# Policy Brief: Growing a Hydrogen Economy in Pennsylvania

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*Project Team (listed alphabetically):*

Seth Blumsack, Professor, John and Willie Leone Family Department of Energy and Mineral Engineering; Earth and Environmental Systems Institute; Co-Director, Center for Energy Law and Policy

Jeremy Gernand, Associate Professor and Associate Department Head for Graduate Education, John and Willie Leone Family Department of Energy and Mineral Engineering

Michael D. Helbing, Staff Attorney, Center for Energy Law and Policy

Anne Menefee, Assistant Professor of Energy and Mineral Engineering, John and Willie Leone Family Department of Energy and Mineral Engineering

Keith Oxley, Graduate Student, Energy Systems Engineering, John and Willie Leone Family Department of Energy and Mineral Engineering

Hannah Wiseman, Professor, Penn State Law and College of Earth and Mineral Sciences; Co-funded Faculty, Institute of Energy and the Environment; Co-Director, Center for Energy Law and Policy

For correspondence about this brief, please contact Seth Blumsack at sab51@psu.edu or Hannah Wiseman at hqw5351@psu.edu.

## Introduction

Hydrogen—a long-used fuel with historically limited applications— is poised to expand in importance with the recent infusion of billions of dollars of U.S. federal funding.[1] This policy brief defines "clean" hydrogen, explores the role of hydrogen in the energy transition, analyzes the strengths that Pennsylvania offers for developing a hydrogen economy, and assesses the policy hurdles that must be overcome to make hydrogen a meaningful player in the state's energy economy. The brief explores options for addressing these hurdles and harnessing the economic, environmental, and equity-based opportunities that hydrogen may offer for Pennsylvania.

## Understanding Clean Hydrogen

Hydrogen is "the most abundant element in the universe" and exists as a gas at normal temperatures.[2] As a gaseous fuel, hydrogen can be burned in nearly all applications in which gasoline, oil, natural gas, or other fossil fuels are burned—ranging from transportation to furnaces, boilers, and power plants. Hydrogen can also power fuel cells, in which a chemical reaction generates electricity.

Hydrogen is not usually a primary energy source like coal or oil— it generally needs to be produced through industrial processes.[3] These processes are commonly denoted using colors.[4] The most common hydrogen production process in the U.S. and the world today is steam-methane reforming, where methane (natural gas) is reacted with steam to produce hydrogen alongside CO and $CO_2$. Hydrogen produced from this process is considered 'grey' hydrogen.[5] If the $CO_2$ produced as a byproduct is then captured and stored underground (i.e., through carbon capture and geologic storage techniques), the hydrogen is considered 'blue' hydrogen.[6]

The second major process for producing hydrogen is electrolysis, which involves the use of electricity to split water atoms. Hydrogen produced via electrolysis is denoted as 'green' hydrogen if the electricity used in the process comes from renewable sources such as wind, solar, or hydroelectricity.[7] Effectually, 'green' hydrogen is zero-carbon hydrogen. So-called 'pink' hydrogen is generated through electrolysis using nuclear energy, which is also carbon-free.[8]

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[1] In October 2023, the U.S. Department of Energy selected seven regional hydrogen hubs to begin negotiations to receive federal funding. Two of these hydrogen hubs would have a footprint in Pennsylvania. The full list of awardees is at https://www.energy.gov/oced/regional-clean-hydrogen-hubs-selections-award-negotiations.

[2] *Hydrogen Explained*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/hydrogen/.

[3] Eric Hand, *Hidden Hydrogen: Does Earth hold vast stores of a renewable, carbon-free fuel?,* SCIENCE (Feb. 16, 2023), https://www.science.org/content/article/hidden-hydrogen-earth-may-hold-vast-stores-renewable-carbon-free-fuel; Laura Paddison, *They went hunting for fossil fuels. What they found could help save the world*, CNN (Oct. 29, 2023), https://www.cnn.com/2023/10/29/climate/white-hydrogen-fossil-fuels-climate/index.html.

[4] *The Hydrogen Colour Spectrum*, NATIONALGRID, https://www.nationalgrid.com/stories/energy-explained/hydrogen-colour-spectrum (last visited: Oct. 31, 2023).

[5] *Id*.

[6] Turner Jackson, MIT Energy Initiative, *3 Questions: Blue Hydrogen and the World's Energy Systems*, MIT NEWS (Oct. 17, 2022), https://news.mit.edu/2022/3-questions-emre-gencer-blue-hydrogen-1017 (last visited: Oct. 31, 2023).

[7] *Green Hydrogen*, SCIENCEDIRECT, https://www.sciencedirect.com/topics/engineering/green-hydrogen (last visited: Oct. 31, 2023).

[8] *The Hydrogen Colour Spectrum*, *supra* note 4; Anmar Frangoul, *There's a Buzz about Green Hydrogen. But Pink Hydrogen, Produced Using Nuclear, May Have a Huge Role to Play too*, CNBC (Feb. 3, 2023),

The selected hydrogen hubs in which Pennsylvania will participate will primarily produce a combination of blue, green, and pink hydrogen. One of the hubs, the Mid Atlantic Clean Hydrogen Hub (MACH2), also hopes to produce some amount of 'orange' hydrogen, which involves releasing naturally-occurring underground hydrogen through a chemical reaction in iron-rich rock.[9]

## The Importance of Hydrogen in the Energy Transition

Hydrogen has been a part of the global economy for more than a century, but only in small quantities and niche applications. More recently, hydrogen has garnered attention as a key component of the energy transition—the move toward sources of energy that emit fewer greenhouse gases than fossil fuels. Many view this transition as urgent due to the increasingly apparent effects of climate change such as extreme weather, periods of heavy rainfall and drought, and heat waves.[10] These effects are close to home: during the summer of 2023, Pennsylvania experienced many smoky days due to the wildfires in Quebec and other parts of Canada. Low amounts of snowfall, high temperatures, and drought contributed to these fires.[11]

Beyond helping to mitigate the impacts of climate change, the energy transition will result in lower emissions of local air pollutants, which are a major source of illness and premature mortality in Pennsylvania and other places.[12] And if designed and implemented properly, the transition could enhance equity by distributing the benefits of clean energy to disadvantaged communities, including rural areas, and addressing disproportionate impacts of energy development and use.

