Rhodium Group

The Economic Benefits of Hydrogen Hubs

Appalachian, California, Gulf Coast, and Midwest hubs

Energy & Climate

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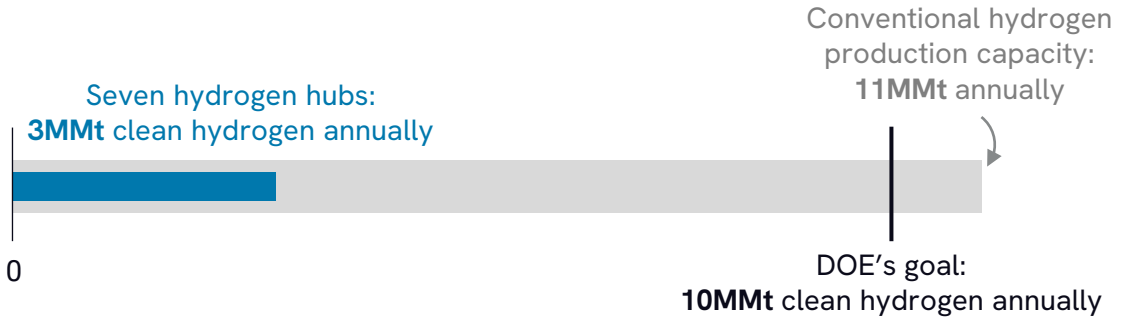
Contents

Analysis overview and objectives

Clean hydrogen is a versatile tool for decarbonizing particularly hard-to-abate sectors, including industry and heavy-duty transport. The Infrastructure Investment and Jobs Act (IIJA) provided the Department of Energy (DOE) with funding for the Regional Clean Hydrogen Hubs program, with a total of $7 billion for seven clean hydrogen hubs across the country. These hubs will provide valuable experience integrating hydrogen into multiple sectors of the economy.



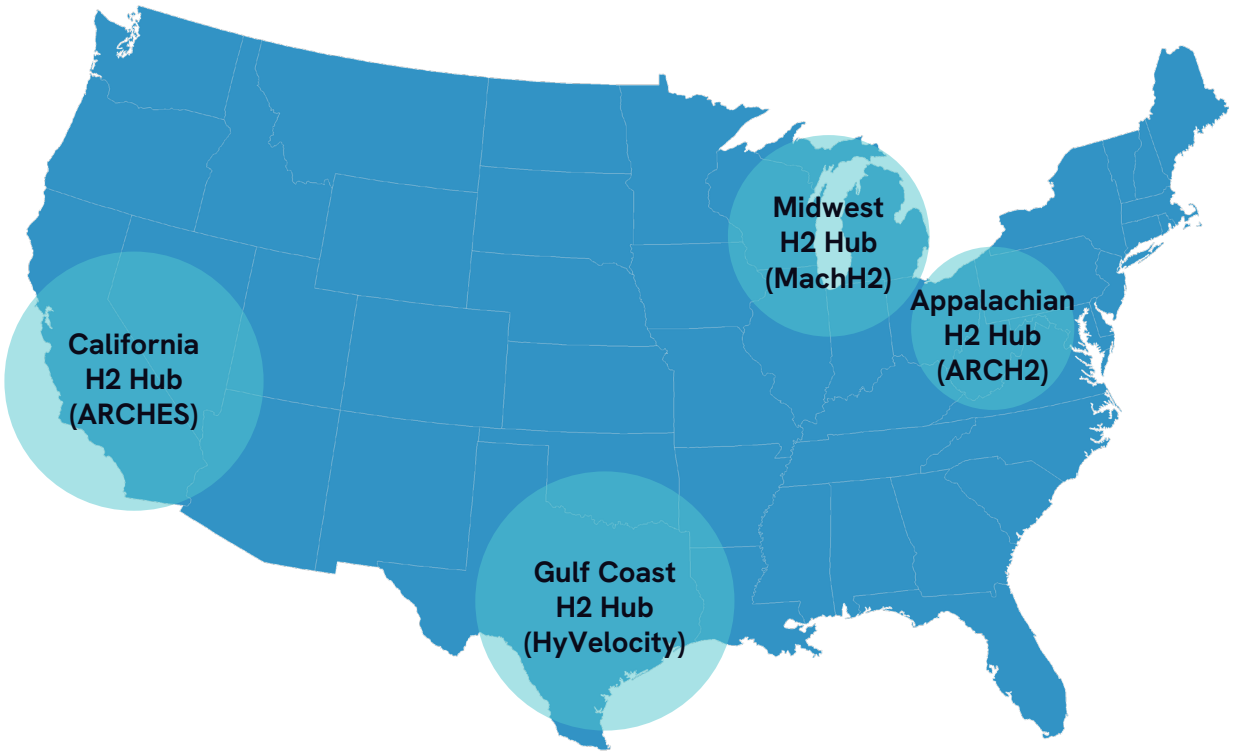
Once developed, the seven hubs aim to produce a total of 3 million metric tons (MMt) of clean hydrogen per year, which would mark progress towards DOE's goal of producing 10 MMt of clean hydrogen annually by 2030. For comparison, today's conventional hydrogen production via steam methane reformation (SMR) amounts to roughly 11 MMt of hydrogen per year.

Each hub will encompass a combination of energy sources, hydrogen production approaches, transport infrastructure, and end-use applications based on local resources and demand. The Great Plains Institute (GPI) commissioned Rhodium Group to conduct an independent analysis exploring the economic benefits associated with four of the hydrogen hubs. This selection of hubs represents a diverse set of geographic locations across the US and captures a variety of hydrogen production pathways. The clean hydrogen production methods at the hubs in focus include electrolytic hydrogen, SMR with carbon capture, and biohydrogen.

Analysis overview

- The IIJA will support seven regional hydrogen (H2) hubs. This analysis focuses on four of the hubs: Appalachian, California, Gulf Coast, and Midwest.
- This analysis explores the direct economic benefits, including investment and employment opportunities, associated with constructing and operating the hubs.
- Reported employment numbers represent regional jobs directly related to the construction, engineering, materials, equipment, and labor to build and operate the hubs, from energy inputs through the point of hydrogen distribution. Our job estimates do not include end-use applications. Each hub has released its own jobs projections, which we expect do include end-use applications.
- The range of job estimates reflects Rhodium's range of cost estimates for H2 production, energy inputs, transport, and distribution infrastructure. They also reflect Rhodium's estimates on distribution infrastructure requirements.

Analyzed hydrogen hubs



Source: Rhodium Group, adapted from Department of Energy's Office of Clean Energy Demonstration.
Note: The size of the circles on the map indicate the expected area in which hub projects will be located.

Methodology and assumptions

Production estimates and cost research

H2 production estimates

Rhodium Group estimated the amount of each type of H2 produced at each hub. To do so, we reviewed project information and production methods released by the hubs as well as external data sources including IEA's hydrogen project database. We validated these production estimates using data from the Clean Investment Monitor. As of May 2024, the hydrogen hubs are still in their planning phase. Therefore, projects are subject to change, which would influence Rhodium's hydrogen production estimates.

Cost research

We reviewed industry cost estimates, national lab models, and academic literature to develop estimates of capital costs and ongoing operations and maintenance costs for H2 production, H2 distribution infrastructure, and CO_2 storage in onshore saline storage reservoirs.

Methodology and assumptions

Employment analysis and outputs

Employment analysis

We use the economic model IMPLAN's state-level tools (2022 data year) to translate costs into an employment analysis in each hubs' region. This analysis includes jobs from energy inputs through the point of H2 distribution infrastructure. It does not include jobs associated with end-use applications.

Outputs

Jobs associated with construction and installation are average annual jobs over a three-year construction period. Ongoing operation jobs represent on-site and off-site jobs associated with producing, powering, and distributing the hubs' H2 each year. Job estimates do not include upstream supply chain jobs or induced jobs. Employment per industrial output is assumed to stay constant over time.

Appalachian Hydrogen Hub

Appalachian Regional Clean Hydrogen Hub (ARCH2)

Key information about the Appalachian hydrogen hub (ARCH2)

West Virginia, Ohio, Pennsylvania, and Kentucky

Hub attributes

- The Appalachian Hub's H2 production will be a combination of steam methane reformation (SMR) with carbon capture and electrolytic hydrogen powered by wind and solar.
- ARCH2 does not report an expected H2 production capacity. Rhodium currently estimates the hub will produce between 2,800 and 3,400 metric tons of H2 per day by 2030.

