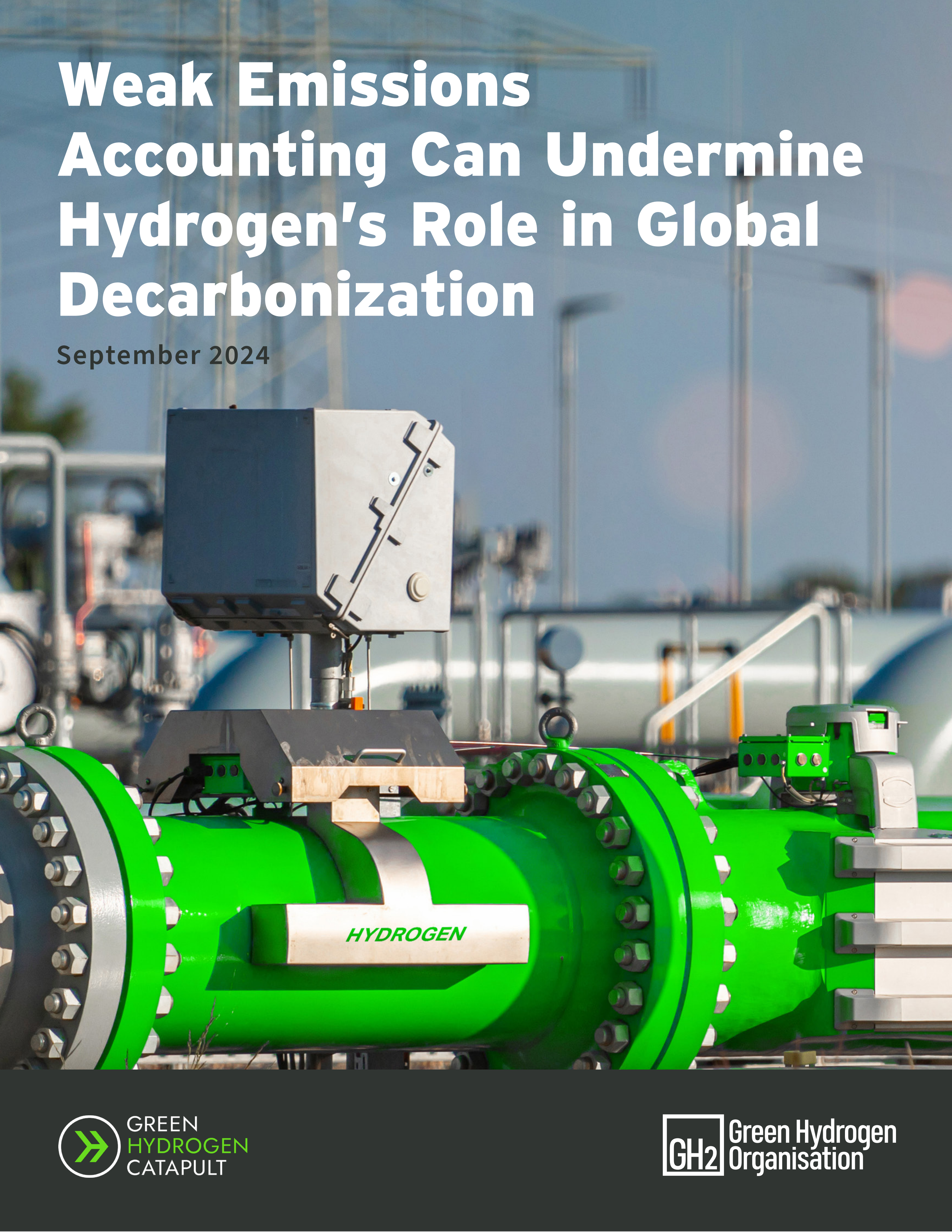
Weak Emissions Accounting Can Undermine Hydrogen's Role in Global Decarbonization

September 2024



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Executive Summary

Key findings:

- To achieve widespread carbon reduction by deploying clean hydrogen, emissions from hydrogen products will need to be managed, monitored, and verified at every step of value chains and across markets.[1]
- Policymakers have made progress defining rules that will govern electrolytic hydrogen production to ensure the use of renewables and avoid unintended consequences with power grids, but gas-derived hydrogen products have not yet received the same scrutiny in regulation.
- Blue hydrogen imports from most countries (except for Norway) will not meet Europe's emission reduction requirements and may stall decarbonization across key sectors in the long term.
- When considering fuel for power generation, combusting blue hydrogen in turbines could be worse than burning coal or LNG from an emissions and cost perspective.
- Under currently-proposed standards, Japan and Korea risk underestimating nearly 50% of hydrogen's lifecycle emissions.
- Given proven variance in upstream emissions for natural gas, locking in theoretical methane leakage values leads to perverse incentives for developers and will allow certain highly emissive hydrogen products to qualify as "clean," jeopardizing climate impact.
- Calibrating international schemes (like the ISO 19870 methodology) to account for full value chain emissions when certifying products is critical to ensure hydrogen from all production pathways can compete on a level playing field across markets.

Clear, robust standards for clean hydrogen products will crucially enable green molecules to displace fossil fuels and guarantee that fuel switching actually reduces carbon emissions in heavy industry and transport. The potential for hydrogen to play a role in reducing emissions depends on its production pathway: hydrogen produced with renewable power (green hydrogen) can achieve near-zero emissions, while hydrogen produced from natural gas (blue hydrogen) can only achieve true "clean" status depending on effective control of upstream methane leakage and carbon capture methods.

Critically, **accurate assessment of emissions reduction potential will depend on how we monitor and verify emissions at every step of the hydrogen value chain**. With governments now finalizing market-defining standards for clean hydrogen and weighing how they'll track hydrogen's carbon intensity, it is vitally important for policymakers to understand the inefficiencies of the emerging patchwork of definitions and standards, and the risks of adopting weaker emissions-accounting frameworks.

