Hydrogen Hubs and Demonstrating the Hydrogen Energy Value Chain

Updated November 17, 2023

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SUMMARY

R47289

November 17, 2023

Martin C. Offutt
Analyst in Energy Policy

The U.S. Department of Energy (DOE) announced seven finalists for $7 billion in grants for Regional Clean Hydrogen Hubs in October 2023—a program authorized by Congress in the Infrastructure Investment and Jobs Act (IIJA, §40315, P.L. 117-58). Congress appropriated $8 billion (Division J, Title III of the IIJA) for the Regional Clean Hydrogen Hubs, and DOE announced plans to spend up to $7 billion for the seven finalists and a further $1 billion for a Demand-side Support Initiative that DOE announced on July 5, 2023.

Generally speaking, hydrogen hubs are emerging centers of activity involving hydrogen production, transport, delivery, and end use to provide modern energy services such as mobility, goods movement, heat for manufacturing processes, and other services. A future economy using hydrogen as an energy carrier and fuel could offer an alternative method to provide the many modern energy services associated with fossil fuels. In addition to providing a fuel for transportation—one of the larger applications envisaged—hydrogen can support industrial processes or building operations or can become part of the energy infrastructure by storing energy.

DOE has funded demonstration programs at small and large scale since its inception in 1977. The essential purpose is to demonstrate technological feasibility. A demonstration project also reduces risk to subsequent investors as the government assumes the role of first mover to some extent. Hydrogen demonstrations to date have ranged from single refueling stations to linked activities for realizing value propositions typical of modern energy services, such as goods movement. To give an example, the Shore-to-Store project at the Port of Los Angeles completed its initial phase in February 2022 to demonstrate the shore-side movement of goods by zero-emission vehicles.

Consumption of hydrogen is focused in a relatively concentrated set of end-users. Almost all produced hydrogen is consumed by the petroleum industry or chemical industry either on site or via delivery through dedicated pipelines from large merchant producers. The hydrogen hubs and the additional supply of hydrogen they will create will likely need to be matched to new sources of demand.

Hydrogen in its current uses has a dedicated infrastructure, but one that is small compared to other energy commodities, such as natural gas. For example, hydrogen pipelines comprise 1,600 miles in the United States compared with 300,000 miles of natural gas transmission pipelines. To service a fleet of numerous and relatively smaller hydrogen refueling stations for fuel cell electric vehicles (FCEVs), for example, will require expanded hydrogen delivery infrastructure, such as additional pipelines and delivery trucks loaded with liquid or compressed, gaseous hydrogen, or advances in onsite hydrogen production.

DOE's 2020 Hydrogen Program Plan identified rights-of-way and permitting for hydrogen pipelines as needs and challenges for hydrogen delivery infrastructure. Key policy issues that Congress may examine include the regulation of pipeline and other infrastructure siting, including potential federal-state jurisdictional conflicts, and the regulation of pipeline rates and terms of service.

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Introduction

Hydrogen hubs are emerging centers of activity involving hydrogen production, transport, delivery and end use to provide energy services, such as mobility, goods movement, and heat for manufacturing processes.[1] The U.S. Department of Energy (DOE) announced seven finalists for a total of up to $7 billion in grants for Regional Clean Hydrogen Hubs in October 2023, authorized in the Infrastructure Investment and Jobs Act (IIJA, P.L. 117-58, §40315).[2] Congress created a new Office of Clean Energy Demonstrations (OCED) to manage these and other demonstration projects. Congress appropriated $8 billion (Division J, Title III of the IIJA), including the $7 billion for the seven finalists and a further $1 billion for a Demand-side Support Initiative that DOE announced on July 5, 2023.[3]

A future economy using hydrogen as an energy carrier[4] and fuel could offer an alternative method to provide the many modern energy services associated with fossil fuels.[5] In addition to providing a fuel for transportation—one of the larger applications envisaged—hydrogen could support industrial processes or building operations or become part of the energy infrastructure by storing energy. Demonstrations of hydrogen technology and value propositions based on hydrogen continue to emerge, ranging from one-off funded projects to public-private partnerships (P3s) with regional scope in the United States and abroad. Many such projects investigate uses of hydrogen as fuel for familiar services such as personal transportation/mobility or industrial heat for manufacturing. The hydrogen energy value chain spans resource extraction, production, storage, and final conversion and end use. Although demonstrations have addressed portions of this value chain, DOE's statements on the Regional Clean Hydrogen Hubs envisage the full value chain, following the prescriptions of the IIJA.

DOE Programs and Demonstrations

DOE Hydrogen Programs

The DOE Hydrogen Program, led by the Hydrogen and Fuel Cell Technologies Office within the Office of Energy Efficiency and Renewable Energy (EERE) and including several other DOE offices, addresses the development of applications that use hydrogen in place of other fuels and technologies. A description of how this funding is divided among DOE offices may be found in

[1] For further discussion of energy services, see A. Grubler et al., *Energy Primer*, International Institute for Applied Systems Analysis, Laxenburg, Austria, August 2015, pp. 8-14, at https://pure.iiasa.ac.at/id/eprint/11190/1/EnergyPrimer_Aug15_HiRes.pdf; M.J. Fell, "Energy Services: A Conceptual Review," *Energy Research and Social Science*, vol. 27 (May 2017), p. 129–140.

[2] DOE, "Biden-Harris Administration Announces $7 Billion For America's First Clean Hydrogen Hubs, Driving Clean Manufacturing and Delivering New Economic Opportunities Nationwide," press release, October 13, 2023, https://www.energy.gov/articles/biden-harris-administration-announces-7-billion-americas-first-clean-hydrogen-hubs-driving.

[3] U.S. Department of Energy, Biden-Harris Administration to Jumpstart Clean Hydrogen Economy with New Initiative to Provide Market Certainty and Unlock Private Investment, July 3, 2023, https://www.energy.gov/articles/biden-harris-administration-jumpstart-clean-hydrogen-economy-new-initiative-provide-market; CRS In Focus IF12514, *DOE Appropriations for Hydrogen and Fuel Cell Activities: FY2024*, by Martin C. Offutt.

[4] Energy carriers are substances or physical phenomena such as electricity that have potential energy, which allows them to perform work or provide heat or light, and that can be transmitted over long distances without substantially losing their potential energy.

[5] For further discussion of a hydrogen economy, see CRS Report R47487, *The Hydrogen Economy: Putting the Pieces Together*, by Martin C. Offutt.