Investment and stakeholders

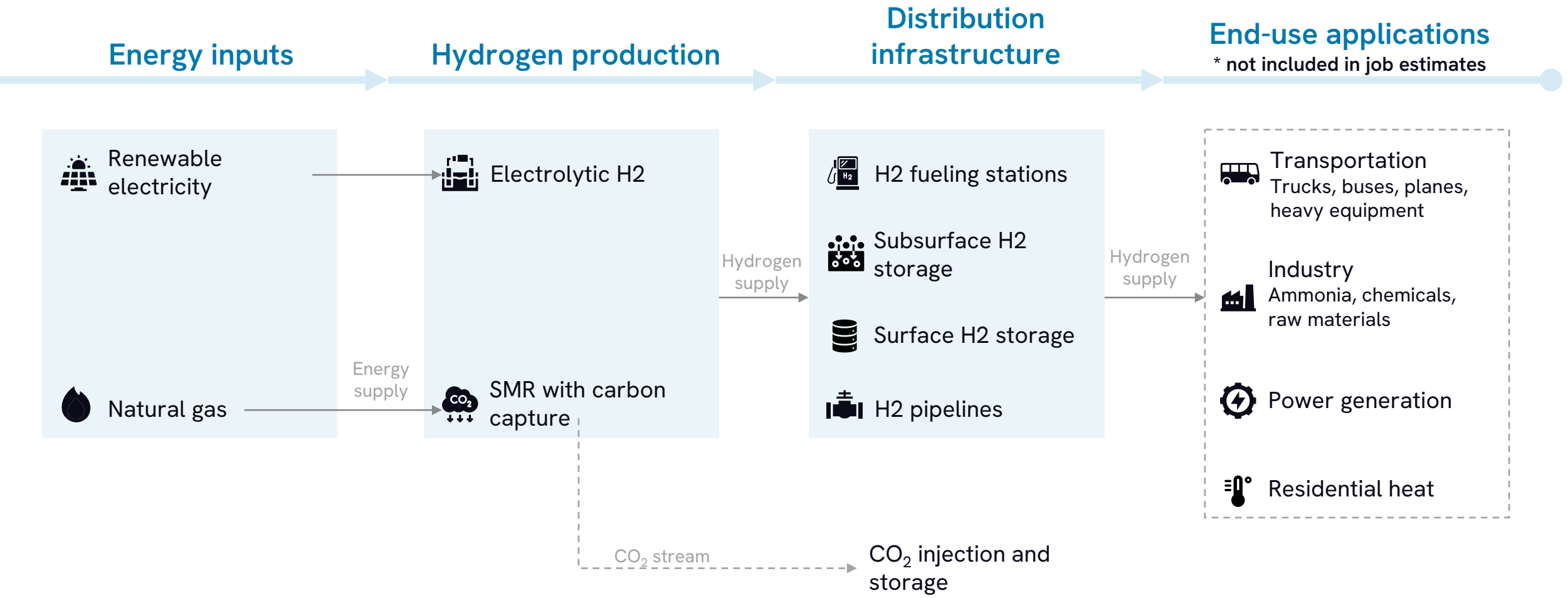
- The federal government has committed up to $925 million in funding to this project under the IIJA.
- The ARCH2 hub reports roughly $6 billion in funding from private investments.
- The hub cites over 50 secured and potential private partners.

Source: Rhodium analysis, ARCH2 Hub, The White House, The Office of Senator Joe Manchin (D-WV), IEA.
Note: A map released by the hub providing more geographic granularity can be found in the Appendix.

ARCH2

Appalachian hydrogen hub overview

West Virginia, Ohio, Pennsylvania, and Kentucky



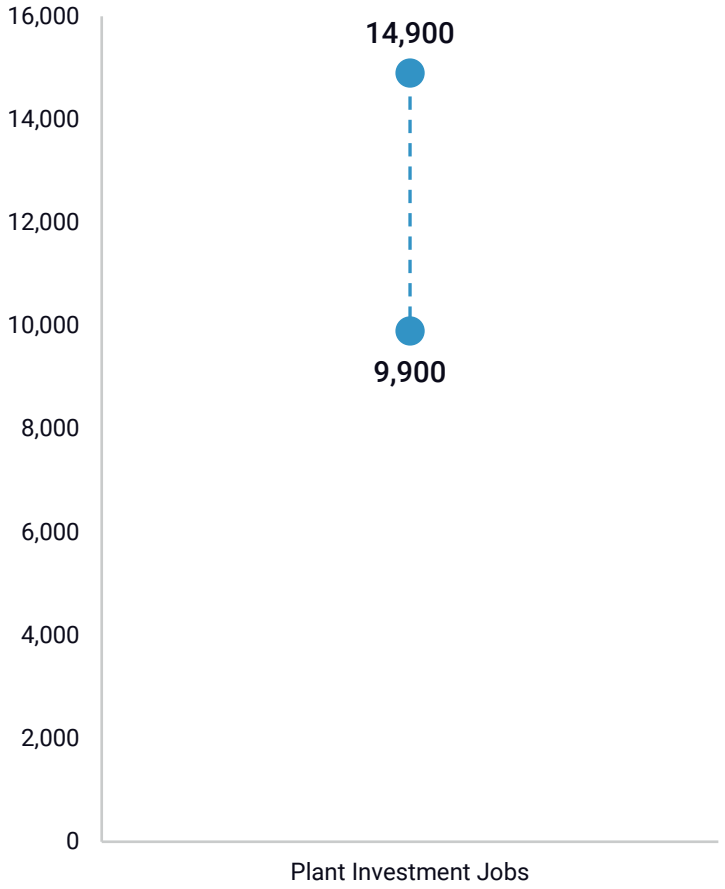
Construction and installation

Jobs through the point of distribution infrastructure

- Jobs associated with constructing and installing the Appalachian hub total 9,900 to 14,900 annual average jobs over the construction period.

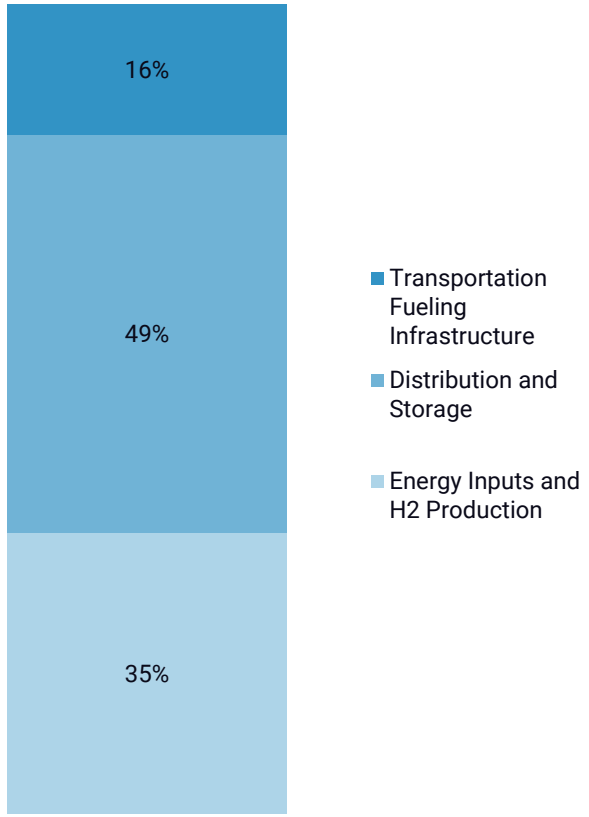
Plant investment jobs

Average annual jobs over 3-year construction period



Breakdown of plant investment jobs

Percentage of jobs by segment



Source: Rhodium Group analysis, Argonne National Laboratory Hydrogen Delivery Scenario Analysis Model (HDSAM), DOE OCED, ARCH2 Hub.
Notes: Values reflect a range of cost estimates for polymer electrolyte membrane (PEM) electrolytic and SMR with carbon capture hydrogen production, energy inputs, hydrogen distribution, and CO_2 injection and storage. We assume annual matching for electrolytic H2 powered by additional renewable electricity. Distribution and storage percentages includes H2 pipelines, H2 surface storage, and CO_2 injection and storage. Transport fueling infrastructure represents fueling stations.

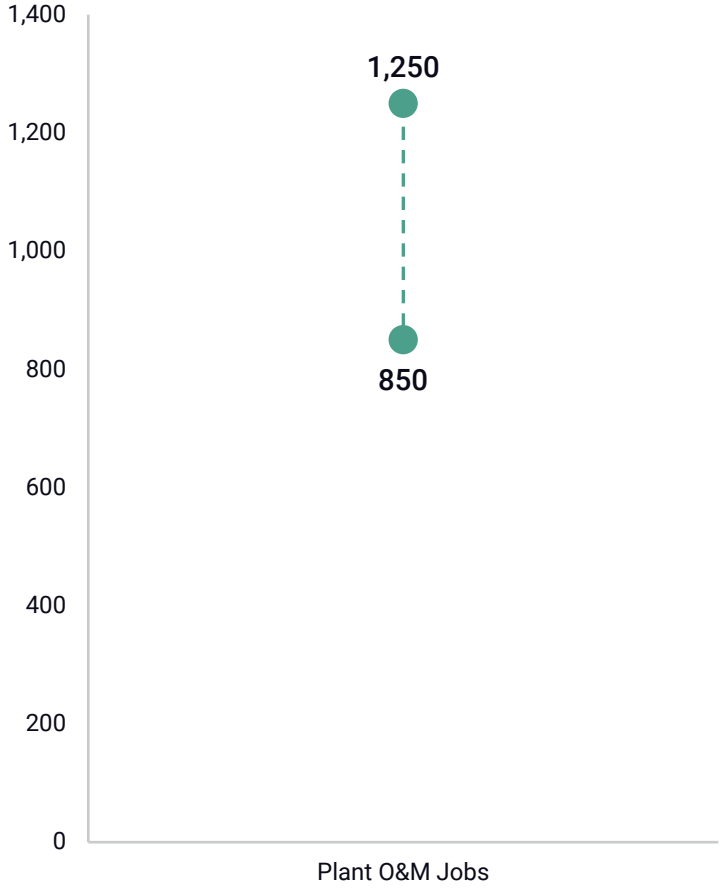
Operations and maintenance (O&M)

Jobs through the point of distribution infrastructure

- Annual jobs to operate the Appalachian hub total 850 to 1,250 ongoing jobs.

