PAYNE INSTITUTE COMMENTARY SERIES: **COMMENTARY**

Developing Hydrogen and Carbon Capture and Storage Projects in the State of Colorado

By Chiang Cheng Siew and Anna Littlefield

Over the past two years, both the hydrogen and carbon capture, utilization, and storage (CCUS) industries have gained momentum in the US. Project development in these industries has been rapidly accelerating with the growing financial incentives from policymakers for the commercial deployment of these projects.

The signing of the Infrastructure Investment and Jobs Act (IIJA), also known as the Bipartisan Infrastructure Law, in November of 2021 marked the US Department of Energy's largest single investment in carbon management, along with significant investments funding clean hydrogen development. The IIJA provides a total of US $9.5 billion for clean hydrogen efforts and nearly US $12 billion for carbon capture, storage, and transportation development, as summarized in the tables below.

Hydrogen Funding from IIJA	Funding Amount
Regional Clean Hydrogen Hubs (Sec. 40314)	US$8 billion
Clean Hydrogen Electrolysis Program (Sec. 40314)	US$1 billion
Research and Development Program and National Clean Hydrogen Strategy and Roadmap (Secs. 40313 and 40314)	US$500 million

CCUS Funding from IIJA	Funding Amount
Research, Development, and Demonstration Provisions	
Carbon Capture Demonstration Projects Program (Sec. 41004)	US$2.54 billion
Large-Scale Carbon Capture Pilot Projects (Sec. 41004)	US$937 million
Carbon Capture Front End Engineering and Design (FEED) Studies (Sec. 40303)	US$100 million
CO_2 Transport and Storage Infrastructure and Permitting	
CO_2 Transportation Infrastructure Finance and Innovation (Sec. 40304)	US$2.7 billion
Carbon Storage Validation and Testing (Sec. 40305)	US$2.5 billion
State Primacy for States to Administer EPA's Underground Injection Control Program (Sec. 40306)	US$50 million
Secure Geologic Storage Permitting (Sec. 40306)	US$25 million
Carbon Utilization Market Development	
Carbon Utilization (Sec. 40302)	US$310 million
Carbon Removal	
Four Regional Direct Air Capture (DAC) Hubs (Sec. 40308)	US$3.5 billion
Direct Air Capture (DAC) Pre-Commercial Prize Competition (Sec. 41005)	US$15 million
Direct Air Capture (DAC) Commercial Prize Competition (Sec. 41005)	US$100 million

The Inflation Reduction Act (IRA), passed in August 2022, provides an even greater boost to the CCUS industry. The federal 45Q tax credit increased from \$50/ton to \$85/ton of CO_2 for saline storage and from \$35/ton to \$60/ton of CO_2 for EOR and utilization operations. The tax credit for CO_2 from DAC technologies was also increased to \$180/ton of CO_2 captured and permanently sequestered, and \$130/ton of CO_2 captured and applied to EOR or other utilization applications. In addition to financial incentives for the CCUS industry, the passing of the IRA represents the largest climate investment in US history, which allocates billions of dollars to climate adaptation of vulnerable communities and protection of areas most affected by climate change. Further details and analysis for the IRA can be seen in recent commentaries from the Payne Institute (Carbon Capture Utilization and Storage in the New Inflation Reduction Act and Aligning Value with Communities: Conceptualizing a 'Carbon Steward' Federal Tax Credit).

Provisions in the IIJA and in the IRA will benefit Colorado as they expand opportunities for clean energy jobs, strengthen local economies, and incentivize the deployment of low-carbon operations across multiple industries in the state, ultimately decarbonizing the Colorado economy. The state's

fossil fuel regulations are among the most stringent in the country, positioning existing regulatory agencies to support the implementation of new hydrogen and carbon storage projects. To further understand the state's efforts to reach its climate targets, we have assessed the current status of hydrogen hubs and CCUS projects in development in Colorado and identified additional opportunities for the combination of hydrogen and CCUS technologies.

Initial Efforts for a Hydrogen Hub in Colorado

A wide variety of sources and methods exist for the production of hydrogen (Figure 1). Colorado's hydrogen opportunities exist mainly in the production of blue hydrogen from natural gas coupled with CCUS and green hydrogen from renewable sourced electrical generation. There are state incentives in place that mostly support the use of hydrogen in these sectors, including the Diesel Emissions Reduction Grant, Industrial and Manufacturing Operations Emissions Reduction Grant, and Impact Assistance Program for Public Fleets. However, additional state incentives would be necessary to encourage other sectors of the Colorado economy to start adopting blue hydrogen as a fuel source and support the state in accelerating its greenhouse gas mitigation goals.