CRS In Focus IF12514, *DOE Appropriations for Hydrogen and Fuel Cell Activities: FY2024*, by Martin C. Offutt. The Hydrogen Program also considers hydrogen in its role as an established chemical feedstock. The Hydrogen Program includes over 400 projects of research and development (R&D), systems integration, demonstrations, and initial deployment activities performed by universities, national laboratories, and industry.[6]

Announced Finalists for Regional Clean Hydrogen Hubs Grants

DOE announced the seven finalists for the initial $7 billion of the Regional Clean Hydrogen Hubs on October 13, 2023.[7] The hubs were funded at $8 billion in the IIJA. Previously, DOE had issued an initial funding opportunity announcement (FOA) in September 2022.[8] DOE had then conducted initial consultations including a Request for Information (RFI) on February 16, 2022.[9] DOE received more than 120 responses to the RFI comprising over 1,300 pages.[10] DOE solicited and accepted concept papers through November 7, 2022, and sent letters of encouragement to authors of 33 of the concept papers. The funding applications were due on April 7, 2023, and 28 organizations applied.[11] **Figure 1** shows the geographies of the seven finalists. DOE is requiring a minimum 50% cost share from nonfederal sources and anticipates projects to be executed over 8 to 12 years.[12]

[6] Sunita Satyapal, Director, DOE Hydrogen and Fuel Cell Technologies Office, *2022 AMR Plenary Session*, June 6, 2022, at https://www.energy.gov/sites/default/files/2022-06/hfto-amr-plenary-satyapal-2022-1.pdf.

[7] DOE, "Biden-Harris Administration Announces $7 Billion For America's First Clean Hydrogen Hubs, Driving Clean Manufacturing and Delivering New Economic Opportunities Nationwide," press release, October 13, 2023, https://www.energy.gov/articles/biden-harris-administration-announces-7-billion-americas-first-clean-hydrogen-hubs-driving.

[8] U.S. Department of Energy, *Bipartisan Infrastructure Law: Additional Clean Hydrogen Programs (Section 40314): Regional Clean Hydrogen Hubs Funding Opportunity Announcement*, DE-FOA-0002779, September 22, 2022, at https://oced-exchange.energy.gov/FileContent.aspx?FileID=e159ff1f-5572-437e-b02d-b68acb461893.

[9] 87 *Federal Register* 8828, February 16, 2022.

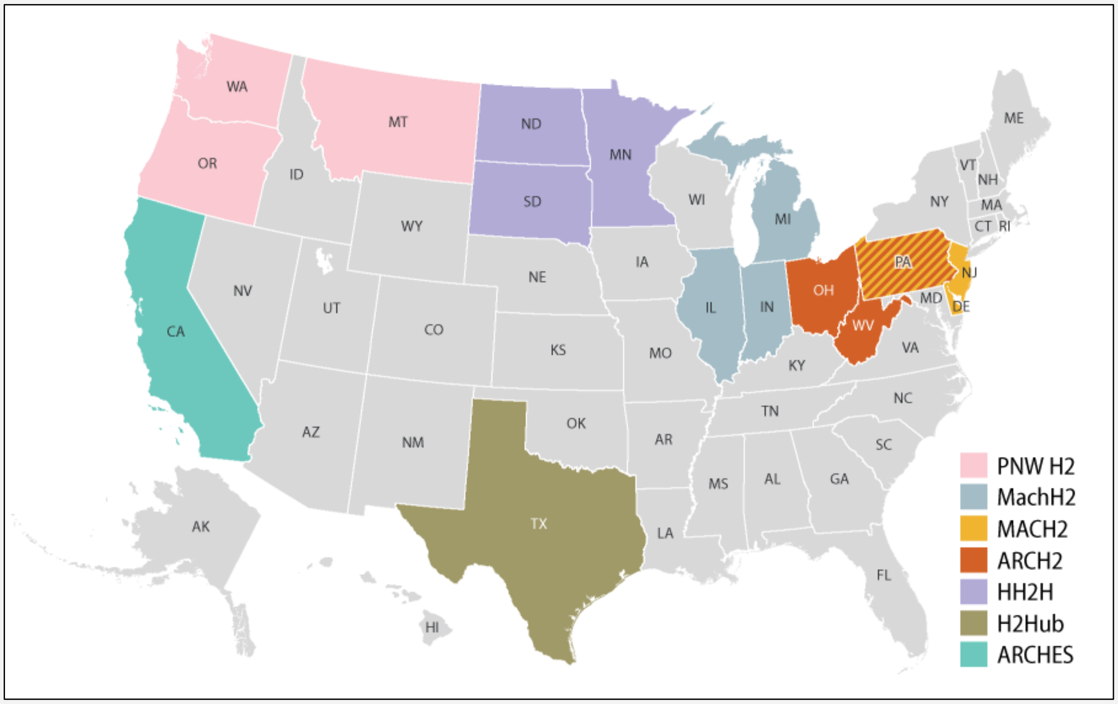
[10] U.S. Department of Energy, Hydrogen and Fuel Cell Technologies Office, *Hydrogen and Fuel Cell Technologies Office Funding Opportunities*, at https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office-funding-opportunities.

[11] U.S. Department of Energy, "Biden-Harris Administration Announces Historic $7 Billion Funding Opportunity to Jump-Start America's Clean Hydrogen Economy," press release, September 22, 2022, at https://www.energy.gov/articles/biden-harris-administration-announces-historic-7-billion-funding-opportunity-jump-start; Colloquy between Senator Cassidy and Under Secretary for Infrastructure Crane, in U.S. Congress, Senate Committee on Energy and Natural Resources, *Full Committee Hearing to Examine the Department of Energy's Decision-Making Process for Awarding Competitive Loans and Grants Funded Through the Inflation Reduction Act and the Bipartisan Infrastructure Law*, 118th Cong., 1st sess., October 19, 2023.

[12] U.S. Department of Energy, *Bipartisan Infrastructure Law: Additional Clean Hydrogen Programs (Section 40314): Regional Clean Hydrogen Hubs Funding Opportunity Announcement*, DE-FOA-0002779, September 22, 2022, p. 17 at https://oced-exchange.energy.gov/FileContent.aspx?FileID=e159ff1f-5572-437e-b02d-b68acb461893.

Figure 1. Locations of Finalists Announced by DOE for Regional Clean Hydrogen Hubs

Total Funding of $7 Billion



Source: CRS figure based on DOE, "Biden-Harris Administration Announces $7 Billion For America's First Clean Hydrogen Hubs, Driving Clean Manufacturing and Delivering New Economic Opportunities Nationwide," press release, October 13, 2023, https://www.energy.gov/articles/biden-harris-administration-announces-7-billion-americas-first-clean-hydrogen-hubs-driving.

Notes: ARCH2 = Appalachian Hydrogen Hub (Appalachian Regional Clean Hydrogen Hub); ARCHES = California Hydrogen Hub (Alliance for Renewable Clean Hydrogen Energy Systems); H2Hub = Gulf Coast Hydrogen Hub (HyVelocity H2Hub); HH2H = Heartland Hydrogen Hub (Heartland Hub); MACH2 = Mid-Atlantic Hydrogen Hub (Mid-Atlantic Clean Hydrogen Hub); MachH2 = Midwest Hydrogen Hub (Midwest Alliance for Clean Hydrogen); and PNW H2 = Pacific Northwest Hydrogen Hub (PNW H2). In the foregoing list, the DOE project name is given first followed by awardee's name in parenthesis. Congress appropriated $8 billion (Division J, Title III of the IIJA), including the $7 billion for the seven finalists and a further $1 billion for a Demand-side Support Initiative that DOE announced on July 5, 2023.

