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Costs of Blue Hydrogen Production Too High Without Fiscal Life Support

Lack of Carbon Capture Progress Leading to Waning Investor Interest in Blue Hydrogen

The extremely limited number of utility-scale power plants and commercial-scale hydrogen plants equipped with carbon capture and storage (CCS) equipment is no anomaly. Costs have been high. Carbon capture systems for large-scale blue hydrogen production are not likely to succeed without permanent taxpayer-funded life support—a prospect that can reasonably be expected to become less and less popular with the public.

A. High Costs, Calls for Government Subsidies

A 2021 study published in *Applied Energy* examined a range of estimates and found achieving higher capture rates of carbon dioxide with CCS technology has required more costly systems than achieving lower rates. The researchers found five out of six estimates for costs of achieving capture rates equal to or below 70 percent were less than $80 per ton of CO_2 (t CO_2). For achieving capture rates above 85 percent, five of seven estimates were more than $80, and two of the estimates were more than $120. The study cautioned governments and energy policy strategists about relying on promises of 90 percent or higher CO_2 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 and have only recently been achieved in the Tomakomai CCS demonstration project, which required very high expenditure [which was $127/t CO_2 to achieve a 99% capture rate]."[1]

The cost for capturing emissions at the Quest hydrogen plant in Alberta, Canada,[2] from 2016 to 2020 averaged $63.70 per ton,[3] but achieved average capture rates of

[1] T. Longden. Clean hydrogen? – Comparing the emissions and costs of fossil fuel versus renewable electricity- based hydrogen. Applied Energy 306 January 2022, p. 5.
[2] Ownership of the Quest project is 90% Canadian Natural Resources and 10% Shell. Global CSS Institute. Facilities Database. Accessed January 16, 2022. https://co2re.co/FacilityData https://www.nsenergybusiness.com/features/top-carbon-capture-storage-projects/
[3] Averaging the annual costs per megawatt-hour, as reported in Quest's Annual Summary for 2020, over the five-year period of 2016-2020 and converting the amounts from Canadian dollars to U.S. dollars, the resulting figure is $63.70 per MWh in U.S. dollars. See: Shell Canada Energy. Project Quest Annual Summary for 2020. 2020, p. 10-4.

slightly more than 80% in its first couple years and under 80% in more recent years.[4]

In analyzing the full costs for captured CO_2 transport, required sequestration and monitoring costs are seldom disclosed. Longden (2021) reports that most current CCS cost estimates do not include transportation and storage costs; even when they do, they tend not to include long-term storage and monitoring costs.[5]

The International Energy Agency (IEA) observed in 2018 that costs of carbon capture were prohibitively high without government funding, stating:

> "It has been acknowledged in public presentations by Air Products that CO_2 capture from an industrial-scale SMR (steam methane reform), such as the highly energy efficient Port Arthur SMR facility, is not yet economic without considerable support in the form of external or government funding. That is due to high capital investment and high O&M costs."[6]

Indeed, two-thirds of the bill for the two existing CCS-equipped commercial hydrogen plants producing more than 1 million tons annually of CO_2 were funded by taxpayers.

- The U.S. Department of Energy (DOE) contributed two-thirds ($284 million) of the construction costs for the Air Products hydrogen project in Port Arthur, Texas, and the remaining portion of the $430.6 million price tag was covered by Air Products.[7]
- Similarly, Canadian provincial and municipal dollars covered almost two-thirds of the expenses to build the Quest hydrogen plant. The plant cost about $1.06 billion, but the Alberta provincial government contributed $583.5 million and the Canadian federal government supplied $94 million.[8]

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Moreover, the dilemma identified by the IEA in 2018 remains a key issue four years later. The Global CCS Institute, an advocacy organization, acknowledges the problem

[4] IEEFA. Reality Check on CO_2 Emissions Capture at Hydrogen-From-Gas Plants. February 2022.
[5] T. Longden, *op. cit.*, p. 6.
[6] International Energy Agency Greenhouse Gas Emissions Program (IEAGHG). The Carbon Capture Project at Air Products' Port Arthur Hydrogen Production Facility. December 2018, p. 94.
[7] *Ibid.*, p. 18.
[8] Figures are converted to U.S. dollars. See: The Canadian Press. Shell's Quest carbon capture project hits milestone of 5M tonnes. July 10, 2020. The plant is now owned by Canadian Natural Resources Ltd., with Shell retaining a 10% interest and serving as plant operator.