Setting strong standards and methodologies for accurately measuring and independently verifying the emissions intensity of clean hydrogen will ensure that:

1. Clean hydrogen **molecules are truly decarbonized** compared to the fossil fuels and feedstocks they're intended to replace;

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[1] We define "clean" hydrogen in our analysis and in this paper as hydrogen that achieves a 70% reduction in emissions intensity from present day fossil fuel comparators (defined by the EU as 94 gCO_2e/MJ) by 2035, and reduces emissions intensity progressively to 1 $kgCO_2e/kgH_2$ by 2050, to comply with global and national carbon budgets.

2. **Consumers can get credit** (and access to public funding) for the decarbonization value of switching to clean fuels and feedstocks to meet decarbonization objectives;
3. All hydrogen products can compete on a **level playing field across both national and international markets**, given accurate measurement and independent verification of emissions intensities; and
4. Clean hydrogen **products can be traded fairly** between markets, unlocking energy security benefits and protecting against carbon leakage.

First mover hydrogen markets (including the European Union, the United States, Japan, and South Korea) have proposed emissions-accounting frameworks for assessing and verifying the carbon intensity of clean hydrogen products. International organizations including the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) and the International Organization for Standardization (ISO) are developing their own methodologies to measure the emissions intensity of hydrogen and derivative products, and will offer a key benchmark for countries looking to adopt their own hydrogen regulations imminently.

These governments and international organizations rightfully have spent considerable time and effort considering how they should establish guardrails for electrolytic hydrogen, to ensure products made using grid electricity were truly decarbonized (in the EU, these rules were codified in the Delegated Acts on Renewable Fuels of Non-biological Origin. In the US, these rules will govern 45V qualification.) Blue hydrogen value chains, though exposed to higher leakage risks, did not receive the same level of scrutiny.

So **significant divergence and gaps in these standards and frameworks persist**, and governments as well as national standards bodies need to work quickly to address key shortcomings, including:

- The **omission of full life-cycle emissions** in some key countries' frameworks, potentially opening the door to the following **inaccuracies and key risks**:
    - Miscalculating the carbon intensity of electricity production due to a lack of transparency
    - Significantly underestimating upstream methane leakage
    - Overestimating capture rates and permanence of sequestration of CO_2 (for blue hydrogen)
    - Miscalculating nitrogen oxide scrubbing efficacy (for shipped products); and
    - Under-reporting hydrogen leakage (for pipeline transport); and
- The **misalignment of definitions and emissions-accounting methodologies** between frameworks, leading to trade inefficiencies, increased certification costs, and divergence on which products will qualify as "renewable" versus "low-carbon" versus "clean" (see Appendix A).

Context

Hydrogen project developers eager for clarity on emissions standards and certification schemes are pushing policymakers to formulate and adopt clear, firm frameworks as soon as possible. It is crucial that national and international policymakers guard against emissions risks when finalizing their regulations and accounting methodologies.

To build a clean, resilient, and global hydrogen economy, key markets need to develop and enact strict and harmonized product standards that account accurately for full life-cycle emissions across hydrogen value chains. This is supported by the findings of our scenario analyses, which illustrate the impacts of inaccurate emissions accounting that tend to significantly overestimate the decarbonization potential in switching to hydrogen.

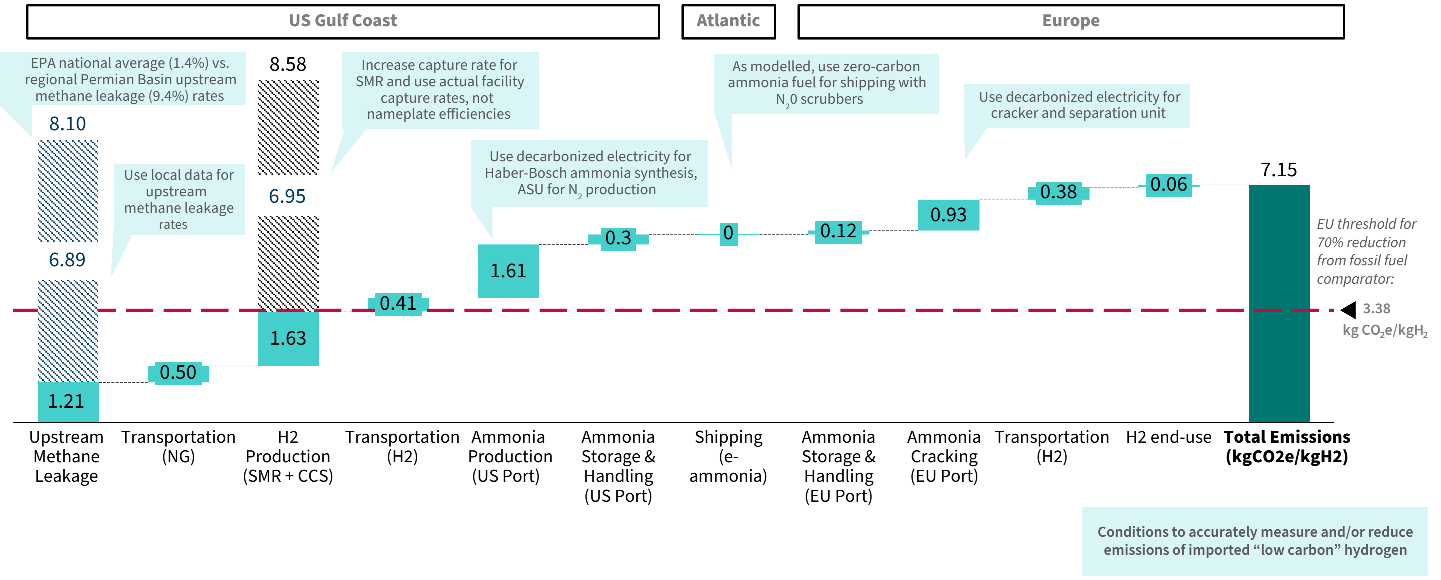
Assessing accounting methodologies for clean hydrogen products and their decarbonization attributes

If policymakers don't enact robust life-cycle emissions accounting frameworks for hydrogen, it will seriously jeopardize the achievement of objectives and timeframes for decarbonization aligned with the goals of the Paris Agreement and the achievement of a net zero economy by 2050 or earlier. Observing first mover markets as helpful case studies, we have modeled several scenarios to assess emission leakage risks for hydrogen products traded between different global markets.

