Blue Hydrogen

Technology Challenges, Weak Commercial Prospects, and Not Green

David Schlissel, Dennis Wamsted, Seth Feaster, Suzanne Mattei, Omar Mawji and Tom Sanzillo

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Executive Summary

- Blue hydrogen requires methane; production is energy-intensive
- Blue hydrogen requires carbon capture and storage (CCS)
- Commercial CCS projects have never achieved the industry target rate over time, despite years of efforts
- CCS projects have been very costly
- Cleaner competition has big head start, investments
- Must play catch-up to other technologies, especially batteries
- Blue hydrogen markets likely to shrink due to green competition

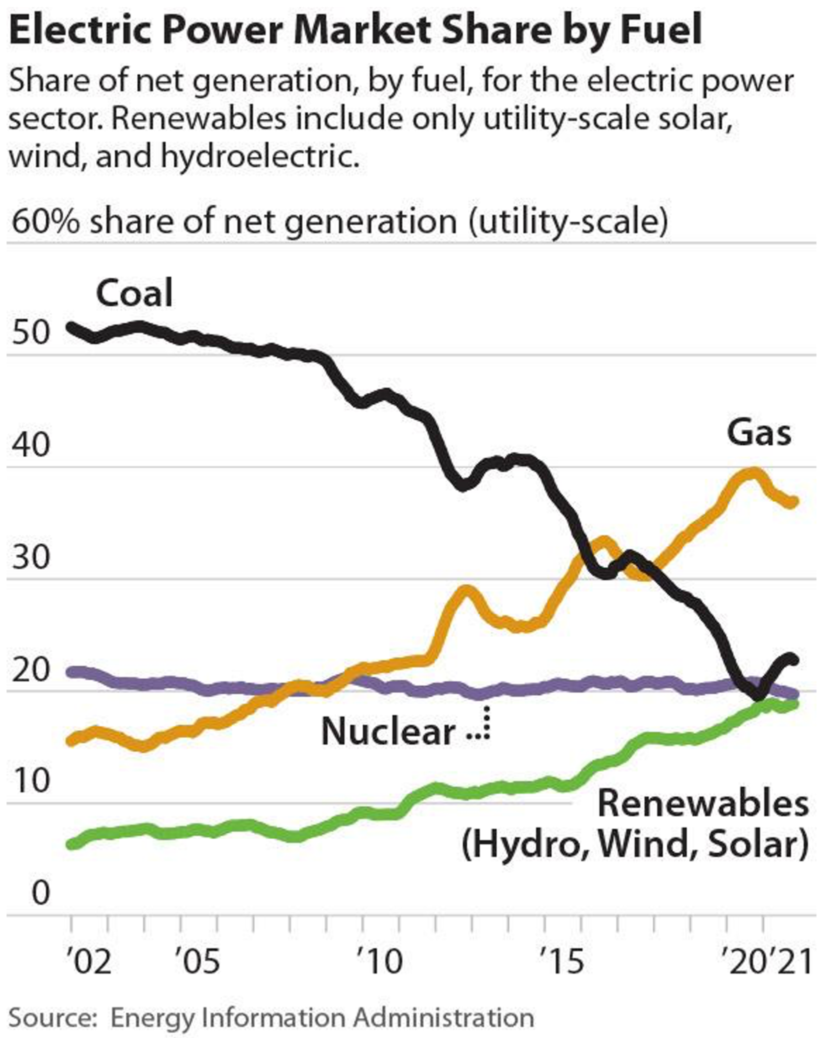
Overview

- **Context:** The energy transition
- **Federal law:** The new federal hydrogen program and incentives
- **The reality of CCS**
- **The cost of carbon capture**
- **Blue hydrogen = fossil fuels**
- **Market viability and competitive landscape**

Context: The Energy Transition and Climate Change

The Energy Transition

The energy transition is a fundamental shift in how the U.S. and the world obtain energy for electric power, industry, transportation, and residential and commercial needs.



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The Energy Transition

- Transition means change
- Change means choices
- Market forces will be a driving factor
- States will lead the way

The Energy Transition: Menu of Effective Options to Achieve Net-Zero Greenhouse Gas Emissions

Energy Sources

- **Renewables:** Solar, wind, hydropower, geothermal
- **Energy storage:** Batteries
- **Electrification:** Cuts local emissions, improves as grid gets cleaner
- **Hydrogen?**

Electricity Use

- **Energy efficiency:** Design/retrofit, heat pumps
- **Demand response:** Reduces non-essential use of energy during times of peak demand

Methods to Produce Hydrogen

- **Green hydrogen:** Made from water using electrolysis powered by renewable energy
- **Pink hydrogen:** Water electrolysis using nuclear energy
- **Blue hydrogen:** Made from natural gas typically using steam methane reforming (SMR), but requires CCS technology
- **Grey hydrogen:** Made from natural gas without CCS
- **Black/brown hydrogen:** Made from coal without CCS

Question of the Day:

Does blue hydrogen belong on the list of effective clean energy options?