Demonstrations

Purpose and Expectations

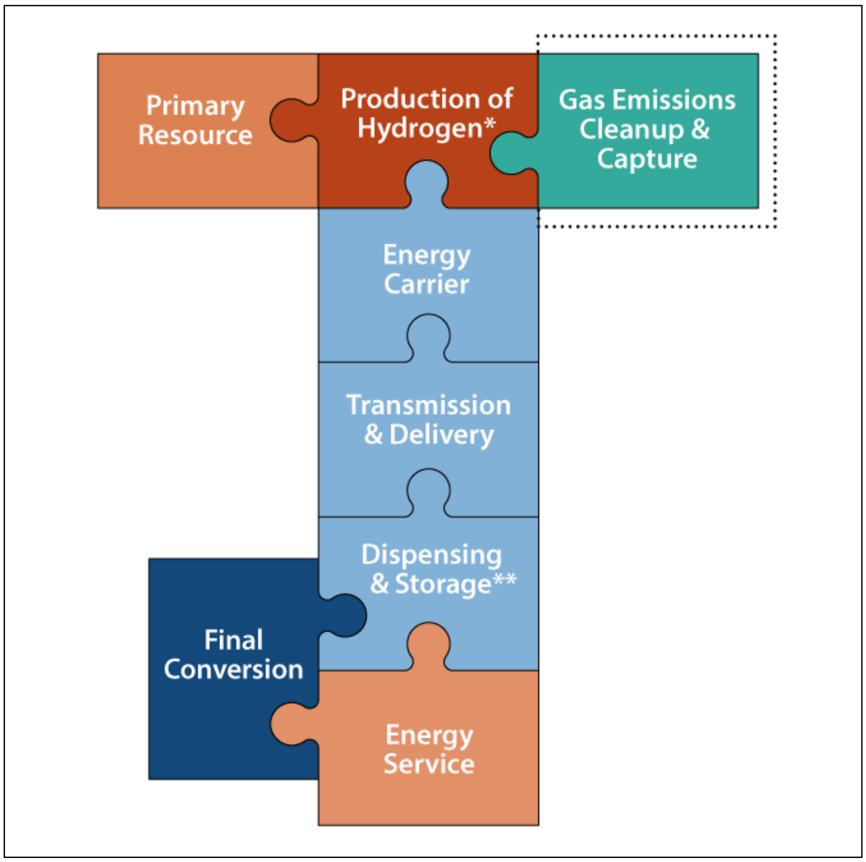
The essential purpose of demonstrations is to show technological feasibility.[13] A demonstration project receiving government support also reduces risk to subsequent investors as the government

[13] See, for example, A. Grubler, F. Aguayo, and K. Gallagher, "Chapter 24—Policies for the Energy Technology Innovation System," in *Global Energy Assessment—Toward a Sustainable Future* (New York and Laxenburg: Cambridge University Press, 2012), p. 1673; L.R. Cohen and R.G. Noll, *The Technology Pork Barrel* (Washington, DC: The Brookings Institution, 1991), p. 39.

assumes the role of first mover to some extent.[14] Inserting a technology into a demonstration project allows testing in relative isolation so that any failures have limited consequences and do not cascade more widely, for example into an energy network such as an electric power grid.[15] Demonstration projects have themselves been part of early deployment by selling products, such as outputs from the demonstration project.[16] DOE has stated that the Regional Clean Hydrogen Hubs will yield insights and validate the claimed benefits (environmental and otherwise) of the hydrogen economy and will identify technology needs.[17]

Hydrogen demonstration projects have addressed portions of the full hydrogen energy value chain depicted in **Figure 2**. Further information on the hydrogen energy value chain is described in CRS Report R47487, *The Hydrogen Economy: Putting the Pieces Together*, by Martin C. Offutt.

Figure 2. Hydrogen Energy Value Chain



Source: CRS

[14] D.M. Hart, "Beyond the Technology Pork Barrel? An Assessment of the Obama Administration's Energy Demonstration Projects," *Energy Policy*, vol. 119 (2018), pp. 367-376.

[15] Ibid.

[16] For discussion of sales of synthetic fuel from a demonstration project, see U.S. General Accounting Office, *Synthetic Fuels: Status of the Great Plains Coal Gasification Project—August 1, 1985*, RCED-86-36, December 1985, p. 19, at https://www.gao.gov/assets/rced-86-36.pdf.

[17] Testimony of Sunita Satyapal, Director, Hydrogen and Fuel Cell Technologies Office, U.S. Department of Energy, during U.S. Congress, Senate Energy and Natural Resources, *Clean Hydrogen*, hearing, 117th Cong., 2nd sess., February 10, 2022.

Notes: Hydrogen may be sourced from numerous primary resources (amber, top left). The hydrogen production step (red) can occur in ways specific to the resource and is packaged and moved as the energy carrier (light blue) over long distances (transmission & delivery, light blue) and, as appropriate, converted to hydrogen and stored near the point of use (e.g., at the scale of a refueling station, light blue). The end-use technology such as the vehicle fuel cell will then convert the carrier into useful energy (dark blue) to provide the energy service (amber, lower right). Depending on the method of hydrogen production, there may be an additional step involving gas emissions cleanup and capture (green, enclosed in dotted lines) to remove pollutants. This description is based on hydrogen as the energy carrier. However, the sequence in the figure can also use other energy carriers as intermediaries where indicated by the asterisks:

(*) energy carrier created in production step (red) could instead be ammonia, electricity, or other.

(**) within the dispensing and storage step (light blue), a non-hydrogen energy carrier would be converted to hydrogen.

Brief History of Demonstrations

DOE has funded demonstration programs and projects at small and large scale since its inception in 1977, many of which have included hydrogen production. Congress authorized these programs for explicit purposes and provided DOE with both annual and one-time supplemental appropriations including from the IIJA and the American Recovery and Reinvestment Act of 2009 (ARRA, P.L. 111-5). The Regional Clean Hydrogen Hubs continue this sort of demonstration activity at a conceptual level.

The Energy Conservation and Production Act (P.L. 94-385) established a demonstration program for buildings energy conservation "to test the feasibility and effectiveness" of financial assistance for the adoption of energy conservation measures.[18] The early DOE demonstrations ranged in scope and scale from over 30 small rooftop solar photo-voltaic generation projects to larger, single demonstrations such as synthetic fuels plants. One such plant, the Great Plains coal gasification plant, attempted to demonstrate the conversion of coal into raw gas containing hydrogen and other constituents for synthesis of ammonia and other gases.[19]

DOE curtailed the number of demonstration plants in the 1980s.[20] Nonetheless, later that decade, nine clean coal demonstrations were established to burn or otherwise use coal in a way that reduces release of pollutants.[21] Later plans for large-scale demonstrations included FutureGen, an effort proposed by DOE in 2003 to build a coal-fired power plant with hydrogen production and carbon capture and storage.[22] The plant was to be based on coal gasification and was supported by outlays both from annual appropriations and $1 billion awarded from ARRA, with roughly $200 million of the latter being spent. The project was re-conceptualized and then ended in 2015.[23]

The Energy Policy Act of 2005 (EPAct05, P.L. 109-58) authorized the Next Generation Nuclear Plant (42 U.S.C. §16021), a prototype plant based on the Generation IV Nuclear Energy Systems Initiative (42 U.S.C. §16272), to generate electricity, hydrogen, or both. Congress appropriated

[18] 12 U.S.C. §1701z-8.