Imports into Europe

In our first scenario (Exhibit 1), we calculated the emissions intensity of blue hydrogen produced in the US Gulf Coast and exported as ammonia to the Netherlands. Exhibit 1 shows that the exported product from the US Gulf Coast would not qualify as low-carbon on a life-cycle basis in the EU based on the set threshold of 3.38 $kgCO_2eq/kgH_2$ (Appendices A and B) using conservative assumptions for upstream methane leakage,[2] zero-carbon shipping, and 85% capture rate for SMR hydrogen production. Accurately accounting for upstream methane leakage values, which are often underreported especially when using national average values, would increase the total life-cycle emissions intensity value (Exhibit 1 and Exhibit C1 in Appendix C). Similarly, even with 100% capture rate at the hydrogen production node, blue hydrogen would not qualify in the EU as low carbon with true capture rates likely far below 85% as seen in real-world applications (Exhibit C2 in Appendix C).

Exhibit 1: Scenario Analysis — Calculated emissions intensity of landed blue hydrogen in Europe
$kgCO_2e/kgH_2$



Note: Transatlantic route from US Gulf Coast to Europe (NL)

Sources: RMI Analysis, Ammonia Energy Association, US DOT Maritime Organization, Methanol Institute, US DOE, Lloyds, UMAS, TechnoEconomic Assessment ZeroCarbonFuels

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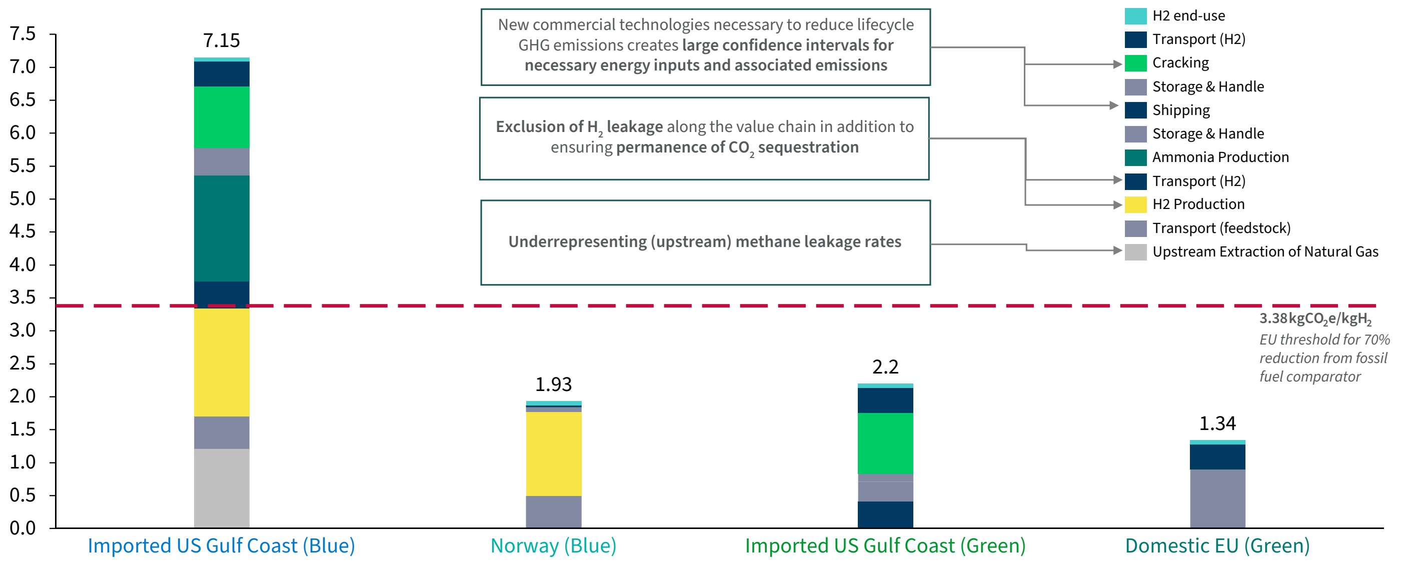
[2] A conservative assumption for upstream methane leakage rate includes using the standard for the average US national value set by the EPA (1.4%), a conservative estimate of actual upstream leakage rates compared to regional or local values (Appendices B and C)

Conversely, Exhibit 2 illustrates that importing blue hydrogen into the EU from a country like Norway will have an emissions profile similar to green hydrogen imported from the US Gulf Coast and green hydrogen produced domestically in the Netherlands. Norwegian blue hydrogen could be in the unique position to qualify for the EU's threshold for low-carbon hydrogen given that Norway has some of the lowest upstream methane leakage rates in the world, mostly due to the following factors: robust regulation; the product is pipelined to mainland Europe instead of shipped; no reconversion ("cracking") is needed to extract hydrogen from ammonia as the transport vector; and the emissions intensity of the Norwegian grid is extremely low (roughly 14x less carbon intensive than the Texas grid, on average).

As European countries like Germany consider blue hydrogen imports due to lower short-term costs, it is imperative that the EU look to create a level playing field for different hydrogen technology products. They can do this by requiring **rigorous measurement and third-party verification** of production processes along the value chain that are prone to emissions leakage (such as upstream methane leakage, permanence of CO_2 sequestration, hydrogen leakage from moving product via pipelines, nitrous oxide [N_2O] scrubbing in ammonia production, cracking, and shipping, etc.). **Otherwise, the EU risks importing hydrogen products that will undermine progress towards achieving its decarbonization objectives**, including the commission's proposal for a 90% reduction in GHG emissions by 2040.

Exhibit 2: Scenario Analysis — Calculated emissions intensity of landed blue and green hydrogen versus domestic hydrogen in Europe
$kgCO_2e/kgH_2$



Note: Transatlantic route from US Gulf Coast to Europe (NL). Pipeline route from Norway to Europe (NL). Imported US Gulf Coast (green) assumes BTM zero-carbon electricity for ammonia production, using grid electricity increases life-cycle emissions 73%. Domestic EU production in Netherlands.