Hydrogen is important to the energy transition because it can help to decarbonize sectors of the economy that are difficult to decarbonize in other ways. Many technology pathways in the energy transition rely primarily on electrification of most economic sectors and the generation of clean energy such as nuclear, solar, wind, and hydroelectricity to power these sectors. There is a push to electrify transportation, industrial processes, and commercial and residential heating and cooking. But electrification will pose challenges in some sectors. Heavy trucks, such as the many freight trucks that carry goods essential to our economy, require a great deal of power. And all electric vehicles have a limited range, which is a challenge for drivers in areas where charging stations are scarce. Some industrial processes, such as steel and cement manufacturing, are also difficult to electrify.[13] Hydrogen could be the fuel to replace gasoline, natural gas,

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https://www.cnbc.com/2023/02/03/why-pink-hydrogen-produced-using-nuclear-may-have-a-big-role-to-play.html (last visited: Oct. 31, 2023).

[9] F. Osselin, *et al.*, *Orange hydrogen is the new green*, 15 NAT. GEOSCI., 765–769 (2022), https://doi.org/10.1038/s41561-022-01043-9. The extent to which orange hydrogen production will be a significant component of the MACH2 hub is not clear, but the effort does include orange hydrogen in its scope. *See* https://www.centredaily.com/news/state/pennsylvania/article280948983.html

[10] *The Effects of Climate Change*, NASA, https://climate.nasa.gov/effects/ (last visited: Oct. 31, 2023). There is also ongoing discussion of the extent to which climate change may affect unusual cold snaps caused by the Arctic polar vortex. *See, e.g.*, *Understanding the Arctic polar vortex*, NOAA, https://www.climate.gov/news-features/understanding-climate/understanding-arctic-polar-vortex (last visited: Oct. 31, 2023).

[11] Benjamin Shingler, *Climate change made weather conditions that powered Quebec fires twice as likely, scientists say*, CBC NEWS (Aug. 22, 2023), https://www.cbc.ca/news/climate/quebec-climate-change-wildfires-research-1.6943502#:~:text=The%20record%2Dsetting%20wildfires%20that,an%20international%20team%20of%20scientists (describing the results of a report for which peer review has not yet been completed).

[12] X. Huang, V*et al.*, *Effects of global climate mitigation on regional air quality and health*, 6 NAT. SUSTAIN. 1054–1066 (2023), https://doi.org/10.1038/s41893-023-01133-5.

[13] *See, e.g.*, Samantha Gross, Brookings, The challenge of decarbonizing heavy industry (June 2021), https://www.brookings.edu/articles/the-challenge-of-decarbonizing-heavy-industry/.

and oil in these and other hard-to-electrify applications. It is already used in cars in California, and in the United Kingdom, the UK Health & Safety Executive, gas producers and distributors conducted successive demonstration trials spanning 2019-2022 whereby a total of 768 residences, a school, several small businesses, a church, and 30 university buildings were supplied a blend of up to 20 percent hydrogen in natural gas as part of the HyDeploy project[14]; these followed extensive investigative studies spanning 2004-2009[15,16] and together resulted in the Energy Network Association (the industry body representing the electricity wires, gas pipes and energy system in the UK and Ireland) declaring its natural gas transmission and distribution systems were ready for hydrogen blending of up to 20 percent.[17,18] Some U.S. utilities and independent power producers are already building power plants that can operate using a blend of hydrogen and natural gas or pure hydrogen.[19]

Although hydrogen will be a key "clean" fuel to power sectors that are difficult or inefficient to electrify, it could also play an important role in the electric grid, which will require more generation as load (demand) increases. Much of this generation will be intermittent; for instance, solar panels do not produce electricity at night and decrease output in cloudy weather, and wind turbines do not generate electricity when the wind stops blowing. Hydrogen fuel cells could store energy and provide electricity during periods of peak demand. Hydrogen can also serve as base load power generation—generation that can run all of the time—because turbines can be retrofitted or replaced to run on hydrogen fuel.[20] In places where solar, wind, and nuclear are not feasible, hydrogen power generation could also help to replace fast-declining generation capacity such as coal-fired power plants within the region of PJM—thse regional power grid that serves Pennsylvania and some surrounding states. Additionally, small hydrogen fuel cells that are part of "microgrids"—local power sources connected to critical infrastructure within communities—can contribute to grid reliability and resilience.

## Opportunities for a Hydrogen Economy in Pennsylvania

Pennsylvania is a major energy state and could be an important player in the push to grow a hydrogen economy. It is the second largest producer of natural gas in the United States, it has geology conducive to the underground storage of $CO_2$ captured from blue hydrogen processes, it is one of the largest producers of nuclear power, and it has industries that could use hydrogen as a fuel.

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[14] *Project Phases*, HYDEPLOY, https://hydeploy.co.uk/project-phases/ (last visited: Oct. 31, 2023).

[15] *NaturalHy-project overview*, THE EUROPEAN GAS RESEARCH GROUP, https://www.gerg.eu/projects/hydrogen/naturalhy/ (last visited: Oct. 31, 2023).

[16] O. Florisson & R.R. Huizing, Gasunie Engineering & Technology, *The Safe Use of the Existing Natural Gas System for Hydrogen (Overview of the Naturalhy-Project)*, https://h2tools.org/bibliography/safe-use-existing-natural-gas-system-hydrogen-overview-naturalhy-project (last visited: Oct. 31, 2023).

[17] Energy Networks Association, *Press release: ENA Announce Next Step Towards Networks' Green Gas Readiness* (Nov. 2, 2022), https://www.energynetworks.org/newsroom/ena-announce-next-step-towards-networks-green-gas-readiness (last visited: Oct. 31, 2023).

[18] Energy Networks Association, *The Gas Networks Are Ready for Hydrogen Blending*, https://www.energynetworks.org/assets/images/GGG%20Hydrogen%20bleiding%20capacity%20maps.pdf (last visited: Oct. 31, 2023).

[19] *Hydrogen Projects in the US*, CLEANENERGYGROUP, https://www.cleanegroup.org/initiatives/hydrogen/projects-in-the-us/ (last visited: Oct. 31, 2023).