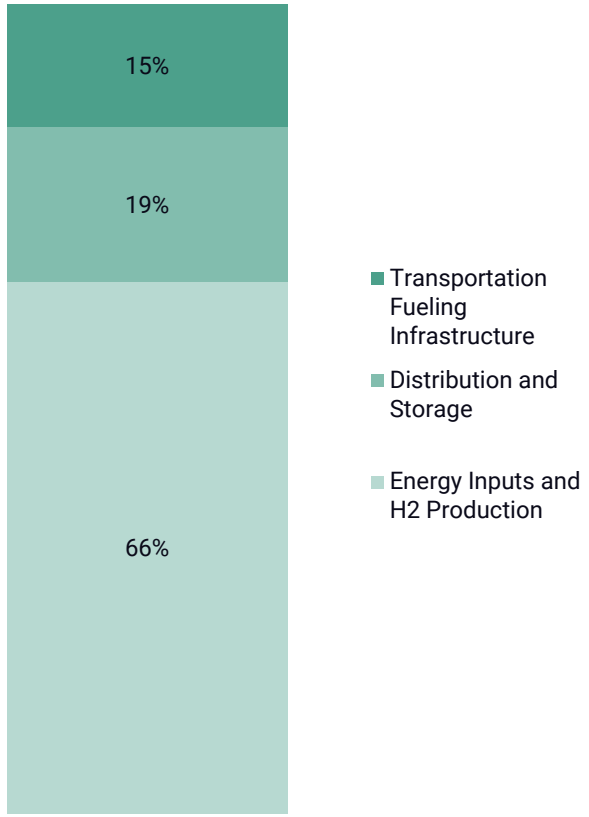
Ongoing O&M jobs

Average annual jobs over the lifetime of the plant



Breakdown of O&M jobs

Percentage of ongoing jobs by segment



Source: Rhodium Group analysis, Argonne National Laboratory HDSAM, DOE OCED, ARCH H2.
Notes: Values reflect a range of cost estimates for PEM electrolytic and SMR with carbon capture hydrogen production, energy inputs, hydrogen distribution, and CO_2 injection and storage. We expect H2 production facilities to be operational for 20-30 years. We assume annual matching for electrolytic H2 powered by additional renewable electricity. Distribution and storage percentages includes H2 pipelines, H2 surface storage, and CO_2 injection and storage. Transport fueling infrastructure represents fueling stations.

California Hydrogen Hub

Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES)

Key information about the California hydrogen hub (ARCHES)

California

Hub attributes

- The California hub's H2 production will be a combination electrolytic hydrogen powered by wind and solar and biohydrogen production.
- ARCHES expects to produce 515 metric tons of H2 per day (TPD) by 2030. Rhodium currently estimates the hub will produce between 500 and 600 TPD by 2030.

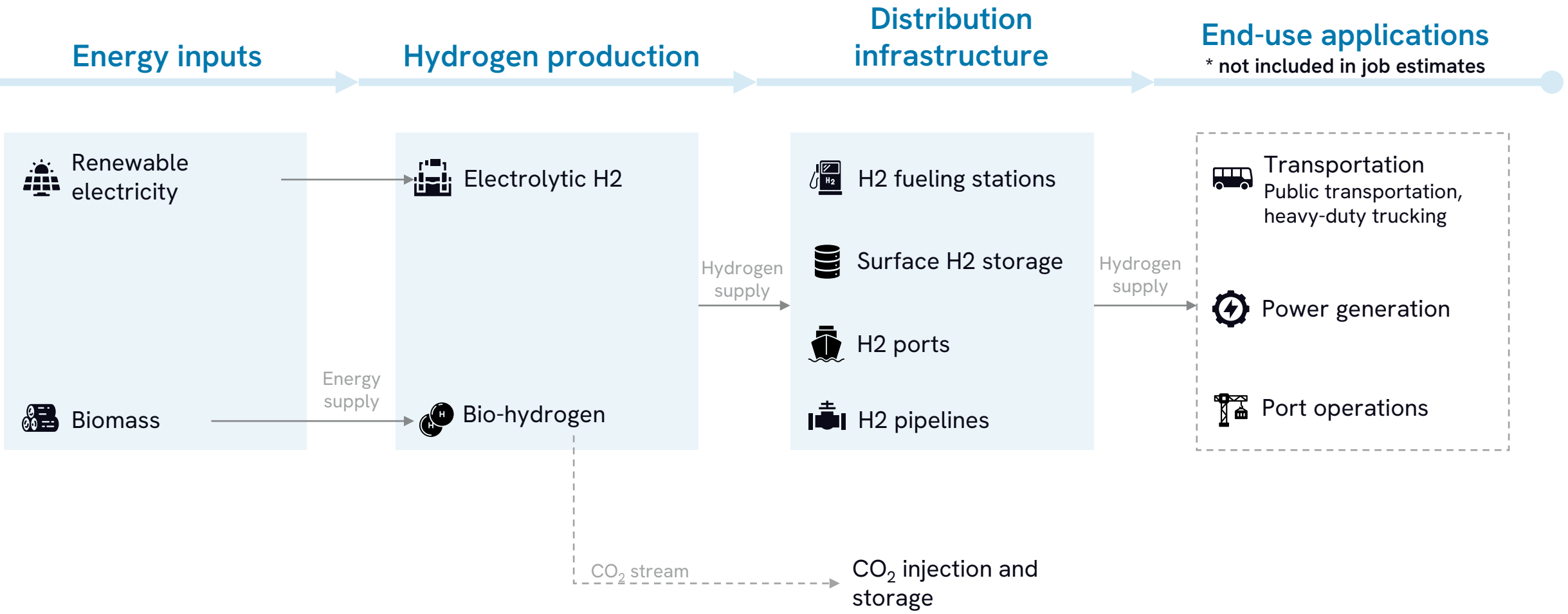
Investment and stakeholders

- The federal government has committed up to $1.2 billion in funding to this project under the IIJA.
- The hub will also receive an additional $2 billion from state level funding.
- Moreover, there is a reported $9 billion in funding from private investments.
- The hub has over 400 public and private member groups.

Source: ARCHES H2, The White House, UC Irvine.
Note: A map released by the hub providing more geographic granularity can be found in the Appendix.

California hydrogen hub overview

California



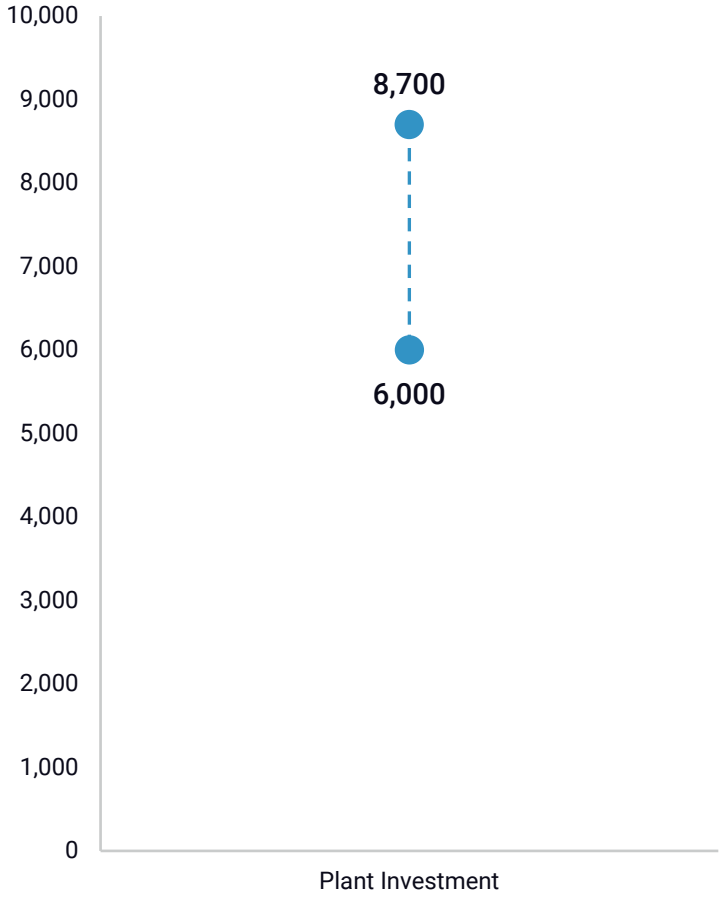
Construction and installation

Jobs through the point of distribution infrastructure

- Jobs associated with constructing and installing the California hub total 6,000 to 8,700 annual average jobs over the construction period.