Sources: RMI Analysis, Ammonia Energy Association, US DOT Maritime Organization, Methanol Institute, US DOE, Lloyds, UMAS, TechnoEconomic Assessment ZeroCarbonFuels

Imports into Japan and other Asian markets

We also assessed a scenario focused on Japan as an import market and calculated the emissions intensity of using imported blue ammonia to generate power in turbines. Exhibit 3 illustrates that blue ammonia exported to Japan from Australia may qualify as low carbon under the current Japanese definition and threshold set on a well-to-gate basis. However, **43% of emissions on a life-cycle basis are not considered under conservative assumption scenarios**, including using a national average value for upstream methane leakage that likely underestimates the true value. Because hydrogen products that meet the country's definition of "low carbon" will be eligible for public support schemes, Japan risks spending billions on hydrogen commodities that will not substantially contribute to its decarbonization.

Additionally, support for higher-carbon products could crowd out support for truly low-emissions hydrogen, stalling investments in a green hydrogen market that would advance Japan's decarbonization objectives.

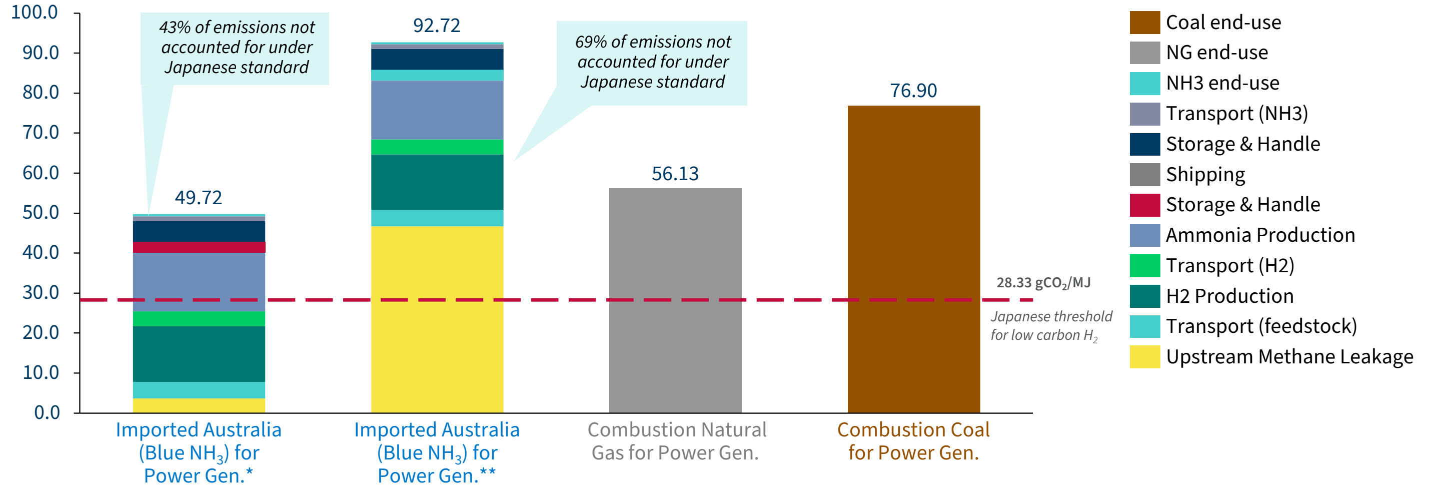
The cumulative emissions profile of trading blue ammonia from Australia in the conservative scenario can be **nearly as "dirty" (in terms of GHG emissions intensity) as combusting natural gas for power generation**, and can be even **dirtier than combusting coal** in the scenario analysis using a regional-specific upstream methane leakage value for Western Australia (Exhibit 3)[3].

As Japan plans to phase in ammonia for power generation by first co-firing with coal, overall emissions would only increase from the scenarios in Exhibit 3 given the foreseen continuation of coal in the fuel mix for power generation. Similar results are shown in Exhibit C3 (Appendix C), demonstrating significantly under-represented life-cycle emissions when exporting blue ammonia from the US Gulf Coast to Japan.

Policymakers in Japan and other markets planning to leverage imported hydrogen (including South Korea) need to reflect emissions across the entire hydrogen production and delivery value chain accurately in their standards. They can thereby help to ensure that public funding support is channeled to truly clean hydrogen products and that investments equally support green hydrogen, which the IEA estimates could be the most cost-competitive in nearly every region of the world by 2030 onwards.

With weaker standards, these countries risk (especially in the short-term) importing hydrogen that nominally qualifies as "clean," but will effectively be as dirty as combusting incumbent fossil fuels.

Exhibit 3: Scenario Analysis — Calculated emissions intensity of landed Australian blue ammonia versus combustion of natural gas and coal in Japan
gCO_2e/MJ



*National average methane leakage value used for Australia

**Regional methane leakage value used for Canning Basin

Note: Route from Australia to Japan. Hydrogen is synthesized into ammonia for power generation end-use, not cracked back into hydrogen. Conservative (national average) and aggressive (regional) upstream methane leakage values modeled.

Sources: RMI Analysis, Ammonia Energy Association, US DOT Maritime Organization, Methanol Institute, US DOE, Lloyds, UMAS, TechnoEconomic Assessment ZeroCarbonFuels, IPCC, Electricity Maps

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[3] It is worth noting in this context that the Australian Government's announced hydrogen production incentives (Hydrogen Headstart and the AUD2 per kg Hydrogen Production Tax Incentive) seek to limit access to government financial support to only "renewable hydrogen" projects that can demonstrate a "well to gate" emissions intensity of <0.6 kg CO_2-e per kgH_2 produced.

Recommendations for Policymakers

Policymakers need to formulate and implement strict and robust emissions accounting frameworks to govern their clean hydrogen markets, and to mitigate the potentially substantial emissions risks that will come with deploying more loosely regulated hydrogen products.

