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CleanEpic Advising appreciated the opportunity to provide comment on the recently released 45V draft guidance. CleanEpic advises several of the DOE H2Hubs as well as the DOE H2 demand side initiative. In addition, the principal of CleanEpic worked a rotation in US DOE to run the commercial analysis team for H2Hubs and 45V. This letter is not meant to represent the interests of any specific client or project, but instead the industry as a whole.

The IRA funding represents an opportunity for the US to capture the growth of the nascent global electrolytic hydrogen industry. The 45V funding can allow for transformational opportunities in the energy system, but the proposed guidance will preclude this. As-is the proposed 45V will result in intermittency issues will result in no amelioration of the first-mover disadvantage that is a hallmark of the energy infrastructure industry. Without some changes to the suggested 45V to provide first-movers with incentive, we forego the following opportunities:

- Moving down the electrolyzer cost curve sufficiently to allow many more projects to fulfill the three pillars economically during the second half of 45V timeline and after 45V support
- Developing a US industrial and maintenance base for renewable hydrogen projects – creating opportunities for high-paying jobs
- Position clean hydrogen in the US to be in a position for success after the 45V and other funding expires
- Allow for another venue for rapid expansion of renewables into hard-to-abate sectors

The primary changes that would be most effective would be one or a combination of the following:

1. 10GW of grandfathering or grandfathering all projects with commercial operation date before 2028
2. Grandfather just hourly matching for EACs for the first 10GW of projects *or* projects built before 2028-
3. Move to hourly averaging to calculate H2 Carbon Intensity for all projects that hit commercial operation date before 2028 *or* all projects going forward
4. Increasing the carve-out for nuclear and hydro power
5. Pushing back *all* strict to 2030/32
6. Pushing back hourly matching alone

The indicators of success would be:

- Moving the total installed cost of electrolyzers from the current $2000/kw down to ~$650/kw
- An increasing US electrolyzer production, installation, and maintenance base including well-compensated manufacturing and maintenance jobs

The proposed guidance will not achieve these successes and will not bring about these benefits. As formulated, the current guidance will result in the cost of *reliably delivered hydrogen* to be much higher than competing blue and gray hydrogen in nearly all geographies. Worse, the current guidance will miss an opportunity to create a transformational change in the hydrogen economy of the US that would enable renewable hydrogen to be cost-competitive across much of the US. The current formulation would only favor incumbents with established monopoly networks by allowing them to replace a portion of their gray hydrogen with green hydrogen while the bulk of the hydrogen deliveries remain gray, and not create new markets.

The following is analysis and opportunities to allow for a US-led renewable hydrogen economy.

Contents

Executive Summary - CapEx Indicators of Success in for a Hydrogen Economy.......... 3
Moving down the cost-learning curve of electrolyzer systems.......... 3
CapEx contribution from 45V and delivered hydrogen cost.......... 3
Analysis of Key Metrics for Success.......... 5
Systems cannot change cost-effectively when the switchover happens.......... 5
Reliability of delivery for electrolytic hydrogen adds significant cost.......... 5
Positive Outcomes of the key metrics of success.......... 6
Net emissions reductions.......... 6
Job creation.......... 6
Providing a pathway for renewables to reach hard-to-abate sectors.......... 6
Renewable expansion.......... 6
Details of options to bring about success.......... 7
Full or Partial three pillars exemptions for projects with commercial operation date before 2028.......... 7
Exemptions on just hourly matching for EACs for the projects built before 2028.......... 7
Exemption to allow hourly averaging to calculate H2 Carbon Intensity for early projects.......... 7
Additionality: increasing the carve-out for nuclear and hydro power.......... 7
Pushing back all strict to 2030/2032 or pushing back just hourly matching.......... 8
Conclusion.......... 8

Executive Summary - CapEx Indicators of Success in for a Hydrogen Economy

Moving down the cost-learning curve of electrolyzer systems

Total installed cost for electrolyzers currently hovers around $2000/kw. Deployment at scale to reach cost reductions to $650/kw would achieve a major milestone – it would become less expensive to build a behind-the meter hydrogen project that *never* connects to the grid than it would be to have a grid-connected project. Hydrogen produced from these projects would have a significantly lower cost than hydrogen produced from grid-connected projects.