Federal and State Roles:

The Hydrogen Program and Incentives

The Federal Role

- **Infrastructure Investment and Jobs Act:** Provides financial incentives for renewable energy, storage/containment technology, electrolysis efficiency and hydrogen production
- **Plans 4 hydrogen hubs:** 1 green, 1 blue, 1 nuclear, 1 any type
- **Application:** U.S. Department of Energy will invite submittals by May 14
- **Decisions due:** Within one year of application deadline
- **Total hydrogen hub spending proposed:** $8 billion

States: The Laboratories for Change

- Must decide how best to build climate change solutions at the local level

- To boost local economies effectively, states need to choose job-generating businesses with real staying power

Due Diligence Questions for State Policymakers: Making Decisions on Blue Hydrogen and CCS

- **What is the real-world experience** in annual average efficiency rates achieved on targeted emissions streams?
- **What onsite emissions escape** the scope of CCS coverage?
- **What is the resulting total onsite carbon removal rate?**
- **What is the complete system cost of CCS?**
- Is blue hydrogen with CCS **attractive to investors?**
- Does blue hydrogen have **a robust market future?**

Reality Check:

CCS Real-World Results and Limitations

Limited and Sometimes Misleading Data

- Limited number of commercial-scale projects:
  - Only two commercial plants in the world are producing hydrogen from natural gas with CCS, and capturing more than 1 million metric tons per annum (mtpa) of CO_2
  - Only one operating commercial coal plant with CCS exists in the world
  - No commercial natural gas power plant in the world with CCS
- Limited amount of publicly disclosed data

How to Measure Success: What Would Make Blue Hydrogen as Clean as Green Hydrogen?

- 100% capture of CO_2 emitted by hydrogen production from natural gas
- 100% capture of CO_2 emitted by onsite power source
- Full control of emissions from upstream methane extraction, processing and transport to the plant
- Full control of emissions from downstream CO_2 leakage from transport and storage

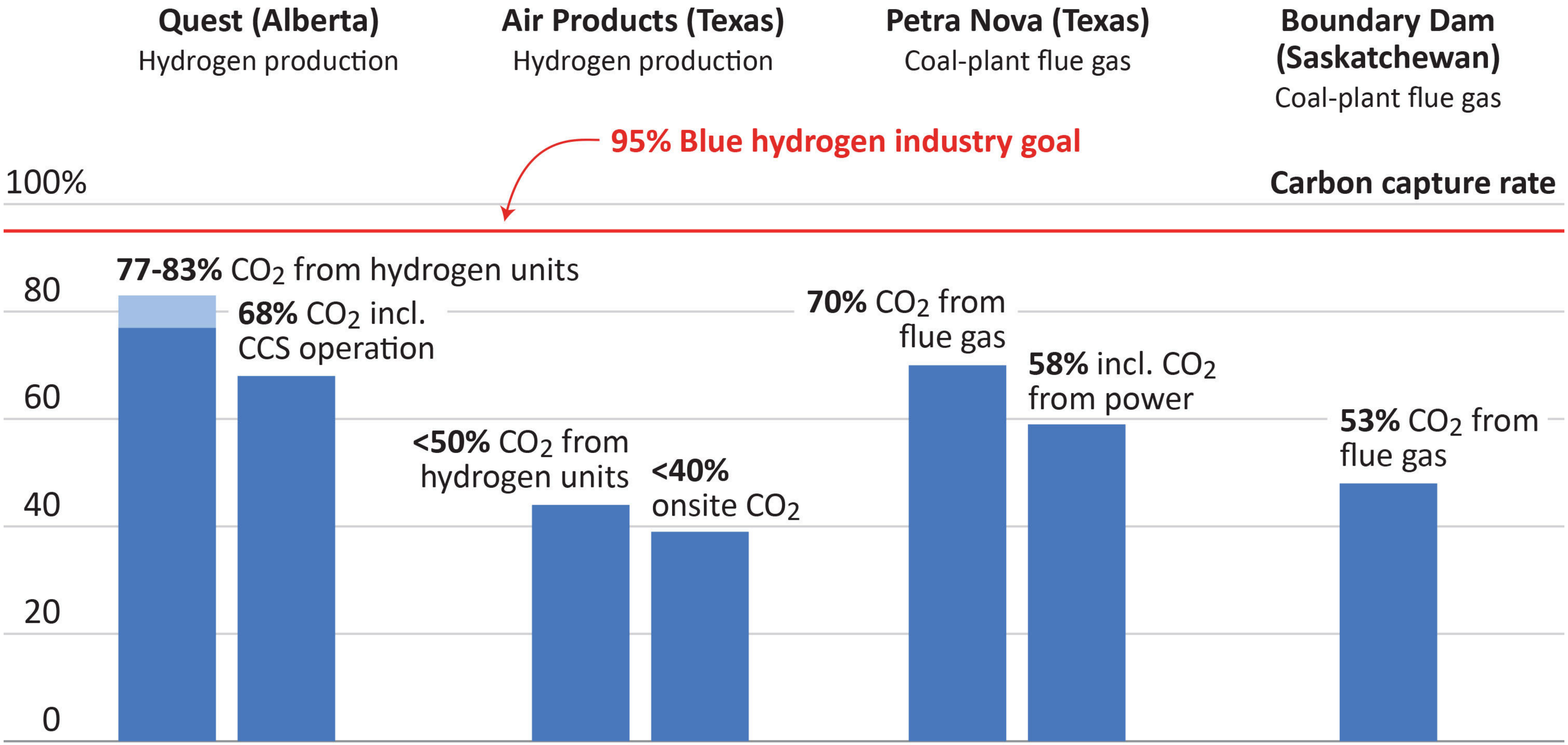
Reality Check on CO_2 Emissions Capture at Commercial Hydrogen-From-Gas Plants