Globally, policymakers should move urgently to better coordinate across international efforts, and seek to enact complementary, lifecycle emissions-inclusive clean hydrogen standards that guard against carbon leakage in new hydrogen markets.

Over the next three months, policymakers can prioritize:

- Adopting and **updating ISO 19870 methodology with tighter standards and third-party verification** for upstream methane leakage, CO_2 permanence, and inclusion of H_2 warming potential;
- **Ensuring accurate reporting of emissions** for new technology and hard-to-measure processes, including green (e-ammonia) shipping, ammonia cracking, and N_2O scrubbing;
- Harmonizing and adopting certifications of hydrogen/hydrogen-derivative products based on an updated, more robust version of ISO 19870 methodology; and
- **Harmonizing (or better aligning) standards and definitions applicable across exporting and importing geographies, in particular across the main anticipated hydrogen trade corridors**.

In the EU, policymakers can ensure that the region's low-carbon hydrogen standard and emissions accounting framework is based upon on a **robust methodology and requirement for third-party verification for upstream methane leakage**, CO_2 permanence, and H_2 warming potential at every step of the value chain.

In the US, policymakers can similarly ensure that the rules governing the Clean Hydrogen Production Tax Credit (45V) account for real upstream methane leakage rates, and do not lock into outdated values that cannot be adapted when more accurate carbon measurement tools come online.

In Japan and South Korea, policymakers can prioritize extending the scope of "low-carbon" and "clean" hydrogen definitions and standards to **include life-cycle emissions of molecules beyond the current well-to-gate definitions**.

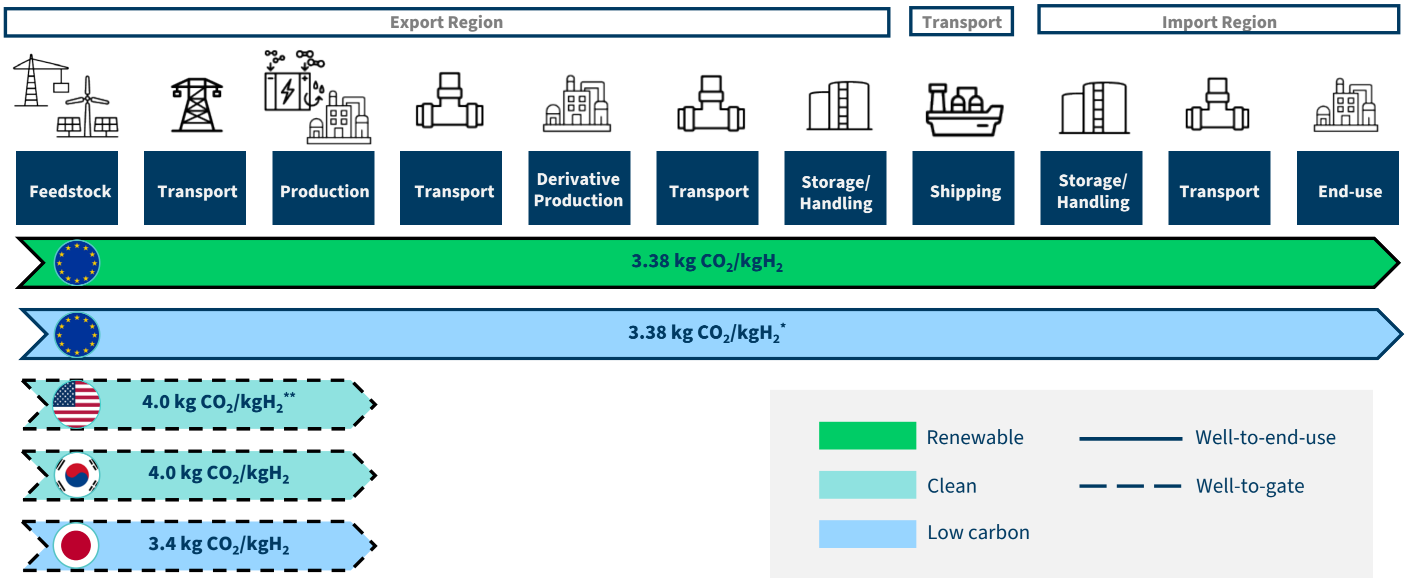
If these first mover markets get standards right and seek to harmonize them, they could influence and successfully shape how other international hydrogen market players govern hydrogen products' emissions intensity, enabling the achievement of decarbonization objectives and setting global hydrogen markets up for sustained success.

Appendices

Appendix A: Standards and definitions in different markets

Standards and definitions for “renewable” vs. “low carbon” vs. “clean” hydrogen still diverge widely across markets, with several key countries not accounting for full value chain emissions.

Exhibit A1: Overview of hydrogen standards for European, US, and Southeast Asian markets



*Methodology for low-carbon hydrogen has not been officially released by the European Commission yet. It is expected to be harmonized with the methodology for RFNBOs.

**The US Clean Hydrogen Production Standard threshold is 4.0 kg CO_2/kg H_2, whereas qualifying for 45V tiered tax credit threshold is between 0.45 kg CO_2/kgH_2 and 4.0 kg CO_2/kgH_2.

