of power.[17] It is therefore not sufficient to demonstrate that a given generator is experiencing curtailment, and it must also be shown that the electrolyzer procuring EACs from that generator is physically able to consume the otherwise curtailed power. This could be demonstrated by recording the LMPs at the respective points of interconnection of the electrolyzer facility *and* generator and validating that both LMPs are zero or negative. Normal deliverability requirements should also apply in this

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[16] Note that it is the formula in the statute that should be used to determine whether a plant would qualify for a nonzero payment rather than requiring the facility to actually receive tax credits under 45U, permitting this test to be applied even after 45U expires (currently scheduled for December 31st, 2032).

[17] Bird, L., Cochran, J., and Wang, X. "Wind and Solar Energy Curtailment: Experience and Practices in the United States." National Renewable Energy Laboratory Technical Report No. NREL/TP-6A20-60983, 2014. https://www.nrel.gov/docs/fy14osti/60983.pdf

case. It should be noted that this LMP-based approach to identifying curtailment is only valid in competitive electricity markets where prices are set by independent system operators. Treasury should therefore limit its availability to those jurisdictions.

D. An Incrementality Exemption for States with Strong Clean Energy Policies

The NOPR suggests that an incrementality requirement may not be necessary in regions "subject to a state or local policy that ensures that new load is met with minimal-emitting electricity generation." This is correct in theory, but it is unlikely that any state or local policies in the US today are rigorous enough to ensure this outcome. One class of state policies that could theoretically mute the carbon impact of hydrogen electrolysis are renewable portfolio standards (or similar clean electricity standard policies), which typically require that a certain percent of electricity demand in a state be served by approved low-carbon resources. However, to ensure new load is met by non-emitting generators without any significant indirect emissions impacts, a state policy would have to meet three criteria: (1) the policy would have to require 100% of demand is met by non-emitting generation, adjusting the required sum of clean generation to account for transmission and distribution and storage losses[18]; (2) demand for EACs to satisfy the requirement would have to be binding (e.g. the supply of available EACs does not exceed the quantity required to meet the state requirement); and (3) the state must not engage in significant import or export of electricity with neighboring states not subject to a similarly stringent 100% RPS/CES requirement. No state policy in the nation meets such standards today. In our peer-reviewed research on the emissions implications of 45V, we found that even ambitious renewable portfolio standard policies currently in place in Oregon, Washington, California and other western states do not provide a backstop against significant increases in emissions in the absence of requirements for incrementality, temporal matching and deliverability. Likewise, NREL's 2022 Cambium dataset projects that the effective compliance price for state renewable portfolio standard policies will be $0 in 2030-2035 across nearly all of the US, indicative that these policies are not 'binding' and do not provide a backstop against additional emissions.[19]

A second class of state policies that could help mute or eliminate the indirect emissions impact of non-incremental clean power procurement is carbon cap-and-trade programs, such as the Regional Greenhouse Gas Initiative[20] implemented in several Northeast and Mid-Atlantic states or state-specific policies implemented by California[21] and Washington.[22] These policies constrain total carbon emissions from the electricity sector (and potentially other sectors) within their jurisdictions, theoretically preventing local increases. However, the presence of a cap-and-trade program is not a guarantee of no carbon impact from local hydrogen production. First, the

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[18] No current state RPS or CES policy makes such an adjustment. All current state RPS or CES requirements are specified as a percentage of retail electricity sales. As electricity is lost in transmission and distribution networks (about 5% on average nationally) and further energy is lost due to round-trip storage losses, electricity generation always exceeds retail sales. Thus, even a state requirement that 100% of retail sales are matched by EACs from non-emitting generators, a significant share of emitting generation may persist within the electricity supply mix.

[19] https://www.nrel.gov/analysis/cambium.html

[20] https://www.rggi.org/

[21] https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program

[22] https://ecology.wa.gov/air-climate/climate-commitment-act/cap-and-invest

cap-and-trade program could be oversupplied with allowances such that the cap is not 'binding' and additional local emissions can still occur. Second, because these states or regions are typically only part of large multi-state electricity systems and trade significant amounts of power with other states or regions in these systems, local electrolysis could still induce additional emissions elsewhere even if a state's carbon cap policy is locally binding.