[19] National Research Council, *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*, Washington, DC, 2001, p. 175.

[20] National Research Council, *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*, Washington, DC, 2001.

[21] L.R. Cohen and R.G. Noll, *The Technology Pork Barrel* (Washington, DC: The Brookings Institution, 1991), p. 31; National Research Council, *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*, Washington, DC, 2001, p. 216.

[22] U.S. Department of Energy, "Abraham and Dobriansky Announce 'FutureGen,'" press release, February 27, 2003, at https://www.energy.gov/management/february-27-2003-abraham-and-dobriansky-announce-futuregen.

[23] Manuel Quinones, "Lawmakers Likely to Scrutinize DOE Closeout of FutureGen Project," *Environment & Energy Daily*, February 4, 2015, at http://www.eenews.net/eedaily/stories/1060012838/.

over $500 million for Phase I of the project, including research and development, design engineering, licensing, and project management.[24] DOE decided not to proceed with Phase II in 2011 following a review by its Nuclear Energy Advisory Committee.[25]

In 2021, the IIJA consolidated demonstration programs under one office, OCED, and appropriated $21.5 billion to support large-scale demonstration projects, including the $8 billion for the Regional Clean Hydrogen Hubs.[26]

The U.S. Synthetic Fuels Corporation and the Great Plains Coal Gasification Plant

In 1980, the Energy Security Act (P.L. 96-294) established the U.S. Synthetic Fuels Corporation (SFC). Congress used $2.8 billion of the Energy Security Reserve, established and funded first in fiscal year 1980 by the Interior and Related Agencies Appropriations Act (P.L. 96-126), to fund the Great Plains coal gasification plant in North Dakota and the Parachute Creek Oil Shale project in Colorado. Five projects entered the construction phase in total and were the beneficiaries of loan and price guarantees. Congress abolished the SFC in 1986 (P.L. 99-190) and rescinded its remaining budget authority, although the projects continued.[27] Following the August 1985 loan default at the Great Plains plant, DOE purchased the plant for $1 billion in 1986 and sold it to the Basin Electric Power Cooperative in 1988.[28]

Regional Clean Hydrogen Hubs

Requirements

Congress required the Regional Clean Hydrogen Hubs must "demonstrate the production, processing, delivery, storage, and end-use of clean hydrogen."[29] The IIJA revised Section 813 of EPAct05 to require the Secretary of Energy to use certain criteria in selecting proposals for the Regional Clean Hydrogen Hubs. The DOE describes these criteria as follows:[30]

- "Feedstock diversity—at least one hub shall demonstrate the production of clean hydrogen from fossil fuels, one hub from renewable energy, and one hub from nuclear energy.
- End-use diversity—at least one hub shall demonstrate the end-use of clean hydrogen in the electric power generation sector, one in the industrial sector, one in the residential and commercial heating sector, and one in the transportation sector.

[24] U.S. Department of Energy, Office of Nuclear Energy, *Next Generation Nuclear Plant: A Report to Congress*, April 2010, p. 7.

[25] U.S. Government Accountability Office, *Advanced Reactor Research: DOE Supports Multiple Technologies but Actions Needed to Ensure a Prototype Is Built*, 14-545, June 2014, p. 11.

[26] M. Klembara, U.S. Department of Energy, "Office of Clean Energy Demonstrations," April 15, 2022, at https://energyresearch.ucf.edu/wp-content/uploads/2022/04/Klembara-OCED_20220415.pdf.

[27] M. Holt, *Energy Policy: Is the U.S. Ready for the 1990s? Energy Security Laws of the 1970s*, Environmental and Energy Study Conference, U.S. Congress, April 18, 1988, pp. 14-15.

[28] National Energy Technology Laboratory, *Gasifipedia:7.5.1. Great Plains Synfuels Plant*, at https://www.netl.doe.gov/research/Coal/energy-systems/gasification/gasifipedia/great-plains; T. W. Lippman, "Huge Synthetic Fuel Plant Now Operating at a Profit," *Washington Post*, February 18, 1990.

[29] 42 U.S.C. §16161a(b)(2).

[30] The criteria are DOE's paraphrasing of 42 U.S.C. §16161a, quoted from *DOE Hydrogen Program, Request for Information # DE-FOA-0002664.0002: Regional Clean Hydrogen Hubs Implementation Strategy*, pp. 4-5, at https://eere-exchange.energy.gov/Default.aspx?foaId=5d96172f-e9b6-48ff-94ac-5579c3531526.

- Geographic diversity—each regional clean hydrogen hub shall be located in a different region of the United States and shall use energy resources that are abundant in that region.
- Hubs in natural gas-producing regions—at least two regional clean hydrogen hubs shall be located in the regions of the United States with the greatest natural gas resources.
- Employment—DOE shall give priority to regional clean hydrogen hubs that are likely to create opportunities for skilled training and long-term employment to the greatest number of residents in the region.
- Additional Criteria—DOE may take into consideration other criteria that are necessary or appropriate to carry out the regional clean hydrogen hubs program."

DOE Funding

DOE received but has not obligated all funds from the IIJA. Unexpended balances include funds for the seven Regional Clean Hydrogen Hubs (IIJA §40314) announced on October 13, 2023—a program which received $1.6 billion in each of FY2022 through FY2024. The Senate Appropriations Committee had stated its expectation that DOE would make award selections by the end of calendar year 2023 (S.Rept. 118-72).

Experience with Hydrogen Projects

Early Deployment

Industrial processes that use hydrogen already occur at large scale, such as petroleum refining or production of ammonia to make urea for fertilizer.[31] Demonstrations of additional industrial uses of hydrogen are being developed in cement, ceramics, and glass manufacturing—substituting hydrogen for operations that currently use other fuels.[32]

The customer-facing hydrogen technologies now available to retail consumers include hydrogen refueling stations and fuel cell electric vehicle (FCEV) cars. Honda, Hyundai, and Toyota have manufactured FCEV cars to buy or lease in North America. According to data maintained by the California Energy Commission (CEC), California had 65 public retail hydrogen refueling stations (HRS) for light-duty vehicles and 6 heavy-duty HRS as of June 30, 2023, with an additional 35 light-duty, 4 heavy-duty, and 5 multi-use HRS planned.[33] There is one public HRS in Hawaii.[34] CEC estimates that California has built almost four times as much dispensing capacity as it needs for the FCEVs in the state.[35]

[31] International Energy Agency (IEA), *The Future of Hydrogen: Seizing Today's Opportunities*, Paris, June 2019, p. 32.

[32] IEA, *Global Hydrogen Review 2021*, Paris, October 2021, p. 6.

[33] California Energy Commission, *Hydrogen Refueling Stations in California*, June 30, 2023, https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/hydrogen-refueling.

[34] U.S. Department of Energy, Alternative Fuels Data Center, *Hydrogen Fueling Station Locations*, at https://afdc.energy.gov/fuels/hydrogen_locations.html#/find/nearest?fuel=HY.