Appendix B: Methodology and trade routes modeled[4]

Exhibit B1: Trade routes modeled

Scenario	Transport Vector (method of transport)	End Product	Type of Scenario (H_2 production method)
Australia > Japan	Ammonia (shipping)	NH_3	🔵
Domestic EU	Hydrogen (pipeline)	H_2	🟢
Norway > EU (NL)	Hydrogen (pipeline)	H_2	🔵
US Gulf Coast > Japan	Ammonia (shipping)	NH_3	🔵
US Gulf Coast > EU (NL)	Ammonia (shipping)	H_2	🔵 🟢

🔵 Blue H_2 (fossil fuels + CCS) 🟢 Green H_2 (electrolysis)

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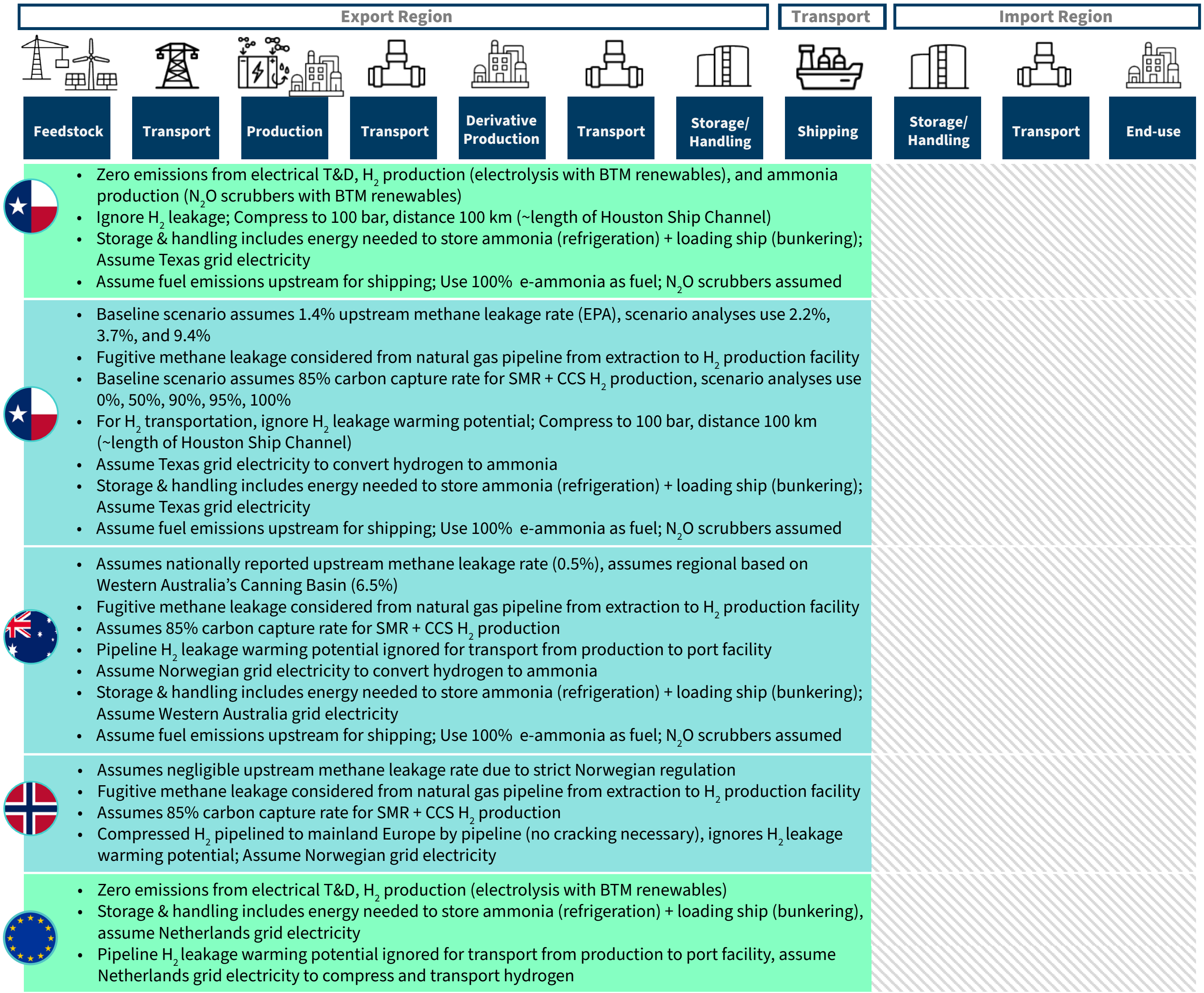
[4] EU RFNBO methodology modeled. Methodology for low-carbon hydrogen has not been officially released by the European Commission yet. It is expected to be harmonized with the methodology for RFNBOs.

Exhibit B2: Export Assumptions: US Gulf Coast (Texas), Australia, Norway, Europe (Netherlands)



- Zero emissions from electrical T&D, H_2 production (electrolysis with BTM renewables), and ammonia production (N_2O scrubbers with BTM renewables)
- Ignore H_2 leakage; Compress to 100 bar, distance 100 km (~length of Houston Ship Channel)
- Storage & handling includes energy needed to store ammonia (refrigeration) + loading ship (bunkering); Assume Texas grid electricity
- Assume fuel emissions upstream for shipping; Use 100% e-ammonia as fuel; N_2O scrubbers assumed

- Baseline scenario assumes 1.4% upstream methane leakage rate (EPA), scenario analyses use 2.2%, 3.7%, and 9.4%
- Fugitive methane leakage considered from natural gas pipeline from extraction to H_2 production facility
- Baseline scenario assumes 85% carbon capture rate for SMR + CCS H_2 production, scenario analyses use 0%, 50%, 90%, 95%, 100%
- For H_2 transportation, ignore H_2 leakage warming potential; Compress to 100 bar, distance 100 km (~length of Houston Ship Channel)
- Assume Texas grid electricity to convert hydrogen to ammonia
- Storage & handling includes energy needed to store ammonia (refrigeration) + loading ship (bunkering); Assume Texas grid electricity
- Assume fuel emissions upstream for shipping; Use 100% e-ammonia as fuel; N_2O scrubbers assumed

- Assumes nationally reported upstream methane leakage rate (0.5%), assumes regional based on Western Australia's Canning Basin (6.5%)
- Fugitive methane leakage considered from natural gas pipeline from extraction to H_2 production facility
- Assumes 85% carbon capture rate for SMR + CCS H_2 production
- Pipeline H_2 leakage warming potential ignored for transport from production to port facility
- Assume Norwegian grid electricity to convert hydrogen to ammonia
- Storage & handling includes energy needed to store ammonia (refrigeration) + loading ship (bunkering); Assume Western Australia grid electricity
- Assume fuel emissions upstream for shipping; Use 100% e-ammonia as fuel; N_2O scrubbers assumed