[20] *See, e.g.*, *Hydrogen fueled gas turbines*, GE GAS POWER, https://www.ge.com/gas-power/future-of-energy/hydrogen-fueled-gas-turbines (last visited: Oct. 31, 2023).

In part owing to these strengths, the U.S. Department of Energy announced in October 2023 that Pennsylvania and neighboring states are slated to receive two grants to form "hydrogen hubs," which are regions that include hydrogen production, transport, and use. The Appalachian Regional Clean Hydrogen Hub (ARCH2) is a blue hydrogen hub that will use "low-cost natural gas to produce low-cost clean hydrogen and permanently store the associated carbon emissions."[21] MACH2, in turn, "plans to develop renewable hydrogen production facilities from renewables and nuclear electricity" and "to expand hydrogen application to industries including heavy transportation (e.g., trucks, buses, refuse trucks, and street sweepers), manufacturing and industrial process improvements, and combined heat and power."[22]

Despite the enormous opportunity posed by these hubs, starting a hydrogen economy from scratch involves numerous challenges—perhaps foremost among them the coordination challenge of simultaneously growing hydrogen production, transportation, and use. Without offtakers who commit to use hydrogen, hydrogen producers are hesitant to make investments. Without an assurance that hydrogen producers will use pipelines to transport their fuel to users, "midstream" pipeline companies are similarly hesitant to build infrastructure. And offtakers are hesitant to change their practices and technologies to accommodate hydrogen unless they are certain that there will be a steady supply of hydrogen. The "hub" strategy pursued by the DOE and Biden Administration is intended to address this coordination problem and demonstrate the commercial viability of multiple hydrogen production processes and end uses.

## Policy Needs for Hydrogen in Pennsylvania

For hydrogen hubs in Pennsylvania and neighboring states to move forward, several changes to policies will be necessary—and they will need to happen more quickly than they are currently progressing. We emphasize four themes here. First, there will need to be more standards or incentives to ensure that hydrogen is in fact "clean." Second, infrastructure development is key, and the policies for constructing and siting (i.e., locating) the infrastructure for a hydrogen economy need rapid clarification. Third, clarification of state hydrogen safety standards and continued federal involvement in encouraging uniform standards will be important, particularly given public concerns in this area.[23] And finally, but perhaps most importantly, Pennsylvania's hydrogen policy must be *equitable*, both with respect to the distribution of the benefits of clean energy development and the negative impacts of such development.

### Ensuring "Clean" Hydrogen Through Policy

The federal statute providing money for the hydrogen hubs selected by the DOE—the Infrastructure Investment and Jobs Act (also called the Bipartisan Infrastructure Law)—requires hydrogen to be "clean." The Act defines "clean hydrogen" as "hydrogen produced with a carbon intensity equal to or less than 2 kilograms of carbon dioxide-equivalent produced at the site of production per kilogram of hydrogen produced."[24] This hydrogen may be produced from "fossil fuels with carbon capture, utilization, and

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[21] Regional Clean Hydrogen Hubs Selections for Award Demonstrations, U.S. DEPT. OF ENERGY, https://www.energy.gov/oced/regional-clean-hydrogen-hubs-selections-award-negotiations (last visited: Oct. 31, 2023).

[22] *Id*.

[23] For a brief summary of policy gaps for all portions of the hydrogen supply chain, *see Hydrogen*, PHMSA, https://primis.phmsa.dot.gov/comm/hydrogen.htm (last visited: Oct. 31, 2023).

[24] Infrastructure Investment and Jobs Act § 822(a), codified at 42 U.S.C. § 16166.

sequestration," renewable energy, and nuclear energy, among other sources.[25] Pennsylvania's hydrogen hubs will likely produce the vast majority of their hydrogen either from natural gas, which requires the capture of the carbon dioxide ($CO_2$) generated by the production process to be "clean," or water, which requires significant amounts of energy to split water atoms into hydrogen and oxygen gas.

While the federal dollars for the hydrogen hubs require clean production, Pennsylvania should look beyond this initial federal investment and take additional steps to incentivize industry to adopt clean hydrogen fuel. One effective approach would be for the Commonwealth to establish binding decarbonization targets that set a clear goal for, say, 2050, while progressively ratcheting up the level of decarbonization required. Well-designed binding targets are technology-agnostic, have transparent timelines, and send clear and credible signals to industry and regulators. They can be highly effective at reducing regulatory uncertainty, which has been identified as a major barrier to the flow of capital towards clean energy projects.[26]

Pennsylvania will need clean electricity on a large scale if the hubs and additional activity that spins off from the hubs will make hydrogen from water. Pennsylvania is in a good position to use nuclear energy to generate hydrogen—it is one of the largest producers of nuclear energy in the United States. But the state has lagged in renewable electricity production (from sources like wind and solar) since the Alternative Energy Portfolio Standard has lapsed, and other states have updated or adopted their own, more ambitious, clean electricity standards. The PJM Interconnection could also face capacity shortfalls as coal plants retire, thus making it more difficult to serve large new electricity loads (uses) such as electrolysis.[27] Pennsylvania will need its own mechanisms to support clean electricity production, and to work with PJM to ensure a robust regional power grid with which this production can interconnect.

### Improving Infrastructure Policy

In addition to necessitating policies to ensure and enable "clean" hydrogen, the growth of a hydrogen economy requires numerous types of supporting infrastructure. Achieving blue hydrogen requires the capture, transportation, and injection of $CO_2$ deep underground for permanent disposal. If the $CO_2$ cannot be injected at the point of hydrogen production, it must be transported through a $CO_2$ pipeline to an injection site. Producers of any color of hydrogen also need hydrogen pipelines to transport hydrogen to markets, and hydrogen distribution lines that run to offtakers. None of this infrastructure currently exists in Pennsylvania, and the laws for its development need clarification, as explored here.

Some existing infrastructure will also likely need expansion and modification. Producing green hydrogen through electrolysis uses a lot of energy. New transmission lines may be needed to connect electrolysis centers to the transmission grid operated by the PJM Interconnection—the regional power grid that serves Pennsylvania and surrounding states. New hydrogen fuel cell centers that serve as energy storage will also need grid interconnection.