of attracting private investors to blue hydrogen projects because of the high capital costs and investor concerns about risk. It 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. Most funding therefore takes place on the balance sheets of large corporations—the corporate finance model. This means CCS investment risks are not reflected in the cost of capital, but lenders have full recourse to corporate assets. Smaller companies and those with constrained balance sheets can't fund CCS facilities this way. They require project finance, which limits recourse to the one funded project, compounding risks and leading to higher cost debt and higher overall project costs. This can create a funding gap."[9]

It declared that government capital grants are needed "to reduce the commercial debt CCS projects need."[10]

Sounding what could be perceived as an almost desperate note, the Global CSS Institute even advocated that governments could "mandate specialist financiers—such as development banks, multilateral banks and export credit agencies—to support CCS investments." It indicated that such specialist financiers could be forced to "provide low-cost loans and insurance to fund the most high-risk components of CCS projects."[11]

Given how long CCS technology has existed—and how many billions of taxpayer dollars have been sunk into research, demonstrations and full-scale projects—a call for mandatory financing does not inspire confidence.

B. After Years of Government Investment, CCS Technology Has Made Only Unimpressive Progress; No Evidence Is Apparent That This Will Speedily Change

CCS is not a new concept. It has been used in a variety of settings since 1972.[12] Yet the technology has racked up limited achievements despite years of public and private investment. A 2021 analysis comparing blue and green hydrogen concluded:

> "Carbon avoidance costs for high capture rates tend to be above \$80/t CO_2. In contrast, the cost of producing zero-carbon hydrogen from electrolysis could fall in the foreseeable future, and be cost-competitive with fossil fuel

[9] Global CCS Institute. Global Status of CCS 2021. 2021, p. 52.
[10] *Ibid.*
[11] *Ibid.*, p.52.
[12] IEEFA. Carbon Capture and Storage Is About Reputation, Not Economics: Supermajors Saving Face More Than Reducing Emissions. July 2020.

> options. This means that the economic case for fossil fuels with CCS is generally limited."[13]

Given the public and private investments made over decades, the outlook is not hopeful.

The U.S. Department of Energy began investing in CCS technology 13 years ago. Since FY2010, Congress has appropriated $14.2 billion for CCS-related research and development, including:

- $7.3 billion for funding within DOE's carbon management office;
- $3.4 billion in the 2009 recovery act for CCS development; and
- $3.5 billion in the 2021 Infrastructure Investment and Jobs Act (IIJA) for carbon capture activities.[14]

Through one initiative, DOE spent roughly $1.1 billion on specific CCS demonstration projects, primarily targeting commercial viability for coal plants and the industrial sector.[15] The Government Accountability Office (GAO) audited the effort in 2021. Of the 11 projects the DOE accepted into the program, only three—one coal project and two industrial projects—actually were built and entered operations.[16] The single coal project, the Petra Nova joint venture in Texas owned by NRG Energy and JX Nippon Oil & Gas, halted operations in 2020 due to financial problems.[17] The two industrial projects remain operational. The other projects were not completed, the GAO reported, "primarily in response to factors affecting their economic viability."[18]

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In contrast, DOE launched the "SunShot Initiative" in 2011 to reduce solar energy costs by 75 percent, to make it competitive on a large scale without subsidies by decade's end. The cost reduction goal was expected to reduce utility-scale solar costs to about six cents per kilowatt-hour (kWh). In 2017, the DOE announced the

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[13] T. Longden, *op. cit.*, p. 9.
[14] Congressional Research Service. Carbon Capture & Sequestration (CCS) in the United States. October 2021, p. 1.
[15] Government Accountability Office. Carbon Capture and Storage: Actions Needed to Improve DOE Management of Demonstration Projects. December 20, 2021.
[16] *Ibid.*, p. 7.
[17] IEEFA. Petra Nova Mothballing Post Mortem. August 2020.
[18] Government Accountability Office, *op. cit.*, p. 7.

SunShot Initiative had met its target three years earlier than expected. The project's goal for 2030 goal is 3 cents per kWh.[19]

The market forces that caused the demise of the federally funded CCS projects for coal are likely to become increasingly relevant to blue hydrogen projects. The GAO reported that the coal-based CCS projects that DOE selected for its carbon capture incentive program about a decade ago were affected by "diminishing economic prospects" caused by:

1. volatility of the fossil fuel commodities markets (and competition of coal with natural gas);
2. uncertainty regarding potential carbon markets and tax incentives;
3. high expected project costs; and
4. the expiration of federal 2009 American Recovery and Reinvestment Act funds.[20]

The GAO reported that the competitiveness of natural gas, as well as the added cost to install and operate CCS equipment, made the coal-powered projects a less attractive investment and affected the projects' economic viability.[21] It observed the industrial CCS projects were less vulnerable because they did not compete in electric power markets and their small size made them easier to self-finance.[22] Today, the added costs of CCS, the volatility of natural gas prices and the competitiveness of renewables are setting up similar constraints for blue hydrogen.

