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WORKSHOP SUMMARY:

Ohio River Valley Hydrogen and CCS Hub Market Formation

July 12, 2021

IN MEMORIAM

Richard L. Trumka 1949-2021

THIS REPORT IS DEDICATED to our friend and colleague Rich Trumka, leader of the AFL-CIO for 12 years. Rich was deeply dedicated to his family, to his friends, and to the cause of making life better for every worker in America. His advocacy for a clean energy future led him to create the Labor Energy Partnership, a joint venture between the AFL-CIO and the Energy Futures Initiative. One of Rich's last public acts was to lead a critical discussion on the importance of supporting both jobs and clean energy options in the Ohio River Valley, and those findings are reflected in this report. As he put it during the workshop: "Hydrogen with carbon capture means we can decarbonize industry without destroying livelihoods and lives."

The LEP will carry on the work of creating and preserving good jobs while tackling the climate crisis in his memory.

"We will honor Rich's life by continuing his life's work—by building and strengthening the Labor Energy Partnership and its commitments to a high-road strategy for the clean energy future. We will push forward to answer the climate crisis, build resilience and preserve and create good-paying union jobs."

– AFL-CIO President Liz Shuler

Ernest Moniz's Tribute: https://bit.ly/3yHq0oV

Acknowledgements

In addition to our deep appreciation to the workshop speakers and participants who made this discussion so valuable, the Labor Energy Partnership is grateful to the team that designed and implemented the workshop and drafted this summary report:

ENERGY FUTURES INITIATIVE

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AFL-CIO

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ABOUT THE LABOR ENERGY PARTNERSHIP

The Labor Energy Partnership (LEP) is based on a shared commitment of the AFL-CIO and the Energy Futures Initiative to promote federal, regional and state energy policies that address the climate crisis while recognizing the imperatives of economic, racial and gender justice through quality jobs and the preservation of workers' rights.

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Introduction

On Monday, July 12th, 2021, the Labor Energy Partnership (LEP), an initiative of the Energy Futures Initiative (EFI) and the American Federation of Labor and Congress of Industrial Organizations (AFL-CIO), held a virtual workshop on hydrogen and carbon capture and storage (CCS) in the Ohio River Valley. The workshop, one in a series on decarbonizing the economy, convened leaders from government, labor, and industry for a robust discussion on the value of hydrogen and CCS market formation to the local economy and global energy transition and what is needed from government, labor, and industry to facilitate its development.

The purpose of this event was to catalyze the conversation among key thought leaders on how a hydrogen and CCS regional hub in the Ohio River Valley region could accelerate the decarbonization of the economy while maintaining the jobs and economic output associated with power generation and industry. To accomplish these objectives in the near-term—an increasingly important timeframe considering net-zero targets—low-carbon fuels and processes will be necessary. Hydrogen, combined with CCS technologies, offers such an option. Showcasing this option is critical as policymakers consider infrastructure funding, continuing economic recovery pathways post-COVID, and implementation of the strengthened U.S. Nationally Determined Contribution developed for COP-26 in Glasgow.

Hydrogen is a clean energy carrier that can support the decarbonization of many critical sectors. Producing hydrogen from natural gas using existing commercial technology, capturing the carbon emissions from hydrogen production, then permanently sequestering the carbon is the definition of "blue hydrogen." The blue hydrogen pathway could also support the policy and regulatory infrastructures that could enable "green hydrogen"—hydrogen produced via electrolysis of water with zero greenhouse gas (GHG) emissions electricity—as the technology becomes affordable.

In addition, CCS technology can be used independently of hydrogen for decarbonization of heavy emitters, including coal and gas fired power plants, and heavy-emitting industrial facilities, such as chemical manufacturers, steel furnaces, and cement plants. Given the multiple production and utilization options, current high costs, and the need for additional storage and transportation infrastructure, regional hubs seem to offer the best way forward to share resources, products, costs, and infrastructure and to accelerate hydrogen market formation. This LEP workshop focused on the Ohio River Valley as a potential leader in the formation of a regional hub for hydrogen and CCS where tri-state (Ohio, Pennsylvania, and West Virginia) cooperation could help meet low-carbon targets while preserving and creating jobs in the region.

WORKSHOP FORMAT AND PARTICIPANTS

The workshop was organized and managed to maximize contributions from the presenters and to be responsive to the public. The workshop focused on two issue areas: (1) understanding what energy and manufacturing communities need most from investors, government, and labor unions; and (2) laying out the infrastructure needs for blue hydrogen production and uses, while at the same time achieving deep decarbonization.

Speakers were asked to provide brief remarks or presentations, depending on the sessions. Further pre-read materials on hydrogen and CCS market formation were provided before the workshop.

KEYNOTE SPEAKERS

Carol Battershell, Workshop Moderator, Distinguished Associate for Energy Futures Initiative

Sherrod Brown, U.S. Senator (D-OH)

Melanie Kenderdine, Principal and Executive Vice President, Energy Futures Initiative

Joe Manchin, U.S. Senator (D-WV)

Gina McCarthy, White House National Climate Advisor

Ernest J. Moniz, CEO, Energy Futures Initiative

Elizabeth Shuler, Secretary-Treasurer,[a] AFL-CIO

Richard Trumka, President, AFL-CIO

Panel #1 Speakers

Brian Anderson, Executive Director for White House Interagency Group on Coal and Power Plant Communities and Economic Revitalization; Director, National Energy Technology Laboratory

Louise Anderson, Electricity Industry Manager, World Economic Forum

Lee Beck, International Director, Carbon Capture at Clean Air Task Force

Brad Markell, Executive Director, AFL-CIO Industrial Union Council and Working for America Institute

Betsy McIntyre, Executive Director, TEAM Consortium, Panel Moderator

Panel #2 Speakers

Roxanne Brown, International Vice President at Large, United Steelworkers

Mike Docherty, Executive Director of In-2-Market, Panel Moderator

Richard Fruehauf, Senior Vice President and Chief Strategy and Sustainability Officer, United States Steel Corporation

Alex Kizer, Senior Vice President of Research and Analysis, Energy Futures Initiative

Toby Rice, President and CEO, EQT Corporation

a Elizabeth Shuler was elected President of AFL-CIO in August 2021.

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Discussion Questions

The following questions were addressed by each panel:

PANEL ONE

Economic and Environmental Benefits of Hydrogen and CCS Market Hubs

1. What are the economic and environmental impacts of hydrogen and CCS and why are they critical to achieving the climate goals of the Biden-Harris administration?
2. What factors will contribute directly to economic revitalization and union job creation?
3. What policy strategies are important to incentivizing decarbonization?

PANEL TWO

What is Needed for Hydrogen and CCS Market Formation: Roles for Industry, Labor Unions, Government, and Non-Profits

1. What incentives, investment, and policies would be helpful to deploy hydrogen and CCS projects?
2. What types of job re-training and other policies are needed to ensure job creation?
3. What regulatory framework is needed to enable and regulate the new market?
4. Why are regional hubs important to the success of hydrogen and CCS?
5. What regional innovation and investment opportunities exist for hydrogen, carbon dioxide, and CCS?