[35] J. Berner, M. Crowell, and A. Martinez, *Joint Agency Staff Report on Assembly Bill 8: 2022 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California*, California Energy Commission, CEC-600-2022-064, December 22, 2022, p. 39, https://www.energy.ca.gov/publications/2022/joint-agency-staff-report-assembly-bill-8-2022-annual-assessment-time-and-cost.

There were 14,900 FCEV cars registered in the United States at the end of 2022.[36] Car makers had sold or leased over 17,000 light-duty vehicles in the United States, cumulative through October 25, 2023.[37] The sales of FCEV cars is small compared to cars of all types sold in the United States, which comprised 3.35 million sales in 2021 alone.[38] Overall, FCEV cars comprised slightly fewer than 1 in every 20,000 cars in the United States at the end of 2021.[39]

DOE has identified other applications in early deployment. These include over 60,000 fork lifts used for logistical operations—known as material handling equipment (MHE)—and hydrogen back-up power devices totaling over 500 megawatts (MW) capacity.[40] The two applications together received roughly $40 million from ARRA.[41]

DOE identified several technology cost advantages of hydrogen versus battery-electric MHE, beginning with lower total cost of ownership[42] for the hydrogen version.[43] Hydrogen MHE require refueling less often than battery-electric MHE require recharging, possibly avoiding work stoppages. DOE has noted that its own funding of purchase of fork lifts has been small relative to that of industry. 524 units were purchased according to a DOE-industry cost-sharing arrangement from the ARRA funding noted above and another 189 from DOE annual appropriations. DOE found that through the end of 2017, a further 21,000 units were in service at the sole expense of industry; users included large "big box" retail, food suppliers and retailers, car makers, and freight movers.[44] By 2020, DOE estimated there were 35,000 such units,[45] and, by 2023, over 60,000.[46]

Advanced Clean Energy Storage, a hydrogen and energy storage facility now majority-owned by a subsidiary of Chevron USA, received a DOE loan guarantee in June 2022.[47] The guarantee was

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[36] U.S. Department of Energy, Alternative Fuels Data Center, *Hydrogen Vehicles Registered in 2022*, at https://afdc.energy.gov/transatlas/#/?fuel=HY&view=vehicle_count.

[37] California Fuel Cell Partnership, *By the Numbers: FCEV Sales, FCEB, and Hydrogen Station Data*, October 25, 2023, at https://cafcp.org/by_the_numbers.

[38] S.C. Davis and R.G. Boundy, *Transportation Energy Data Book, Edition 40*, Oak Ridge National Laboratory, ORNL/TM-2022/2376, Oak Ridge, TN, June 2022, p. 3-9.

[39] R.C. Samsun et al., "Deployment of Fuel Cell Vehicles and Hydrogen Refueling Station Infrastructure: A Global Overview and Perspectives," *Energies*, vol. 15, no. 4975 (July 7, 2022), p. 23.

[40] U.S. Department of Energy, *DOE National Clean Hydrogen Strategy and Roadmap*, June 2023, pp. 14 and 36, at https://www.hydrogen.energy.gov/library/roadmaps-vision/clean-hydrogen-strategy-roadmap.

[41] See note 53 to U.S. Department of Energy, *DOE National Clean Hydrogen Strategy and Roadmap*, June 2023, p. 86 and 36, at https://www.hydrogen.energy.gov/library/roadmaps-vision/clean-hydrogen-strategy-roadmap.

[42] Total cost of ownership refers to the sum of the initial cost plus any operation and maintenance costs including fuel consumption over the lifetime of the equipment.

[43] DOE Office of Energy Efficiency and Renewable Energy, *Early Markets: Fuel Cells for Material Handling Equipment*, DOE/EE-0751, February 2014, at https://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/early_markets_mhe_fact_sheet.pdf.

[44] P. Devlin and G. Moreland, *Industry Deployed Fuel Cell Powered Lift Trucks*, Record # 18002, May 23, 2018, at https://www.hydrogen.energy.gov/library/program-records.

[45] U.S. Department of Energy, *Hydrogen Program Plan*, DOE/EE-2128, Washington, DC, November 2020, p. 28.

[46] Sunita Satyapal, Director, DOE Hydrogen and Fuel Cell Technologies Office, *2022 AMR Plenary Session*, June 6, pp. 5 and 49, 2022, at https://www.energy.gov/sites/default/files/2022-06/hfto-amr-plenary-satyapal-2022-1.pdf.

[47] U.S. Department of Energy, *DOE Announces First Loan Guarantee for a Clean Energy Project in Nearly a Decade*, June 8, 2022, at https://www.energy.gov/articles/doe-announces-first-loan-guarantee-clean-energy-project-nearly-decade; Chevron Corporation, "Chevron Acquires Majority Stake in the Advanced Clean Energy Storage Hydrogen Project in Delta, Utah," press release, September 12, 2023, https://www.chevron.com/newsroom/2023/q3/chevron-acquires-majority-stake-in-advanced-clean-energy-storage-project-delta-utah.

for a $504 million loan[48] to construct 220 MW of electrolyzers[49] in Delta, UT, paired with underground caverns to store the hydrogen. The estimated storage capacity in each of two caverns is 5.5 million kg of hydrogen. Each cavern would have roughly 110 gigawatt-hours (GWh) of stored potential energy, assuming a combined-cycle gas turbine were used to re-electrify the hydrogen.[50] Mitsubishi Power delivered two of its J-class hydrogen-capable combustion turbines in June and July 2023, which the off-taker is to operate using fuel from the caverns.[51]

Hydrogen Demonstration Projects

Hydrogen demonstration projects have ranged from single refueling stations to linked activities for realizing broader value propositions.[52] As one example, the Shore-to-Store project at the Port of Los Angeles, completed its initial phase in February 2022 to demonstrate the shore-side movement of goods by zero-emission vehicles. Shell Oil Products US built and operated two hydrogen refueling stations. Kenworth, a truck manufacturer group within vehicle and parts maker PACCAR, provided 10 vehicles—the hydrogen fuel cell version of its T680, a class 8 tractor, with Toyota's fuel cell electric system.[53] Project partners contributed $41.4 million and the California Air Resources Board (CARB) contributed $41.1 million.[54] Air Liquide, an industrial chemicals maker, announced a project at the Port of Houston in December 2022 that would involve fuel cell-electric trucks for hauling offloaded cargo within a port (i.e., drayage) and other shore-side hauling needs.[55]

The buildings sector includes demonstrations of hydrogen technologies and hydrogen fuel applications, though there is almost no evidence of retail use of hydrogen.[56] A number of demonstration projects are underway aimed at so-called hydrogen injection into existing natural gas distribution assets; these include projects in France, the United Kingdom (UK), and elsewhere and serve one hundred or more dwellings per project.[57]

[48] Title XVII of the Energy Policy Act of 2005, P.L. 109-58, authorizes DOE to issue loan guarantees.

[49] An electrolyzer is an electrochemical device, powered by electricity, that decomposes water into hydrogen and oxygen.

[50] Email communication from Mitsubishi Power, January 27, 2023.

[51] Mitsubishi Power Americas, "Mitsubishi Power delivers Hydrogen-Ready Gas Turbines to "IPP Renewed" Project in Utah to meet Decarbonization Goals in the Western US," press release, July 28, 2023, https://power.mhi.com/regions/amer/news/20230727.