The GAO found many of the failed projects had counted on continued federal support, including a CO_2 cap-and-trade market.[23] Although the GAO encouraged the DOE to improve oversight of CCS incentive programs, it concluded:

> "Finally, improving program-level practices alone might not sufficiently address the risk of senior DOE leadership placing taxpayer funds at risk if future CCS demonstration projects struggle to meet key performance milestones. Implementing a congressional mechanism to provide greater oversight and accountability of DOE CCS demonstration project expenditures—such as requiring regular DOE reporting on project funding and status—could help reduce the risks to taxpayer funds. Absent such a mechanism, DOE is at risk of expending significant funds on CCS demonstration projects that have little likelihood of success."[24]

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[19] U.S. Department of Energy. The SunShot Initiative. Accessed January 18, 2022. Also see: Climate Scorecard. The SunShot Initiative in the U.S. April 17, 2021.
[20] GAO, *op. cit,* p. 12.
[21] *Ibid.*
[22] *Ibid.,* p. 13.
[23] *Ibid.*, p. 13.
[24] *Ibid.*, p. 24.

The GAO's concern is consistent with the concern of the IEA and suggests that following the Global CCS Institute's proposal of mandatory financing would not be wise.

Even in markets where hydrogen is preferred as a feedstock or energy alternative, blue hydrogen may not prevail against green hydrogen. BloombergNEF comments:

> "As the price of electrolyzers rapidly declines, 'green' hydrogen from renewables will be cheaper to make than 'blue' hydrogen—produced from natural gas with carbon capture and storage—across the world by 2030. Blue hydrogen project developers will increasingly need subsidies to stay viable."[25]

Government subsidies for blue hydrogen—especially if viewed as a life-support measure rather than a temporary bridge to financial independence—may become less and less popular, and consequently more and more limited. Opposition to funding of blue hydrogen already exists, and is likely to grow as more members of the public become aware of the actual carbon footprint of the technology, and as renewable or renewable-based alternatives continue to gain more market share, diminishing opportunities for the complex and costly technology required to manufacture blue hydrogen.[26]

Government subsidies for blue hydrogen may become less and less popular.

C. Carbon Capture Technology Is Becoming Less Attractive to Private Investors and Industry

Francesco Starace, CEO of Enel, a multinational energy firm, gave his opinion of CCS in 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."[27]

[25] BloombergNEF. Hydrogen—10 predictions for 2022. January 21, 2022.
[26] See: IEEFA. Blue Hydrogen Has Extremely Limited Future in U.S. Energy Market. February 2022.
[27] CNBC. 'For us, it is not a solution': Enel CEO skeptical of carbon capture. November 25, 2011.

Starace suggested the better climate solution would be to "stop emitting carbon." He added, "I'm not saying it's not worth trying again but we're not going to do it. Maybe other industries can try harder and succeed. For us, it is not a solution."[28]

He is not alone.

Brian Gutknecht, chief marketing officer of GE Power, said at a 2019 Edison Electric Institute conference, "At this point, it's not economically viable to use carbon capture and sequestration at scale," although he suggested a carbon tax or other measure could improve the economics. He reported that from his company's perspective, although "the economics of producing affordable [green] hydrogen are still not there, it's more of a focus for the company than CCS."[29]

ADM, a large ethanol producer, commissioned a study from WSP Global that essentially concluded no viable road exists to produce blue ethanol or blue hydrogen in the near term. The company reported:

> "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."[30]

A 2020 IEEFA analysis of the future of carbon capture noted that neither TotalEnergies nor Shell were spending a material percentage of annual capital expenditure on CCS, and none of their investments were quantified in annual reports.[31]

Example: Dearth of Investors for Enchant Energy CCS Coal Plant Retrofit

Enchant Energy's proposed carbon capture retrofit at the coal-fired San Juan Generating Station in New Mexico has been a string of broken promises. The company asserted it would find private investors to fund a $1.5 billion effort to capture as much as 90 percent of the plant's CO_2 emissions. That was in 2019. It planned to close on financing in mid-2020. It didn't happen. IEEFA noted:

> "The company has tried to shift blame for its glaring failure onto the COVID-19 pandemic, but a much more likely explanation is simply lack of investor interest. While Enchant could not entice investors to back the risky coal plant retrofit project, money poured into the renewable energy sector in 2020, with a record 36 gigawatts of new solar and wind capacity installed across the country."[32]

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[28] *Ibid.*
[29] Utility Dive. GE: Hydrogen trumps CCS in preserving gas turbines in a carbon-free grid. June 11, 2019.
[30] WSP USA. Carbon Reduction Feasibility Study for ADM. March 2020, p. 10.
[31] IEEFA, Carbon Capture and Storage Is About Reputation, Not Economics, p. 3. July 2020.
[32] Utility Dive. Coal-fired carbon capture projects are a waste of tax dollars. June 22, 2021.