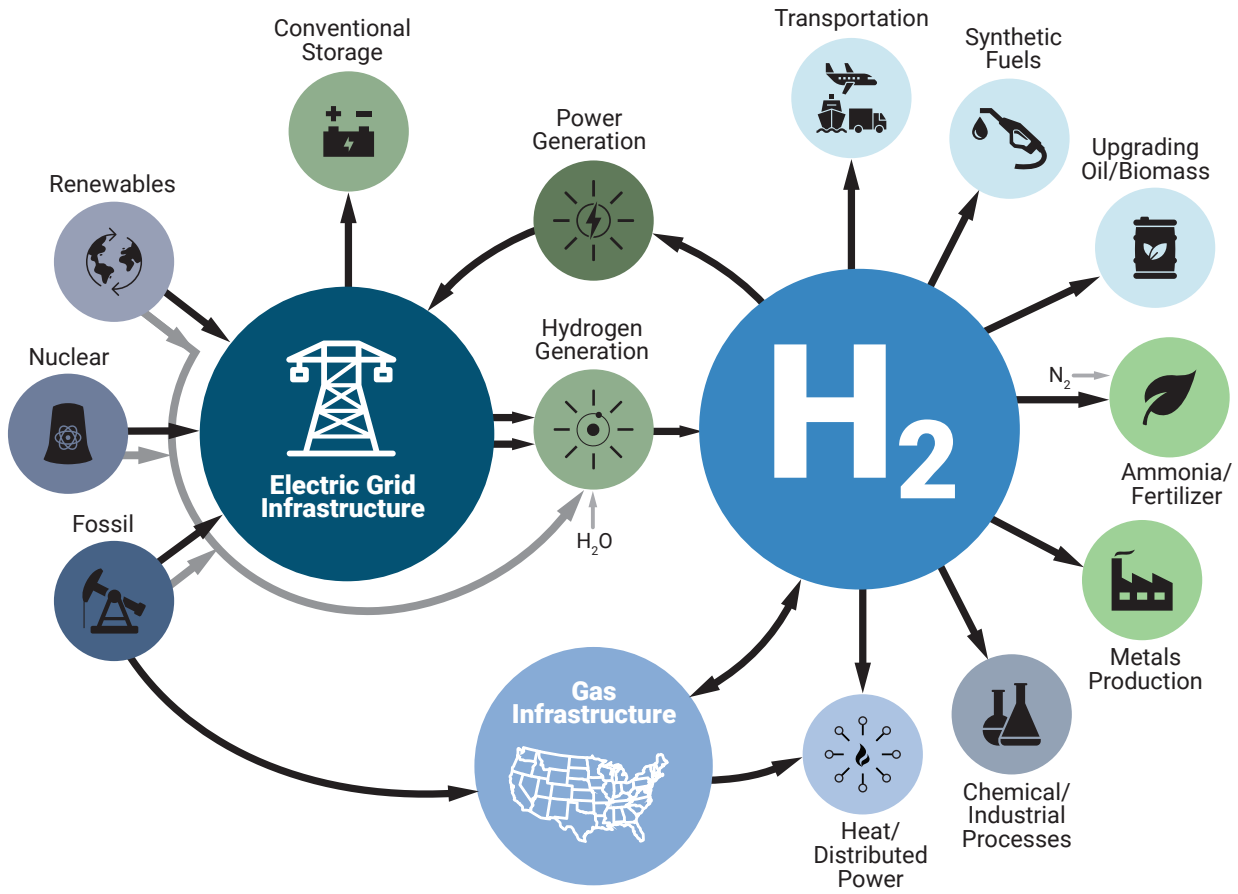
Workshop Summary and Findings

Preserving jobs in the industrial heartland while driving down U.S. emissions has often been deemed nearly impossible. However, thanks to growing innovation supported by decades of research and development, the United States now has a once-in-a-generation opportunity to invest in energy infrastructure and launch hydrogen and CCS hubs.

Deploying commercial-scale hydrogen infrastructure in the Ohio River Valley can help fulfill the Biden Administration's goals to slash U.S. emissions in half by 2030 and preserve and create good-paying jobs in unionized sectors.

As the White House Climate Advisor, Gina McCarthy, emphasized in her opening remarks, President Biden has chosen an all-of-the-above strategy in addressing climate change. Hydrogen and CCS market formation is an important element for accelerating the decarbonization of the economy and helping mitigate climate change. Hydrogen typically takes a back seat to near-term, less expensive abatement pathways, such as battery electric light duty vehicles. However, hydrogen can help decarbonize many sectors of the economy that are not easily decarbonized by other technologies. Figure 1 highlights the research areas of Department of Energy's (DOE) H_2@SCALE projects and the potential for hydrogen deployment. For example, hydrogen is a more viable replacement fuel for heavy-duty vehicles, which need high-power capacity that batteries cannot deliver without adding substantial weight. Additionally, certain heavy-duty vehicles, such as buses and forklifts, require less fueling infrastructure as they return to the same place for refueling. Other promising applications for hydrogen technology include industrial energy and chemical process modification, combined heat and power for industrial complexes and commercial buildings, and carbon-free balancing power for electricity generation. As Senator Joe Manchin (D-WV) pointed out, "Hydrogen and carbon capture utilization and sequestration are a crucial part of any climate economic development goals in transportation, industrial electrical power, buildings, and even as uses for fertilizer in the agricultural sector."

Figure 1. Department of Energy H_2@Scale Research Areas[1]



The breadth of the DOE H_2@scale program illustrates the potential roles for hydrogen in a low-carbon economy: grid storage, power generation, heat, industrial processes, and transportation. Source: DOE, 2021.

Around the world, clean hydrogen is embraced as a strategy to decarbonize industrial centers. The Northern Endurance Partnership––a public-private partnership in the United Kingdom––plans to construct a CCS and hydrogen hub in the Humber region.[2] The Humber cluster would anchor around a blue hydrogen plant, led by Equinor, at a chemical production facility. This project plans to eventually use offshore wind to produce green hydrogen. The U.K. government has supported this hydrogen and CCS cluster with over US$80 million in grants.[3] The Humber cluster leverages the region's large industrial emitters, proximate geologic formations for storing CO_2, and supportive government to catalyze an industrial transition.