As part of the same supplementary modeling referenced in our discussion of the 5-10% blanket exemption proposal,[15] we also investigate a hypothetical case where a region of the grid in the US Pacific Northwest implements a binding electricity sector carbon cap. In this case, the emissions impact of electrolysis using non-incremental power declines only marginally from 17 $kgCO_2e/kgH_2$ to 15 $kgCO_2e/kgH_2$. The still significant indirect emissions 'leakage' induced in this case largely result from increased consumption of locally-generated hydropower in the Pacific Northwest, reducing exports to other regions that in turn backfill the lost supply with a mix of clean and dirty resources. While some state cap-and-trade policies incorporate border adjustment mechanisms in an effort to mitigate leakage from imports of carbon-intensive power, there is a significant body of peer-reviewed academic research demonstrating that the mechanisms used in US state policies today are ineffective at accomplishing this goal.[23,24] Furthermore, no existing policies account for leakage from reduced exports, the primary mechanism of leakage observed in our results.

It is possible that future state or regional cap-and-trade policies could be designed to minimize carbon leakage from both imports and exports. However, further analysis would be required to validate such novel mechanisms as sufficiently robust. Based on a preponderance of evidence, we therefore encourage Treasury and IRS to consider exemptions to an incrementality requirement only for facilities covered by state policies that have been affirmatively demonstrated to mitigate all risk of induced indirect carbon emissions, both locally and elsewhere. This demonstration would ideally be based on a robust study, likely incorporating high-fidelity electricity system capacity modeling and conducted by the Department of Energy or a trusted third party like the National Renewable Energy Laboratory. Without such affirmative demonstration, it should be assumed that *no current or existing state policies* are capable of ensuring that electrolysis not subject to an incrementality requirement induces system-wide emissions below the legal threshold for 45V qualification.

E. Incrementality for Generators with Carbon Capture and Storage Retrofits

Treasury and IRS request comment on whether existing fossil-fired generators could be considered an incremental source of power for electrolysis if they are retrofitted with carbon capture and storage (CCS) technology. In this scenario, an electrolysis facility adds electricity

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[23] Xu, Q. and Hobbs, B. F. "Economic efficiency of alternative border carbon adjustment schemes: A case study of California Carbon Pricing and the Western North American power market," *Energy Policy* Vol. 156, 2021. https://www.sciencedirect.com/science/article/abs/pii/S0301421521003335

[24] Bushnell, J., Chen, Y., and Zaragoza-Watkins, M. "Downstream regulation of CO2 emissions in California's electricity sector," *Energy Policy* Vol. 64, 2014. https://www.sciencedirect.com/science/article/abs/pii/S0301421513008690

demand to the grid and an unabated fossil-fired power plant is effectively replaced by an abated one. The overall balance of emissions induced by this series of actions depends on how often the original existing fossil plant operated, how often the new plant with CCS operates, and what resources come online to meet the net increase in demand from the electrolysis facility. The answers to all these questions are highly uncertain, and it is very possible that the retrofitting of an existing fossil plant with CCS and diversion of its power to electrolysis could force the grid to fall back on the next-most-expensive power source, likely another fossil plant with higher emissions. Because the indirect emission impacts of this scenario are unknown and potentially significant, Treasury should refrain entirely from qualifying CCS retrofits as incremental or do so only after rigorous study on a case-by-case basis.

Temporal Matching

Treasury and IRS propose to require hourly temporal matching of a hydrogen production facility's electricity consumption with qualifying EACs for all projects after January 1, 2028, *without grandfathering* or exempting any facilities online before this date. The proposed hourly matching requirement is in line with the best available scientific research, which has demonstrated that looser temporal matching requirements are almost entirely ineffective at constraining carbon emissions.[3,4,5,6] The proposal allows annual matching for all EACs used through 2027, ostensibly to allow for hourly EAC tracking systems to come online. We do not see any technical necessity to delay implementation of the hourly matching requirement, as several EAC registries are already able to perform hourly tracking and a number of others interviewed by Treasury indicated that they could bring similar systems online within one to two years. Importantly, even before EAC registries with hourly tracking availability are widely available, hydrogen production facilities could demonstrate hourly matching by retiring conventional EACs (ensuring no double counting or conflicting claims to the EACs) alongside auditable records of hourly metering data from the hydrogen facility and generator showing temporal alignment between clean generation and electricity consumption by the electrolyzer. We therefore encourage Treasury and IRS to explore an earlier or immediate hourly matching requirement. Finally, we applaud Treasury for proposing that any transition to hourly matching apply to *all projects*, rather than employing a 'grandfathering' approach that would lock in highly emitting projects built before the deadline for more than a decade. It is critical that the current approach to a phase-in be maintained if Treasury does not implement an immediate hourly matching requirement, as it incentivizes all developers to design their projects with hourly matching in mind. As a recent ZERO Lab analysis demonstrates, [25] keeping the current 2028 phase-in proposal but allowing grandfathering of projects that commence construction before