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[25] Infrastructure Investment and Jobs Act § 822(a), cross referencing and amending Energy Policy Act of 2005 § 805, codified at 42 U.S.C. § 16154.

[26] This point was emphasized at a recent roundtable discussion among energy sector leaders sponsored by the Center for Energy Law and Policy and Climate Risk Management Center at Penn State. A white paper based on the roundtable discussion is available at https://celp.psu.edu/energyroundtable.

[27] PJM, Energy Transition in PJM: Resource Retirements, Replacements, and Risks (2023), https://www.pjm.com/-/media/library/reports-notices/special-reports/2023/energy-transition-in-pjm-resource-retirements-replacements-and-risks.ashx.

*Carbon Dioxide Injection Wells and Hydrogen Storage*

Through blue hydrogen production, as will occur in the ARCH2 hub, a company applies steam-methane reforming (SMR) to natural gas and captures the $CO_2$ emitted from this process. Once the $CO_2$ is captured, it must be permanently stored somewhere so that it does not enter the atmosphere. In Pennsylvania and neighboring states, the $CO_2$ will primarily be stored deep underground in the open pores within rock formations. This process is alternately called geologic carbon sequestration or geologic carbon storage (GCS), which requires compressing and injecting $CO_2$ deep underground.

Drilling an injection well for GCS requires a permit under the federal Safe Drinking Water Act to ensure that the injected $CO_2$ will not endanger underground sources of drinking water. The EPA regulates various categories of injection into the subsurface through the Underground Injection Control (UIC) program, and GCS permits fall under Class VI.[28] States may apply to take over the Class VI permitting process through "primacy," meaning that the state's environmental agency issues the permit to the injector instead of the federal Environmental Protection Agency (EPA). Pennsylvania's Department of Environmental Protection (DEP) has announced that it intends to apply for primacy, but it has not yet submitted its application. The process for obtaining primacy is likely to take at least two years. Obtaining state control over Class VI permitting would likely speed up the injection well permitting process, but given the time required for Pennsylvania to attain primacy, it needs to start soon.

In addition to obtaining a Class VI permit, to drill an injection well in Pennsylvania, injectors also need a permit to drill from the DEP. Although the DEP and EPA coordinate to some extent, injectors must submit large amounts of data to both the EPA and DEP. The dual permit process is therefore onerous and, to some degree, requires that injectors submit duplicative information to a federal agency and a state agency.

Beyond the need to better coordinate the Class VI and permit-to-drill approval processes and obtain primacy, Pennsylvania needs to develop a comprehensive legal regime for GCS—a process that has stalled in the legislature. This regime needs to address property rights issues, conflicts among different users of subsurface space, and long-term liability, among other issues.

GCS requires a $CO_2$ injector to obtain property rights in subsurface pore space within a relatively large area. The injector needs to negotiate with the owner of the pore space, and typically with multiple owners because of the size of the underground injection space. States therefore need to clarify who owns the subsurface pore space so that injectors know whom to approach to negotiate for property rights. Many states have enacted legislation to clarify this issue; Pennsylvania has not.[29]

Due to the potential for pore space owners within a proposed GCS injection area to hold out and demand untenable amounts of money, a mechanism to help injectors piece together numerous subsurface properties needed for the project would make injection projects more feasible. This mechanism could be eminent domain granted by the state, which would give the injector the power, if good faith negotiations failed, to condemn the property in court and pay the property owners "just compensation" (the fair market value of their property). Federal eminent domain authority is available for underground natural gas storage projects connected to interstate gas pipelines; similar eminent domain authority is unavailable for GCS.

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[28] 42 U.S.C. § 300h-9.

[29] Hannah Wiseman, Defining Pore Space Ownership and Related Issues: A Summary 3 (2023), https://celp.psu.edu/wp-content/uploads/2022/12/Definition-of-pore-space-and-related-issues_Summary-for-posting.pdf.

Some states, however, such as Louisiana and Indiana, provide eminent domain authority for injection for GCS.[30] Oklahoma and Wyoming expressly prohibit the use of eminent domain for GCS.[31] Pennsylvania, in turn, does not have an eminent domain provision for GCS. If Pennsylvania were to allow eminent domain for the acquisition of property for GCS, mechanisms for valuing the pore space will need to be developed.

As an alternative to often-controversial eminent domain—and likely a more feasible pathway for Pennsylvania—injectors could have "compulsory pooling" or compulsory unitization authority. Under compulsory pooling, after obtaining permission from the owners of a minimum percentage of the pore space in a proposed injection area (say, 50 percent of the pore space), the injector—with the state's permission—could require the remaining property owners in the proposed injection area to cede their pore space rights, for compensation. North Dakota and Nebraska allow their oil and gas commissions to compulsorily pool pore space for $CO_2$ with no minimum percentage of agreeing property owners.[32] Kentucky provides for compulsory pooling after the owners of 51 percent of the pore space in the proposed injection area have agreed to participate, Montana sets the minimum amount at 60 percent,[33] West Virginia sets the minimum amount at 75 percent,[34] and Wyoming's minimum is 80 percent.[35]

Beyond property rights acquisition and aggregation for injection facilities, companies involved in GCS will need clarity on how to address potential conflicts that may emerge when: 1) different subsurface users at different vertical layers conflict (e.g., a GCS company drilling an injection well through an active gas production area), and 2) subsurface owners near GCS facilities claim that $CO_2$ has leaked into their pore space and has caused a trespass. Few states have addressed the trespass issue—an omission that could substantially delay injection activity. States have only begun to address conflicts among different users of subsurface property at different layers. Several states provide that oil and gas companies may drill down through subsurface $CO_2$ storage areas, provided the companies follow environmental laws. These states do not address numerous other subsurface conflicts that could arise, however, such as $CO_2$ injectors drilling down through active oil and gas production, groundwater storage areas, or other subsurface uses. Pennsylvania has no legislation addressing any of these areas.[36]

Another important policy issue that many states have addressed—but not Pennsylvania—is long-term liability for injected $CO_2$. Some states transfer liability from the GCS company to the state 10 years after closure; others transfer the liability after a longer period, such as 50 years.[37] Pennsylvania has not yet addressed the issue, which will be critical to support early adopters of GCS technologies.