An ideal region to deploy hydrogen and CCS technologies in the United States would have several components. First, there would be large industrial and utility emissions sources that are the centers of economic output in need of pathways for decarbonizing their processes. These emissions sources would ideally be in close enough proximity to share infrastructure and knowledge across parties. Second, the region needs plentiful natural

gas resources to supply low-cost blue hydrogen production, as well as geologic formations for storing the captured carbon. Third, the region needs policymakers who are supportive of hydrogen and CCS as pathways to decarbonizing. The Ohio River Valley has each of these three critical elements. Senator Sherrod Brown (D-OH) summarized the potential of this region by stating that "our state [Ohio] perhaps has the proudest history and the best manufacturing talent in the country. We have the history of the workers... the passion... the innovation. And we certainly have the physical capital. We have the factories. We have the space ready to be retooled and repurposed. We just need the investment."

OPENING KEYNOTE FOR THE WORKSHOP

Secretary Moniz provided context for the workshop in his opening remarks, stating, "this is a very important workshop in a very important year... the ambition is being increasingly expressed in terms of a net-zero commitment by mid-century [with] that commitment being put forward by an increasing number of countries and a very large number of private companies all of which suggests that this is going to be a very, very serious effort." To reach such goals, Moniz added that "we will need to clean our electricity system—we'll need to do some electrification in other sectors, but we also know we are going to have to supplement that [with] hydrogen as an essential complement to low-carbon electricity." Decarbonizing the economy cannot be fully achieved solely by decarbonizing the power sector and electrifying.

Low-carbon fuels, technologies, and processes will also be needed for other critical uses and hydrogen can address many of these decarbonization needs. Hydrogen is highly versatile, spanning many critical sectors. CCS technology can also decarbonize existing power plants and industrial facilities, either directly or by enabling blue hydrogen use. Hydrogen can be produced from multiple resources by multiple methods. Hydrogen production from fossil fuels includes several types of natural gas reforming, pyrolysis, and gasification of coal, biomass, and wastes such as plastic or municipal solid waste. Green hydrogen can also be produced by electrolysis with nuclear or renewable power.

As noted, hydrogen is also versatile in its uses across sectors. Most of the hydrogen currently used in the United States is for petroleum refining, the treatment and production of iron and steel, processing foods, ammonia and fertilizer production, and for a range of processes in the pulp and paper industry.

In addition to decarbonizing industrial processes, other potential uses of hydrogen include:

- Combustion in a turbine to generate electricity (blended with natural gas or in turbines designed for pure hydrogen).
- Fuel cells for power or transportation.
- Storing energy at utility scale.
- Replacing fossil fuels for industrial heating (industries with needs for high quantities of heat include steel, glass, and cement).

Industrial emissions make up about 20 percent of all emissions. Adding CCS to a range of industrial processes will produce "clean hydrogen," reducing emissions from the range of hydrogen uses by as much as 90 percent. CCS technologies used for industrial processes can also reduce criteria pollutants, an important benefit for frontline communities. CCS is the only technology currently capable of decarbonizing the high-grade process

heat required in energy intensive industries, including steel and aluminum production. It is also needed for other high-emitting activities, including pulp and paper, chemicals, and cement.

Regional hubs allow industries to share expertise, costs, products, and infrastructure.

Aggregating hydrogen demand in a hub can take advantage of economies of scale to incentivize hydrogen production. At the same time, aggregating emitters to form hubs can align carbon dioxide sources with companies and entities capable of transporting and storing carbon dioxide. Infrastructure for both is, however, a critical need. To minimize risks associated with the lack of hydrogen and carbon dioxide infrastructure early in the development of a hub, Mr. Toby Rice, of EQT Corporation, explained his strategy to "produce local and sell local" as "hydrogen can be produced for $1 per kilogram but moving it to market costs $4 per kilogram."

Many CCS projects in development around the world are also part of hubs, where geographically clustered emission sources share carbon dioxide pipelines and geologic storage sites. Ms. Louise Anderson, of the World Economic Forum (WEF), described why the WEF started an initiative on the role of industrial clusters in accelerating the path to net zero. She said, "Over the past 12-18 months, 80 percent of the global economy has committed to net-zero, but what is missing is how the markets are going to achieve those commitments. We believe industrial clusters will play a really important role. What is missing is the 'reality on the ground'... co-located supply and demand, ... playgrounds for scaling technology, attract[ing] new companies to the cluster."

In the United States, given the proximity of many stationary emitting facilities to robust permanent geologic storage resources, developing local networks of carbon dioxide and hydrogen infrastructure can underpin significant regional emissions reduction, cost sharing, job opportunities, and economic activity. Ms. Gina McCarthy, the White House National Climate Advisor, believes "these hubs demonstrate the capacity we have as the United States to be moving forward with innovative technologies in a way that makes sense to the local communities, in a way that invests in those communities that have been left behind, in a way that reinvigorates our manufacturing sector...hubs are not only essential to get the deployment and scale that we actually need but...brings hope again."

Ms. Melanie Kenderdine, of EFI, provided powerful visual context for the industries, workforce, geology, and natural resources in the Ohio River Valley that make it an excellent location for a hydrogen and CCS hub. Figure 2 depicts an overlay of a map of the Energy Information Administration's ten electricity regions on top of a map of potential sequestration sites, including oil and gas reservoirs and saline formations. It also identifies large industrial emitters and their approximate locations across the country, as well as possible locations for hydrogen and CCS hubs. In addition to the potential for hub formation, these sites and their associated geologic formations could enable other key technologies such as bioenergy with carbon capture and storage (BECCS), hydrogen as an energy storage medium, and compressed air energy storage.

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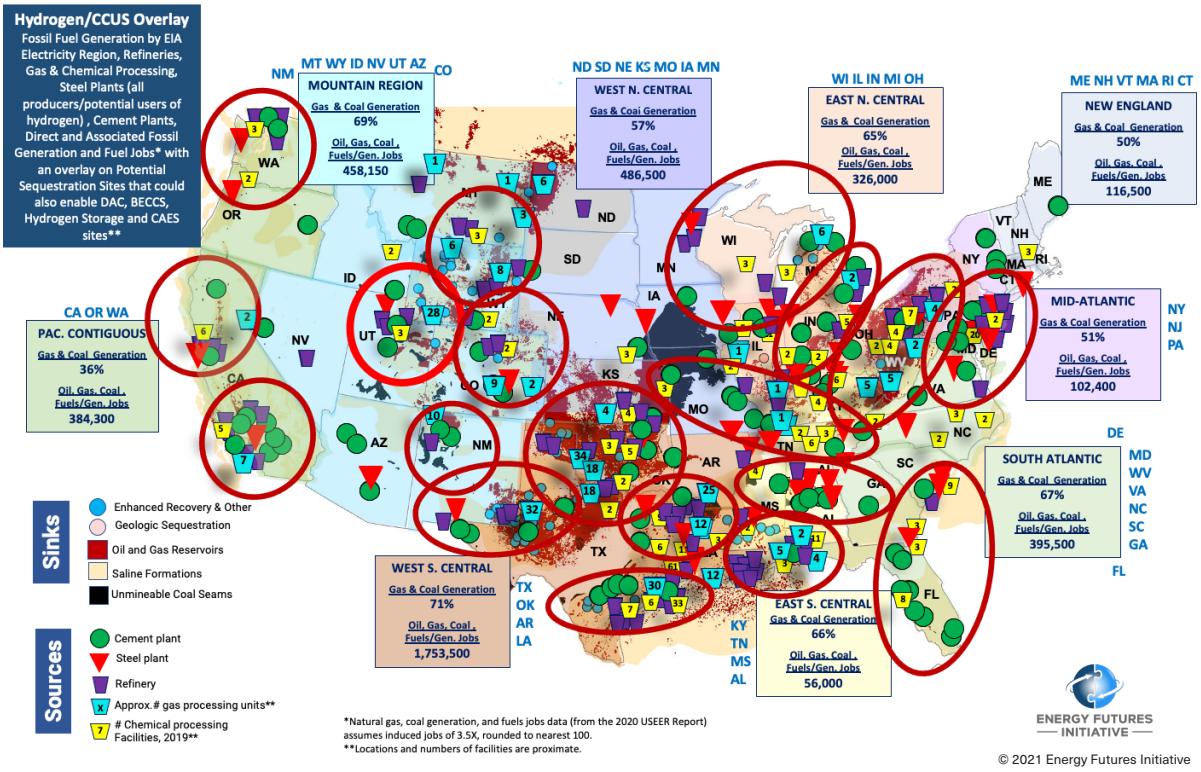
Figure 2. EFI Hydrogen and CCS Data Overlay Map with Potential for Hub and Market Formation[4,5,6,7,8,9,10,11,12]