- Assumes negligible upstream methane leakage rate due to strict Norwegian regulation
- Fugitive methane leakage considered from natural gas pipeline from extraction to H_2 production facility
- Assumes 85% carbon capture rate for SMR + CCS H_2 production
- Compressed H_2 pipelined to mainland Europe by pipeline (no cracking necessary), ignores H_2 leakage warming potential; Assume Norwegian grid electricity

- Zero emissions from electrical T&D, H_2 production (electrolysis with BTM renewables)
- Storage & handling includes energy needed to store ammonia (refrigeration) + loading ship (bunkering), assume Netherlands grid electricity
- Pipeline H_2 leakage warming potential ignored for transport from production to port facility, assume Netherlands grid electricity to compress and transport hydrogen

🟦 Blue hydrogen (fossil fuels + CCS) production assumptions modeled

🟩 Green hydrogen (electrolysis) production assumptions modeled

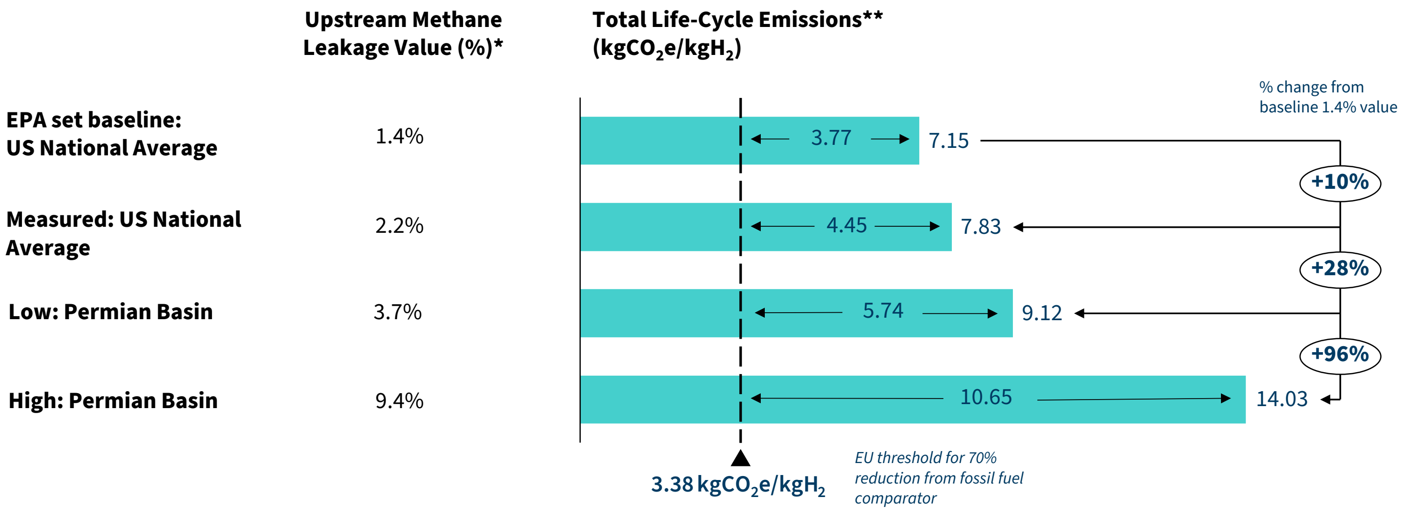
Exhibit B3: Import Assumptions: Europe (Netherlands), Japan

	Export Region							Transport	Import Region		
	Feedstock	**Transport**	**Production**	**Transport**	**Derivative Production**	**Transport**	**Storage/ Handling**	**Shipping**	**Storage/ Handling**	**Transport**	**End Use**
🇪🇺									• Storage & handling uses Netherlands (NL) grid electricity • Ammonia used as heat source for cracking, assume N_20 scrubbers • For H_2 transportation, ignore H_2 leakage warming potential • Assume zero emissions from H_2 combustion; Electrical energy to run facility based on NL grid intensity		
🇯🇵									• Tokyo prefecture grid emissions intensity assumed for ammonia storage & handling and transport (pipeline) from port to end-use facility • 100% ammonia firing for power generation assumed, assume 100% effective N_2O scrubbers for ammonia combustion • Energy content and carbon intensity of coal combustion based on sub-bituminous grade		

Appendix C: Calculated emissions intensities of various scenarios

Accurate emissions accounting will require using local and independently verified data for upstream methane leakage, because relying on national averages can produce inaccurate (and underestimated) life-cycle emissions values.

Exhibit C1: Calculated emissions intensity of landed blue hydrogen in EU using different upstream methane leakage values

