Implications of 45V Guidance for the Future of the Green Hydrogen Industry
Executive Summary

February 2024

Key takeaways

Green hydrogen is key to decarbonization

To reach net-zero emission target by 2050, the US requires 50-80 mmtpa of low-carbon H_2 deployment, of which over 50% will be sourced from green H_2

The lower carbon intensity of green H_2 is key to driving a lower CI H_2 supply mix in support of net-zero ambitions

Market context is already challenging for green hydrogen

Scalability of green H_2 industry is necessary to lower costs and improve its competitiveness

However, green H_2 projects face a significant number of challenges across the project lifecycle, limiting progress for green H_2 project commercialization and potentially leading to delays in low-carbon H_2 deployment

45V has the potential to make a big impact in accelerating green hydrogen deployment

$_2$ industry by reducing the LCOH of green H_2 and bringing it to parity with blue H_2 and other fuels

However, requiring hourly 45V CI matching in 2028 impacts green H_2 CF and LCOH, at a critical time for innovation and growth

UST Guidelines make economics, adoption and deployment challenging for green hydrogen

LCOH is estimated to be orders of magnitude above the price range for adoption at scale, driven largely by the complexity the UST guidelines drive in H_2 power procurement

UST guidelines will likely lead to greater blue H_2 deployment, limited scaling of green H_2, and ultimately a higher CI for H_2 supply

ACP's proposal would enable greater green hydrogen deployment, enabling the industry to get closer to key DOE Targets for the industry which are needed to support wider decarbonization goals

The low-carbon H_2 industry is nascent and needs to overcome challenges to scale

Project Development Challenges

Feedstock Sourcing
Complex sourcing strategies are needed to source reliable, low CI, and low-cost renewables or natural gas for sustaining continuous commercial operations at a competitive cost

Policy / Regulatory Guidance
Despite the momentum of 45V PTC and BIL, stringent regulatory requirements may deter first movers from scale-up operations, impeding growth potential and keeping costs higher for IET1 42.7 3lq0.00001072

EPC / Supply Chain / Technology
Clean hydrogen production technology and supply chain have yet to achieve commercial maturity to fully achieve large-scale production

Project Bankability / Financing Progress

Market Access and Delivery
Lack of existing and emerging demand markets, as well as limited infrastructure for connecting production to demand centers

Marketing Progress (Offtakers & Revenues)

Source: Wood Mackenzie

Lack of cost competitiveness limits green H_2

Only 5% of projects likely to take FID in the next 2 years will be green hydrogen projects

Over 95% of low-carbon hydrogen project capacities have yet to achieve commercial operations

27 projects are currently operational and contribute 0.26 mmtpa of capacity

9 projects are under construction and will potentially come online before 2028, but only account for 0.12 mmtpa of capacity

80+ projects are still progressing to achieve FID, reflecting 15.75 mmtpa capacity

4 projects are delayed or cancelled, totaling 0.24 mmtpa

Source: Wood Mackenzie Lens Hydrogen

Green H_2 economics must fall within $1-2/kg, on a delivered to customer basis, to encourage adoption at scale

Potential low-carbon H_2 demand sectors and corresponding price range for adoption at scale

H_2 price range of adoption at scale for each demand sector represents the price at which end-users are willing to adopt hydrogen in their operations

Green H_2 production costs could be competitive in the medium and heavy-duty vehicle sectors compared to other competing fuels, such as electricity and petroleum derivatives. However, it becomes less competitive when factoring in the costs of compression/liquefaction and trucking to the end user

Other sectors, including biofuels, ammonia, and power, currently consume cheap fossil feedstocks, so green H_2 must be low cost to be competitive. Large-scale consumers benefit from the ability to access feedstock supplies via lower cost high-capacity delivery infrastructure

The 45V incentive could bring green H_2 cost closer

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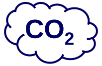
demand creation, yet strict guidelines may prolong high costs, risking adoption and future deployment

Source: Department of Energy, Wood Mackenzie

The 45V PTC aims to catalyze the nascent low-carbon hydrogen industry

In this report, we analyze the implications of capping the duration of annual matching to 2028

Motivation for a LCI H_2 45V Production Tax Credit



US Decarbonization Need

H_2 is required for US to reach net-zero by 2050

Green H_2 supply is necessary as blue supply will be insufficient

Current Obstacle   Current Costs & Competition

Without government support, there will be limited progression of green H_2 projects given costs are currently higher than competing fuels

Implementation challenges

CONCEPTUAL

The lower the CF, the higher the cost of hydrogen on a levelized basis due to a lower volume of production

What is LCOH?