The key to achieving this milestone is the reduction of the total installed cost of electrolyzers – current high costs of installation overly burden the CapEx portion of the hydrogen cost stack which in turn requires high equipment utilization to remedy. If we have sufficient deployment of electrolysis to move down the cost learning curve, projects can have lower utilization and suffer less increase to the CapEx portion of the cost stack. The result is below in figure 1:

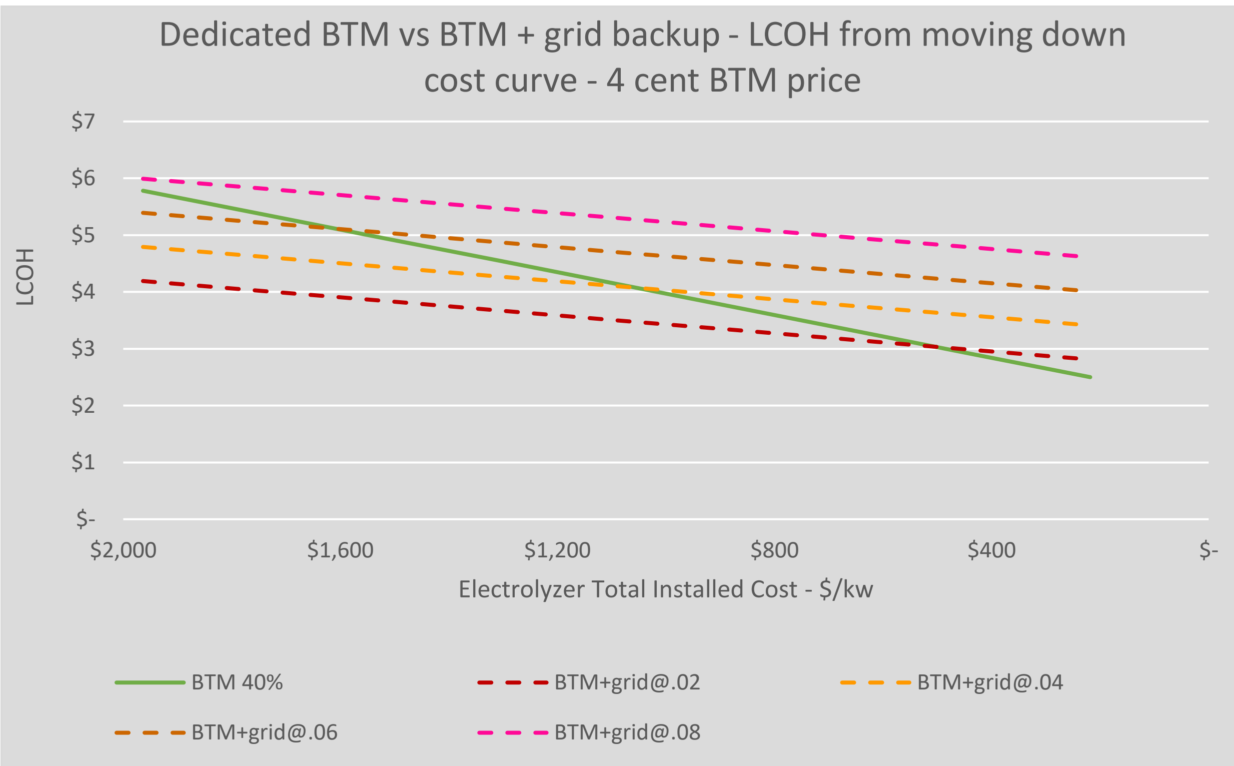

Figure 1: levelized cost of hydrogen from behind-the-meter vs grid connected electrolyzer systems. The dashed lines are grid-connected projects with a grid fee included in the power. The solid line is the LCOH from behind-the-meter projects.

Most projects will face 2-4 cents per kwh grid fees, making the total installed cost of ~$650/kw the sweet spot for deploying behind-the-meter projects without any grid support. In these projects, connecting to the grid will add more cost compared to a hydrogen project that does not connect to the power grid. It would be uneconomical to connect to the grid, guaranteeing adherence to the three pillars for new projects.

Reaching this point requires the *delivered cost of hydrogen* from initial projects with high electrolyzer cost to be competitive with gray and blue hydrogen. This will require exempting all or a portion of at least the hourly matching requirement.

CapEx contribution from 45V and delivered hydrogen cost

A project will not reach final investment decision (FID) without reliable offtake. When the DOE was writing the DOE H2 Pathways to Commercial Liftoff, we found that for every 100kg of announced projects in hydrogen only 2kg had offtake.

This means 2% of the projects were likely to go from announced projects to FID. The economy will remain the same now with strict 45V– most announced projects will not hit FID owing to the complexities of reliable hydrogen delivery. The "project pipelines" that many companies have announced will not come to fruition.

