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White Paper

Differences in Carbon Intensity Criteria Will Impact Global Electrolyzer Adoption

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Introduction

Policymakers generally agree that green hydrogen produced using renewable electricity is critical for decarbonization, particularly in hard to abate sectors. However, **developing support schemes for green hydrogen projects has presented a range of definitional questions that have proven tough to resolve.**

For instance, exactly how should rule makers determine that the electricity consumed by an electrolyzer is renewable, especially if drawn from the grid? Are rules required to make sure green hydrogen projects do not divert renewable electricity away from decarbonizing existing electricity demand? What guidelines should be applied to imports of hydrogen and derivative products such as ammonia or direct reduced iron? **At the core of each of these issues is a common dilemma: ensuring that green hydrogen delivers emissions reductions without placing unreasonable regulatory constraints on hydrogen producers.**

Earlier in 2023, European Union (EU) policymakers finalized a pair of delegated acts appended to the recast Renewable Energy Directive (RED) after several rounds of revisions. These rules establish conditions for electrolytic hydrogen production to qualify as renewable, which determines whether projects can secure access to subsidies and contribute to renewable energy uptake targets in transportation and industry.

So far, **the EU and the UK are the only major economies to introduce detailed carbon intensity (CI) guidance for green hydrogen projects.** Countries such as the US and India have provided CI thresholds for green hydrogen projects but have yet to determine the supporting methodology.

This paper summarizes the current status of CI criteria applied to green hydrogen projects in key global markets. It provides an overview of the core concepts involved, including the cost implications and CI impacts of producing hydrogen from various electricity sources, and the rationale for rules on additionality and geographic/temporal correlation. It also offers insights into the future development of CI rules, consequences for international trade, and the role of certification schemes.

Status of CI Rules in Key Markets: EU, US, UK, India

Several countries have set CI thresholds for clean hydrogen, but only the EU and the UK have provided detailed methodologies for assessing emissions from electricity usage.

Jurisdiction	Current Status
EU	• Hydrogen from renewable electricity is prioritized rather than a broader range of low CI production pathways. • Detailed prescriptions exist for additionality, geographic correlation, and temporal correlation, with more lenient rules for projects that come online in the 2020s. • Use of grid-sourced electricity is supported only under certain circumstances—for instance, if accompanied by a power purchase agreement (PPA) in a low CI bidding area, or if obtained during grid imbalance periods.
US	• Production Tax Credit (PTC) support under the Inflation Reduction Act (IRA) is offered to clean hydrogen projects that meet specific CI thresholds. Higher support levels are offered to projects with low CI. • Criteria for determining CI will be confirmed by upcoming guidance from the Department of the Treasury.
UK	• The UK's Low Carbon Hydrogen Standard sets a threshold of 20 g of CO_2e/MJ_{LHV} of hydrogen for low carbon hydrogen across all pathways. Producers must provide proof that electricity is sourced from a low carbon generator (e.g., via a PPA). • Temporal correlation must be demonstrated over a 30-minute period. Electrolyzer operators can also use grid-sourced electricity that would otherwise have been curtailed, provided this can be demonstrated.
India	• A maximum CI threshold of 2 kg of CO_2e/kg of hydrogen for electrolytic hydrogen is required to be considered renewable. • Electricity can be sourced from the grid, but no rules are provided on the use of PPA agreements, additionality, or geographic/temporal correlation.

Status of CI Rules in Key Markets: Brazil, Canada, South Korea, China

Policymakers in Brazil have produced a draft law that closely mirrors the EU definition of renewable hydrogen.