Levelized cost of hydrogen (LCOH) is the preferred

production economics (US$/kg) across the different color production pathways

$$= \frac{(\quad)}{(\quad\quad)}$$

The biggest driver of ***Costs*** are power price and capex

The biggest driver of ***Production*** is the Capacity Factor (CF) since less operating time simply translates into less production

The 45V Production Tax Credit (PTC) aims to make low-carbon hydrogen competitive vs. carbon-intensive hydrogen by reducing the costs and resulting LCOH of low-carbon hydrogen, driving H_2 producers to adopt the least carbon intensive technologies

How does temporality affect the capacity factor and LCOH?

Electrolyzer demand matches the availability of renewable

Hourly Matching

Source: Wood Mackenzie

ACP proposed an alternative to US Treasury Guidelines, which delays the hourly matching requirement, supporting the emergence of new green H_2 projects

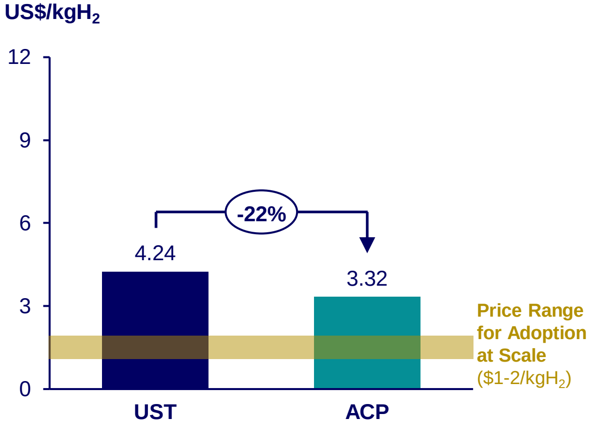
ACP proposed changes to the three pillars of the US Treasury Guidelines to 45V

Pillars		US Treasury Guidelines (**UST Scenario**)		ACP Proposal **(ACP Scenario)**	
TEMPORALITY	**Annual Matching**	**Timing:**	Through 2027	**Timing:**	1st 10 years of operation
		Eligibility:	All H_2 facilities	**Eligibility:**	Construction start before 2029, COD before 2033
	Hourly Matching	**Timing:**	2028 & beyond	**Timing:**	2033 & beyond
		Eligibility:	All H_2 facilities	**Eligibility:**	All H_2 facilities except those

In 2028, H_2 production costs are still too high to drive adoption in most sectors; annual matching reduces the cost to consumers by 20-30%

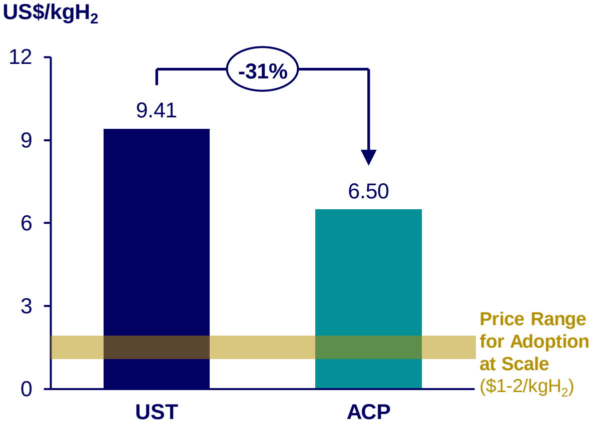
Regions with high quality wind are economically advantaged, but not enough to meet DOE H_2 shot goals

2028 ERCOT LCOH under UST vs ACP scenario (post 45V tax credit)



RE overbuild	3.4	3.4
Power config.	Hourly matching	Annual matching
Power cost (US$/MWh)	59.47	63.85
H_2 CF (%)	80%	100%

2028 CAISO LCOH under UST vs ACP scenario (post 45V tax credit)



RE overbuild	4.1	4.1
Power config.	Hourly matching	Annual matching
Power cost (US$/MWh)	99.20	136.51
H_2 CF (%)	44%	100%

In ERCOT, high-quality solar and wind resources and overbuild capacity yield 80% H_2 capacity factor (CF) in the UST scenario, narrowing the gap between proposals. This highlights that hourly matching has the least negative consequences only in regions with robust solar and wind resources to support sufficient H_2 production

In CAISO, higher power costs and lower H_2 CF drive a significantly higher LCOH compared to the ERCOT LCOH

Despite substantial LCOH reduction from ACP proposals, the resulting LCOH is 3-6x higher $_2$ Shot goal of US$1/kg and significantly above the price range for adoption at scale for end-use customers, potentially impeding green H_2 adoption