The complex overlay of essential elements for hydrogen and CCS market formation (industrial plants that make or use hydrogen, large CO_2 emitters, geologic carbon dioxide sinks, oil and gas generation and jobs) shows regional concentrations that have the potential to be industrial hubs. Data from Google Maps, 2021; Earth Justice, 2021; Data Basin, 2017; EIA, 2019; EPA, 2019; and NASEO and EFI, 2020. © 2021 Energy Futures Initiative.

A recent report released by the LEP modeled three regional hubs in the context of developing a roadmap for CO_2 transport and storage.[a] Table 1 shows high carbon dioxide emissions from the Ohio River Valley, the industries in the region that could become part of a hub, and the amount of storage and transportation infrastructure needed. Geospatial analysis found that as few as eight carbon dioxide sinks and 855 miles of carbon dioxide pipeline could permanently dispose of emissions from all facilities analyzed in this study.

a Click here to download the full report.

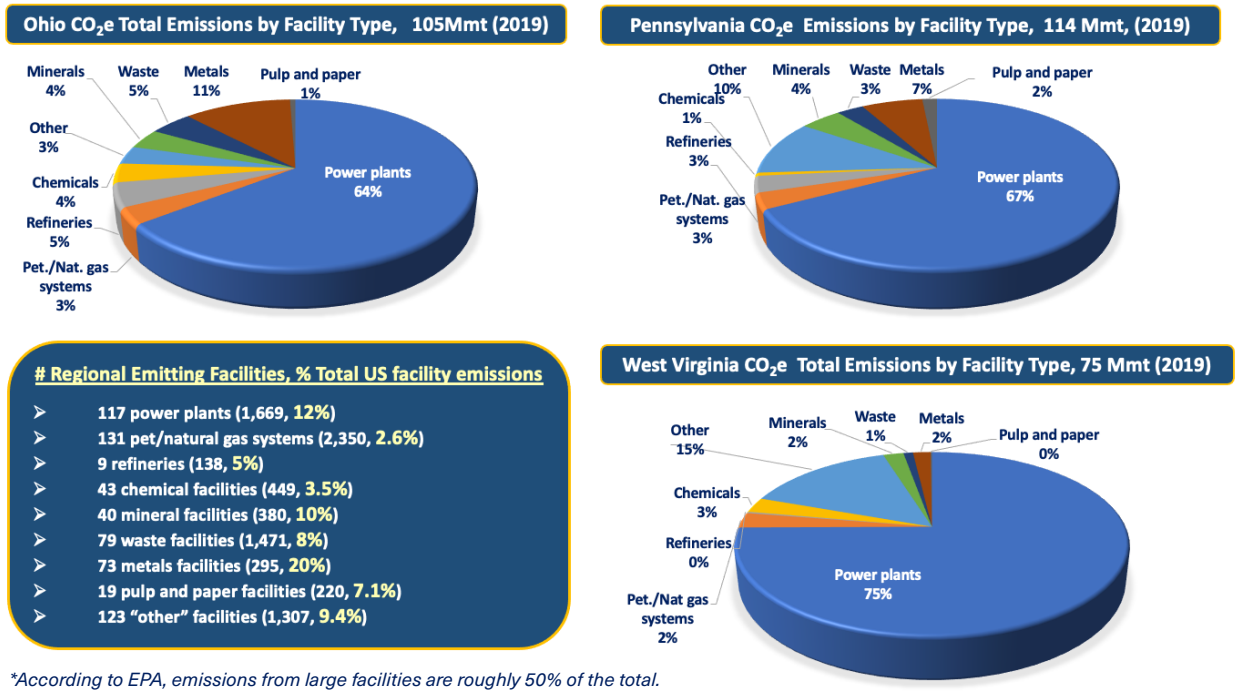
Table 1: Modeled CO_2 Reduction, CCS Hub Projects, and Infrastructure Needs in the Ohio River Valley[13]

Region	Total Emissions Reduction	Hub Facilities
Ohio River Valley	**123 $MtCO_2$ /year**	Sources: 29 power generation, 19 iron and steel/aluminum, 5 chemicals manufacturing & production, 2 refinery, and 1 mineral plant Modeled Needed Infrastructure: 8 geologic storage sites, 855 miles of carbon dioxide pipelines

The LEP report on CO_2 transport and storage infrastructure modeled infrastructure needs for three potential industrial hubs. The model results for the Ohio River Valley showed that eight storage sites and about 850 miles of pipeline could serve the region's 56 industrial facilities. Source: The Labor Energy Partnership, 2021.

It should be noted that, as a reference point, the states in the Ohio River Valley comprised around eight percent of the total U.S. population in 2019. Given the region's economic base, emissions from chemical, minerals, and pulp and paper are higher than the region's share of the population; emissions from metals facilities are almost 25% of the nation's total emissions from that sector. Figure 3 details the emissions in the Ohio River Valley associated with some of the major industrial activities in the region, providing additional detail on the emissions associated with many of those industrial activities highlighted in Figure 2.

Figure 3. Ohio, Pennsylvania, West Virginia Emissions by Large Facility Type, 2019 (Mt CO_2e)[14]



According to EPA, emissions from large facilities are roughly 50% of the total.

The Ohio River Valley economic base includes power, chemical, minerals, and pulp and paper. Concentrated emissions in the region offer significant opportunities for carbon capture and storage. Many facilities are also producers or consumers of hydrogen. Data from EPA, 2019.