Jurisdiction	Current Status
Brazil	• Draft law closely mirrors EU definition of green hydrogen to enable export projects to comply with RED requirements. • The law introduces nearly identical requirements for additionality, geographic/temporal correlation, and use of grid-sourced electricity from grids with high renewable energy penetration.
Canada	• Canada intends to provide Investment Tax Credits (ITCs) to clean hydrogen projects, with ITC values determined by the CI of the production pathway. • The government has yet to provide a methodology for assessing the CI of electrolytic hydrogen production, although the country's anticipated role as an exporter means that the rules are likely to follow EU and/or US approaches.
South Korea	• South Korea plans to establish a national certification system for clean hydrogen by 2024, as a preparatory step to the establishment of a hydrogen power bidding market. • The government has indicated a tentative upper threshold of 4 kg of CO_2e/kg of hydrogen, although it has yet to announce a methodology for assessing the emissions intensity of electrolytic hydrogen.
China	• A single CI threshold is applied to hydrogen used for fuel cell vehicles under China's pilot city program, which covers five urban areas. No detailed supporting methodology is provided, but emissions from electricity generation appear to be excluded. • No CI rules are set for hydrogen produced outside of the pilot city program, including for large-scale industrial applications.

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Regulations Must Account for Various Electricity Sourcing Options

Guidelines are especially important for grid-connected electrolyzer projects.

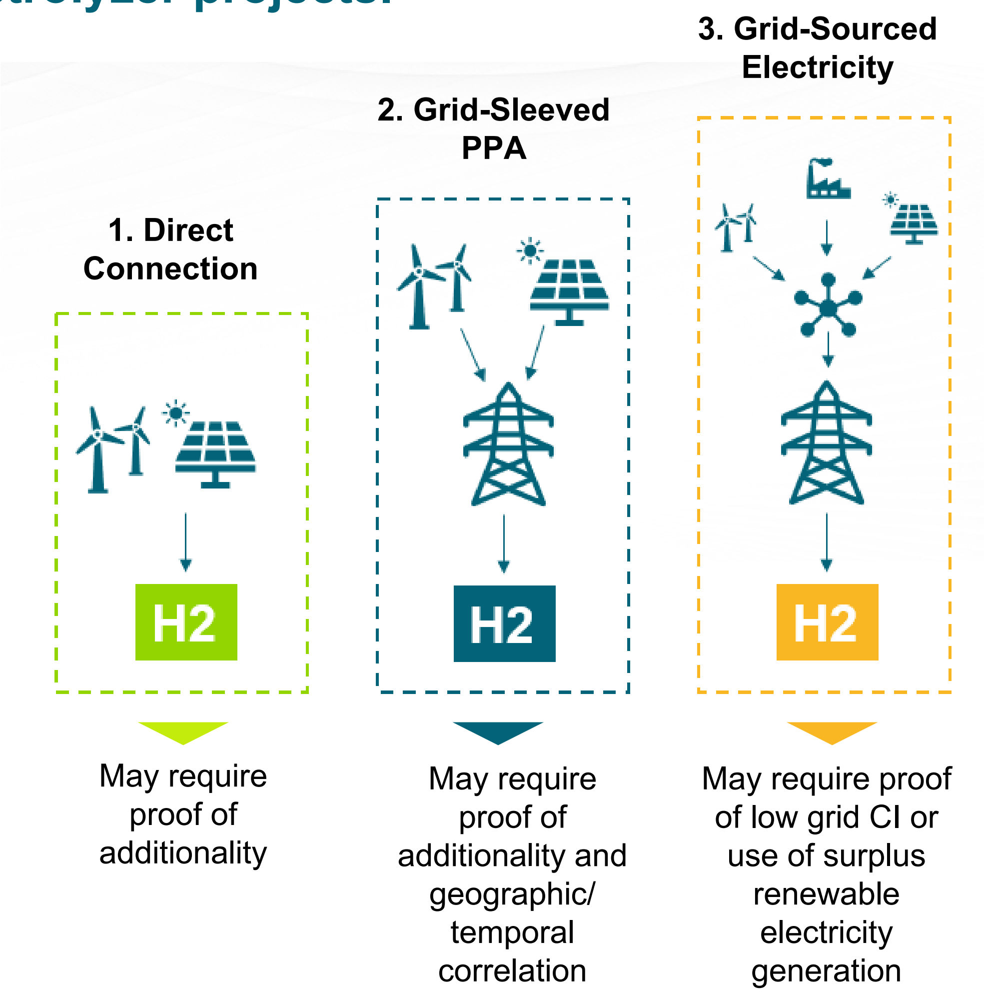
The following requirements can be used to ensure that electrolytic hydrogen is produced at low CI or from renewable energy sources:

- **Additionality** requirements ensure that only recently commissioned renewable energy projects can provide electricity for green hydrogen production. This prevents green hydrogen projects from diverting renewable electricity away from the grid.