The crux of the problem is *reliable* delivery. Reformation hydrogen has storage built-in – the supply of natural gas for reformation is from a natural gas grid with natural gas storage. For hydrogen, the solution for 24/7 reliable hydrogen delivery would be grid backup, which 45V functionally precludes, or oversizing hydrogen production for lower uptime with hourly matching and having a significant amount of hydrogen storage – which is prohibitively expensive. Shown below is the resulting cost of hydrogen from these various scenarios:

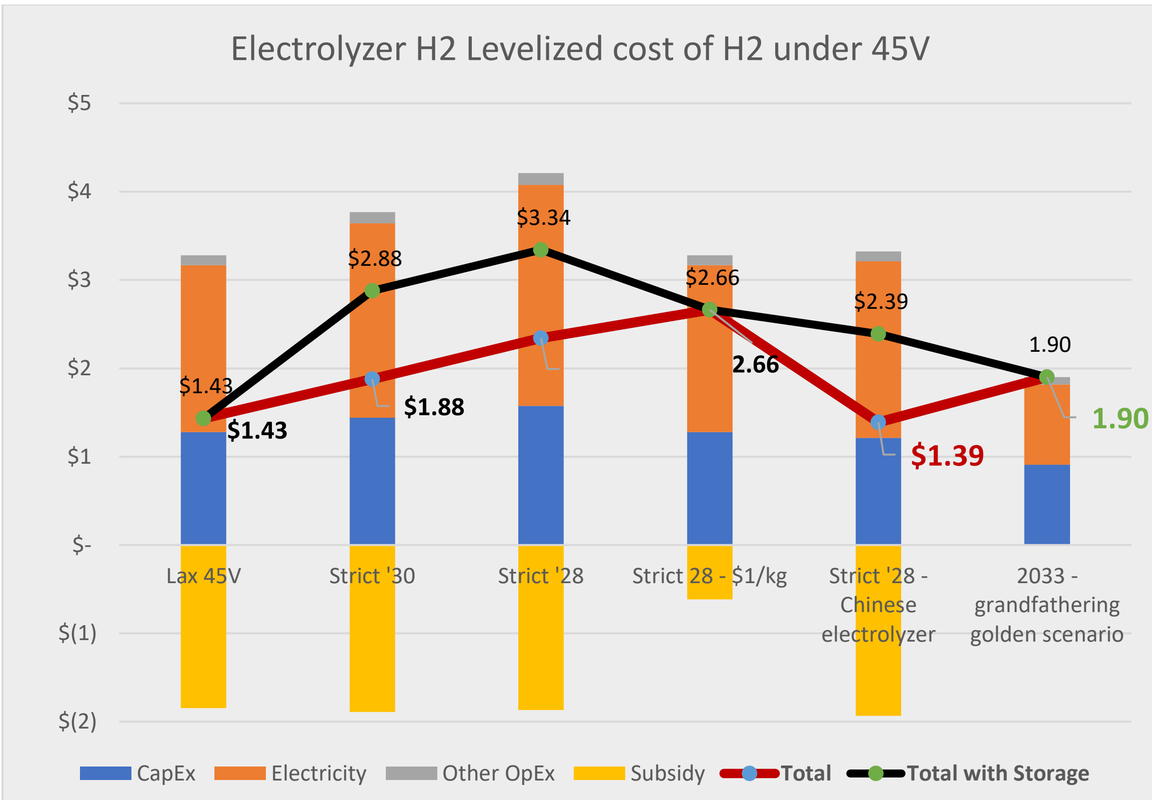

Figure 2: Total LCOH under 45V. The red line is the total cost of *produced* hydrogen under various scenarios, the black line is the additional cost with hydrogen storage for scenarios with intermittent production. On the far right is a hydrogen project in 2033 post PTC if we achieve the key cost down metric.