Hydrogen and CCS market formation requires creating a viable, profitable, regional system for the production and use of hydrogen plus the capture and utilization or storage of carbon dioxide.

Hydrogen, to date, has been considered a specialty chemical or feedstock, not an energy commodity traded in large volumes in both domestic and international markets. Regulation of hydrogen is largely focused on safety. On the CCS side of the equation, permitting of CO_2 storage sites is often a lengthy process that introduces significant timing uncertainty, increasing project risk and cost. Consumers and producers of hydrogen have different motivations and many potential hub regions cross state boundaries, including potential underground CO_2 storage sites. In short, although there is great environmental and economic value associated with CO_2 storage and hydrogen production and use, establishing hydrogen and CCS hubs is complicated.

Market formation requires multiple elements to come together in location and timing, from companies and federal, state, and local governments. Elements include:

- Industries to produce hydrogen.
- Demand for hydrogen.
- Marketplace or trading hub for hydrogen.
- Proven and economic (or incentivized) carbon capture and storage technologies.
- Physical infrastructure to move and store both hydrogen and carbon dioxide.
- Suitable geologic storage for carbon dioxide.
- Skilled, trained workers.
- Industry collaboration and innovation.
- Improvements in hydrogen and carbon dioxide safety.
- Increased public awareness and acceptance of hydrogen and sequestration.
- Policies, regulatory structures, and government incentives.
- Private investors.

Appropriate political support will also be needed for a regional hub to form. The Labor Energy Partnership was honored to have Senator Joe Manchin, Senator Sherrod Brown, and White House Climate Advisor Gina McCarthy open this program and be upfront with their support for an Ohio River Valley hydrogen and CCS hub.

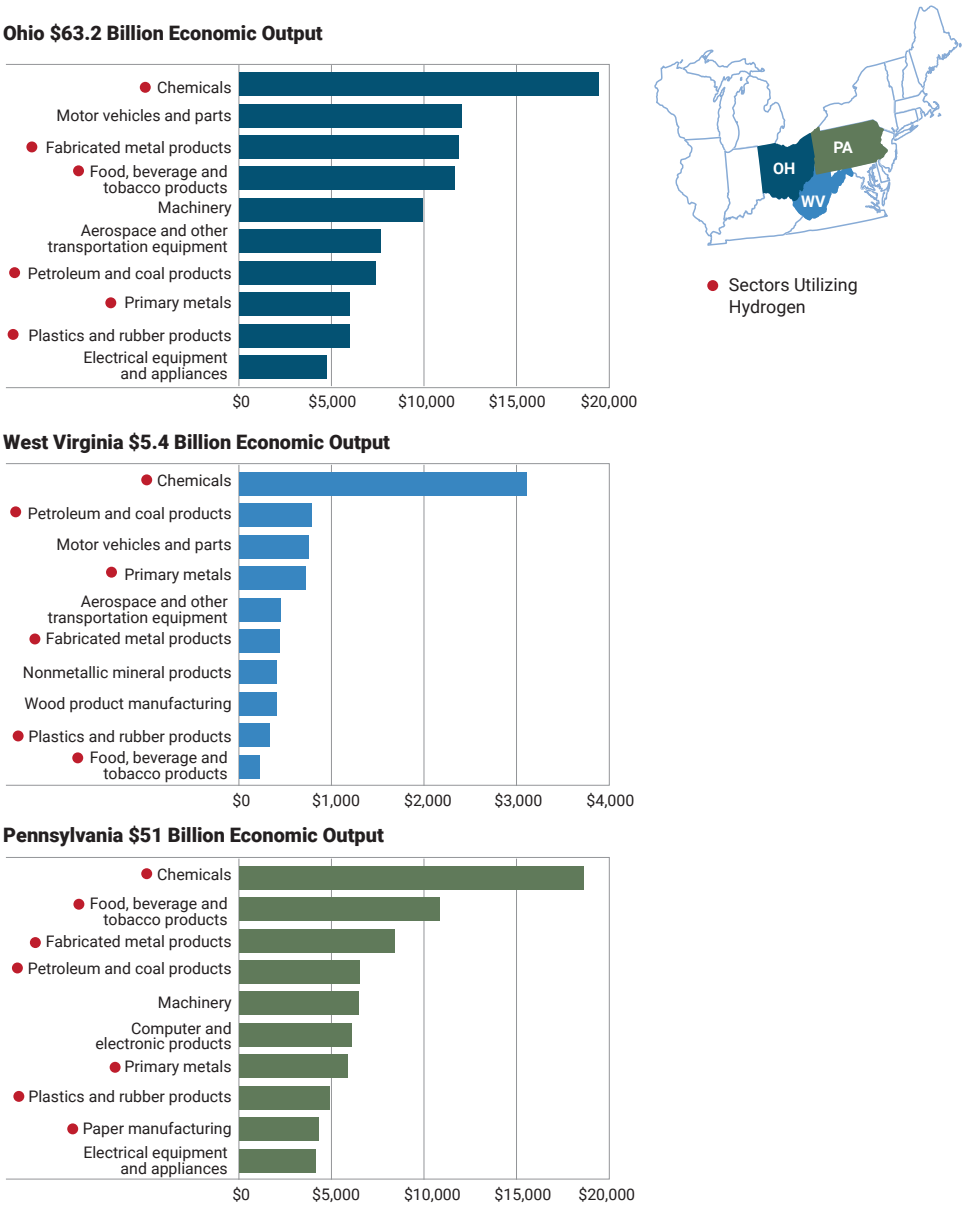
The Ohio River Valley has many characteristics desirable for a hydrogen and CCS hub and many elements needed for accelerating market formation.

This region is an excellent location for hydrogen and CCS market formation because the region has:

- Multiple companies that are already producing hydrogen (refineries), are using hydrogen (ammonia plants), or could utilize hydrogen (cement, steel, glass).
- An abundance of natural gas to produce hydrogen.
- Plentiful carbon dioxide storage capacity in saline reservoirs.
- Skilled workers, some of whom are displaced from the energy sector or manufacturing employment, with many more at risk of being displaced.
- Interested investors.
- Motivated local and state governments to support market formation through policy efforts.

In addition to the geologic storage potential highlighted in Figure 2, the economic output of potential consumers of hydrogen in the region are highlighted in Figure 4. The combined total economic output from manufacturing sectors that could utilize hydrogen in the three Ohio River Valley states was almost $120 billion in 2019, underscoring the simultaneous need to maintain and support this activity while rapidly decarbonizing these and other activities in the region.[15, 16,17]

Figure 4: Economic Output from Ohio River Valley Manufacturing Sectors that Could Utilize Hydrogen, 2019[18, 19,20]



The economic output (value of all sales, goods, and services) from the industries that could utilize hydrogen to decarbonize in the three states comprising the Ohio River Valley (Ohio, Pennsylvania, and West Virginia) was nearly $120 billion in 2019. Source: National Association of Manufacturing, 2021.