[25] "RE Section 45V clean hydrogen tax credit implementation: Calculating the emissions impacts of different hourly matching phase-in regimes." ZERO Lab Policy Memo, 2023. https://www.dropbox.com/scl/fi/55n05qiti3aygj0a6zapv/45V-Calculating-the-emissions-impacts-of-different-hourly-matching-phase-in-regimes.docx?rlkey=1kjn6hpdnmm41jmdjzfxfeuaa&dl=0&fbclid=IwAR0PNEDHFZBa1xTpKoYw9KXdtbsR21WWSIBQbP_t4Sz2CwgNxADiwSxFOVE; https://www.dropbox.com/s/jxqewlwof7leb5b/45V%20-%20Hourly%20Matching%20Phase-In%20Options.xlsx?e=1&fbclid=IwAR2ggL4SEojzTY6e-4dGs5YCqZhds7TgFs_HIRZvWHUT80-cXkH-q3gdh-0&dl=0

that date into an annual matching regime could easily result in 700 million tons of excess CO_2 emissions directly attributable to 45V-subsidized electrolysis (see Figure 2).

	Total MMT H2 covered by annual matching								
Date of phase-out	2024	2025	2026	2027	2028	2029	2030	2031	2032
Phase-out (no grandfathering)	0	0	0	0	1	2	4	8	15
Placed in service (grandfathering)	0	0	1	3	6	11	21	39	69
Commence construction (grandfathering)	6	11	21	39	69	103	141	182	227

	Total MMT CO2e induced by phase-in								
Date of phase-out	2024	2025	2026	2027	2028	2029	2030	2031	2032
Phase-out (no grandfathering)	0	0	1	4	10	21	42	81	150
Placed in service (grandfathering)	0	0	10	28	59	115	213	387	694
Commence construction (grandfathering)	59	115	213	387	694	1033	1405	1815	2266

	Total $B Spent on Annual Matched H2 Subsidies								
Date of phase-out	2024	2025	2026	2027	2028	2029	2030	2031	2032
Phase-out (no grandfathering)	0	0	0	1	3	6	13	24	45
Placed in service (grandfathering)	0	0	3	8	18	34	64	116	208
Commence construction (grandfathering)	18	34	64	116	208	310	422	545	680

Figure 2: Impacts of different schemes and dates for phase-out of annual matching and transition hourly matching requirements. Blue cells indicate outcomes under the current proposed approach, and the purple cells indicate outcomes under an approach that allows for grandfathering of projects that commence construction before the phase-in date.

Deliverability

Treasury and IRS propose requiring that power associated with an EAC be physically deliverable from the generator to any electrolyzer facility that wishes to claim use of it. A deliverability requirement is essential in order for claims of physical use of clean power to be credible, and ZERO Lab research has shown that emissions impacts from electrolysis can increase significantly in the absence of one. We approve of Treasury's decision to implement a deliverability requirement via a zonal approach, which recognizes that the US grid can be decomposed into regions with fairly strong internal transmission connectivity and only limited connections to neighboring regions. However, we note that the thirteen deliverability zones for the contiguous United States that Treasury has adopted from the DOE's National Transmission Needs Study are fairly large and are, by the study's own findings, likely to experience some amount of internal congestion.[26] For example, the study notes that Texas will likely experience major ongoing congestion between the wind-rich western part of the state and demand centers in the east. Furthermore, the US grid is currently undergoing a major evolution that will likely result in shifting patterns of congestion compared to the present day. Treasury and IRS should therefore incorporate updates to the deliverability zone topology into planned updates of the 45VH2-GREET model, using the latest analysis of current and anticipated future congestion from DOE's ongoing National Transmission Needs Study series. This will ensure that the 45V deliverability requirements remain up-to-date with the realities of grid congestion.

[26] "National Transmission Needs Study 2023." US Department of Energy, 2023. https://www.energy.gov/gdo/national-transmission-needs-study

In addition to rigorously and regularly updating deliverability zones, Treasury and IRS should consider mechanisms that allow for wheeling of power between zones based on real-time deliverability metrics. For example, differences in locational marginal electricity prices (where these are available) between a generator's and electrolysis facility's respective points of interconnection could be used to determine whether power is physically deliverable from one to the other in an hour when a given EAC is claimed. While LMPs between nodes on the grid can differ marginally due to transmission losses, large differences are always the result of congestion and a telltale sign that power is not physically deliverable from the lower-priced node to the higher-priced node. Treasury and IRS could therefore allow an EAC to be claimed from a deliverability zone adjacent to an electrolyzer's if the LMP at the electrolyzer's point of interconnection is less than or equal to the LMP at the generator in the hour in which the EAC is generated.