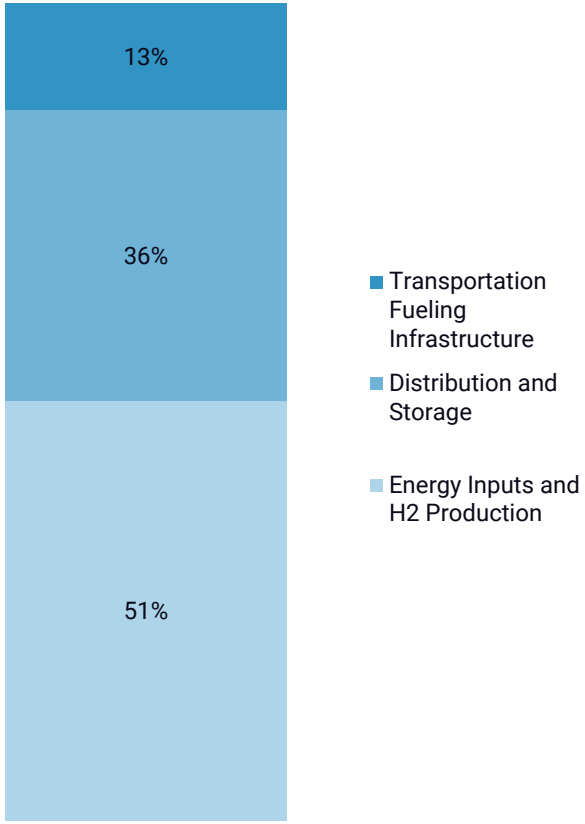
Plant investment jobs

Average annual jobs over 3-year construction period



Breakdown of plant investment jobs

Percentage of jobs by segment



Source: Rhodium Group analysis, Argonne National Laboratory HDSAM, DOE OCED, ARCHES H2.
Notes: Values reflect a range of cost estimates for PEM electrolytic H2 and biomass gasification biohydrogen production, energy inputs, hydrogen distribution, and CO_2 injection and storage. We assume annual matching for electrolytic H2 powered by additional renewable electricity. Distribution and storage percentages includes H2 pipelines, H2 surface storage, and CO2 injection and storage. Transport fueling infrastructure represents fueling stations and ports.

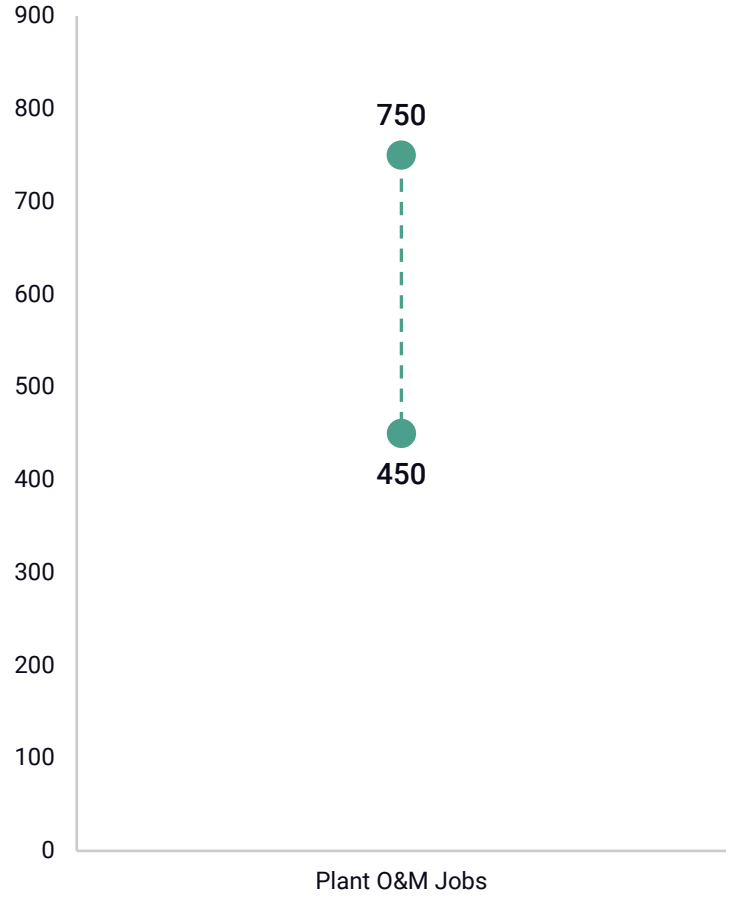
Operations and maintenance (O&M)

Jobs through the point of distribution infrastructure

- Annual jobs to operate the California hub total 450 to 750 ongoing jobs.

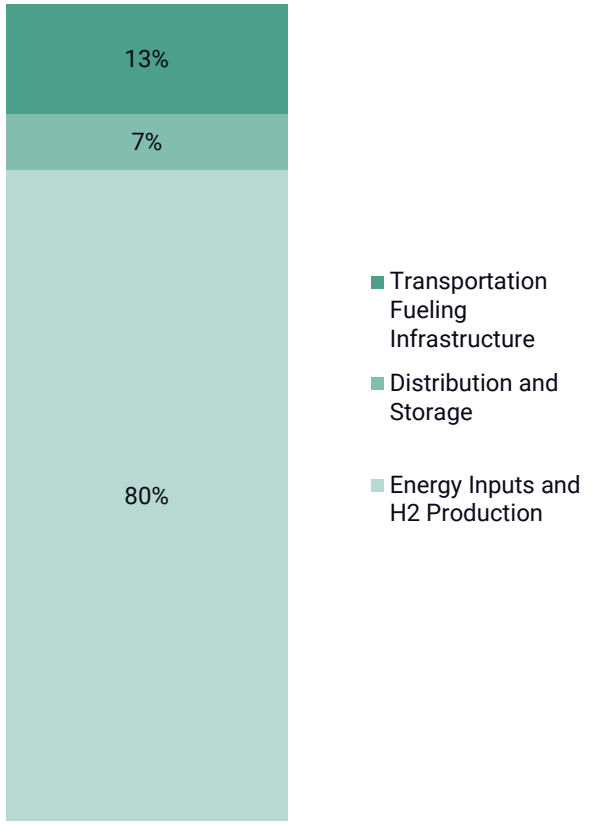
Ongoing O&M jobs

Average annual jobs over the lifetime of the plant



Breakdown of O&M jobs

Percentage of ongoing jobs by segment



Source: Rhodium Group analysis, Argonne National Laboratory HDSAM, DOE OCED, ARCHES H2.
Notes: Values reflect a range of cost estimates for PEM electrolytic H2 and biomass gasification biohydrogen production, energy inputs, hydrogen distribution, and CO_2 injection and storage. We expect H2 production facilities to be operational for 20-30 years. We assume annual matching for electrolytic H2 powered by additional renewable electricity. Distribution and storage percentages includes H2 pipelines, H2 surface storage, and CO_2 injection and storage. Transport fueling infrastructure represents fueling stations and ports

Gulf Coast Hydrogen Hub

HyVelocity Hub

Key information about the Gulf Coast hydrogen hub (HyVelocity)

Texas and Louisiana

Hub attributes

- The Gulf Coast hub's H2 production will be a combination of steam methane reformation (SMR) with carbon capture and electrolytic hydrogen powered by wind and solar.
- HyVelocity expects to produce over 5,000 metric tons of H2 per day but does not specify a timeframe. Rhodium currently estimates the hub will produce between 2,900 and 3,500 TPD by 2030.

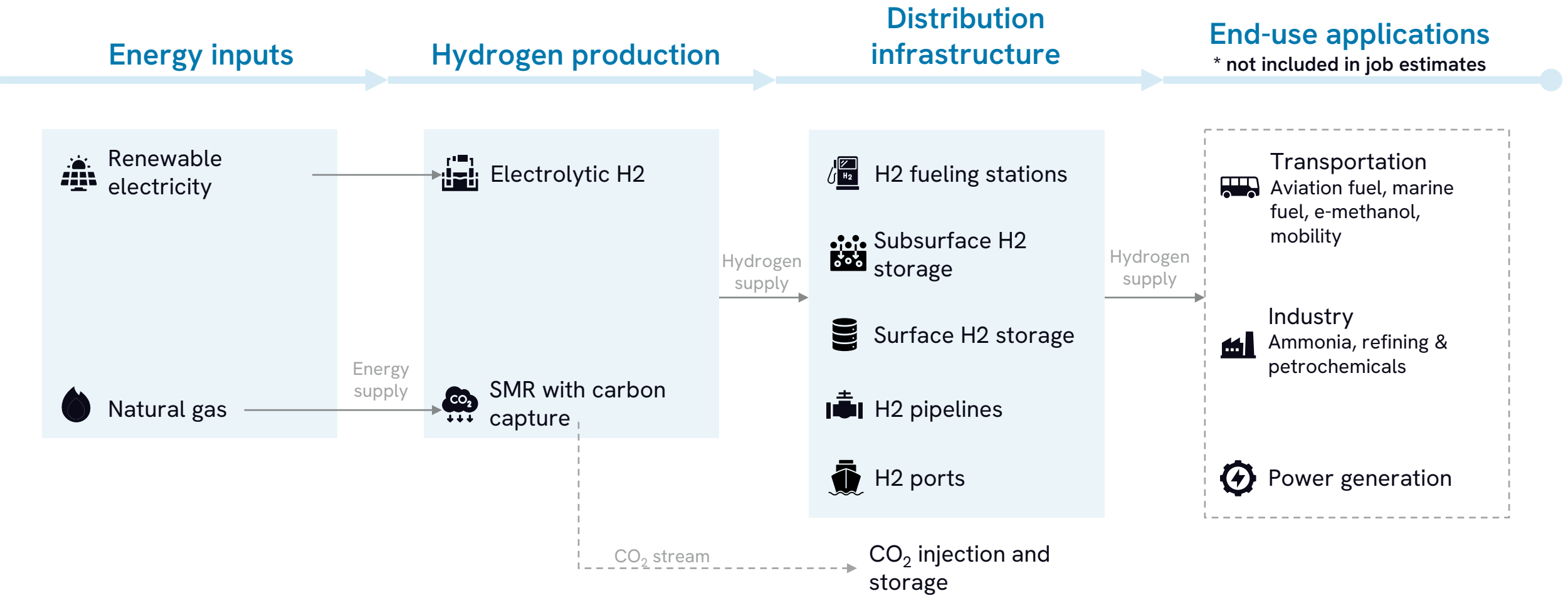
Investment and Stakeholders

- The federal government has committed up to $1.2 billion in funding to this project under the IIJA.
- This hub has not announced private or state level funding.
- This hub has over 90 public and private partners.