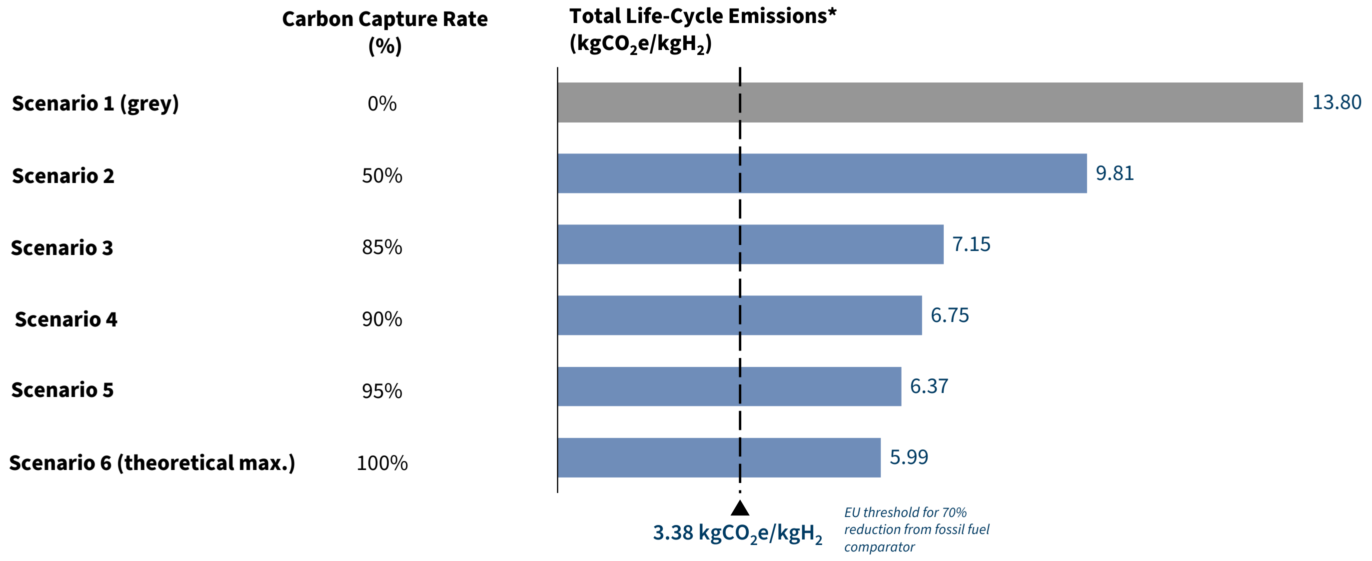


Sources: EPA, Kairos Aerospace, EDF, Stanford, RMI Analysis

***Life-Cycle emissions calculated for transatlantic route from US Gulf Coast to Europe (NL). Assuming 85% carbon capture rate across all scenarios*

Even with aggressive carbon capture rates, blue hydrogen from the US Gulf Coast will have a hard time qualifying as low carbon when imported to the EU.

Exhibit C2: Calculated emissions intensity of landed blue hydrogen in EU using different carbon capture rates



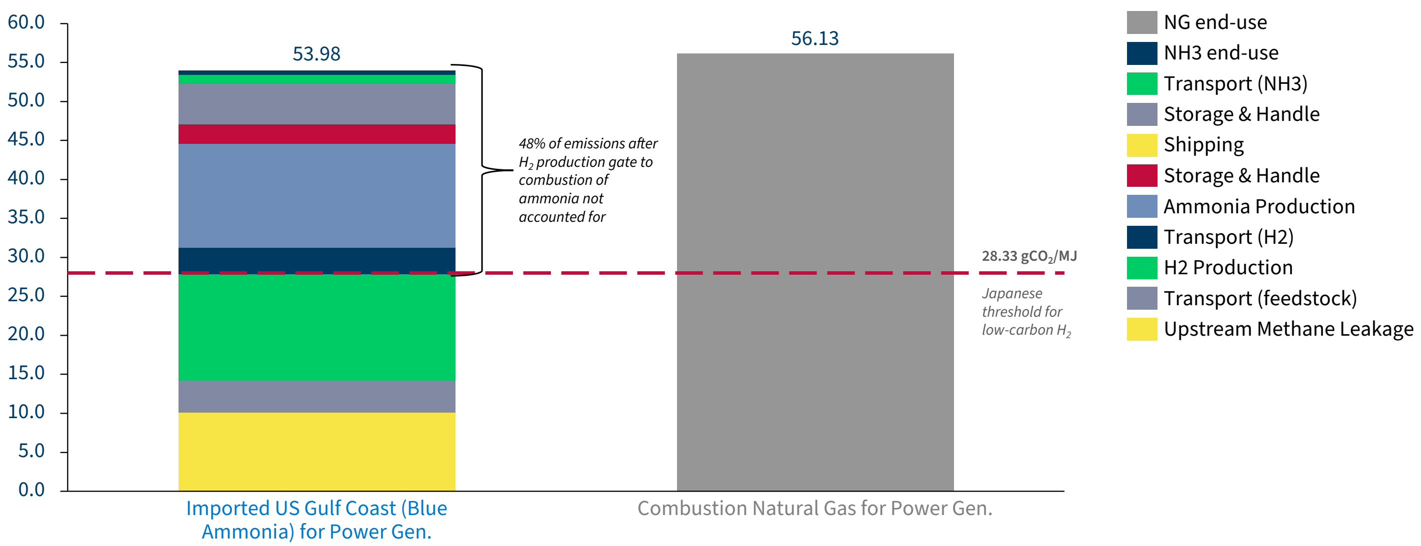
**Life-Cycle emissions calculated for transatlantic route from US Gulf Coast to Europe (NL). Assuming 1.4% upstream methane leakage rate across all scenarios*

Sources: RMI Analysis , Ammonia Energy Association, US DOT Maritime Organization, Methanol Institute, US DOE, Lloyds, UMAS, TechnoEconomic Assessment ZeroCarbonFuels

In Japan, using blue ammonia imported from the US Gulf Coast in power plants will result in emissions comparable to using imported liquefied natural gas. 48% of these life-cycle emissions would not be accounted for under the current Japanese standard for low-carbon hydrogen.

Exhibit C3: Calculated emissions intensity of landed blue ammonia versus combustion of natural gas in Japan

gCO_2e/MJ



Note: Transatlantic route from US Gulf Coast to Japan. Note, hydrogen is synthesized into ammonia for power generation end-use, not cracked back into hydrogen.

Sources: RMI Analysis, Ammonia Energy Association, US DOT Maritime Organization, Methanol Institute, US DOE, Lloyds, UMAS, TechnoEconomic Assessment ZeroCarbonFuels, IPCC, Electricity Maps

The Green Hydrogen Catapult is a global initiative convened with the support of the UN High Level Champions for Global Climate Action and hosted by RMI. It was founded and is led by a group of leading global industrials aiming to accelerate green hydrogen adoption at scale.
www.greenh2catapult.com

The Green Hydrogen Organisation (GH2) is a global non-profit foundation incorporated in Switzerland. GH2 was established in 2021 to dramatically accelerate the deployment of green hydrogen and to differentiate green hydrogen from production pathways based on fossil fuels. GH2 is a multistakeholder organisation with a wide range of corporate members, government and civil society partners. In addition to its office in Geneva, GH2 has a presence in Beijing, Chennai, Jakarta, London, Nairobi, Oslo and Perth.
www.gh2.org

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