- **Geographic correlation** requirements oblige electrolyzer operators to prove that the corresponding renewable energy asset is located in the same bidding zone or grid area. This prevents electrolyzer operators from claiming renewable attributes from generators located in a different region.

- **Temporal correlation** requirements oblige electrolyzer operators to prove that production periods approximately match generation periods for the corresponding renewable energy asset. This ensures that green hydrogen producers do not source electricity from the grid during periods of low renewable energy output.

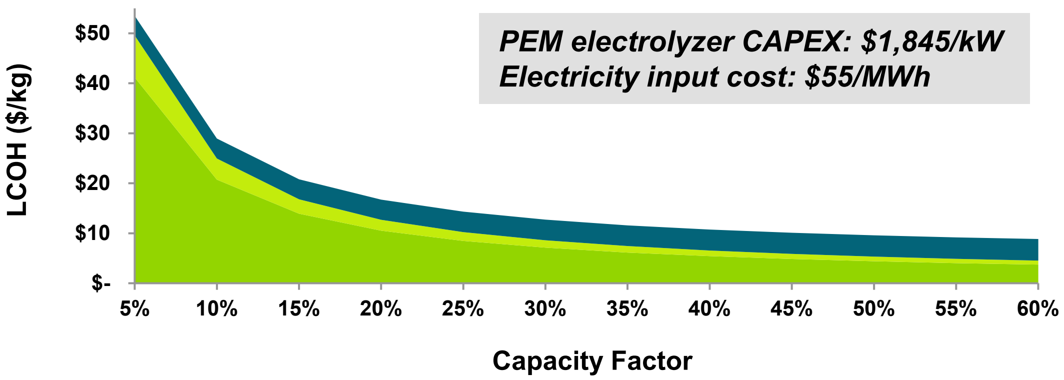
- **Grid CI** requirements specify a maximum CI for grid-sourced electricity used in the absence of a PPA with a renewable energy asset.



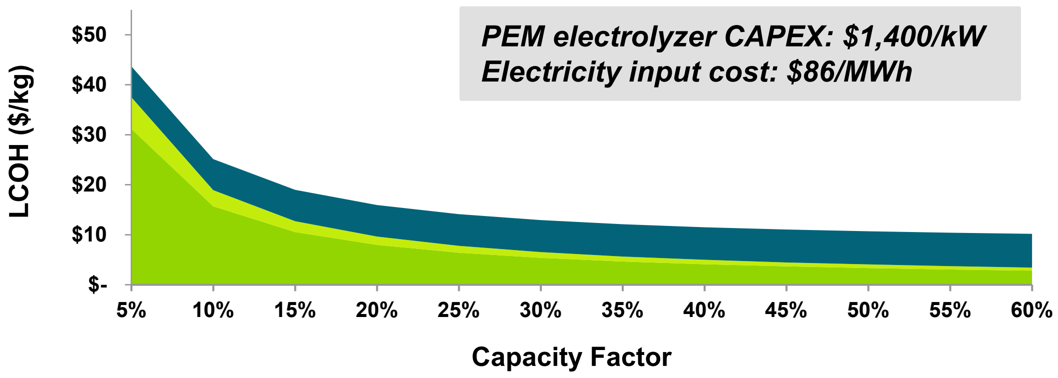
Levelized Cost of Hydrogen (LCOH) Considerations

There is substantial variability in achievable LCOH values depending on electrolyzer CAPEX, electricity sourcing costs, and plant capacity factors.