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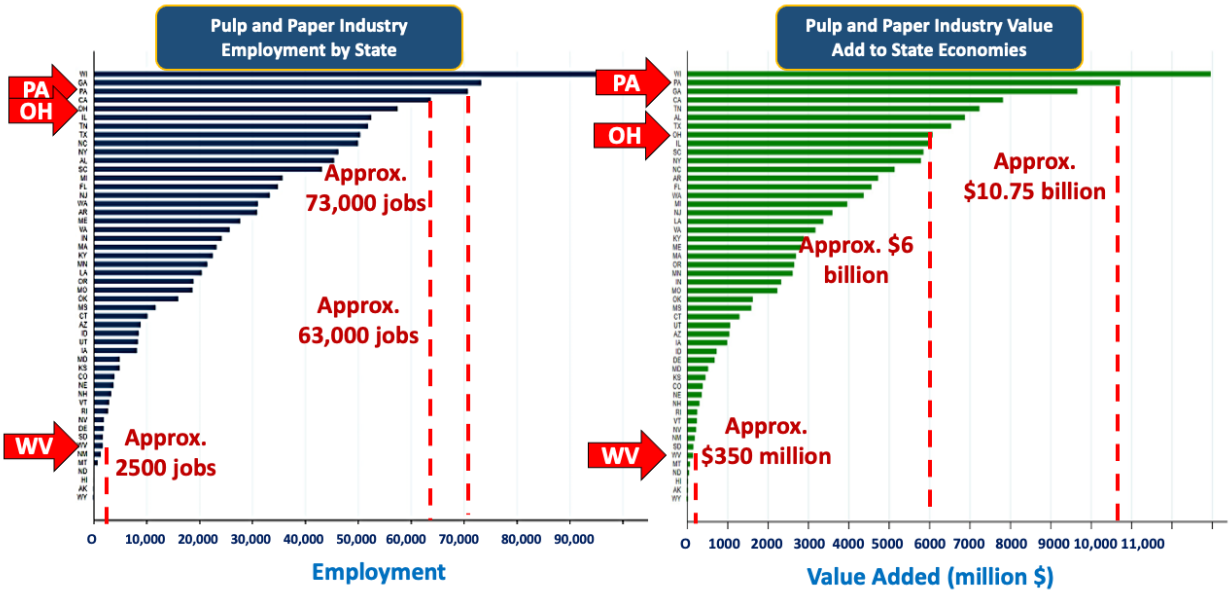
The pulp and paper industry in the region offers another case in point (Figure 5). Hydrogen is used for making pulp and paper. Hydrogen peroxide, for example, is used for the bleaching of cellulose, and of wood pulp, and the recycling of wastepaper, specifically for de-inking. The regional economic output for the pulp and paper industry in the Ohio River Valley Region is over $15 billion a year and employed over 138,000 workers in the region in 2019.[21]

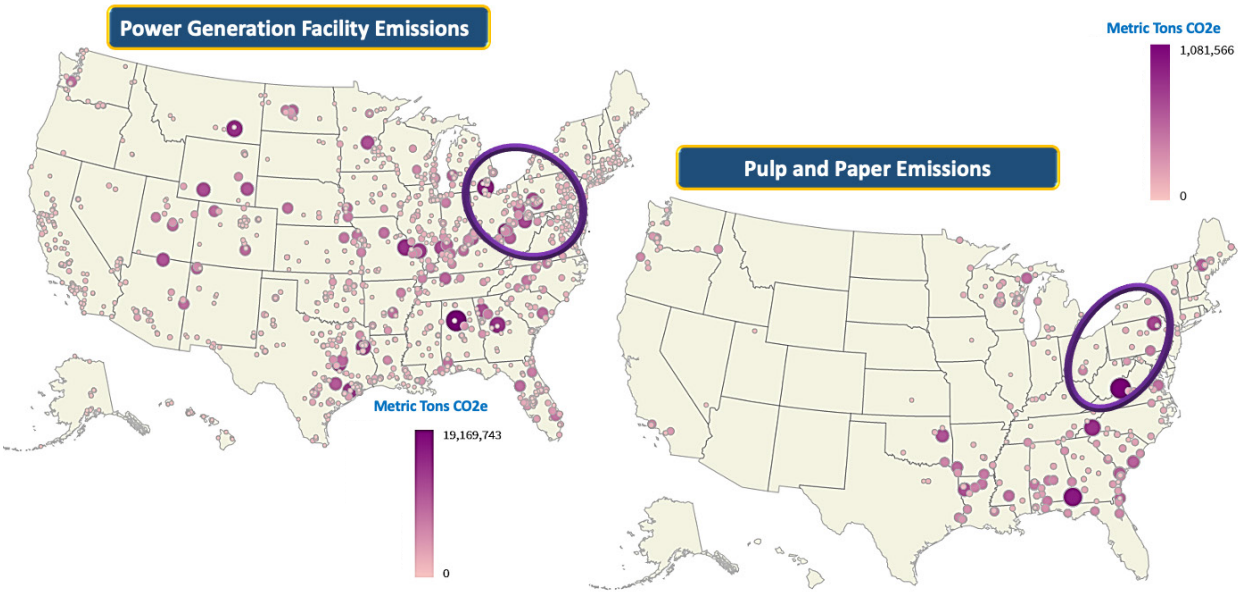
Figure 5. Pulp and Paper Jobs and Economic Value (2019) in the Ohio River Valley[22]



The pulp and paper industry is an important industry in the region and uses hydrogen in its processes. In 2019, the economic output for the pulp and paper industry in the Ohio River Valley tristate area was over $15 billion, and it employed over 138,000 workers. Data from G. J. Jolley, 2020.

The pulp and paper industry is a discrete emissions category in the Environmental Protection Agency's GHG inventory; emissions associated with this activity must be dramatically reduced. Figure 6 highlights emissions in the region from both the pulp and paper sector and from power generation.

Figure 6: Ohio River Valley Emissions from Power Generation and Pulp and Paper Facilities, 2019[23,24]



The power sector accounted for 32 percent of total U.S. energy-related CO_2 emissions in 2020 according to EIA. The pulp and paper industry is a discrete emissions category in the Environmental Protection Agency's GHG inventory. The Ohio River Valley has significant emissions from both the power sector and the pulp and paper subsector. Source: EPA, 2020.

The Ohio River Valley has been hit hard by recent industrial and energy transitions and is one of the poorest regions in the United States.