Source: HyVelocity Hub, The White House.
Note: A map released by the hub providing more geographic granularity can be found in the Appendix.

Gulf Coast hydrogen hub overview

Texas and Louisiana



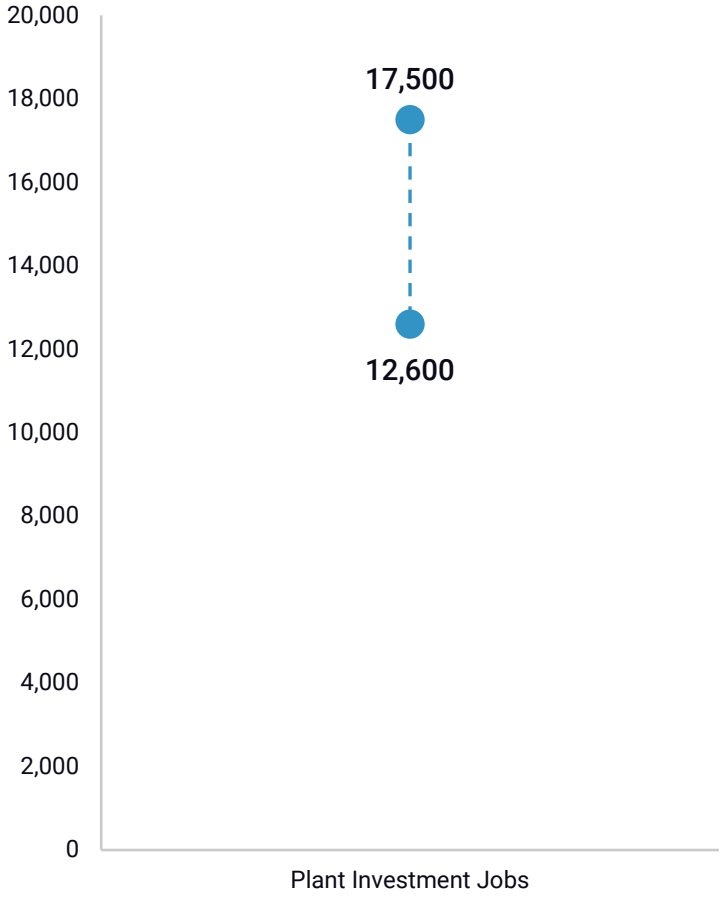
Construction and installation

Jobs through the point of distribution infrastructure

- Jobs associated with constructing and installing the Gulf Coast hub total 12,600 to 17,500 annual average jobs over the construction period.

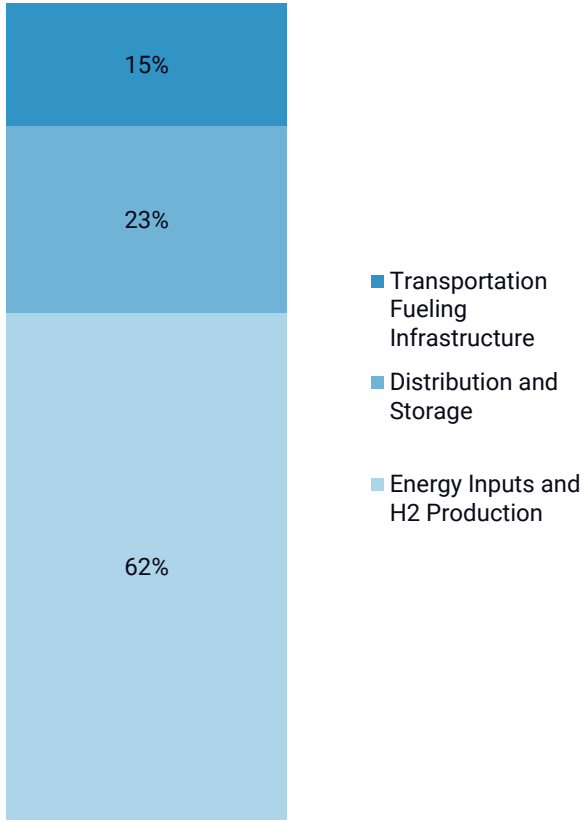
Plant investment jobs

Average annual jobs over 3-year construction period



Breakdown of plant investment jobs

Percentage of jobs by segment



Source: Rhodium Group analysis, Argonne National Laboratory HDSAM, DOE OCED, HyVelocity Hub.
Notes: Values reflect a range of cost estimates for PEM electrolytic H2 and SMR with carbon capture H2 production, energy inputs, hydrogen distribution, and CO_2 injection and storage. We assume annual matching for electrolytic H2 powered by additional renewable electricity. Distribution and storage percentages includes H2 pipelines, H2 surface and subsurface storage, and CO_2 injection and storage. Transport fueling infrastructure represents fueling stations and ports.

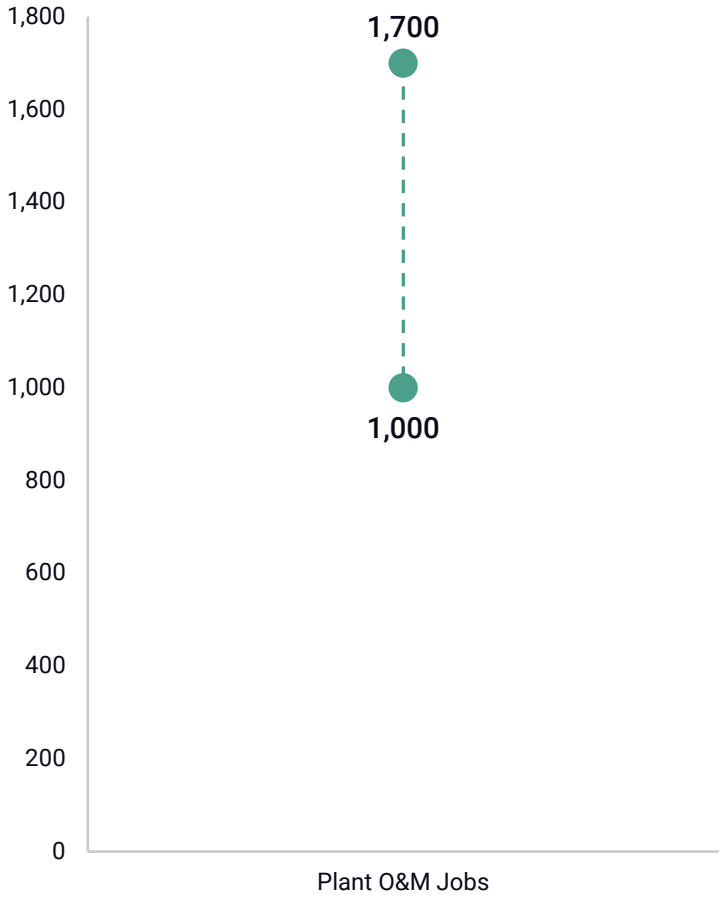
Operations and maintenance (O&M)

Jobs through the point of distribution infrastructure

- Annual jobs to operate the Gulf Coast hub total 1,000 to 1,700 ongoing jobs.

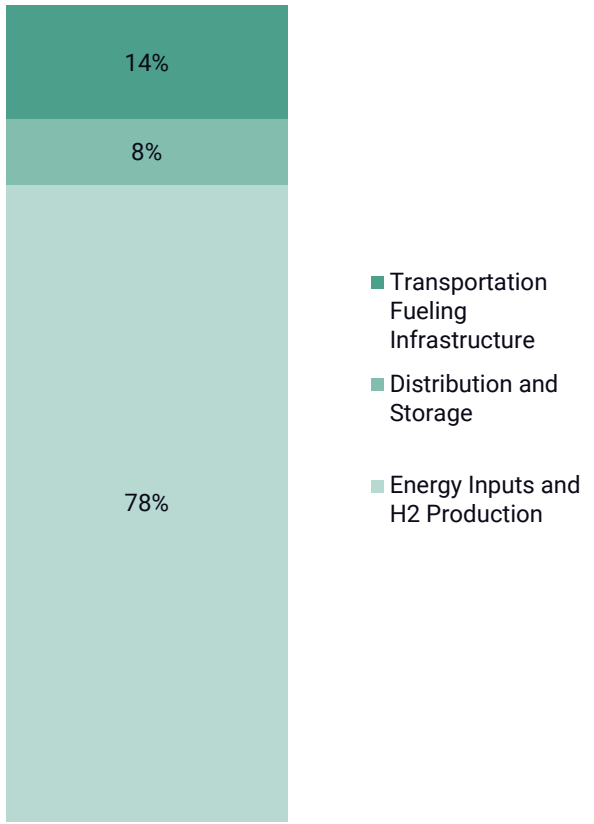
Ongoing O&M jobs

Average annual jobs over the lifetime of the plant



Breakdown of O&M jobs

Percentage of ongoing jobs by segment



Source: Rhodium Group analysis, Argonne National Laboratory HDSAM, DOE OCED, HyVelocity Hub.
Notes: Values reflect a range of cost estimates for PEM electrolytic H2 and SMR with carbon capture hydrogen production, energy inputs, hydrogen distribution, and CO_2 injection and storage. We expect H2 production facilities to be operational for 20-30 years. We assume annual matching for electrolytic H2 powered by additional renewable electricity. Distribution and storage percentages includes H2 pipelines, H2 surface and subsurface storage, and CO_2 injection and storage. Transport fueling infrastructure represents fueling stations and ports.