Beyond GCS, companies producing hydrogen will also need to store it. Hydrogen can be stored in tanks or injected underground, similar to $CO_2$. All of the above legal issues for $CO_2$ injection therefore also apply to hydrogen. Pennsylvania has no legislation addressing hydrogen storage.

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[30] IND. CODE § 14-39-1-7; LA. REV. STAT. § 30:1108.

[31] OKLA. STAT. tit. 27A § 3-5-106; WYO. STAT. ANN. § 35-11-316.

[32] N.D. CENT. CODE § 38-22-10; NEB. REV. STAT.§ 57-1612.

[33] MONTANA CODE ANN. §§ 82-11-101(16) (effective on occurrence of contingency); 82-11-204(1).

[34] W, VA, CODE § 22-11B-19.

[35] WYO. STAT. ANN. § 35-11-316.

[36] W. VA. CODE § 22-11B-9.

[37] Derek W. Eugene, Interstate Oil & Gas Compact Commn., Passing Geologic Storage Legislation: Perspectives, Problems, Opportunities and Challenges 28-37 (2009), https://iogcc.ok.gov/sites/g/files/gmc836/f/passing_ccs_legislation_v2_new_master_0.pdf.

*Carbon Dioxide Pipelines*

In hydrogen hubs, $CO_2$ pipelines will be needed to transport $CO_2$ captured at blue hydrogen production facilities to injection sites for permanent underground disposal in cases where injection does not occur on site. In a highly decarbonized energy economy, $CO_2$ pipelines are not only likely to grow in number but also to cross state lines. The federal Pipeline and Hazardous Materials Safety Administration (PHMSA) regulates the safe operation of $CO_2$ pipelines. However, states currently have primary authority over the approval and siting (location) of these pipelines. Without federal oversight of the permitting process for interstate $CO_2$ pipelines (which currently does not exist), pipeline developers would face different regulatory regimes and standards in different states. Other infrastructure networks such as interstate oil pipelines have historically been built across state lines following state-by-state siting, permitting, and eminent domain processes.[38] But new infrastructure built under this state-by-state system—particularly interstate electricity transmission lines—has faced major hurdles.[39] State-by-state permitting of "long" infrastructure such as interstate $CO_2$ pipelines adds to complexity and can pose an obstacle to carbon sequestration.

Pipeline developers also must get federal permits for the pipelines, including Clean Water Act permits (reviewed and sometimes blocked by states), Endangered Species Act permits if any endangered or threatened species will be impacted, Rivers and Harbors Act permits for any water crossing, etc. There is "streamlined" review for these permits as specified by the US IT Act,[40] but the regulatory process involved requires careful navigation which can be time-consuming.

Some states (such as Indiana, Louisiana, and Texas) provide state eminent domain authority for developers of $CO_2$ pipelines who are unable to reach agreements with landowners for property acquisition.[41] Pennsylvania lacks such eminent domain authority, although a *hydrogen* (as opposed to $CO_2$) pipeline company that was deemed to be a "public utility" might have such authority. The state gives public utilities that transport "artificial or natural gas" condemnation authority.[42] Pipeline companies can build "long" infrastructure such as pipelines without eminent domain, but this construction can be difficult. Landowners along the proposed route for a pipeline sometimes "hold out," demanding large sums of money because they know that their property is an essential component of a larger project. But the use of eminent domain—in which companies condemn private property owners' land in court and pay just compensation—is controversial, and proposed use of eminent domain for individual $CO_2$ pipelines in places such as South Dakota has already raised landowners' ire.[43] If Pennsylvania were to establish eminent domain for $CO_2$ pipelines, it would be important to require that developers attempt good faith

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[38] Alexandra B. Klass & Danielle Meinhardt, *Transporting Oil and Gas: U.S. Infrastructure Challenges*, 100 IOWA L. REV. 947 (2015), https://ilr.law.uiowa.edu/sites/ilr.law.uiowa.edu/files/2023-02/ILR-100-3-Klass-Meinhardt.pdf.

[39] James W. Coleman & Alexandra B. Klass, *Energy and Eminent Domain*, 104 MINN. L. REV. 659, 731-35 (2019), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3348630 (identifying compensation policy options).

[40] Consolidated Appropriations Act, 2021, Pub. L. No. 116-260 (2020). *See also* at CONGR. RES. SVC., CARBON DIOXIDE (CO2) PIPELINE DEVELOPMENT: FEDERAL INITIATIVES 2 (2023), https://crsreports.congress.gov/product/pdf/IN/IN12169#:~:text=The%20Pipelines%20and%20Hazardous%20Materials,of%20CO2%20pipelines%20(49%20C.F.R (noting streamlined review).

[41] Ind. Code § 14-39-1-7; La. Rev. Stat. § 30:1108. In Texas, the $CO_2$ and hydrogen pipelines must demonstrate that they are common carriers to receive eminent domain authority. Tex. Nat. Res. §§ 111.002, 111.019

[42] 15 PA. C.S.A. § 1511.

[43] Christopher Vondracek, Eminent domain laws are splitting Midwest landowner attitudes toward CO2 pipelines, The Gazette (Aug. 19, 2023), https://www.thegazette.com/agriculture/eminent-domain-laws-are-splitting-midwest-landowner-attitudes-toward-co2-pipelines/.

negotiations with landowners prior to applying to condemn property—a practice that many developers follow anyway but is good to formalize to ensure landowner protections. It would also be important for Pennsylvania to establish requirements for prior notice to the landowner and the community in which condemnation was proposed. Additionally, the state would need to address equity concerns if it were to allow eminent domain for $CO_2$ and hydrogen pipelines, as pipeline developers sometimes, even if unintentionally, seek out routes through the least valuable land—often in low-income communities—in order to pay lower compensation for land acquisition. Any eminent domain regime in Pennsylvania should consider compensation schemes such as tying landowner compensation to the value of the project (the pipeline) rather than land value or setting above-market compensation amounts.[44]

The federal Pipeline and Hazardous Safety Materials Administration (PHMSA) regulates the safety of $CO_2$ pipelines. PHMSA has announced that it will publish a draft rule with updated $CO_2$ pipeline safety standards in 2024, with no date announced for the anticipated final rule.[45] State pressure on PHMSA and the federal government to move this process along and provide previews of likely requirements, while ensuring that PHMSA writes well-informed rules for safety, is important.