[52] However, there is not one agreed-upon data set of all such projects; see, for example, European Commission, Clean Hydrogen Partnership, *Demo Projects Hub*, at https://www.clean-hydrogen.europa.eu/get-involved/regions-hub/demo-projects-hub_en.

[53] "Kenworth: Port of Los Angeles Rolls Out Hydrogen Fuel Cell Electric Freight Demonstration," *Automotive World*, June 7, 2021, at https://www.automotiveworld.com/news-releases/electric-mobility-news-releases/kenworth-port-of-los-angeles-rolls-out-hydrogen-fuel-cell-electric-freight-demonstration/.

[54] "Port of Los Angeles, Partners Launch Zero-Emission Project," *Transport Topics*, June 11, 2021.

[55] Air Liquide, "Air Liquide Fuels First Hydrogen Fuel Cell Truck Demonstration at Port of Houston," press release, January 12, 2023, https://usa.airliquide.com/hyzon-port-of-houston.

[56] IEA, *Global Hydrogen Review 2021*, Paris, October 2021, pp. 90, 97.

[57] For information on specific projects, see ENGIE, *GRHYD: Rouvelons nos energies: Présentation*, at https://grhyd.fr/presentation/;. HyDeploy, "Pioneering the Safe Use of Blended Hydrogen in Gas Networks to Reduce Carbon Emissions," press release, 2022, at https://hydeploy.co.uk/; Jacob Dijkstra, *Ameland: Frontrunner in the Energy Transition*, Duurzaam Ameland, Brussels, October 11, 2017, at http://www.pace-energy.eu/wp-content/uploads/2017/10/Jacob-Dijkstra_The-exemplary-role-of-local-communities-in-the-energy-transition_The-Ameland-island-story.pdf.

Barriers to Early Deployment

Refueling Infrastructure

DOE's informal survey of stakeholders identified a number of perceived barriers to hydrogen market adoption, including the cost to the end-user of hydrogen technologies; need for sufficient hydrogen infrastructure; and public awareness and understanding.[58] Addressing this perceived need for sufficient infrastructure, and the cost involved, CARB modeled a year-by-year build-out of hydrogen refueling stations and estimated that 1,000 refueling stations would be needed for an assumed 1 million FCEV cars,[59] at an estimated cost of $1.9 million (in 2016 dollars) per station.[60]

Recent federal programs address refueling as part of wider measures for alternative fuels. The IIJA, Section 11401, authorized grants for charging and fueling infrastructure along designated alternative fuel corridors. Such corridors may be designed so that vehicles travelling along them encounter one refueling station within a few miles of the highway at specified distances (e.g., 50 miles). Grantees may use the funds for a variety of alternative fuel infrastructure, including battery recharging or hydrogen fueling. The IIJA, Section 11101(b)(1)(C)), provides a total of approximately $2.5 billion for FY2022 to FY2026 from the Highway Trust Fund[61] for this program.[62] The program is being implemented by the Federal Highway Administration (FHWA) and is composed of a (1) Community Charging and Fueling Grants (Community Program); and (2) Alternative Fuel Corridor Grants (Corridor Program).[63] The Corridor Program has three Focus Area Categories, one of which is zero-emission corridors for medium- and heavy-duty vehicles,[64] including along the National Highway Freight Network (23 U.S.C. §151(f)(5)(A)(vi)).[65] The first tranche of funding was $700 million, from FY2022 and FY2023, and is to focus on projects in urban and rural communities in publicly accessible locations.[66]

Section 13404 of P.L. 117-169, known as the Inflation Reduction Act of 2022, amends Section 30C of the Internal Revenue Code (IRC) to provide an Alternative Fuel Refueling Property Credit. IRC 30C provides a tax credit up to 30% of the cost of alternative fuel refueling property up to $100,000.

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[58] Sunita Satyapal, Director, DOE Hydrogen and Fuel Cell Technologies Office, *2022 AMR Plenary Session*, June 6, 2022, p. 33, at https://www.energy.gov/sites/default/files/2022-06/hfto-amr-plenary-satyapal-2022-1.pdf.

[59] California Fuel Cell Partnership, *The California Fuel Cell Revolution: A Vision for Advancing Economic, Social, and Environmental Priorities*, July 2018, p. 14, at https://cafcp.org/sites/default/files/CAFCR.pdf.

[60] The estimate is based on vendor quotes for the first 111 stations planned or built. M. Koleva and M. Melaina, *DOE Hydrogen Program Record: Hydrogen Fueling Stations Cost*, U.S. Department of Energy, Record 21002, November 2, 2020, at https://www.hydrogen.energy.gov/library/program-records.

[61] For a description of the Highway Trust Fund, see CRS Report R47022, *Federal Highway Programs: In Brief*, by Robert S. Kirk.

[62] CRS Report R47034, *Energy and Minerals Provisions in the Infrastructure Investment and Jobs Act (P.L. 117-58)*, coordinated by Brent D. Yacobucci. See "Division A—Surface Transportation," prepared by Melissa N. Diaz.

[63] Federal Highway Administration (FHWA), *Charging and Fueling Infrastructure Discretionary Grant Program*, May 15, 2023, https://www.fhwa.dot.gov/environment/cfi/.

[64] Medium- and Heavy-Duty Vehicles (MHDVs) are on-road vehicles with gross vehicle weights over 10,000 pounds made with a variety of body and trailer or chassis combinations and generally having GVWs no greater than 80,000 pounds.

[65] FHWA, *Charging and Fueling Infrastructure Discretionary Grant Program: Webinar*, March 22, 2023, https://www.fhwa.dot.gov/environment/cfi/cfi_webinar_2023-2-21.pdf.

[66] FHWA, *Charging and Fueling Infrastructure Discretionary Grant Program*, May 15, 2023, https://www.fhwa.dot.gov/environment/cfi/.

Matching Supply and Demand

In the RFI issued for comment on the Regional Clean Hydrogen Hubs, DOE noted that "one key pathway to achieving large-scale, commercially viable deployment of clean hydrogen is through matching the scale up of clean hydrogen supplies with a concomitant and growing regional demand."[67] DOE has taken steps to ensure that suppliers and users of hydrogen can connect with one another by creating an online information resource called Hydrogen Matchmaker.[68] The tool is still online, but DOE is no longer accepting submissions of information. The $1 billion DOE announced on July 5, 2023, for its Demand-side Support Initiative is aimed at ensuring market certainty for both producers and end users.[69]

International Experience

Demonstration and early deployment of the hydrogen value chain outside the United States includes planned and nascent activities similar to Regional Clean Hydrogen Hubs. A European Commission (EC)-sponsored project conducts global surveillance of selected hydrogen activities in deployment phase that are large in scale, have a clear geographic center, cover multiple steps in the value chain, and provide supply to multiple end uses—calling these "hydrogen valleys."[70] The hydrogen valleys are a similar idea to the IIJA's Regional Clean Hydrogen Hubs. The EC project currently surveys 84 hydrogen valleys worldwide, including four in the United States, in various stages of planning and execution.[71]

The EC-sponsored project identified permitting as the number one policy barrier during a survey of participants.[72] Respondents to the survey noted that local permitting authorities were not familiar with hydrogen. Five projects are listed as operational, and seven under constructions.