Midwest Hydrogen Hub

Midwest Alliance for Clean Hydrogen (MachH2)

Key information about the Midwest hydrogen hub (MachH2)

Illinois, Indiana, and Michigan

Hub attributes

- The Midwest hub's H2 production will be a combination of SMR with carbon capture and electrolytic hydrogen powered by renewable electricity and nuclear.
- MachH2 does not report an expected H2 production capacity. Rhodium currently estimates the hub will produce between 1,100 and 1,300 metric tons of H2 per day by 2030.

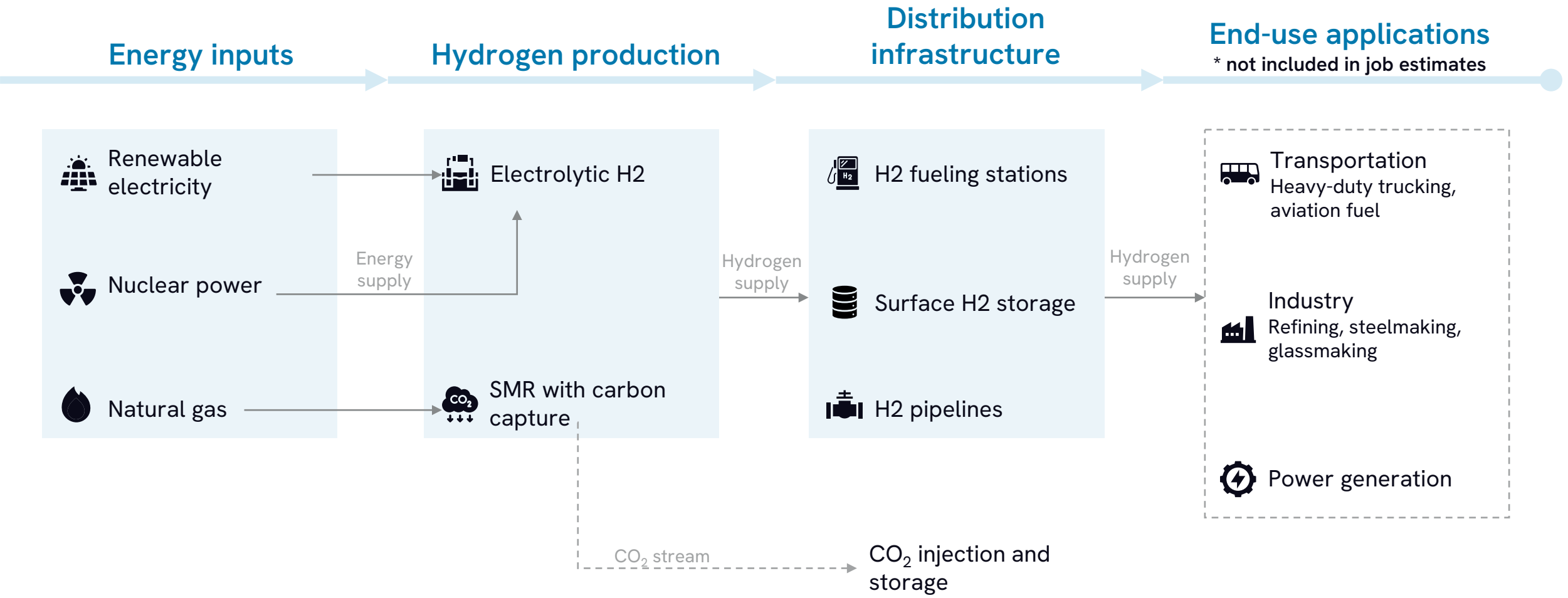
Investment and stakeholders

- The federal government has committed up to $1.0 billion in funding to this project under the IIJA.
- This hub has not announced private or state level funding.
- The hub has over 70 private and public partners.

Source: Rhodium analysis, Midwest Alliance for Clean Hydrogen, The White House, Constellation Energy.
Note: A map released by the hub providing more geographic granularity can be found in the Appendix.

Midwest hydrogen hub overview

Illinois, Indiana, and Michigan



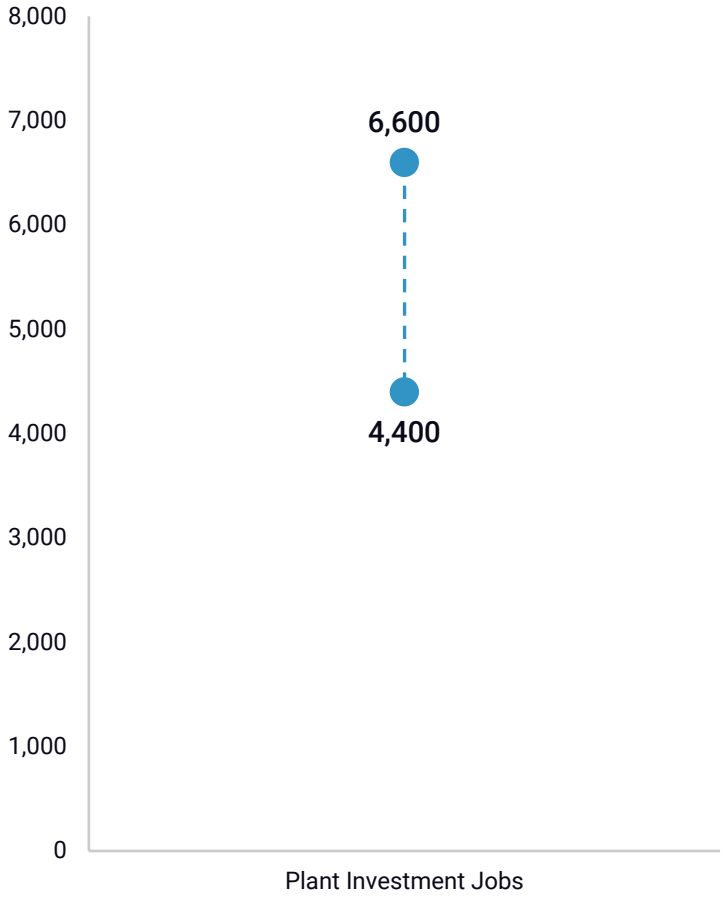
Construction and installation

Jobs through the point of distribution infrastructure

- Jobs associated with constructing and installing the Midwest hub total 4,400 to 6,600 annual average jobs over the construction period.

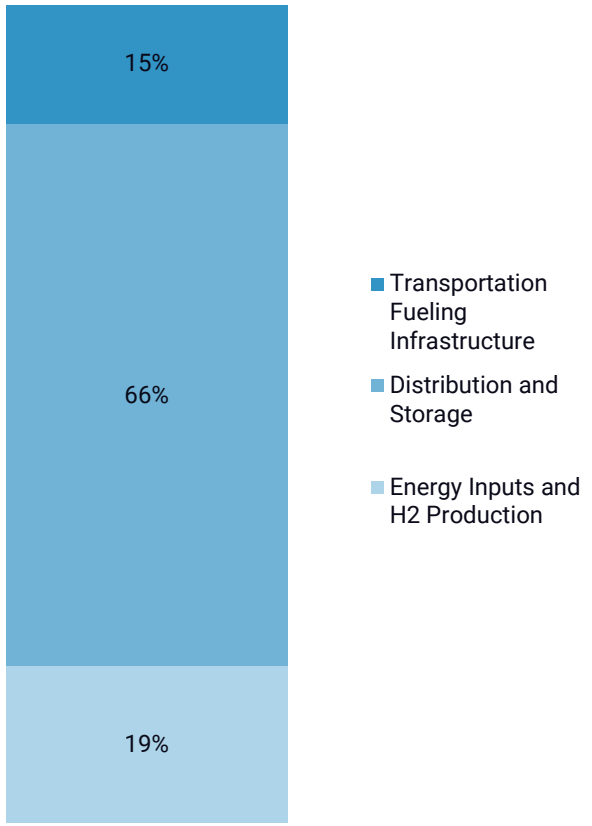
Plant investment jobs

Average annual jobs over 3-year construction period



Breakdown of plant investment jobs

Percentage of jobs by segment



Source: Rhodium Group analysis, Argonne National Laboratory HDSAM, DOE OCED, Midwest Alliance for Clean Hydrogen.
Notes: Values reflect a range of cost estimates for PEM electrolytic H2 and SMR with carbon capture H2 production, energy inputs, hydrogen distribution, and CO_2 injection and storage. We assume annual matching for electrolytic H2 powered by existing nuclear and additional renewable electricity. Distribution and storage percentages includes H2 pipelines, H2 surface storage, and CO_2 injection and storage. Transport fueling infrastructure represents fueling stations.