IEEFA warned that the power costs from San Juan are already high, while competing clean resources are less expensive.[33] So, Enchant Energy now is seeking $1 billion in DOE funding to cover two-thirds of the project's construction costs. Enchant also admits that only half of the carbon capture project is likely to be in service at the end of 2024, and it expects the entire project will not be completed until mid-2025.[34]

In contrast, private investors are investing heavily in wind and solar energy. For example:

- Private equity firm Blackstone announced in January 2022 that it is investing $3 billion in Invenergy, a major renewable energy developer.[35]
- Copenhagen Infrastructure Partners (CIP), the world's largest dedicated fund manager within greenfield renewable energy investments, announced a plan in November 2021 to make $87.5 billion in green energy investments by 2030.[36]
- Carlyle, a global investment firm, recently committed over $100 million to NineDot Energy and Fermata Energy for battery storage and electric vehicle infrastructure. The investment brings its total capital commitments to renewable and sustainable energy companies over the past 24 months to more than $1.2 billion.[37]
- BlackRock announced a large emerging market renewable fund in November 2021, with an emphasis on economies across Africa, Asia and Latin America.[38] The focus is on renewable energy, energy efficiency, transmission/distribution, and energy storage.[39]
- Institutional investor EIG agreed to invest $400 million in solar developer 8minute Solar Energy, a

The renewable energy sector has demonstrated competitive financial viability. Blue hydrogen has not.

[33] *Ibid.*
[34] IEEFA. Where's the Beef? Enchant's San Juan Generating Station CCS retrofit remains behind schedule, financially unviable. May 2021.
[35] Power Technology. Blackstone to invest 3bn in Invenergy Renewables Holdings. January 10, 2022.
[36] Copenhagen Infrastructure Partners. CIP aims for EUR 100bn in renewable energy investments by 2030. November 1, 2021.
[37] Carlyle. Carlyle commits over $100 million to battery storage and electric vehicles infrastructure technologies to advance the energy transition. January 14, 2022.
[38] Reuters. BlackRock raises 653 million climate-focused infrastructure fund. November 2, 2021.
[39] BlackRock. Climate Finance Partnership. Accessed January 18, 2022.

company with a large backlog of solar and storage projects.[40]

This does not mean that various government incentives are not important to renewable energy. Rather, it means that the private investment sector is able to take the lead in the proliferation of renewable energy and energy storage projects. And while government incentives can and should speed the development of more renewable energy technology and projects, the sector also has its own strength and momentum. The renewable energy sector has demonstrated competitive financial viability. Blue hydrogen has not.

D. Blue Hydrogen's Dependence on Natural Gas, a Feedstock With a Price Volatility Problem, Adds Further Uncertainty to Project Economics

IEEFA recently reviewed the problem of the current high prices for natural gas in the United States, observing that the wholesale price of U.S. gas has roughly tripled from 2020's COVID-19 pandemic lows. IEEFA concluded that a significant factor driving the price hikes is the increasing amount of U.S. exports of liquified natural gas (LNG). IEEFA noted that the high prices are having an impact not only on households but also on businesses.[41] A DOE study focused on approving more export capacity estimated natural gas prices could be from $5.00 to $6.50 per million British thermal units in 2040.[42] An industry trade association, the Industrial Energy Consumers of America, wrote a letter of concern to the DOE this past fall, urging the agency to reduce export rates. Citing the DOE prediction, it said: "Prices that were supposed to be reflective of 2040 are already here."[43]

Volatility can make it difficult to analyze a blue hydrogen project's long-term profitability. Also, higher feedstock and fuel prices can affect the project's competitive value.[44] Overall, the financial headwinds do not bode well for blue hydrogen.

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[40] Business Wire. 8Minute Solar Energy closes $400 million in financing from EIG. January 19, 2022.
[41] IEEFA. Booming U.S. natural gas exports fuel high prices. November 4, 2021.
[42] U.S. Department of Energy. Macroeconomic Outcomes of Market Determined Levels of U.S. LNG Exports. U.S. Department of Energy. June 7, 2018, p. 54.
[43] Industrial Energy Consumers of America. Letter to Hon. Jennifer Granholm, Secretary, U.S. Department of Energy. September 17, 2021.
[44] IEEFA recently discussed the potential effects of volatile gas prices on PJM power plant economics. See: IEEFA. Rapidly changing investment climate challenges planned PJM gas plants. November 2021.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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