Another study reported on emerging "hydrogen clusters," not unlike hydrogen hubs, in the Netherlands, Chile, Spain, and the United Kingdom.[73] In the Netherlands, for example, the study identified three ports with plans for green and blue hydrogen[74] aided by proximity to demand from existing refineries and ammonia and steel plants. These locations allow for integration; for example, the oxygen byproduct from electrolysis of water is being repurposed for use in basic

[67] 87 *Federal Register* 8828, February 16, 2022.

[68] U.S. Department of Energy, Hydrogen and Fuel Cell Technologies Office, *H2 Matchmaker*, at https://www.energy.gov/eere/fuelcells/h2-matchmaker.

[69] U.S. Department of Energy, Biden-Harris Administration to Jumpstart Clean Hydrogen Economy with New Initiative to Provide Market Certainty And Unlock Private Investment, July 3, 2023, https://www.energy.gov/articles/biden-harris-administration-jumpstart-clean-hydrogen-economy-new-initiative-provide-market.

[70] Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU), *Hydrogen Valleys as a Stepping Stone Towards the New Hydrogen Economy*, Luxembourg, 2021, p. 13, at https://h2v.eu/analysis/reports.

[71] Fuel Cells and Hydrogen Joint Undertaking (FCH 2 JU), *Hydrogen Valleys*, at https://h2v.eu/hydrogen-valleys.

[72] Uwe Weichenhain et al., *Hydrogen Valleys: Insights into the Emerging Hydrogen Economies Around the World*, Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU), Luxembourg, 2021.

[73] Energy Transitions Commission, *Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy*, Version 1.2, April 2021, p. 67.

[74] Hydrogen produced via electrolyzers is generally referred to as "green hydrogen" if the source of electricity is renewable. "Blue hydrogen" results when the carbon released from steam reforming of natural gas is captured and stored (i.e., carbon capture, utilization and storage (CCUS)), either for reuse in another industrial process or sequestered underground in mines or caverns. Blue hydrogen is sometimes referred to as "carbon neutral" as the emissions are not dispersed in the atmosphere. See CRS Report R46436, *Hydrogen in Electricity's Future*, by Richard J. Campbell.

oxygen furnaces for steelmaking.[75] The study identified further opportunities for clusters to include activities at transport hubs and ports.

Size, Scope, and Scale of Future Hydrogen Hubs

Studies have speculated on the size, scope, and scale of future hydrogen hubs. One study noted the advantages and economies of co-location of various industries, as this might allow integration between energy requirements and chemical byproducts, and suggested this might be a driver for the formation of hydrogen hubs.[76] The study considered four characteristic scenarios for hydrogen hubs, constructed around the following demand centers: a city; a port; fertilizer manufacture and petroleum refining; and steelmaking.

Another study surveyed existing and emerging hydrogen hubs in an international context and determined these and future hubs might evolve from existing facilities or plans for existing facilities. These hubs are illustrated in **Figure 3**. The scale of production increases, left-to-right, in the figure; the geographic orientation ranges from local to regional to international, left-to-right. The left-most hub concept, mobility, is envisaged as a public-private partnership, while the other two hub concepts are envisaged as wholly private sector. The studies do not exhaust all possibilities.

Other concepts for hydrogen hubs might combine different applications, scales of production, and off-takers. For example, DOE's Hydrogen Shot program—which supports making hydrogen commercially available at a cost of $1 for 1 kilogram in 1 decade—noted emerging "clusters" in the United States based on other industries and geographies.[77] DOE differentiated the clusters according to resources; influences such as population, policy, or pollution; and end-uses.

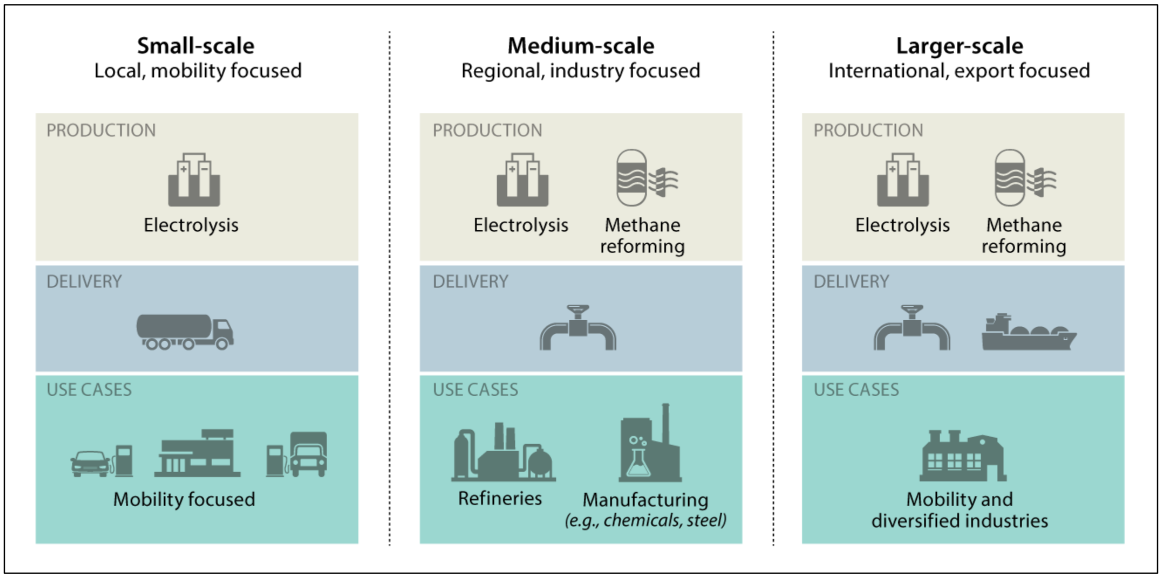
The Regional Clean Hydrogen Hubs, should DOE make the details available, may provide an additional window on the size, scope, and scale of future hydrogen hubs.

[75] Energy Transitions Commission, *Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy*, Version 1.2, April 2021, p. 67.

[76] Energy Transitions Commission, *Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy*, Version 1.2, April 2021, p. 67.

[77] U.S. Department of Energy, Hydrogen and Fuel Cell Technologies Office, *DOE Update on Hydrogen Shot, RFI Results, and Summary of Hydrogen Provisions in the Bipartisan Infrastructure Law*, December 9, 2021, at https://www.energy.gov/eere/fuelcells/articles/doe-update-hydrogen-shot-rfi-results-and-summary-hydrogen-provisions. The DOE launched Hydrogen Shot in June 2021.

Figure 3. Possible Layouts of Hydrogen Hubs



Source: Adapted from Uwe Weichenhain et al., *Hydrogen Valleys: Insights into the Emerging Hydrogen Economies Around the World*, Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU), Luxembourg, 2021.

Notes: Delivery is by truck with hydrogen liquid or pressurized gas, by pipeline, or by ocean-going tanker.