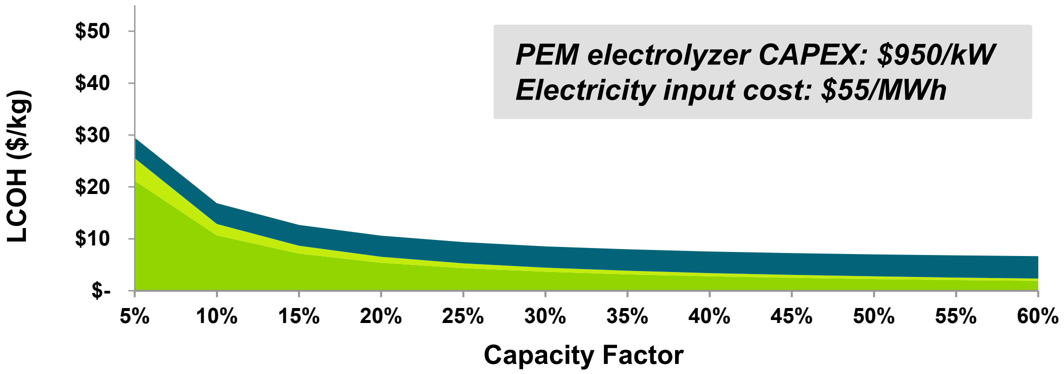
High Electrolyzer CAPEX Scenario



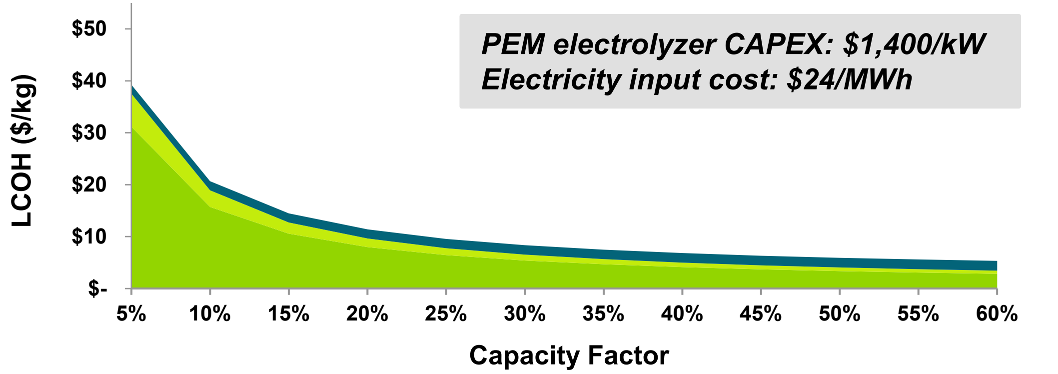
High Electricity Input Cost Scenario



Low Electrolyzer CAPEX Scenario



Low Electricity Input Cost Scenario



■ Total Plant CAPEX ■ OPEX Excluding Electricity ■ Electricity Sourcing Costs

(Source: Guidehouse Insights)