Note: All green H2 analysis in this study assumes green H2 production to receive the full 45V tax credits ($3/kgH2) by having <0.45kgCO2/kgH2 of carbon intensity. Detailed assumptions for LCOH calculation can be found in the Appendix
Source: Wood Mackenzie

In 2032, renewable & electrolyzer CapEx reductions lessen the impact of a lower

Still, even advantaged renewable resource regions like ERCOT are not able to fall in the $1-2/kg range

2032 ERCOT LCOH under UST vs ACP scenario (post 45V tax credit)

2032 CAISO LCOH under UST vs ACP scenario (post 45V tax credit)

LCOH under the UST hourly match regime has fallen by ~20% in both regions relative to 2028, signaling significant progress

However, cost reductions are not enough to get into a price range for adoption at scale of US$1-2/kg$H_2$ by 2032 in either scenario, which reflects an inflection point for large-scale green hydrogen adoption

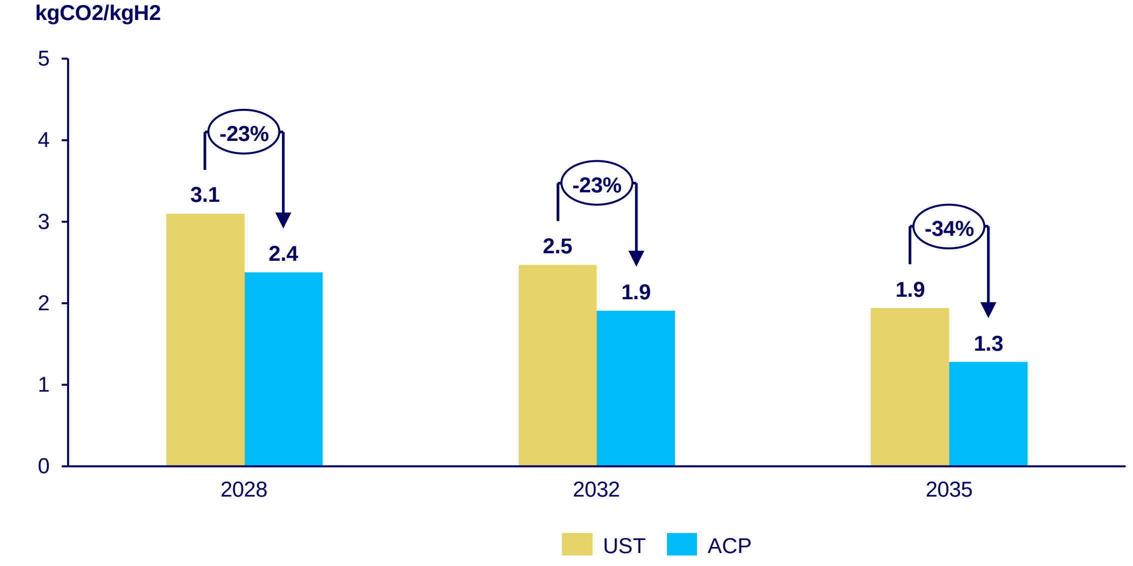
-carbon H_2 deployment long-term, accelerating the deployment required to approach net-zero ambitions

The deployment of blue H_2 increases under the UST guidelines to fill in for lost green H_2

refers to both blue and turquoise H2

Higher green H_2 development under the ACP scenario, results in a lower CI of low-carbon H_2 supply

Carbon intensity of US low-carbon H_2 supply under UST vs ACP scenario



-carbon H_2 carbon intensity (CI) analysis focuses on how the green vs. blue H_2 evolution will impact decarbonization. The analysis is done by evaluating the average of green and blue H_2 CI, weighted by their respective deployment levels

Blue H_2 CI is estimated based on a lifecycle emissions analysis of the natural gas value chain inclusive of CO_2 and CH_4, while green H_2 CI has zero CI:

- For UST scenario, H_2 production results in zero CI
- For ACP scenario, H_2 production uses annual RECs from dedicated renewables assets (incrementality pillar) to match grid power requirements, where the grid CI is above zero[1]

The ACP scenario anticipates higher green H_2 deployment, which contributes to the 20-35% CI reduction in the ACP scenario compared to the UST scenario, and the gap widens in the later years

1. Although the current policy guidance lacks detail on this mechanism, developing a demand-agnostic carbon matching scheme is critical to ensure new electricity loads are served by renewable energy, supporting a broader decarbonization strategy

refers to both blue and turquoise H2. All green H2 analysis in this study assumes green H2 production to receive the full 45V tax credits ($3/kgH2) by having <0.45kgCO2/kgH2 of carbon intensity.

Source: Wood Mackenzie