Finally, we recommend that Treasury and IRS include consideration of transmission and distribution losses in determining the amount of qualifying clean generation required to claim consumption of clean power at an electrolyzer facility. Because there is a 5% average transmission and distribution loss rate in the US grid,[27] an electrolyzer facility that procures EACs from grid-based clean resources in an amount exactly matching its power consumption will in fact be drawing up to 5% of its power from other sources. This is more than enough to push an electrolysis facility's effective emissions rate above the threshold for the top tier of 45V in most US grid regions. Treasury should therefore require that any electrolyzer facilities sourcing power from grid-based clean generators procure EACs in a volume equal to roughly 105% of their claimed clean power consumption. This requirement would be aligned with the current 45VH2-GREET model, which assumes for the purpose of emissions calculations that 4.9% of electricity generation is lost in transmission and distribution. Truing-up EACs to account for losses in this manner would not be necessary for clean generators co-located with an electrolysis facility.

Methods for Evaluating Qualification for 45V

Treasury and IRS propose to evaluate qualification for 45V at the facility level based on the annual average carbon intensity of all hydrogen produced by that facility. For electrolysis, the preliminary 45VH2-GREET model uses the weighted-average emissions intensities of all electricity sources used by a facility in a given year to determine the lifecycle emissions intensity of all hydrogen produced by that facility in that year. This approach has the advantage of simplicity, but it comes with several notable downsides. First, it creates a large binary risk for project developers that could miss qualification for the top 45V credit on all hydrogen production in a year if they fail to match power consumption with procured EACs in enough hours. While this is likely a very manageable risk, its existence could potentially threaten the bankability of projects. Second, the averaging of emissions intensities effectively allows some amount of dirty power consumption to be diluted by larger amounts of clean power, enabling all hydrogen

[27] https://www.eia.gov/tools/faqs/faq.php?id=105

production to qualify for a higher credit tier when in reality some of this production was associated with power sources far too carbon-intensive to qualify. This problem could be most extreme if future updates to 45VH2-GREET allow for negative-carbon-intensity EACs. Landfill gas used in steam methane reforming with carbon capture and sequestration is considered a negative-emissions hydrogen production pathway in the 45VH2-GREET, creating a potential precedent for negative-emissions EACs associated with combustion of landfill gas in a power plant with carbon capture and sequestration. If such EACs were included in an electrolysis facility's average carbon intensity calculation, they could effectively offset emissions from other power sources that are too carbon intensive to qualify for a given credit threshold. Allowing hydrogen production using carbon-intensive electricity to be pulled into higher credit tiers via offsets would be in direct conflict with the legislative intent of 45V, which was to incentivize hydrogen production processes that achieve lifecycle emissions thresholds on their own merits.

Both of the potential downsides of the proposed annual averaging approach discussed above could be mitigated by evaluating qualification for 45V on a *feedstock-by-feedstock* basis. That is, every unit of hydrogen produced at an electrolysis facility would be matched with a single electricity source, e.g. wind power, solar power, or undifferentiated grid power. All qualifying EACs from zero-carbon generators would produce hydrogen with zero lifecycle emissions receiving the top credit, while all non-matched grid power would produce hydrogen with lifecycle emissions based on the grid average carbon intensity. Furthermore, hydrogen production backed by negative-emissions EACs would simply receive the top credit without offsetting production associated with carbon-intensive sources. This outcome makes sense given the 45V credit's structure, which offers no additional financial incentives to emissions intensities below the top threshold of 0.45 $kgCO_2e/kgH_2$, even negative ones. It would also be aligned with the way in which SMR-based production pathways are handled in 45VH2-GREET, which considers SMR with landfill gas to be a fully separate production process from SMR with fossil gas.

Because a facility would receive the top credit for all hydrogen production backed by qualifying EACs under a feedstock-by-feedstock approach, there would be no binary risk associated with 'missed' hours where a facility operator fails to procure enough qualifying EACs to match their total power consumption. Instead, the facility would merely lose the top credit for each unit of production not backed by qualifying EACs. While this framework would reduce the financial incentive to avoid missed hours, this incentive would remain very large. Production of hydrogen without the 45V subsidy would almost certainly be uneconomic, especially given that the hours when this is most likely to occur – those when renewable energy output is lowest – are the same hours when electricity prices are highest. While it might be possible to run an electrolysis facility 'baseload' using credited production to cross-subsidize non-credited production, project developers would have every incentive to avoid this outcome by investing in flexible systems, additional clean generation, and storage for both hydrogen and electricity. This incentive could be further strengthened by requiring that the average lifecycle emissions intensity of all hydrogen production from a facility receiving 45V meet at least the emissions threshold for the lowest tier of the credit, 4 $kgCO_2e/kgH_2$. Such a requirement would increase certainty that 45V credits are not indirectly cross-subsidizing non-qualifying hydrogen production at the same facility.