The three states in this region (West Virginia, Pennsylvania, and Ohio) accounted for eight percent of the U.S. population in 2019, but host 12 percent of the nation's power plants and 22 percent of iron and steel production. The region is vulnerable to job losses associated with the changing energy mix and environmental policies. Eight of the remaining 26 coal plants in the three states are scheduled for retirement in the coming years; most other plants belong to companies with publicly announced decarbonization targets.[25]

At the same time, poverty, environmental injustice, and dislocations from previous industrial transitions are all prominent issues for the 54 counties that comprise the Ohio River Valley region. Poverty rates exceed the national average in 42 of the 54 counties. This area also has an above average portion of individuals on disability; in some counties, it is nearly a quarter of the population. Additionally, seven counties in the region ranked in the 90th percentile in the country for particulate matter pollution. Nine counties are in the 95th percentile for cancer risks. Because the capture of carbon dioxide from industrial and power-sector sources also reduces particulate matter and other pollutants, the formation of a hydrogen and CCS hub would confer significant public health benefits to the region.

Being referred to as The Rust Belt, which Senator Brown identified during the workshop as "an outdated and offensive term," adds insult to injury for the residents of this region. The Senator went on to say "it's up to us in government, new energy industries, and [the] labor movement to show workers in Ohio and around the country that there's real opportunity to make their lives better. Fighting climate change isn't just an environmental issue; it's an economic one too."

Workers and communities in the Ohio River Valley have had to accommodate past transitions in energy and industry, often resulting in job losses and economic dislocation. Ms. Roxanne Brown, of the United Steelworkers, shared the view that "our critical job as a labor union is making sure that members have a role not just in this economy but into the future." She encouraged industry and government to "look to our unions as a conduit for how we build out these hubs, because we will have a real strong sense of what facilities might make the most sense."

The presentation from Ms. Kenderdine, of EFI, which provided context for the suitability and desirability of the Ohio River Valley as an industrial hub, also underscored the economic importance of the industries in the region. Figure 7 shows that the iron and steel industry in Ohio, Pennsylvania, and West Virginia produces about $46 billion of direct economic output per year and provides approximately 76,000 jobs. Other important industries in the region that could be part of a hydrogen and CCS market include fertilizer and pulp and paper. Fertilizer produces almost $7 billion of annual economic output and provides 32,000 jobs, and, highlighted earlier in Figure 5, pulp and paper plants provide about $17 billion of output and over 138,000 jobs. Advocates for a hydrogen and CCS hub believe that these middle-class manufacturing jobs can be preserved and even expanded in this region.

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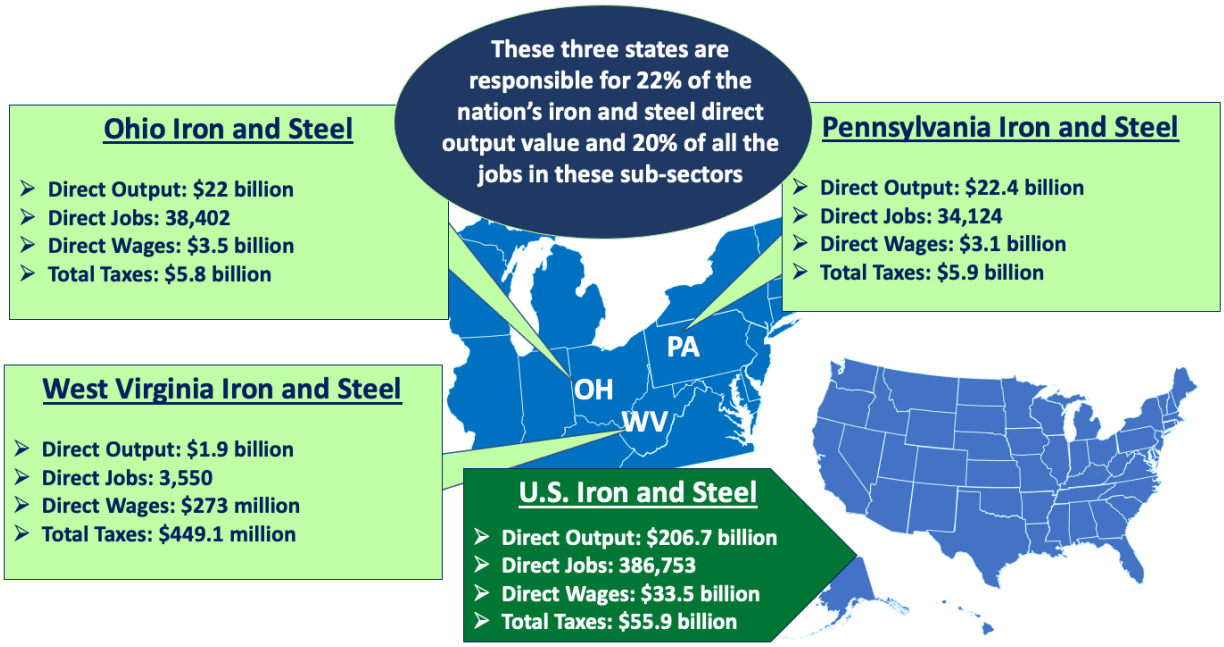
Figure 7: Ohio River Valley Iron and Steel Industry Economic Impacts, Wages, Jobs, Taxes[26, 27,28]



The Ohio River Valley Region accounts for 22% of the nation's direct economic output from the iron and steel sector (about $46 billion) and 20% of the sector's employment (approximately 76 thousand jobs). Data from National Association of Manufacturing, 2021.

Labor protection and labor participation are needed to create and maintain middle class jobs.

Several workshop speakers expressed consensus: creating better jobs with labor protections and guaranteeing workers' rights is vital for the success of the clean energy transition. In a discussion on how to lift labor standards to create more middle-class jobs, Mr. Richard Trumka, of the AFL-CIO, asserted that "labor needs to be at the table when [officials are] making decisions, in negotiations and on policy." He noted that labor had not been at the table for past trade agreements, and the AFL-CIO pushed to include labor in United States-Mexico-Canada Agreement. He highlighted that the AFL-CIO supports the PRO Act, legislation recently passed in the House with bipartisan support that aims to guarantee free and fair pathways for unionization.[29]

Senator Brown observed: "the research shows [that] when unions are involved and the company takes a collaborative approach from the beginning, productivity and innovation go up." Ms. Liz Shuler, of the AFL-CIO, summarized that we need to build a clean energy future with "social equity at the center and labor at the table."

To support environmental justice, the Biden Administration issued an Executive Order to develop recommendations on how to direct 40 percent of climate-related federal investments to communities suffering from environmental injustice and economic dislocation. This targeted federal investment is beneficial, but it is better to

not strand communities. To this end, President Biden requires that good paying union jobs be created by the measures we take to mitigate emissions and adapt to climate change.

CCS and hydrogen industries create manufacturing and infrastructure jobs.

CCS and hydrogen hubs can support and, importantly, expand economic activity in the Ohio River Valley while dramatically reducing emissions. Building a new regional industry in carbon capture, storage, and transport can decarbonize industrial activity while retaining the associated jobs and economic output. Decarbonizing heavy industry could maintain and even increase regional jobs in power, steel, cement, paper, and fertilizer. Developing a CCS and hydrogen hub would also create new middle-class jobs in manufacturing and infrastructure.