In February of 2022 a memorandum of understanding was signed between the states of Colorado, New Mexico, Utah, and Wyoming to coordinate, develop, and manage a regional clean hydrogen hub ("Western Inter-States Hydrogen Hub"), in collaboration with the Rocky Mountain Alliance for Next Generation Energy. The four states have together submitted a proposal for the Western Inter-States Hydrogen Hub, marking Colorado's first efforts at the state level towards developing a hydrogen distribution facility. This multistate partnership is contending for a portion of the $8 million allocated by the IIJA for the development of regional clean hydrogen hubs.

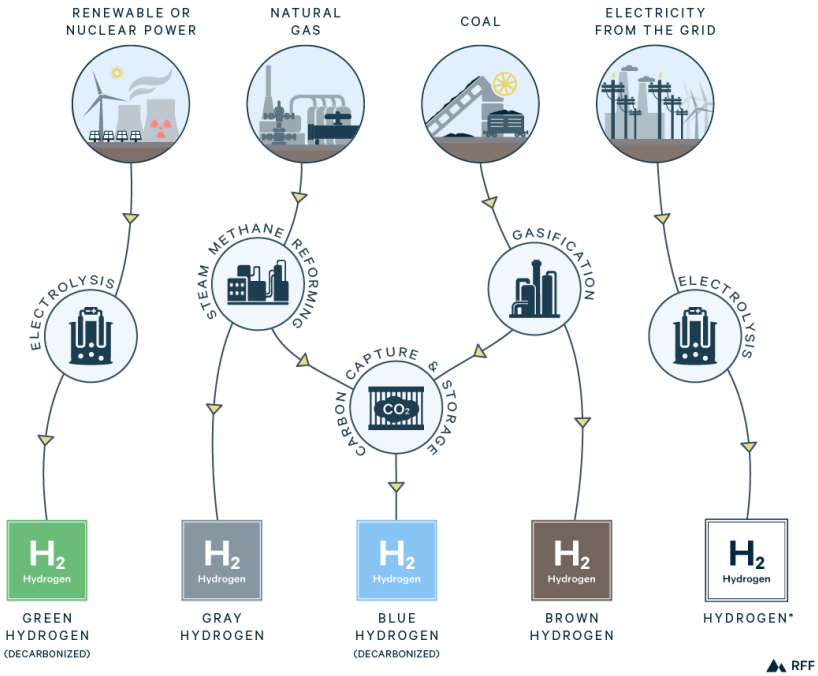

Figure 1. Hydrogen production processes by Resources for the Future.

Status for CCUS Projects in Colorado

The development of CCUS in Colorado is in its relatively early stages, but much progress has been made this past year from the public and private sectors. The CCUS industry started taking shape in December 2018 with Xcel Energy publicly considering CCUS as a viable decarbonization technology for their zero-carbon electricity by 2050 target. The following year, Colorado passed an aggressive greenhouse gas (GHG) reduction bill, aimed at reducing emissions from all sources by 26% in 2025, 50% by 2030, and 90% by 2050. Since then, the Colorado Energy Office has been releasing roadmaps that outline achievable pathways to meet the state's climate targets using hydrogen and CCUS, including the Greenhouse Gas Pollution Roadmap and the Opportunities for Low-Carbon Hydrogen in Colorado Roadmap, both released in 2021. In addition, the Colorado CCUS Task Force was formed in March 2021 with members from academia, industry, government, and nonprofit groups. The multidisciplinary team concluded that the deployment of CCUS technologies will be requisite to meet Colorado's ambitious climate goals.

Policy support from the state government and federal financial incentives have encouraged new projects and new partnerships to study and deploy CCUS throughout Colorado. A recent example is Carbon America's announcement of the first-commercial scale CCUS project in northeastern Colorado. Expected to come online in 2024, the company will be capturing CO_2 produced at two ethanol production facilities (Sterling and Yuma) and will be storing 95% of the CO_2 nearly one mile underground. Because Colorado does not have primacy (primary authority for permit approval) over Class VI wells for CO_2 injection, the approval process sits with the EPA. The ability for operators to obtain permits to inject and store CO_2 will likely be a controlling factor in the ability to rapidly execute projects in Colorado.