### *Electric Transmission Lines*

Beyond necessitating pipelines and underground storage, a build-out of hydrogen hubs in Pennsylvania could impact the need for electric transmission lines. Facilities that use electrolysis are energy-intensive, and any new electrolysis facilities will be large electricity users that will require approval for grid interconnection. In some cases, transmission grid upgrades may be necessary to accommodate these large loads. PJM and other grid operators should update interconnection rules to address the role of electrolysis and hydrogen storage in the interconnection queue and whether these resources should be treated any differently than other resources awaiting interconnection.

Despite necessitating some new transmission lines, hydrogen could also offer an important alternative to transmission. PJM is currently unable to handle the large number of grid interconnection requests from new generators—primarily solar generators—which has resulted in PJM placing a moratorium on new interconnection requests. Completely working through the backlog of requests, even once reforms to the interconnection process are complete, will likely take years. Some solar farms could generate hydrogen through electrolysis and then transport the hydrogen to other locations to be used as a fuel; this would serve as a form of energy storage that would be an alternative to electricity transmission. Additionally, hydrogen fuel cells located on particularly congested portions of the grid could serve as important back-up generators for peak demand and potentially as an alternative to additional long-distance transmission lines needed to import electricity from distant generation reserves.

### *Hydrogen Pipelines*

Just as $CO_2$ will sometimes need to be transported from the point where it is captured (a blue hydrogen production facility) to an injection well facility, hydrogen will often not be produced at the site where it is used. It will therefore need to be transported through pipelines—sometimes long-distance pipelines—and distribution lines that carry hydrogen to offtakers. Current policies do not make clear which agency has

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[44] *See* Coleman & Klass, *supra* note 39, at 731-35 (identifying compensation policy options).

[45] CONG. RES. SVC., *supra* note 40, at 1.

jurisdiction over the construction, siting, and operation of interstate hydrogen pipelines.[46] Specifically, it is not clear who will: 1) determine whether the pipeline is economically needed (through a certificate of public good process), 2) determine where the pipeline should be located and whether the pipeline company should have eminent domain authority to acquire private land, and 3) whether the pipeline must be "open access" for all users and what rates the pipeline company may charge. The Federal Energy Regulatory Commission or Surface Transportation Board might have authority over interstate hydrogen pipelines under several federal acts, but it is not clear whether these agencies do in fact have this authority.[47]

As a result of this regulatory uncertainty, states currently exercise jurisdiction over hydrogen pipeline construction and siting. Pennsylvania has no laws addressing hydrogen pipeline siting and construction. With respect to the operation of hydrogen pipelines, PHMSA regulates some aspects of safe operation, but gaps remain.[48]

### Selecting Safety Standards

As just noted in the context of hydrogen pipelines, in addition to supporting the construction and siting of new infrastructure, the development of a hydrogen economy will require the operation of all this new infrastructure, including hydrogen production facilities (the "upstream" portion of the hydrogen supply chain), storage facilities, pipelines and distribution lines, and specialized equipment for downstream users of hydrogen. There is a broad array of legislation and regulation that applies to upstream, midstream, and downstream energy infrastructure relating to the siting, construction, operation, and rates charged However, much of this regulation does not apply or only partially applies to hydrogen infrastructure or the repurposing of existing infrastructure like natural gas pipelines for hydrogen, leaving regulatory gaps that could impede the development of a hydrogen economy.

As often occurs in nascent industries, standards development organizations have taken steps to try to fill the gaps in regulations. The challenge in this space is that *numerous* private standards are being established for the safe handling and use of hydrogen.[49] As the Department of Energy recognizes, it would be better for there to be a single standard per technology.[50] DOE and standards development organizations like the American National Standards Institute should continue to work to develop consensus that will minimize confusion and uncertainty as the hydrogen industry matures.

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[46] For discussion of jurisdictional issues, *see, e.g.*, William G. Bolgiano, *FERC's Authority to Regulate Hydrogen Pipelines Under the Interstate Commerce Act*, 43 ENERGY BAR ASSN. 1 (2022), https://www.eba-net.org/wp-content/uploads/2023/02/4-Bolgiano-1-78.pdf; Christopher Psihoules & Daniel Salomon, Norton Rose Fulbright, *Hydrogen pipeline regulation* (June 23, 2023), https://www.projectfinance.law/publications/2023/june/hydrogen-pipeline-regulation/.

[47] Michael Diamond, Van Ness Feldman, *Jurisdiction Over Hydrogen Pipelines and Pathways to an Effective Regulatory Regime*, 3 Energy Bar Assn. Brief (2022), https://www.vnf.com/Hydrogen-Pipelines; CONGR. RES. SVC., PIPELINE TRANSPORTATION OF HYDROGEN: REGULATION, RESEARCH, AND POLICY 9 (2021), https://crsreports.congress.gov/product/pdf/R/R46700.

[48] VINCENT HOLOHAN & ROBERT SMITH, PHMSA, HYDROGEN GAS: PIPELINE SAFETY AND RESEARCH & DEVELOPMENT PROGRAM (Feb. 10, 2022), https://www.energy.gov/sites/default/files/2022-03/Bulk%20Storage%20Workshop_Day1_12.pdf.

[49] *Regulations, Guidelines, and Codes and Standards*, U.S. Dept. of Energy, HYDROGEN AND FUEL CELLS TECHNOLOGY OFFICE, https://www.energy.gov/eere/fuelcells/regulations-guidelines-and-codes-and-standards (last visited Oct. 31, 2023).

[50] *Codes and Standards*, U.S. Dept. of Energy, HYDROGEN AND FUEL CELLS TECHNOLOGY OFFICE, https://www.energy.gov/eere/fuelcells/codes-and-standards (last accessed: Oct. 31, 2023).

Table 1 summarizes some of the major private standards for hydrogen.