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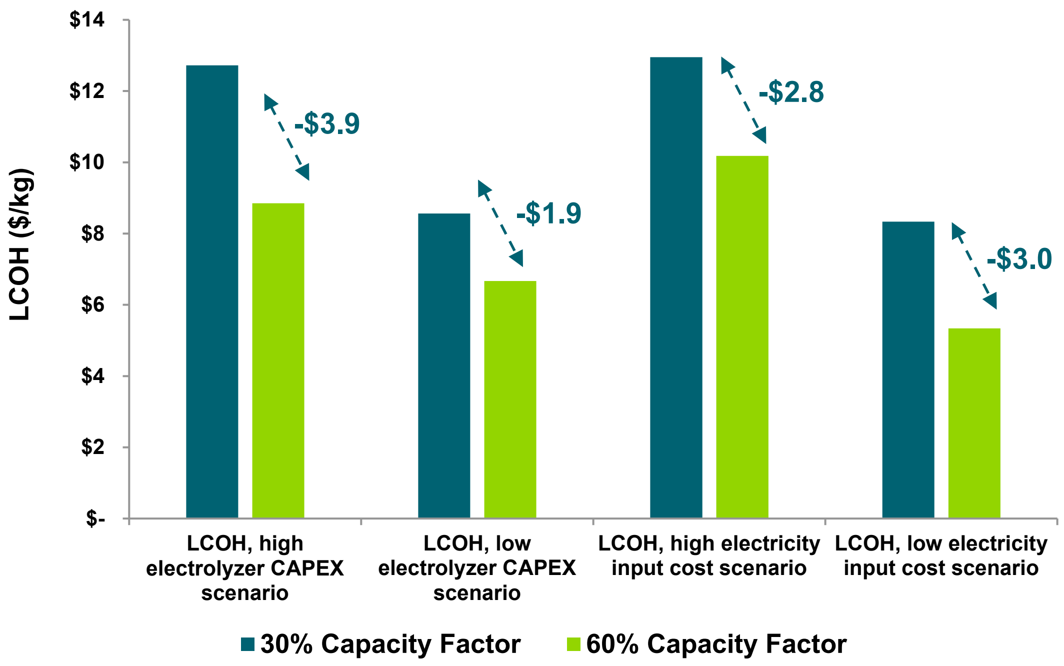
Impact of Capacity Factors on the LCOH

Higher electrolyzer capacity factors suppress the CAPEX component of the LCOH, but operating electrolyzers more frequently can result in higher CI values if grid-sourced electricity is used.

Comparison of Capacity Factor Impacts on the LCOH



(Source: Guidehouse Insights)

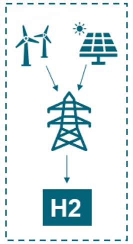
- The chart to the left summarizes the impact of capacity factors on the LCOH across the four scenarios outlined on the previous page. The greatest reduction in LCOH values is achieved in the high electrolyzer CAPEX scenario, with a capacity factor increase from 30% to 60% associated with an LCOH decline of $3.9/kg.
- **Operating at high capacity factors also offers economic benefits that are not fully reflected in like-for-like LCOH calculations.** These benefits include reductions in production and storage capacity for industrial end users that need a continuous stream of hydrogen, as well as shorter amortization periods for plant owners.
- Approaches to increasing capacity utilization include oversizing renewable energy assets, combining wind with solar electricity, and deploying battery energy storage systems (BESS) between the renewable energy asset and electrolyzer, all of which typically raise project costs. **Alternatively, electrolyzer operators can supplement renewable electricity inputs with grid-sourced electricity, which raises the CI of hydrogen production.**
- Grid-sourced electricity and BESS solutions may also be used to reduce load variability for electrolyzer systems, which helps limit degradation rates and maintain optimal conversion efficiencies.

Delegated Act on Article 27 of RED

The rules set out the criteria for green hydrogen and its derivatives to contribute to RED targets, initially for transportation and later for industry.

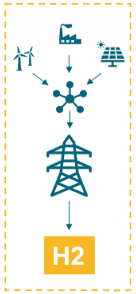
Rules for direct connection

- **Direct connection:** Proof is required of a direct line of connection between the electrolyzer and renewable energy asset, or of renewable energy production and hydrogen production occurring in the same facility.
- **Additionality:** The renewable energy asset must not be commissioned more than 36 months before the electrolyzer. If additional production capacity is added, the 36-month limit still applies.



Rules for grid-sleeved PPAs

- **Additionality:** The renewable energy asset must not be commissioned more than 36 months before the electrolyzer. If additional production capacity is added, the 36-month limit still applies.
- **Geographic correlation**: The renewable energy asset must be located in the same bidding zone as the electrolyzer.
- **Temporal correlation:** Through the end of 2029, operational hours for the electrolyzer should not exceed those of the generator in the same calendar month. From 2030 on, this will be reduced to an hourly period.