Shown above are the following scenarios for first-mover projects:

- Grandfathered 45V for the first projects – no storage required because grid backup allows for reliable production. **Hydrogen is cost-competitive with other pathways from early projects**
- Switch to strict 45V in 2030 with storage required. **Early projects are not cost-competitive with other pathways owing to H2 storage requirements – some projects could work if open-access pipelines and storage existed – but they don't exist and won't for a decade**
- Switch to strict in 2028. **Early movers can't compete with other pathways before considering storage requirements and are far from competitive with H2 storage included**
- Switch to strict in '28 and use grid backup to continue to produce H2 – increasing the carbon intensity and lowering the subsidy. **This includes $1/kg subsidy which, with grid backup, is not achievable in nearly all of the regions of the US. Nonetheless, while this does not require storage, the much lower subsidy results in delivered H2 costs significantly higher than existing pathways and most projects will not move forward**
- Using a much lower cost foreign electrolyzer with strict 45V – **Closer to cost competitive, but storage costs remain an issue**
- The goal scenario - 2033 hydrogen renewable hydrogen production, provided we achieve $650/kw installed cost

Overall, strict 45V will result in variable and intermittent production rates, drastically reducing the viability of offtake. One potential solution that several projects are looking at will be to use foreign electrolyzers – we've already seen the DOE Loan Programs Office funded projects using Chinese electrolyzers to reduce cost, and without 45V or with strict 45V, this is the path for most projects. If the cost of electrolyzers becomes sufficiently low, however, this risk of foreign purchases can be mitigated for future projects.

Analysis of Key Metrics for Success

Systems cannot change cost-effectively when the switchover happens

In the absence of grandfathering of any sort, projects need to be built from the start with strict 45V in mind – adding additional equipment for reliable hydrogen delivery under the three pillars *after* the switchover is never cost effective. This means that a required switch to three pillars is effectively the same as requiring the three pillars today. As a result, the combined cost of equipment for first-movers to reliably produce and delivery hydrogen is cost-prohibitive. There is no clear "first mover" to bring the total installed cost of electrolysis down from $2000/kw to an amount that would allow for cost-competitive deployment under the three pillars.

Reliability of delivery for electrolytic hydrogen adds significant cost

Shown below is an excerpt from DOE's hydrogen commercial liftoff report indicating the equipment necessary to operate a clean hydrogen project.