**Table 1.** Examples of Major Hydrogen Industry Standards and Their Timelines[51]

| **Industry Area** | **Standard-Writing Organization** | **Timing of Initial Publication and Revision, If Any** |
|---|---|---|
| Hydrogen transportation tanks and storage vessels | American Society of Mechanical Engineers | 2004 (transportation tanks); 2010 (plastic pressure vessels). New rules being developed by Project Team on Hydrogen Tanks.[52] |
| Sampling for pollutants in hydrogen fuel; screening hydrogen fuel cell quality | Society of Automotive Engineers (fuel cells)<br>ASTM International (fuel) | 2005; revised 2008 and 2011, reaffirmed 2015, published 2020<br>Some standards as early as 2010; subsequent updates and withdrawals through 2022. Some standards withdrawn because better sampling methods were identified; others withdrawn due to lack of activity. |
| Hydrogen pipelines: design | American Society of Mechanical Engineers<br>Compressed Gas Association (joint international standard) | B31.12 Hydrogen Piping & Pipelines 2008, 2011, 2014 and 2019 (latest)<br>G-5.6 Hydrogen Pipeline Systems (EIGA Doc. 121 /04) 2005; 2013 reaffirmation |
| Hydrogen pipelines: materials, testing, operation, maintenance, etc. | American Society of Mechanical Engineers<br>Compressed Gas Association (joint international standard)<br>Pipeline and Hazardous Materials Safety Administration | B31.12 Hydrogen Piping & Pipelines 2008, 2011, 2014 and 2019 (latest)<br>G-5.6 Hydrogen Pipeline Systems (EIGA Doc. 121 /04) 2005; 2013 reaffirmation<br>CFR Title 49 Subtitle B Chapter I Subchapter D Part 192 |

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[51] Table 1 is from Daniel Walters & Hannah Wiseman, *Self-Regulation and Innovation* (working draft, 2023), using data from AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, GUIDE TO SAFETY OF HYDROGEN AND HYDROGEN SYSTEMS (ANSI/AIAA G-095A-2017) (2017), https://arc.aiaa.org/doi/book/10.2514/4.105197.

[52] *See also Hydrogen Codes and Standards*, ASME.org, https://www.asme.org/resources/clean-hydrogen#codes-and-standards (last visited: Oct. 31, 2023) (standards for pressure vessels and transport tanks); *Hydrogen Storage*, U.S. DEPT. OF ENERGY, https://www.energy.gov/eere/fuelcells/hydrogen-storage (last visited: Oct. 31, 2023); *Empowering the Energy Economy*, SAFE HYDROGEN PROJECT, https://safehydrogenproject.org/ (last visited: Oct. 31, 2023).

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|---|---|---|
| Hydrogen vehicle fueling protocols | Society of Automotive Engineers | 2010 Technical Information Report; 2014 standard, revisions 2016 and 2020 |
| Hydrogen road vehicles and fueling equipment | International Organization for Standardization<br>ANSI/CSA America | 2014; various reconfirmations and amendments for different components, other new publications 2016, 2017, and currently under development<br>2015; re-affirmed 2019 |
| Hydrogen vehicle fuel containers | ANSI/CSA America | 2014; re-affirmed 2019, second edition 2021 |
| Hydrogen producers ("generators" of hydrogen) – electrolysis | CSA Group | 2023[53] |

Safety standards are controlled by states for other portions of the hydrogen supply chain, such as fueling stations. Pennsylvania has no hydrogen fueling station regulations even as both hydrogen hubs will strive to use hydrogen in fleet vehicles.[54] Contrast this gap with states such as Colorado, which finalized fueling station regulations to be effective in 2017.[55] In providing grants for hydrogen fueling stations in recent years, the Pennsylvania DEP defined the private standards to be followed—specifically NFPA 2 and Society of Automotive Engineers standards.[56] NFPA 2 "provides fundamental safeguards for the generation, installation, storage, piping, use, and handling of hydrogen" and was adopted by California in the state's Fire Code and Building Code to support hydrogen fueling and similar hydrogen applications.[57] At a minimum, Pennsylvania should produce clarity by selecting and formally adopting these standards in a regulation (rather than only a grant document) applicable to hydrogen fueling. Standards adoption will also be important for a variety of other hydrogen end uses.

There also remains a set of questions not yet addressed by any regulations or voluntary standards regarding the safe repurposing of existing equipment and infrastructure originally intended for natural gas or other gaseous fuels for use with hydrogen or blends of hydrogen. This could include industrial burners and ovens, large and small pipelines, pressure vessels, generators, and other similar and associated hardware. Repurposing equipment and infrastructure, if accomplished safely, would be a significant aid to the economic expansion of industrial uses for hydrogen and therefore to the partial or complete decarbonization of those industries. However, currently existing hydrogen standards envision only newly-

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[53] CAS/ANSI B22734:23, https://www.csagroup.org/store/product/2705341/.

[54] *See Pennsylvania Laws and Incentives*, Alternative Fuels Data Center, U.S. Dept. of Energy, https://afdc.energy.gov/laws/state_summary?state=PA.

[55] Retail Hydrogen Fueling Regulations, 7 Colo. Code Regs. § 1101-17, https://ops.colorado.gov/sites/ops/files/Retail%20Hydrogen%20Fueling%20Regulations%20010117.pdf.

[56] Pa. Dept. of Envtl. Prot., DC Fast Charging and Hydrogen Fueling Grant Program 8 (2021), https://files.dep.state.pa.us/Air/Volkswagen/DCFCH2ProgramGuidelines.pdf.

[57] *Hydrogen Technologies Code*, NFPA 2, Natl. Fire Protection Assoc., https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=2; Walters & Wiseman, *supra* note 51, at 39-40 (discussing California's adoption of NFPA 2 in its fire code and building code.

built hydrogen-compatible equipment and infrastructure, since there are lingering unknowns as to how partially aged materials may be affected by hydrogen exposure. Pennsylvania could facilitate activity on this kind of standards generation by engineering societies and other stakeholders, which could expand the potential customers for hydrogen.