Developers of blue hydrogen plants are promising 90% to 95% capture rates

> "While these high capture rates are assumed in many national strategies and major reports, they have not yet been achieved in a large-scale commercial plant"

— T. Longden, *et al.* 'Clean hydrogen? – Comparing the emissions and costs of fossil fuel versus renewable electricity-based hydrogen. Applied Energy. 306: 1181-45. 2021, p. 5

Reality Check: Real-World CO_2 Capture Far Below Promised Rate



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Reality Check: Air Products (Port Arthur, Texas) Limited Effectiveness and Limited Scope

- The CCS system captures <50% of the CO_2 generated by the hydrogen production units
- Does not capture any emissions from the power produced onsite to run the hydrogen production units
- Combining the two, the effective onsite CO_2 capture rate is <40%
- Does not account for methane leaks upstream during extraction, processing and transportation, or CO_2 leaks downstream before injection

Reality Check: Quest (Alberta, Canada) Limited Effectiveness and Limited Scope

- CCS project built by Shell at the Scotford upgrader facility in Alberta
- Produces hydrogen from natural gas by steam methane reformation and uses it to upgrade bitumen (heavy oil) to generate lighter synthetic crude oils
- Annual average CO_2 capture rate on hydrogen units ranges from 77% to 83%, but 5-year average is just 68% when including the uncaptured CO_2 from CCS operation, transport and storage (about 35% of total facility emissions)
- Does not capture emissions from power used to run hydrogen production units
- Does not account for methane leaks upstream during extraction, processing and transportation; CO_2 leaks downstream before injection; or emissions from end-use combustion of synthetic crude oil produced

Reality Check: Petra Nova (Thompsons, Texas) Coal Power Plant with CCS, Mothballed May 2020

- One of only two utility-scale coal CCS projects built worldwide
- Designed to capture CO_2 from a 240MW flue-gas slipstream from Unit 8 at the W.A. Parish coal plant owned by NRG Energy
- Began operations in early 2017; target capture rate was 90%
  - Actual CO_2 capture rate averaged 70% from 2017 through 2019
  - Does not include CO_2 emissions from gas-fired combustion turbine used to power facility; adding that lowers total capture rate to 58%

Reality Check: Boundary Dam (Saskatchewan, Canada) Coal Power Plant with CCS

- Project came online in late 2014; CO_2 capture target was about 90% of total projected emissions, or 1 million metric tons annually (mtpa)
  - Operational data show the actual CO_2 capture rate between October 2014 and December 2021 was 53%
  - Project has never reached the 1 mtpa capture target and has lowered the goal significantly since it came online
  - Serious problem with CO_2 compression system in 2021 prevented or impaired capture for several months; highlights the complexity of the process: When part of the system fails, the entire system fails

Reality Check: Major Commercial-Scale CCS Failures

- Kemper / Southern Company
  - Project designed to gasify lignite; capture CO_2 prior to combustion
  - Cost initially pegged at $3 billion; planned startup date of 2014
  - Project cancelled in 2017 after costs ballooned to $7.5 billion
- Edwardsport / Duke Energy
  - Designed to gasify coal
  - Cost when proposed in 2006 was $2 billion; jumped to more than $3.5 billion by completion in 2013
  - Plan to add CCS dropped after Duke found the costs would be excessive

CCS is Expensive to Build and Operate: Who Will Pay?