Rules for grid-sourced electricity

- **High renewable energy penetration:** The electrolyzer must be located in a bidding zone where the average share of renewable electricity exceeded 90% in the previous calendar year.
- **Grid CI:** If the previous requirement is not satisfied, electrolyzers may be located in a bidding zone with an average emissions intensity of 18 g of CO_2e/MJ or lower. A PPA with a renewable energy asset must also be obtained to cover an equivalent amount of electricity demand, although temporal correlation requirements will not be applied.

Role of CBAM and ETS Reforms

CBAM implementation will affect imports of hydrogen and certain derivatives, as well as incentivize green hydrogen use by enabling the phaseout of free emissions allowances.

The Carbon Border Adjustment Mechanism (CBAM) will apply a levy to imports of carbon-intensive goods that compete directly with domestic output from industries covered by the Emissions Trading System (ETS), the EU's carbon pricing mechanism. Imports of hydrogen, fertilizers (including ammonia), and iron and steel are all covered by the CBAM.

Industrial energy users in the EU have historically benefitted from free emissions allowances to protect against carbon leakage, which occurs if domestic goods are displaced by substitutes from non-EU countries where lower (or no) carbon prices are levied. CBAM tariffs will be imposed starting in 2026, accompanied by the phaseout of free allowances as part of a broader package of ETS reforms. Until 2026, importers will be expected to declare embedded emissions from affected goods without paying tariffs.

2023-2025: Transitional period	2026-2030: Full implementation	2030: Expansion
Monitoring and reporting begins	Importers begin declaring emissions, surrendering certificates	CBAM extended to other sectors covered by the EU ETS

Reporting requirements for indirect emissions from hydrogen production are currently set to expire in 2026.

Under the European Commission's reporting methodology for the CBAM, hydrogen is treated as a CBAM-affected good or as a potential precursor for other affected goods. During the transitional period, importers of hydrogen or goods produced using hydrogen are expected to separately declare indirect emissions associated with hydrogen production, including electricity consumption.

If an electrolytic hydrogen production facility has been certified to comply with the delegated act on Article 27 of RED, indirect emissions are treated as zero. In all other cases, a standard emissions factor for grid electricity in the relevant geography is applied.

Under the current version of the rules, hydrogen producers will be exempted from declaring indirect emissions once the transitional period concludes. While imported hydrogen and ammonia will still need to comply with the delegated act to contribute to RED targets (and access any associated subsidies), the lack of a reporting obligation for indirect emissions after 2026 may incentivize the use of electrolytic hydrogen with unclear CI attributes to reduce CBAM compliance costs. **Guidehouse Insights therefore expects the European Commission to make further adjustments to the rules once the transitional period concludes.**