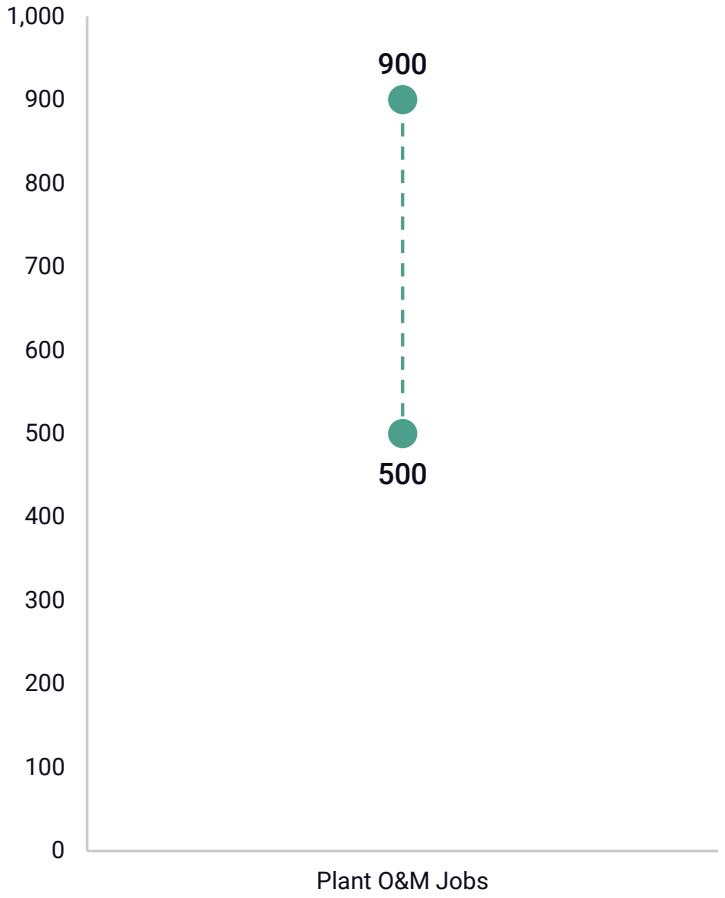
Operations and maintenance (O&M)

Jobs through the point of distribution infrastructure

- Annual jobs to operate the Midwest hub total 500 to 900 ongoing jobs.

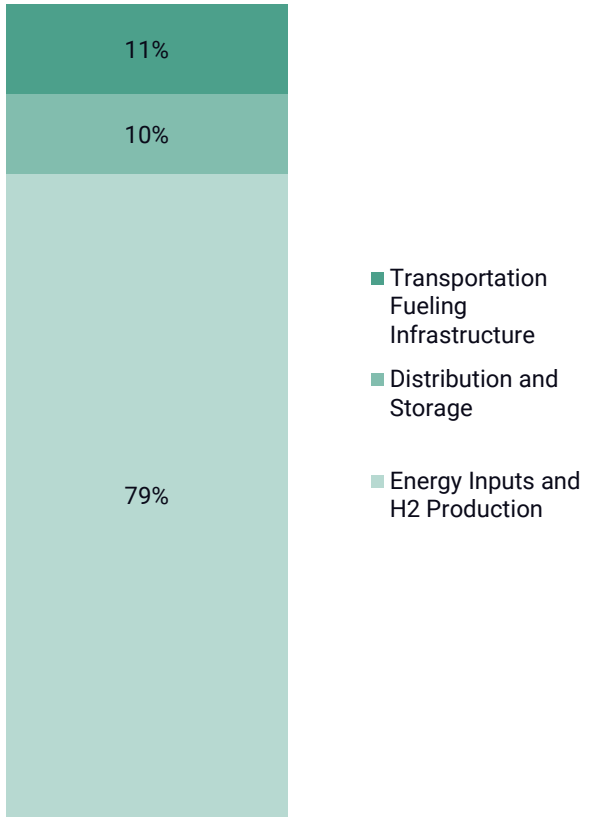
Ongoing O&M jobs

Average annual jobs over the lifetime of the plant



Breakdown of O&M jobs

Percentage of ongoing jobs by segment



Source: Rhodium Group analysis, Argonne National Laboratory HDSAM, DOE OCED, Midwest Alliance for Clean Hydrogen.
Notes: Values reflect a range of cost estimates for PEM electrolytic H2 and SMR with carbon capture hydrogen production, energy inputs, hydrogen distribution, and CO_2 injection and storage. We expect H2 production facilities to be operational for 20-30 years. We assume annual matching for electrolytic H2 powered by additional renewable electricity. Distribution and storage percentages includes H2 pipelines, H2 surface storage, and CO_2 injection and storage. Transport fueling infrastructure represents fueling stations.

Economic Benefits Summary

Appalachian, California, Gulf Coast, and Midwest hubs

Total economic benefits of the four hydrogen hubs examined

Appalachian, California, Gulf Coast, and Midwest hubs

The federal government has committed up to $4.3 billion in funding in total to these projects under the IIJA, of $7 billion overall in the Regional Clean Hydrogen Hubs Program.

Rhodium estimates these four hubs will produce between 7,300 and 8,800 metric tons of H2 per day by 2030.

Jobs associated with constructing and installing these hubs total 32,900 to 47,700 annual average jobs over a 3-year construction period.

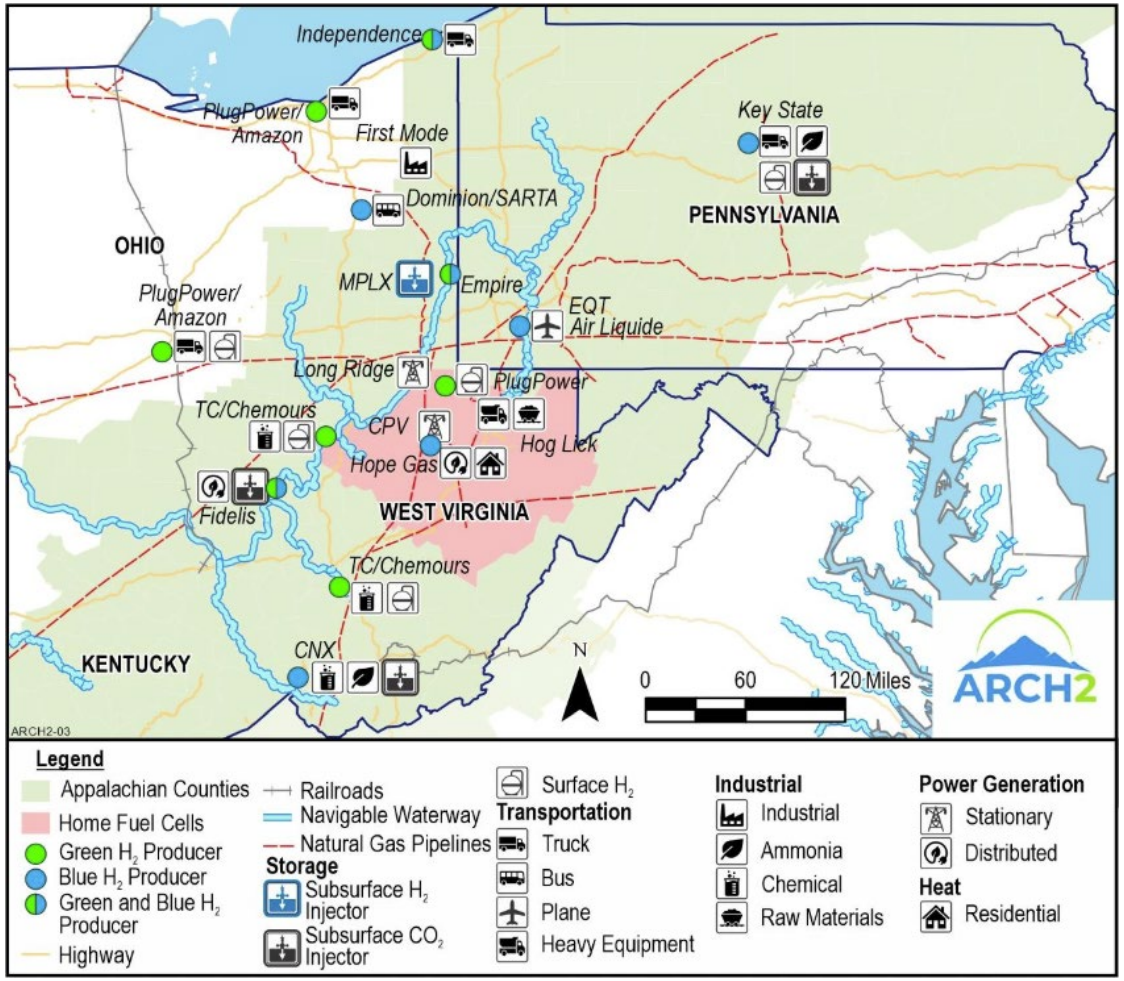
Annual jobs to operate these hubs total 2,800 to 4,600 ongoing jobs.