A new partnership between Colorado School of Mines, Colorado Springs Utilities, Oxy Low Carbon Ventures, DOE and Carbon Utilization and Storage Project (CUSP) was launched in October 2021 (funded by the US Department of Energy and CUSP). This project will evaluate the potential for a CCUS project in Colorado, with CO_2 capture from a gas power plant and a storage within a saline aquifer near the emitter. The assessments from this feasibility study should address key technical challenges and regional infrastructure necessary for a successful CCUS project in Colorado. Although the unique characteristics of this particular project site will not be translatable statewide, the successes and challenges identified will ideally inform policymakers, regulators and operators about Colorado's potential to deploy CCUS projects across the state.

Opportunities for Low Carbon Hydrogen and CCUS in Colorado

Colorado has been providing incentives for developing hydrogen and CCUS separately, but a lesser explored avenue that utilizes the two jointly, production of "blue" hydrogen, presents a unique opportunity. Blue hydrogen is produced when natural gas is split into hydrogen and CO_2, most commonly through a process called steam methane reforming. The emitted CO_2 is captured and then stored permanently underground – this results in low-carbon hydrogen that produces no CO_2. Although green hydrogen, derived from renewable sources, could dominate in the long term, blue hydrogen can reduce emissions in the near-term using existing natural gas sources for its production. It is less expensive than green hydrogen, can deploy proven CO_2 capture technologies, and sequester the captured CO_2 underground as the industry has decades of experience in CO_2 storage. For the state to reach its ambitious climate targets, Colorado should consider blue hydrogen coupled with CCUS technologies in the near term to achieve rapid decarbonization, while also fostering the green hydrogen

economy to accelerate decarbonization efforts moving forward. The state has the intellectual capital in the natural gas industry as well as a commitment from state leadership to decarbonize the economy, positioning Colorado to lead in the development and scale-up of low carbon hydrogen and CCUS in the US.

The Payne Institute for Public Policy

COLORADOSCHOOLOFMINES

ABOUT THE AUTHORS

Chiang Cheng Siew
MS Natural Resources & Energy Policy and Mineral & Energy Economics, Colorado School of Mines

Chiang Cheng Siew is a second-year student at Colorado School of Mines pursuing a dual master's degree in Natural Resources & Energy Policy and in Mineral & Energy Economics, in addition to pursuing a graduate certificate in Carbon Capture, Utilization and Storage. Siew is a graduate researcher for the Payne Institute and expresses interest in the energy policy development in the US and in Brazil. She has previously worked for the ESG operations at Quantum Energy Partners and worked as an analyst for natural gas markets at BTU Analytics

Anna Littlefield
Payne Institute CCUS Program Manager and Research Associate
PhD Student, Geology and Geological Engineering, Colorado School of Mines

Anna Littlefield is the Program Manager for Carbon Capture Utilization and Sequestration for the Payne Institute at the Colorado School of Mines. As a current PhD student in the Mines geology department, her research focuses on the geochemical impacts of injecting CO2 into the subsurface as well as the overlap of geotechnical considerations with policy-making. Anna joins the Payne Institute with 8 years' experience in the oil and gas industry, where she worked development, appraisal, exploration, new ventures, and carbon sequestration projects. Her academic background is in hydrogeology with an M.S. in geology from Texas A&M University, and a B.S. in geology from Appalachian State University. Anna is passionate about addressing both the societal and technical challenges of the energy transition and applying her experience to advance this effort.

The Payne Institute for Public Policy

COLORADO SCHOOL OF MINES

ABOUT THE PAYNE INSTITUTE

The mission of the Payne Institute at Colorado School of Mines is to provide world-class scientific insights, helping to inform and shape public policy on earth resources, energy, and environment. The Institute was established with an endowment from Jim and Arlene Payne, and seeks to link the strong scientific and engineering research and expertise at Mines with issues related to public policy and national security.

The Payne Institute Commentary Series offers independent insights and research on a wide range of topics related to energy, natural resources, and environmental policy. The series accommodates three categories namely: Viewpoints, Essays, and Working Papers.

For more information about the Payne Institute please visit:

https://payneinstitute.mines.edu/