US CI Guidance Has Been Delayed and May be Released in 2024

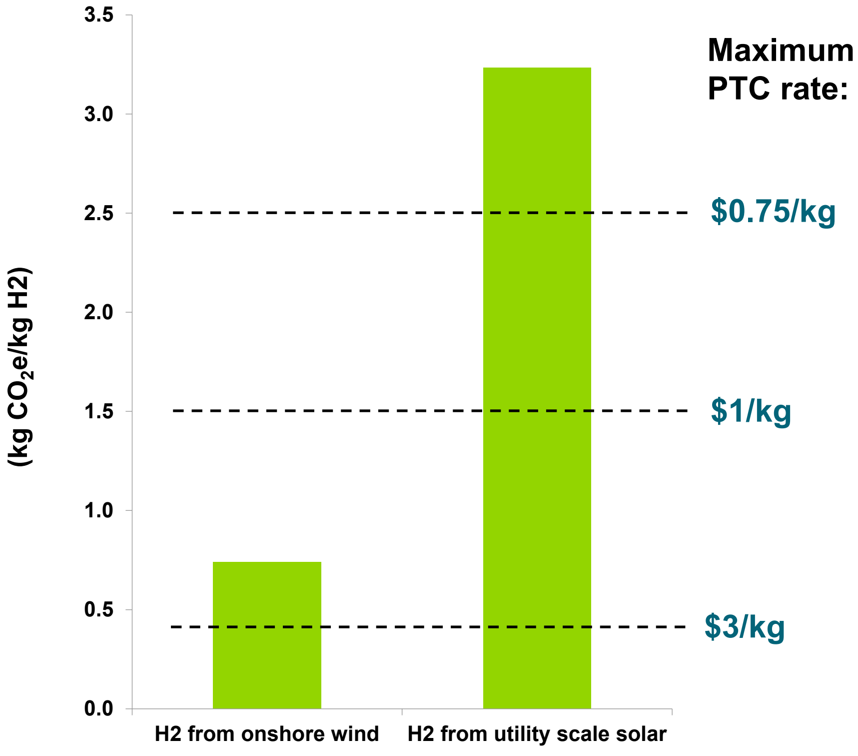
Rules will affect the types of projects able to access higher IRA PTCs and ITCs.

- Tax credits established under the IRA will be offered to hydrogen producers based on CI, with the highest rates offered to producers with a CI below 0.45 kg of CO_2e/kg of hydrogen.
- A detailed methodology for CI calculation was not included in the IRA, although the text suggests that the methodology may make use of the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model.
- The IRA established a 1-year deadline for the Department of the Treasury and the Department of Energy to provide a full methodology. This deadline expired in August 2023, with publication reportedly delayed due to anticipated legal challenges.

Guidehouse Insights has the following expectations for the upcoming guidance:

- If the US government opts to include rules on additionality and temporal correlation, it is likely to designate a leniency period with less stringent requirements for early-stage projects. This is in line with the approach taken in the EU.
- Current CI thresholds would prohibit green hydrogen produced from 100% renewable energy from accessing the highest PTC rate if the full lifecycle emissions of solar and wind energy are included (i.e., emissions associated with manufacturing). This is shown in the chart to the right. Renewable electricity is instead likely to be assigned a nominal CI value of zero, in line with GREET model assumptions.

Estimated Minimum Emissions Intensity of Green Hydrogen, Full Lifecycle*



*Assuming a 1:1 renewable electricity to electrolyzer capacity ratio

(Source: Guidehouse Insights)

Role of Voluntary Certification Schemes

Certification schemes can enable electrolyzer projects to prove compliance with CI requirements, but international harmonization remains a long-term prospect.

Certification bodies issue certificates to hydrogen producers after an external auditor has assessed the sustainability attributes of a project's production model. This creates transparency between producers and purchasers of green hydrogen. It also enables producers to demonstrate compliance with CI thresholds and guidelines imposed by regulators.

Exporting projects will need to be certified by an EU-recognized scheme:

The European Commission currently recognizes 15 voluntary and national certification schemes that can be used to demonstrate regulatory compliance across the hydrogen, derivatives, and bioenergy sectors. Nine further schemes have applied for recognition and are currently under review. Projects that plan to export into the EU will need to secure certification from an EU-approved certification body in order to contribute to RED targets.

International certification schemes:

A number of bodies currently issue certification at an international level, including CertifHY, the Green Hydrogen Organisation, and the International Partnership for Hydrogen and Fuel Cells in the Economy. However, there are significant variations between individual schemes, as well as between emerging national-level regulations. These include differences in system boundaries, accounting methodologies, validating processes for renewable energy use, and the application of emissions thresholds.

As global import and export markets for hydrogen and derivatives emerge, producers may need to obtain multiple forms of certification to access different national markets—for instance if exporting to both the EU and North America. To avoid this outcome, some stakeholders have advocated for the adoption of an international hydrogen standard that could be uniformly applied across geographies. However, since this would also require alignment among policymakers in the design of national incentive schemes, progress remains at an early stage.