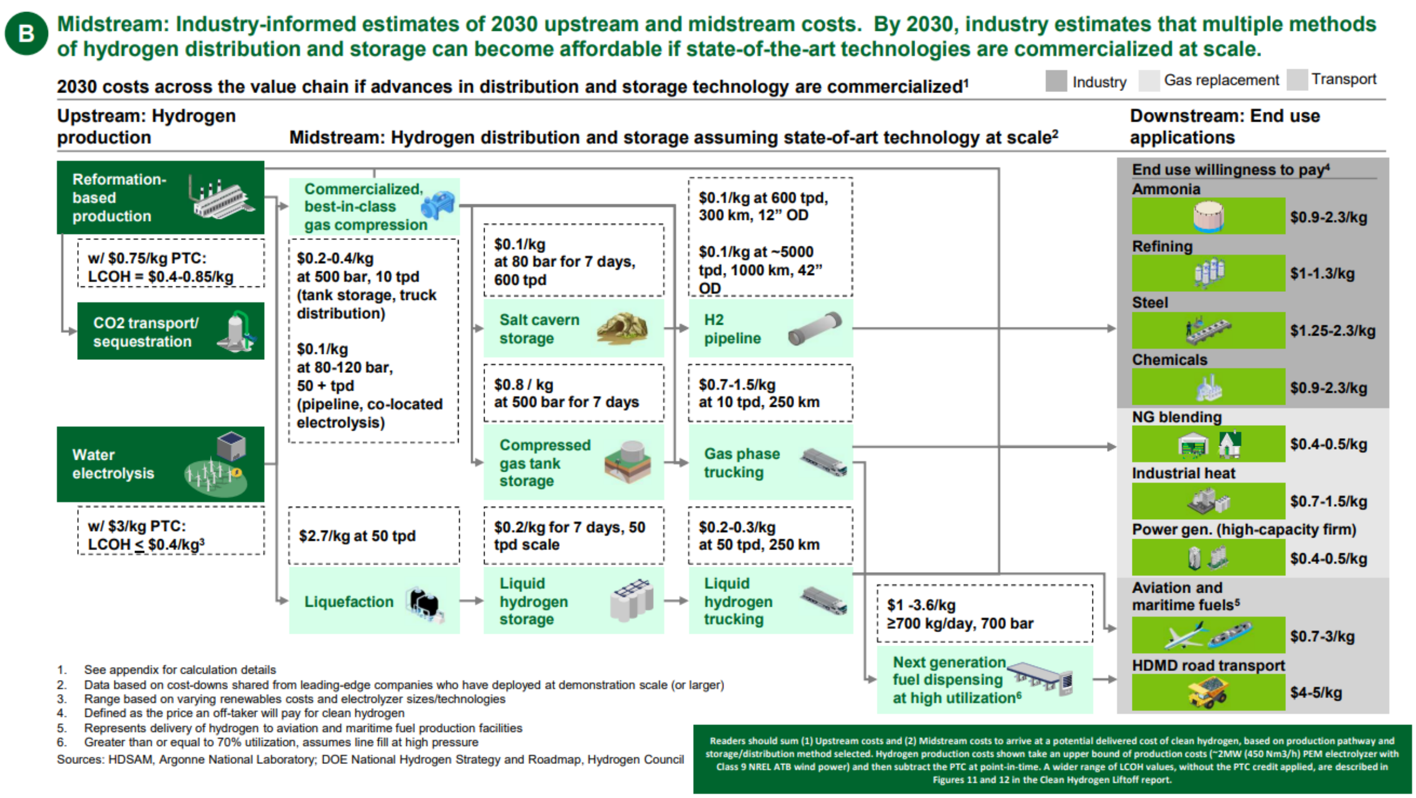

Figure 3: Except from DOE's Hydrogen Pathways to Commercial Liftoff showing the hydrogen ecosystem

Until there are hydrogen pipelines and storage, all hydrogen projects will require consistent and reliable delivery. The intermittency of the renewable-only production can be met with some form of storage, but three pillars and the early stage of the hydrogen market preclude any cost-effective form of storage. By comparison, reformation hydrogen has built-in storage in that the natural gas grid provides. This gives reformation hydrogen a strong advantage compared to electrolytic hydrogen of about $1/kg or more in levelized cost. Renewable hydrogen equivalent would be one of the following:

- Grid backup power
  - Three pillars prevents grid as backup power
- Geologic Hydrogen storage
  - There are few locations where geologic storage are viable
- Other cost effective hydrogen storage
  - Other storage options such as aboveground pressurized storage and hydrogen carriers add over $1/kg to have reliable hydrogen
- Flexible offtake
  - No flexible offtake markets have developed to support intermittent production
- Delivery into an existing network
  - Delivery into the natural gas network. Feasible, but not economic, with every $1/kg for H2 being equivalent to $9/mmbtu and no markets paying green premiuns
  - Delivery into existing hydrogen delivery networks – feasible, but limited in geography and to only three pipeline closed-access owners in the US

Unless this issue is addressed, there will not be sufficient projects deployed to move electrolytic hydrogen down the initial portion of the cost curve.

Positive Outcomes of the key metrics of success

The following outcomes all require electrolyzers to move down the cost curve. To get there, early movers need exemptions to make renewable hydrogen cost-effective enough to deploy widely.

Net emissions reductions

As figure 3 shows, sufficient cost reductions will bring new end uses from hard-to-abate sectors. For every gallon of diesel displaced in transportation, 10kg of CO_2 are displaced. Currently for heavy duty trucking 1kg of H_2 displaces 1-1.5 gallon of diesel, for a CI of -10kg to -15kg CO_2 per kg H_2. An electrolyzer with an exemption for time-matching would have a net positive CI in these use cases provided it has 50% or more adherence to the three pillars. In addition, these hard-to-abate end uses have significant emissions of criteria air pollutants. Allowing 45V to reach cost-parity with renewable hydrogen is the best path towards serving these industries and reducing these pollutants.

Reaching these sectors with renewable hydrogen requires early deployments at sufficient scale to move down the electrolyzer cost curve. These early projects aren't economic with the current strict three pillars with no exemptions. Allowing for a partial exemption for grid support for a few early projects would allow more of these hard-to-abate sectors to be addressed by hydrogen.

Job creation

Rapid deployment will result in significant job creation in electrolyzer manufacturing jobs. Electrolysis systems will require ongoing maintenance and operation to create more jobs. Without early incentives to deploy quickly, these jobs will not come until 2030 or later – after foreign electrolyzers have brought costs down, and with foreign competition owning much of the market, much like we see with solar panels.

Providing a pathway for renewables to reach hard-to-abate sectors

Hydrogen is one of the best ways for renewables to reach several hard-to-abate sectors. Whether it is high-grade heat that electricity can't achieve alone, chemical reduction that typically uses fossil energy, or lightweight energy carrier for heavy transportation and off-road uses. Hydrogen is the most cost-effective vector for these use cases.

Renewable expansion

Figure 1 shows that near $650/kw installed cost, electrolysis will be one of the least expensive and fastest ways to get renewables to many hard-to-abate sectors. At sufficiently low installed cost, renewables can bypass the interconnection queue via hydrogen. Prior to development of hydrogen pipeline networks, projects can use hydrogen trucking to economically move hydrogen with significantly fewer right-of-way issues than power lines to renewables would represent.