The Two Existing Commercial-Scale Hydrogen Projects That Capture >1 mtpa CO_2 Were 2/3 Funded by Government

- The Air Products hydrogen plant in Port Arthur, Texas, cost roughly $430.6 million, but the U.S. Department of Energy provided 66% ($284 million) of the total, with remainder covered by Air Products.
- The Quest CCS system cost about $1.06 billion, but the Alberta provincial government supplied $583 million in a loan, and the Canadian federal government added $94 million in grant money—64% in public funds (plus 2-for-1 carbon credits from the Alberta provincial government).

High Costs for Carbon Capture

Achieving high capture rates is more costly.

- DOE estimates the cost of capturing CO_2 from coal plants is $60-$65 per metric tonne (or $55-$59 per ton) of CO_2. As we've seen, the capture rates for coal have been very low.
- The Quest system reported costs that averaged $63.70 per ton for capture rates below 85%.
- For rates above 85%, the Longden study published in Applied Energy found that five of seven cost estimates were more than $80/ton and two were more than $120/ton.
- CCS proponents acknowledge that this cost must be reduced to about $30 per metric tonne (which is $27 per ton) by 2030 for CCS to be financially viable. They have a long way to go.

High Costs for Carbon Capture

- Some misleadingly claim that the costs of capturing CO_2 already are declining but there is no evidence to support this claim. Only the estimates of the future costs capturing CO_2 at plants that have not yet been built have declined.
- CO_2 concentrations in the flue gas from natural gas-fired plants is much lower (~4%) than from coal plants (~14-15%). Therefore, capture from gas plants can be expected to be more energy intensive and therefore more expensive.
- Note: These capture costs estimates do not include the costs for compressing, transporting, injecting and monitoring geologically stored CO_2 – which have been estimated to add another $20-$25 per ton to the total cost of capture and storage. But that's only an estimate.

Other Cost Concerns for States to Consider When Reviewing Natural Gas-Based Hydrogen Proposals

- Siting and constructing new pipelines and compression stations for natural gas, hydrogen and CO_2 transport—plus storage facilities for gases where needed—add costs and time
- Volatility of natural gas prices; potential new costs to better control upstream methane; and potential accidents and liabilities
- Oversight costs: More expenses for staffing to permit and monitor projects, more violation proceedings

Blue Hydrogen = Fossil Fuels

Blue Hydrogen Projects Are Fossil Fuel Projects: Limited Value for Investors Seeking Green Credentials

- Natural gas is primarily composed of methane. Methane is a powerful greenhouse gas, 86 times more powerful than CO_2 over a 20-year period.
- Venting and fugitive methane emissions from drilling and pipeline transport of natural gas are a big problem; aerial and satellite data show higher levels of methane pollution than previously estimated.
- Reducing these emissions would require substantial investment by drilling and pipeline companies; extensive, vigorous monitoring and enforcement; elimination of emissions is likely not possible.

No EPA Standards Exist to Define and Monitor Natural Gas Extraction/Transport Claiming to Be "Responsibly Sourced"

- The Environmental Protection Agency (EPA) has not established government standards for "responsibly sourced" natural gas.

- EPA's past efforts based on 2012 and 2016 regulations to curb methane emissions from extraction and pipeline transport have been ineffective, with an annual decline of only 0.3% from 1990 through 2019.

No EPA Standards Exist to Define and Monitor Natural Gas Extraction/Transport Claiming to Be “Responsibly Sourced”

- EPA seeks to develop new methane standards but received more than 280,000 comments from industry, think tanks and public interest organizations in a public review period that closed January 31, 2022.

- The final details of the regulations will take a long time to be worked out, and implementation and enforcement will be a challenge.

Market Prospects and An Intensely Competitive Landscape

Blue Hydrogen's Market Prospects: Weak and Vulnerable

- Blue hydrogen technology: High costs and uncertainties
- Many promises but a weak track record
- Government investment has not solved blue hydrogen's cost issue; in contrast, the U.S. Department of Energy's SunShot Initiative cut solar energy costs by 75% between 2011 and 2017
- Other green technologies are improving in cost-effectiveness

Time Is Not on Blue Hydrogen's Side

By the time new blue hydrogen plants are up and running,

the potential markets likely will be eclipsed—

by greener, cheaper energy options.

