A Hydrogen Future? Exploring Pathways to Decarbonization

RFF Live

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Decarbonized Hydrogen in the US Power and Industrial Sectors: Overview

• Our focus is on how to design policy for decarbonized hydrogen
  • So, there are two main questions that guide our report:

1. What are the net climate benefits of decarbonized H₂?
   • What are the emissions displaced by using decarbonized H₂?
   • What are the emissions from the production of decarbonized H₂?

2. After accounting for its net climate benefits, is decarbonized H₂ likely to be competitive with high- and low-carbon alternatives?
   • What are the costs of decarbonized H₂?
   • What are the costs of high- and low-carbon alternatives to decarbonized H₂?

• Note: we evaluate decarbonized H₂ for use only in the power and industrial sectors
  • H₂ has potential in the transportation, residential, and commercial sectors, but outside our scope
Hydrogen Production Processes, Indicated by Color

Consumes 6% of global natural gas supply
• Gray H₂ accounts for nearly all US hydrogen production
• CH₄ + H₂O + Heat → H₂ + CO₂

Together, responsible for over 2% of global CO₂ emissions

Consumes 2% of global coal supply (predominant in China)
What are the Emissions from Hydrogen Production?

- Carbon Dioxide (CO₂) Emissions Vary by Hydrogen Production Method

- **Brown H₂** has nearly double the emissions of **Gray H₂**, reflecting the different CO₂ intensities of coal and natural gas.

- Emissions from **Blue H₂** (from natural gas reforming) depend on capture rate.
  - Partial capture: Process CO₂
  - Full Capture: Heat and Process CO₂

- **Green H₂** has essentially zero emissions.
  - CO₂ from electrolytic H₂ using average US grid power are roughly double Gray H₂ emissions.

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Source: International Energy Agency 2019
What are the Current and Projected Costs of Hydrogen Production?

- Does not include H₂ transportation and storage costs, which are significant

Blue H₂ costs depend on capture rate (partial vs. full)

Cost of gray H₂ as low as $1.05/kg today

• Green H₂ not competitive today, but has significant long-term potential
• Electrolyzer cost, utilization, and power price are determinants

Blue H₂ cost projection with CCUS cost decline and switch to ATR

Bars indicate cost ranges; circle indicates point estimate. Gray and blue hydrogen assume a delivered natural gas price of $3.50 per million British thermal units. Estimates exclude the social costs of greenhouse gas emissions. "SMR" refers to "steam methane reforming," "CCUS" refers to carbon capture, utilization, and storage," and "ATR" refers to autothermal reforming. Sources: Friedmann et al. (2019); International Renewable Energy Agency (2019); Hydrogen Council (2020); Mathis and Thornhill (2019).
What are the Benefits of Decarbonized Hydrogen?

- CO₂ Reduction from Zero-Carbon Hydrogen, by Application and Fuel or Feedstock Displaced

Climate benefit from using decarbonized hydrogen varies widely by application:

- CO₂ content of energy source (e.g., coal vs. natural gas)
- Efficiency of energy use (e.g., natural gas vs. gray hydrogen)
- Carbon in the final product (e.g., urea and methanol)
Is Decarbonized Hydrogen Socially Beneficial?

- Example 1: Comparison of Power from Hydrogen, Unabated Natural Gas, and Natural Gas with CCUS

Zero-carbon hydrogen at a low delivered cost range of $1/kg to $2/kg

Natural gas at $3.75/MMBtu and range of $61/tCO₂ (2030 SCC) to $84/tCO₂ (2050 SCC)

Upshot: Decarbonized H₂ could be socially efficient for power, but likely only in the long term
- With delivered cost of H₂ less than $1.20/kg

Why so long-term?
- Relatively low climate benefit
- Low cost of high-carbon alternative
- Moderate cost of low-carbon alternative
Is Decarbonized Hydrogen Socially Beneficial?

- Example 2: Marginal Costs of Decarbonized Hydrogen versus Gray Hydrogen in Ammonia / Refining

Marginal cost of Blue H₂ with 53% capture is roughly equal to the 2020 SCC of $50/tCO₂.

Marginal costs of Blue H₂ with 90% capture and Green H₂ could be far less than the 2030 SCC and 2050 SCC.

**Upshot**
Decarbonized H₂ may already be socially efficient
- And deeper decarbonization efficient with projected cost reductions

Why so near-term, compared with previous example?
- Greater climate benefit
- Higher cost of high-carbon alternative
- No low-carbon alternatives
Policy Options

• Carbon tax: Doesn’t pick winners. Not politically feasible

• Clean Energy Standard: Doesn’t pick winners; more complex for industry than in the power sector
  • Extra credit for DH2 mixed in the natural gas

• DH2 standard – too expensive now

• Green government procurement: complimentary policy is easily implemented and may incentivize market/technologies; costly to government

• 45Q-like tax credit: Familiar tool, can pass through budget reconciliation; costs the government money
Case I. Grey to Blue Hydrogen made and used by a manufacturing plant

\[ \text{H}_2 = \text{CO}_2 \]
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\[ \text{H}_2 = \text{CO}_2 \]
Case II. Grey to Blue Hydrogen to a manufacturing plant

= CO2
Case II. Grey to Blue Hydrogen to a manufacturing plant

= CO₂
Case III. Grey to Blue Hydrogen sold in market

1. Grey Hydrogen production
2. Blue Hydrogen production
3. CO₂ capture
4. Market for mixed hydrogen

= CO₂
Case IV. Grey to Blue Hydrogen sold in market with natural gas substitution
Case IV. Grey to Blue Hydrogen sold in market with natural gas substitution

\[ \text{Market} = \text{CO}_2 \]

\[ \text{Blue H}_2 \rightarrow \text{Market} \]

\[ \text{Gray H}_2 \rightarrow \text{Market} \]

\[ \text{Mixed H}_2 \rightarrow \text{Factory} \]

\[ = \text{CO}_2 \]
DH2 Tax Credit details

• Options for credit basis: CO2 reduction, DH2 produced
• One program or two (addressing partnerships)
• Establishing the baseline (including pipeline leaks)
• Coordination with 45Q
• Size of the credit: SCC or cost basis
• Timing issues
• Monitoring, reporting and verification
DH2 Tax Credit Examples

- Company/plant both makes and consumes hydrogen. Company puts in an application to add a carbon capture facility on site. They get the credit equal to the CO2 reduced from their previous baseline, as reported (I assume) to EPA under the GHGRP and based on whatever process they are using.

- A refinery buys SMR-based hydrogen from another and gets it through a dedicated pipeline. The two companies form a partnership to add CC to the SMR facility. This creates a 60% reduction credit against their GHG baseline. The credit goes to the partnership. The partnership contract contains the details of how the credit is split and the price. Where is the pipeline company in all this? If the credit is on CO2 reduced in use, then any pipeline leaks deduct the CO2e from any leaked H2. This means the partnership needs to include the pipeline company.

- The DH2 is sold in a market. There are no dedicated pipelines. A refinery pays a premium to buy the DH2 but gets a credit for using the DH2 rather than the SMR H2. The hydrogen it buys is a mix of DH2 and H2 because the pipelines are not dedicated (just like renewable electricity situation). Somewhere there needs to be an accounting so this particular DH2 purchase is not counted twice (RECs/H2ECs). What happens with the producer? Have they applied separately? I think not. That would be double counting. And if there are pipeline leaks, that has to be figured in as well.