There is significant past experience several generations ago, in the US and other nations, but more recently in the UK, with the distribution and use of gasified coal, also known as "town gas", which contains up to 52% hydrogen.[58] The piping networks that transported this hydrogen blend still partially exist in many places (now transporting natural gas) along with some of the people who used and maintained them providing a potential source of knowledge on the safe operation of this technology for the current time.[59]

Achieving Equity in Hydrogen Policy

In developing all of the policies necessary to support hydrogen hubs and a broader hydrogen economy in Pennsylvania, considerations of equity are paramount. "Equity" is the distribution of burdens and benefits in a manner that is more equal, taking into consideration the fact that some communities or groups of people have historically borne more or fewer burdens or received more or fewer benefits. Justice is sometimes used as a synonym for equity but can also refer to equity in the longer term—the development of policies designed to achieve equity now and in the future.

The field of energy justice focuses on ways of making the distribution of the burdens and benefits of energy development, such as hydrogen, more equitable. This requires a *recognitional* component of energy policy—acknowledgment that some communities and groups have historically hosted more energy infrastructure with negative environmental externalities, for example, or have received fewer benefits such as low-cost or clean energy.[60] Energy justice also has a *distributional* component—ensuring that benefits are more equitably apportioned and reducing disproportionate burdens of energy development and use.[61] Further, achieving such distributional improvements requires better *procedures* for decision-making—processes in which all impacted groups have a seat at the decision-making table, the potential to influence outcomes, and the resources needed to effectively participate in decision-making processes.[62]

Pennsylvania designates certain portions of the state as "Environmental Justice (EJ) Areas" and subjects projects (including energy projects) located in those areas to stricter review. Until September 16, 2023, EJ Areas in Pennsylvania were defined as follows:

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[58] Allen W. Hatheway & Briget C. Doyle, *Technical History of the Town Gas Plants of the British Isles*, International 564 ASS'N OF ENGINEERING GEOLOGISTS CONFERENCE (2006), https://media.geolsoc.org.uk/iaeg2006/PAPERS/IAEG_564.PDF.

[59] National Grid and Atlantic Hydrogen, Inc., Hydrogen-Enriched Natural Gas – Bridge to an Ultra-Low Carbon World, https://www.osti.gov/etdeweb/servlets/purl/21396875.

[60] K. Jenkins, *et al.*, *Advancing Energy Justice: The Triumvirate of Tenets*, 32 INTL. ENERGY L. REV. 107 (2013); Benjamin Sovacool, Niek Mouter, Nick Hacking, Mary-Kate Burns and Darren McCauley, *The methodologies, geographies, and technologies of energy justice: a systematic and comprehensive review*, 16 ENV'T RES. LETTERS (2021), https://doi.org/10.1088/1748-9326/abd78c.

[61] *Id.*

[62] *Id.*

> [A]ny census tract where 20 percent or more individuals live at or below the federal poverty line, and/or 30 percent or more of the population identifies as a non-white minority, based on data from the U.S. Census Bureau and the federal guidelines for poverty.[63]

Under a new interim final policy, the Pennsylvania DEP now uses a more complex definition of EJ Area based on "more than 30 environmental, health, and socioeconomic indicators."[64] As Pennsylvania builds out hydrogen infrastructure, it will be critical for the state to consider how constructing new $CO_2$ or hydrogen pipelines, injection wells, electrolysis facilities, hydrogen fueling stations, and other infrastructure will benefit and harm communities. While much of this infrastructure will create economic benefits, the externalities of the infrastructure, such as dust, noise, and road traffic during construction and residents' safety concerns, must be adequately taken into account and addressed. Further, it is imperative to consider that the repurposing of old infrastructure, such as transforming a natural gas pipeline to a $CO_2$ pipeline, could have economic benefits but could also involve the continuation of disproportionate burdens in communities that already host energy infrastructure.

In addition to concerns about potentially disproportionate infrastructural impacts, hydrogen generates some pollution. Hydrogen can be produced in a zero-carbon or net-zero carbon way, but the combustion of hydrogen in power plants, industrial facilities and other applications produces air emissions of oxides of nitrogen ($NO_x$), which can degrade local air quality. Poor air quality already disproportionately affects low-income and minority populations in Pennsylvania.[65] Replacing the use of natural gas or coal by a use of hydrogen at a particular site would tend to reduce the emissions of pollutants such as soot and sulfur oxides ($SO_x$) and reduce local health-related impacts, meaning net improvements in air quality are possible, but simple additions of hydrogen uses to existing industrial areas will have some negative impact to the surrounding area.

## Conclusion

For hydrogen hubs to be successful in Pennsylvania, the state must enact new policies, push the federal government to speed up proposed rulemakings and enact legislation where gaps remain, and work with neighboring states to harmonize or coordinate laws, such as pipeline siting laws. And it must do so quickly. Some of the requisite technologies for the hubs, such as $CO_2$ injection wells, are ready for immediate implementation but face substantial permitting delays. Although many of the needs outlined in this briefing are urgent, a rush to update policy to enable an emerging economy could stimulate a rapid build-out of infrastructure and activities that heaps more burdens on communities that already endure disproportionately negative impacts from energy infrastructure. Nor should the policy changes proceed in a manner that concentrates the benefits of clean hydrogen to the exclusion of groups who could benefit the most—from hydrogen microgrids that enhance the reliability and resilience of a local electric grid, for example, or from potentially lower electricity bills if hydrogen fuel cells were to provide storage at critical, congested points on the electricity grid.

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[63] *Pa. Environmental Justice Areas*, PA. DEPT. OF ENVTL. PROT., https://www.dep.pa.gov/PublicParticipation/OfficeofEnvironmentalJustice/Pages/PA-Environmental-Justice-Areas.aspx (last visited: Oct. 31, 2023).

[64] *Id*.

[65] The case of Allegheny County, for example is detailed at Jon Hurdle, *For Low-Income Pittsburgh, Clean Air Remains and Elusive Goal*, YALE ENVIRONMENT 360 (Jan. 27, 2022), https://e360.yale.edu/features/for-low-income-pittsburgh-clean-air-remains-an-elusive-goal,

Rapidly creating and updating policy for a growing, relatively new technology in a truly equitable manner is a Herculean task, but one that Pennsylvania can achieve. As a major historic producer of fossil fuel resources and an exporter of electricity—including a growing fleet of lower-carbon electricity—Pennsylvania is home to innovative, knowledgeable people who are up to the task ahead.