Conclusions

1. Introducing overly stringent CI rules at early stages of electrolyzer capacity deployment poses barriers to project financing while providing minimal system-level greenhouse gas reduction benefits. Phasing in CI criteria removes impediments to initial capacity build-out while ensuring that green hydrogen projects contribute to emissions reductions as the industry scales.

2. Since many large, export-focused projects planned for the early 2030s are located in remote regions with high renewable energy potential, these projects typically include new dedicated renewable energy assets. This means that the effects of additionality and temporal correlation criteria on imports of green hydrogen and derivatives are likely to diminish as the industry matures.

3. Because the EU is both a first mover on CI guidance and expected to be a major import market, its approach is likely to shape guidance issued elsewhere in the world—especially in countries that are expected to be exporters. However, some importing countries may look to introduce less stringent rules to secure cheaper imports.

4. The primary goal of the RED guidelines is to ensure that electrolytic hydrogen is produced from renewable energy sources rather than at low CIs. Divergence should also be expected in markets that see a more prominent role for pink hydrogen produced from nuclear energy, including the US.

5. The development of a robust and liquid global market for green hydrogen and derivatives will require greater harmonization of CI guidance than is currently apparent. International certification schemes and multilateral trade partnerships between importing and exporting countries can play a key role in facilitating cross-border hydrogen flows.

Acronyms & Additional Resources

- **BESS** Battery Energy Storage Systems
- **CAPEX** Capital Expenditure
- **CBAM** Carbon Border Adjustment Mechanism
- **CI** Carbon Intensity
- **CO_2e** Carbon Dioxide Equivalent
- **ETS** Emissions Trading System
- **EU** European Union
- **g** Gram
- **GREET** Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
- **H2** Hydrogen
- **IRA** Inflation Reduction Act
- **ITC** Investment Tax Credit
- **kg** Kilogram
- **kW** Kilowatt
- **LCOH** Levelized Cost of Hydrogen
- **LHV** Lower Heating Value
- **MJ** Megajoule
- **MWh** Megawatt-Hour
- **OPEX** Operating Expenditure
- **PEM** Proton Exchange Membrane
- **PPA** Power Purchase Agreement
- **PTC** Production Tax Credit
- **RED** Renewable Energy Directive
- **UK** United Kingdom
- **US** United States

Explore the Guidehouse Insights **Hydrogen Innovations** page.

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- ***Hydrogen Electrolyzer Tracker***
- ***Carbon Capture, Utilization, and Storage Tracker***

Read related reports:

- ***Electrolyzer Supply and Demand Outlook***
- ***Navigating Uncertainties in the Clean Hydrogen Trade***
- ***Leveraging Ammonia as a Hydrogen Carrier and Decarbonization Tool***

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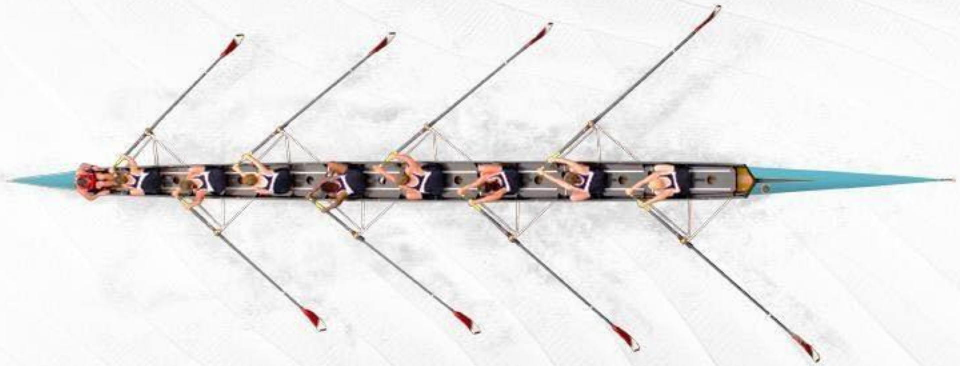

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