Issues for Congress

Investment and Sufficient Off-Takers to Consume Hydrogen

Consumption of hydrogen today is focused in a relatively concentrated set of end-users. Almost all is consumed by the oil industry or chemical industry either after onsite production or via delivery through dedicated pipelines from large merchant producers.[78] The hydrogen hubs and the additional supply of hydrogen they aim to create will need to be matched to new sources of demand in order to be economically feasible. DOE addressed this in the Hydrogen Matchmaker database and more recently in announcing its Demand-side Support Initiative on July 5, 2023, aimed at ensuring market certainty for both producers and end users.[79]

Global experience with hydrogen hubs underscores the urgency for finding off-takers, which one EC-funded project identifies as one of the largest financial barriers to realizing such projects.[80] At an October 2023 hearing of the Senate Energy and Natural Resources (ENR) Committee, Senator Cassidy (LA) described the hydrogen demand of 3,000 metric tons per day envisaged in the unsuccessful application by the HALO Hydrogen Hub (comprised of partners in Alabama,

[78] U.S. Department of Energy, Office of Fossil Energy, *Hydrogen Strategy: Enabling a Low-Carbon Economy*, Washington, DC, July 2020, p. 9, at https://www.energy.gov/sites/prod/files/2020/07/f76/USDOE_FE_Hydrogen_Strategy_July2020.pdf.

[79] U.S. Department of Energy, Biden-Harris Administration to Jumpstart Clean Hydrogen Economy with New Initiative to Provide Market Certainty and Unlock Private Investment, July 3, 2023, https://www.energy.gov/articles/biden-harris-administration-jumpstart-clean-hydrogen-economy-new-initiative-provide-market; CRS In Focus IF12514, *DOE Appropriations for Hydrogen and Fuel Cell Activities: FY2024*, by Martin C. Offutt.

[80] Uwe Weichenhain et al., *Hydrogen Valleys: Insights into the Emerging Hydrogen Economies Around the World*, Fuel Cells and Hydrogen 2 Joint Undertaking, Luxembourg, 2021, p. 39.

Louisiana, and Oklahoma).[81] Congress may monitor the deployment of hydrogen hubs to see if the demand for the newly created hydrogen supply is sufficient and stable and is attracting the needed investment.

Appropriate Regulation of Hydrogen Pipelines

DOE's 2020 Hydrogen Program Plan identified rights-of-way and permitting for hydrogen pipelines as two of the challenges to overcome for hydrogen delivery infrastructure.[82] Key policy issues that Congress may examine include the regulation of pipeline siting, including potential federal-state jurisdictional conflicts, and the regulation of pipeline rates and terms of service.[83] For example, some hydrogen proponents have suggested that Congress establish federal siting authority for interstate hydrogen pipelines analogous to the Federal Energy Regulatory Commission natural gas siting authority under the Natural Gas Act (15 U.S.C. §§717 et seq.).[84] Preempting state authority in this way could simplify the siting process; however, it would not necessarily ensure such pipelines would be constructed and might raise concerns from affected states.[85]

Sufficient Transmission, Distribution, and Delivery Infrastructure

Hydrogen in its current uses has a dedicated infrastructure, but one that is small compared to natural gas. Hydrogen pipelines comprise 1,600 miles in the United States compared with 300,000 miles of natural gas transmission pipelines.[86] The layout of these pipelines provides service to a relatively concentrated set of end-users, with most hydrogen pipelines owned by merchant hydrogen producers who sell their hydrogen to industry in bulk.[87] To service a fleet of numerous and relatively small hydrogen refueling stations for FCEVs, for example, will require a different hydrogen delivery infrastructure. This might include additional pipelines and delivery trucks loaded with liquid or compressed hydrogen gas, or onsite hydrogen production from electricity or natural gas. During the legislative activity on the IIJA, the House Committee on Transportation and Infrastructure noted, "The committee believes that robust private sector involvement is necessary to maximize investment in and widespread availability of electric

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[81] Colloquy between Senator Cassidy and Under Secretary for Infrastructure Crane, in U.S. Congress, Senate Committee on Energy and Natural Resources, *Full Committee Hearing to Examine the Department of Energy's Decision-Making Process for Awarding Competitive Loans and Grants Funded Through the Inflation Reduction Act and the Bipartisan Infrastructure Law*, 118th Cong., 1st sess., October 19, 2023.

[82] U.S. Department of Energy, *Hydrogen Program Plan*, DOE/EE-2128, Washington, DC, November 2020, p. 6.

[83] Regulation of hydrogen pipeline siting, commercial service, security, and safety is divided among federal agencies and the states. Federal jurisdiction resides variously with the Surface Transportation Board (STB), the Federal Energy Regulatory Commission (FERC), the Transportation Security Administration (TSA), and the Pipeline and Hazardous Materials Safety Administration (PHMSA). For more information see CRS Report R46700, *Pipeline Transportation of Hydrogen: Regulation, Research, and Policy*, by Paul W. Parfomak.

[84] James Bowe and William Rice, "Building the Hydrogen Sector Will Require New Laws, Regs," *Law360*, January 13, 2021.

[85] For more information see CRS Report R46700, *Pipeline Transportation of Hydrogen: Regulation, Research, and Policy*, by Paul W. Parfomak.

[86] U.S. Department of Transportation: Pipeline and Hazardous Materials Safety Administration, *Annual Report Mileage for Natural Gas Transmission & Gathering Systems*, May 2, 2022. Over 90%, by mile of pipeline, are in Texas and Louisiana with 10 other states having fewer than 35 miles each. U.S. Department of Energy, Hydrogen and Fuel Cell Technologies Office, *Hydrogen Pipelines*, at https://www.energy.gov/eere/fuelcells/hydrogen-pipelines; Hydrogen Tools, *Hydrogen Pipelines*, at https://h2tools.org/hyarc/hydrogen-data/hydrogen-pipelines.

[87] IEA, *Global Hydrogen Review*, Paris, 2021, at https://www.iea.org/reports/global-hydrogen-review-2021, p. 44.

vehicle charging and hydrogen fueling infrastructure."[88] In the example of California, the CEC estimated it had built almost four times as much dispensing capacity as it needs for the FCEVs in the state.[89] Congress may monitor the build-out of refueling infrastructure and consider whether federal financial incentives would correct any shortfalls or, conversely, if the number of FCEVs is sufficient to justify the policies on refueling infrastructure.

Author Information

Martin C. Offutt
Analyst in Energy Policy

Acknowledgments

Mari Lee and Calvin DeSouza developed the graphics for the figures.

Disclaimer

[88] U.S. Congress, House Committee on Transportation and Infrastructure, *Investing in a New Vision for the Transportation in America Act*, Report of the Committee on Transportation and Infrastructure to Accompany H.R. 3684, 117th Cong., 1st sess., June 22, 2021, H.Rept. 117-70 (Washington: GPO, 2021), p. 537.

[89] J. Berner, M. Crowell, and A. Martinez, *Joint Agency Staff Report on Assembly Bill 8: 2022 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California*, California Energy Commission, CEC-600-2022-064, December 22, 2022, p. 39, https://www.energy.ca.gov/publications/2022/joint-agency-staff-report-assembly-bill-8-2022-annual-assessment-time-and-cost.