Details of options to bring about success

Several of the proposed options alone would be sufficient to achieve commercial liftoff with renewable hydrogen. Others, however, will require a mix-and-match approach with several parts of each option in order to create a successful economy.

Full or Partial three pillars exemptions for projects with commercial operation date before 2028

The EU embraces full exemptions on many first-mover clean energy projects, and this is a strong action to help build the US electrolyzer economy. Partial three pillars exemption of up to 15-25% of EAC requirements for early projects would allow these projects go have the requisite around-the-clock service to provide consistent hydrogen production. This would limit the amount of induced emissions, trigger net reductions in emissions, and allow for the first major projects to get off the ground.

This would provide the strongest incentive to increase electrolyzer production and deployment capacity and reduce cost, induce hydrogen use in hard-to-abate sectors earlier, and produce very large long-term net carbon reductions. This may come at the cost of initial higher emissions, but this will be compensated for with deployment of hydrogen in hard-to-abate end uses. Limiting the exemption to 15-25% of required EACs will mitigate most of the induced emissions.

Exemptions on just hourly matching for EACs for the projects built before 2028

Hourly matching is the most difficult pillar for most projects to meet. Allowing full or partial exemption for early projects will allow the first critical projects to get off the ground. Partial exemption of 15-25% of EAC requirements for early projects would allow projects in many regions to move forward while ensuring induced emissions are low.

This exemption will have similar effect to fully or partially exempting all three pillars.

Exemption to allow hourly averaging to calculate H2 Carbon Intensity for early projects

Currently GREET calculations are averaged annually. Given that hourly matching of EACs will require verification and validation to an hourly basis, CI for the first projects should be calculated on an hourly average rather than the current annual average. With this, projects can use grid backup for their projects, but they will not receive subsidies for hydrogen produced while operating from the grid – they will only receive subsidies when they have sufficient EACs in each our of production.

If instead annual CI averaging is used, grid backup can nearly never be used and projects need to shut down when EACs are not available. This creates an untenable commercial situation in a market that isn't merchant.

This pathway represent the most market-neutral option: only clean hydrogen will be subsidized, but the arrangement is flexible enough that if a project must provide consistent hydrogen production, it can, albeit it a much higher cost when using grid support and foregoing subsidy for those molecules of H2. In other words, this will subsidize clean hydrogen production and functionally penalize grid-supported hydrogen production by removing the subsidy in those hours while allowing early-mover projects to provide consistent hydrogen to offtakers.

Additionality: increasing the carve-out for nuclear and hydro power

If a portion of early-mover project EACs were allowed exemptions of 15-25% of their total EACs, partial exemptions either hourly matching or additionally on many regions would allow for much higher utilization of assets and reliable delivery of hydrogen. In addition, recent MIT studies have shown that the model of direct competition for baseload zero emission power sources is questionable[1]. Allowing a small percent of exemption for additionality on early projects would allow many more projects to go forward while limiting induced grid emissions.

Pushing back all strict to 2032 or pushing back just hourly matching

While pushing back the three pillars has demonstrable cost savings (see figure 2), the true value could be in allowing more time for both cleaner grid and regional hydrogen hubs with hydrogen storage to come online. Either path would afford significant cost savings and project viability in certain regions – but the main detriment still remains in regions without open access hydrogen infrastructure or clean grids – these locations would still not be able to affordably host renewable hydrogen projects owing to storage issues.

Pushing back hourly matching or doing a phased-in approach as the US grid gets cleaner would also be of significant benefit in allowing early movers to successfully deploy. This would not be as effective as full or partial exemptions on early projects and may produce more induced grid emissions than partial exemptions on early projects.

Conclusion

45V and the hydrogen hubs can provide a pivotal opportunity for the US to seize leadership in the electrolyzer industry. Moderate changes to 45V to support first movers with partial exemptions to the three pillars requirement will kickstart the domestic electrolyzer industry while mitigating the risk of induced emissions. This will allow for a rapid deployment to achieve the goals in prior sections, putting the US in a leading role to fight climate change while improving local air quality.

Sincerely,

Jason Munster
Principal, CleanEpic Advising

[1] https://energy.mit.edu/publication/producing-hydrogen-from-electricity-how-modeling-additionality-drives-the-emissions-impact-of-time-matching-requirements/