Late to the Party: Blue Hydrogen Is a Competitive Laggard Behind the Innovation Curve in Multiple Markets

- Utility-scale power: **Solar power** is expected to account for almost half (46%) of utility-scale power generation capacity installed in U.S. in 2022
- Peak demand power: **Battery storage** advances will likely eclipse blue hydrogen in meeting peak power supply needs
- Home and commercial heat: **Electrification** is already advancing for home and building heat, with none of hydrogen's technological challenges
- Transportation: **Electric vehicles** will likely eclipse hydrogen (green or blue) even for trucks, leaving only very limited transportation markets
- Industry: Fertilizer makers and certain manufacturers needing high-temperature heat will likely favor **green hydrogen** over blue

What Does This Mean for Jobs in Blue Hydrogen?

- Potential for robust future as a reliable, growing jobs engine is highly questionable
- Likely to see declining production levels over time
- Likely to see job layoffs and a diminishing employment trajectory
- May see stranded assets

Investors Are Wary

- The Global CCS Institute (2021) admits: “From a business perspective, there are barriers to financing CCS projects. CCS projects are perceived as high-risk (driving up the cost of capital) and are capital intensive.”
- Enchant Energy said it would find private investors to fund a $1.5 billion proposed CCS retrofit at the coal-fired San Juan Generating Station in New Mexico, but it didn’t happen; now, the company seeks $1 billion in federal funding to cover two-thirds of the project’s construction costs.
- The Global CCS Institute asserts government capital grants are required and it even advocates for governments to “mandate specialist financiers—such as development banks, multilateral banks and export credit agencies—to support CCS investments.”

CEOs Are Skeptical

- Francesco Starace, CEO of Enel, 2021: "The fact is, it doesn't work, it hasn't worked for us so far … And there is a rule of thumb here: If a technology doesn't really pick up in five years—and here we're talking about more than five, we're talking about 15, at least—you better drop it."

- Brian Gutknecht, GE Power chief marketing officer, 2019: "At this point, it's not economically viable to use carbon capture and sequestration at scale."

- WSP Global study for ADM (large ethanol producer), 2020: "The ability to capture stack emissions and sequester them is likely 10 years out, due to the technology and energy needed to separate and process the stack gas sufficiently to inject the CO_2 in the sequestration well."

Private Investors Are Heavily Engaged in Green Energy

- Private equity firm Blackstone announced in January 2022 it is investing $3 billion in Invenergy, a major renewable energy developer.
- Copenhagen Infrastructure Partners (CIP, world's largest dedicated fund manager with greenfield renewable energy investments), announced it will make €100 billion in green energy investments by 2030.
- Carlyle recently brought its total capital commitments to renewable and sustainable energy over the past 24 months to more than $1.2 billion.
- BlackRock announced a large emerging-markets renewable fund in November 2021, with an emphasis on emerging economies across Africa, Asia and Latin America with a focus on renewable energy, energy efficiency, transmission/distribution, and energy storage.

Green Hydrogen: With Rising Investment and Policy Support, a Transition Energy Worth the Time, Money and Resources

- **On the move**
  - From cottage industry to gigawatt scale
  - From venture capital to commercialization
- **Building blocks in place**
  - Innovation curve—following solar & wind—meeting goals ahead of schedule
  - Manufacturing supply chain accelerating; electrolyzer expansion to scale
  - $100 + trillion capital shift to transition (BlackRock)
- **Public and private policy support for solutions**
  - South Korea, Japan, China are leaders; U.S. is late to the game
  - BlackRock and industry leaders—demanding transition plans

Conclusion

The Bottom Line for States' Decision-Making

- The blue hydrogen industry must provide more transparency on CCS effectiveness, onsite emissions that escape capture, upstream emissions, downstream risks and full costs.
- States should make decisions based on:

  Robust, accurate data

  Comprehensive environmental and costs assessments

  Vigorous analysis of the long-term market and job impacts in light of competition

Question of the Day:

Does blue hydrogen belong on the list of effective clean energy options?

NO

Analytical Notes and References

- Blue Hydrogen: The Federal Role
- Reality Check on CO2 Emissions Capture at Hydrogen-From-Gas Plants
- Costs of Blue Hydrogen Production Too High Without Fiscal Life Support
- Blue Hydrogen Has Weak Case When It Comes to Emission Reductions
- Blue Hydrogen Has Extremely Limited Future in U.S. Energy Market

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