Appendix

Maps released by the hubs

Appalachian hydrogen hub

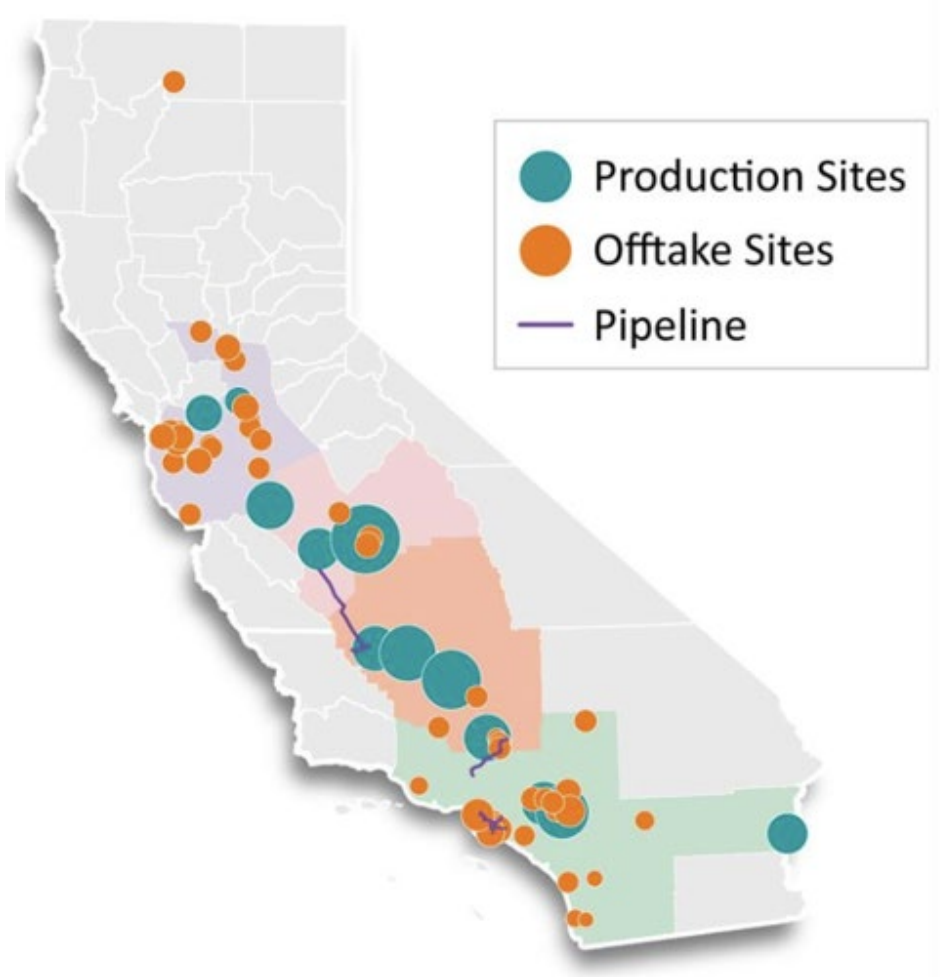
ARCH2 map



Source: OCED Appalachian Regional H2Hub Community Briefing.
Note: Map shows general preliminary project locations, which are subject to change during future negotiations and site planning.

California hydrogen hub

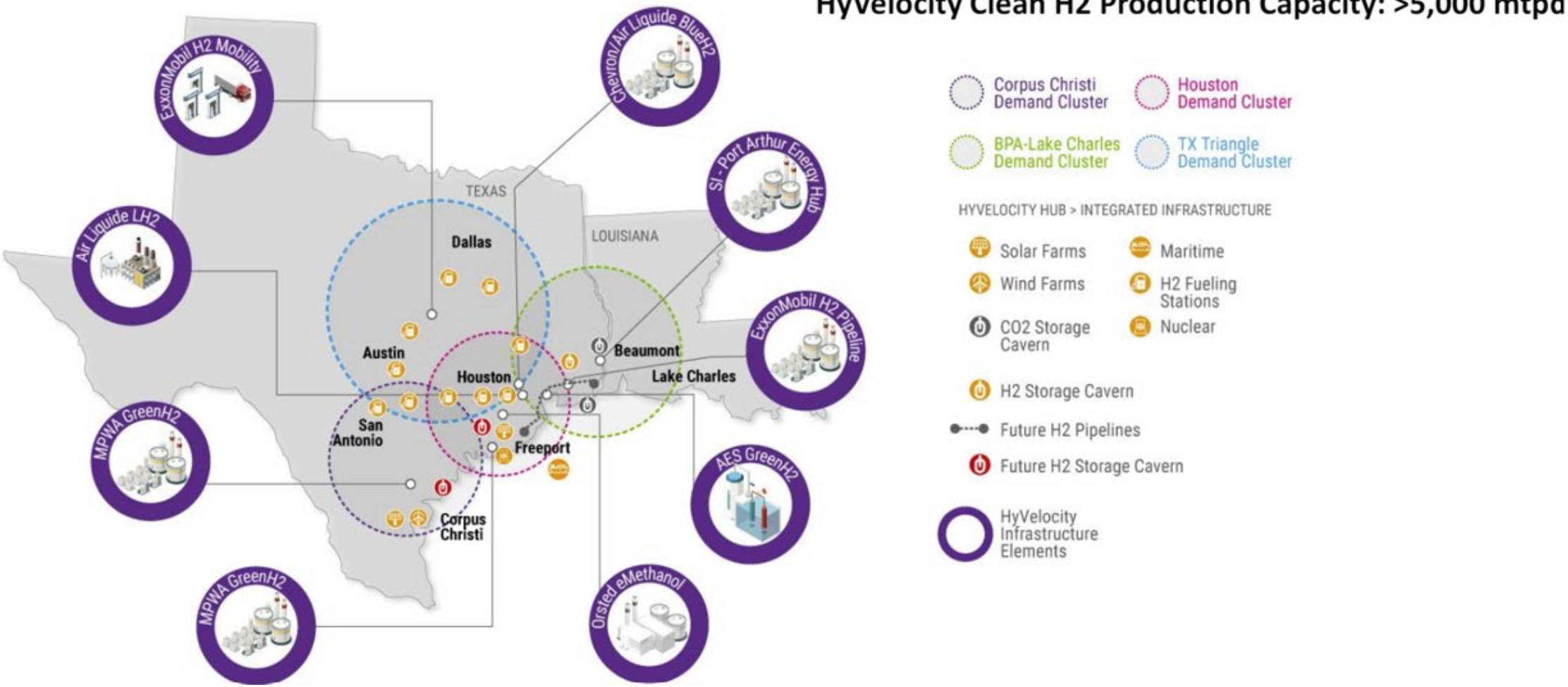
ARCHES map



Source: OCED California Regional H2Hub Community Briefing.
Note: Map shows general preliminary project locations, which are subject to change during future negotiations and site planning.

Gulf Coast hydrogen hub

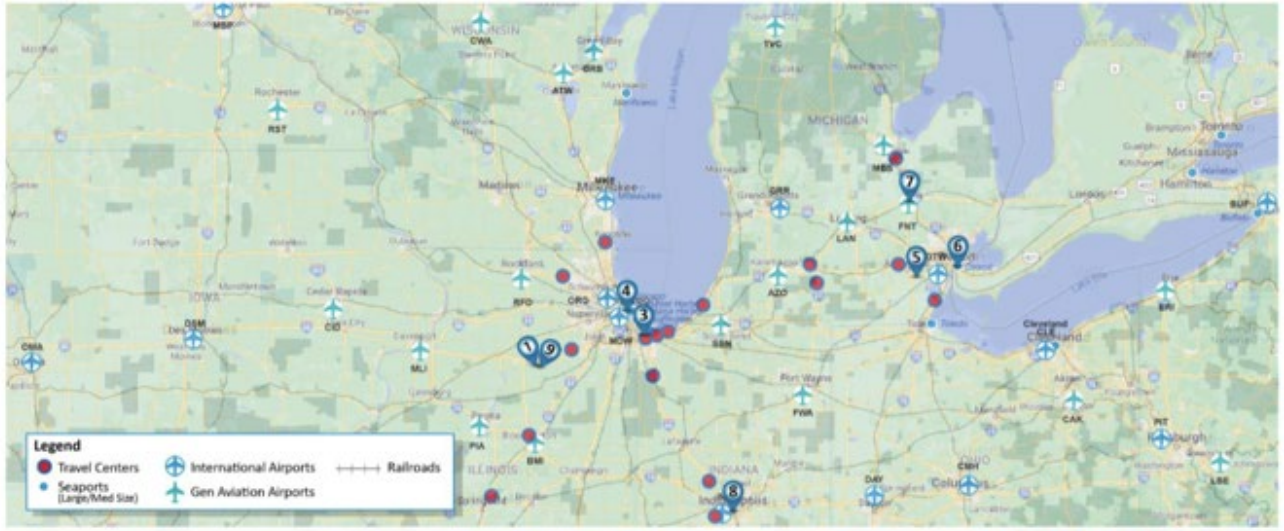
HyVelocity map



Source: OCED Gulf Coast Regional H2Hub Community Briefing.
Note: Map shows general preliminary project locations, which are subject to change during future negotiations and site planning.

Midwest hydrogen hub

MachH2 map



Projects to Establish and Integrate the Regional H2 Hub

1. **Nuclear-Powered Electrolysis**
   Constellation Energy
2. **Liquid H2 to Decarbonize Midwestern Logistics**
   Invenergy and Air Liquide
3. **Northern Indiana Clean H2 Node**
   bp
4. **SWITCH – Solutions Working to transform Industry and Transportation to Clean H2**
   GTI Energy

Projects to Decarbonize Midwestern Transportation Corridors

5. **H2 for MI Freight and Transit**
   American Center for Mobility (ACM)
6. **H2 Truck Stop of the Future**
   Michigan Infrastructure Office (MIO)
7. **H2 Fueling Station Expansion**
   Mass Transportation Authority (MTA)
8. **Midwest Mobility Project**
   Midwest Hydrogen Corridor Coalition, LLC (MHCC)

Projects to Decarbonize Industrial Processes and Products

9. **H2 Pipeline Distribution and End Use**
   Nicor Gas

Source: OCED Midwest Regional H2Hub Community Briefing.
Note: Map shows general preliminary project locations, which are subject to change during future negotiations and site planning.

Rhodium Group

The Economic Benefits of Hydrogen Hubs

New York | California | Washington, DC | Paris
Website: www.rhg.com