According to the LEP's recently released study, *Building to Net Zero: A U.S. Policy Blueprint for Gigaton-Scale CO_2 Transport and Storage Infrastructure*, "New low-carbon industries hold enormous promise for wealth creation and job growth, especially for employees located outside of urban areas where job growth over recent years was highest. The Alberta Carbon Trunk Line, a hub of three CCS projects in Canada, for example, is estimated to create over 6,000 jobs for those three projects over the four-year construction period. In the United States, NET Power developed an innovative technology for oxygen combustion with CO_2 capture technology for gas-fired power generation and recently initiated the development process for commercial-scale plants in Colorado and Illinois. These projects were estimated to each create 1,000 jobs over the construction and implementation phase."

Mr. Trumka noted that, "hydrogen with carbon capture means we can decarbonize industry without destroying livelihoods and lives. We can use the region's existing abundant natural gas resources to create a clean fuel that preserves existing jobs and creates new ones. Answering the climate crisis doesn't have to cost American jobs, it can create them."

The LEP study referenced above identified skillsets that would be needed for CCS; there are significant and similar needs for developing hydrogen infrastructure. The study noted that, "Workers in industries that have declining demand—whether a result of climate mitigation policies or continued structural changes in the global economy—often have the skills necessary for new, clean industries. Implementing CO_2 transport infrastructure requires boilermakers and construction trades...pipeline workers and welders to build or repurpose the network of pipes...and subsurface engineers, welders, rig operators, and roustabouts... These trades stand to gain significant work in new industries and increased demand for their skilled labor; many of these are permanent jobs."

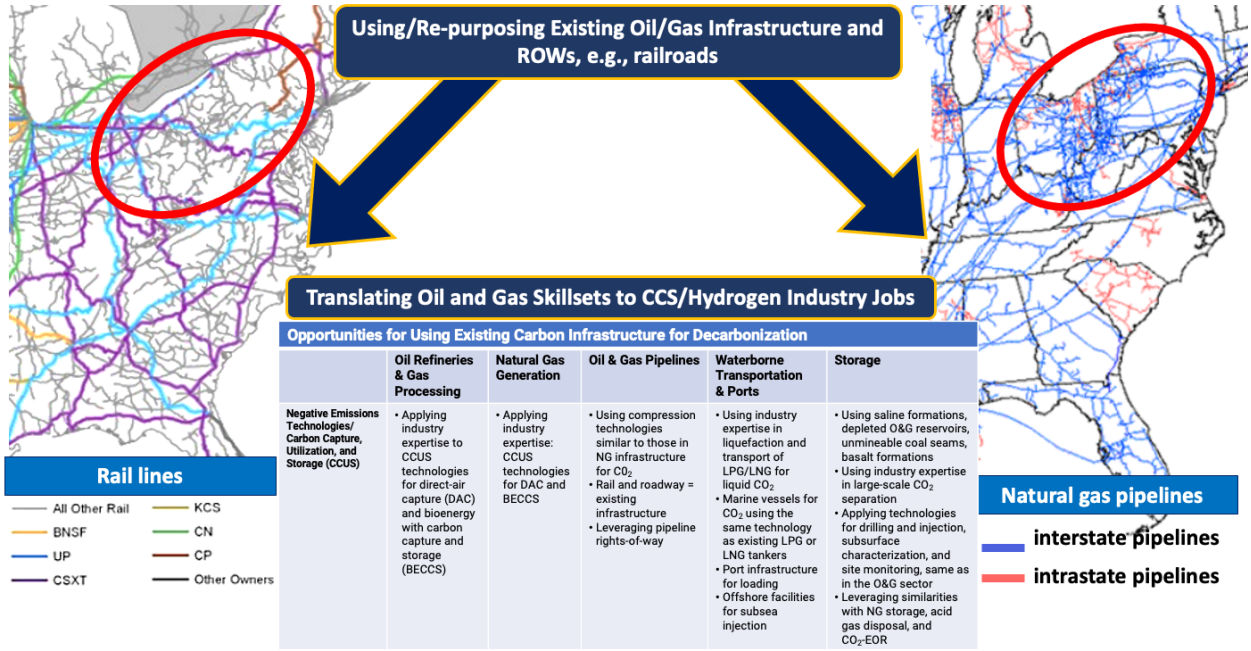
The Ohio River Valley workforce is capable, motivated, and well supported through existing training programs.

Unions are ready for CCS and hydrogen because of training programs, like those supported by the AFL-CIO. Union apprenticeship programs "integrate systematic on-the-job training, guided by an experienced master-level practitioner in an occupation, with classroom instruction. The federal government, in cooperation with the states, registers apprenticeship programs that meet federal and state standards. The best programs—which provide multiple industries with

highly skilled workers who earn family-sustaining wages—are registered with government agencies, operated by sponsors representing labor and management organizations and funded through collectively bargained contributions to tax-exempt trust funds."[30]

There are union training centers throughout the Ohio River Valley. Mr. Brad Markell, of the AFL-CIO, explained, "When you [enter] a union apprenticeship, you leave with no debt, connected to work, and of course, trained to the highest standards available." At the same time, it highlights the potential for repurposing existing infrastructures and rights of way. Figure 8 underscores the value of and need for such training programs, where oil and gas skillsets of workers in the region are suited to hydrogen and CCS hub needs, with training for specific activities and needs.

Figure 8. Oil and Gas Infrastructure and Skillsets Can Translate into CCS and Hydrogen Hub Infrastructure, Jobs, and a Clean Energy Transition[31,32]



Opportunities for Using Existing Carbon Infrastructure for Decarbonization

	Oil Refineries & Gas Processing	Natural Gas Generation	Oil & Gas Pipelines	Waterborne Transportation & Ports	Storage
Negative Emissions Technologies/ Carbon Capture, Utilization, and Storage (CCUS)	• Applying industry expertise to CCUS technologies for direct-air capture (DAC) and bioenergy with carbon capture and storage (BECCS)	• Applying industry expertise: CCUS technologies for DAC and BECCS	• Using compression technologies similar to those in NG infrastructure for CO_2 • Rail and roadway = existing infrastructure • Leveraging pipeline rights-of-way	• Using industry expertise in liquefaction and transport of LPG/LNG for liquid CO_2 • Marine vessels for CO_2 using the same technology as existing LPG or LNG tankers • Port infrastructure for loading • Offshore facilities for subsea injection	• Using saline formations, depleted O&G reservoirs, unmineable coal seams, basalt formations • Using industry expertise in large-scale CO_2 separation • Applying technologies for drilling and injection, subsurface characterization, and site monitoring, same as in the O&G sector • Leveraging similarities with NG storage, acid gas disposal, and CO_2-EOR

It may be possible to repurpose some of the oil and gas infrastructure in the Ohio River Valley region for hydrogen and CCS uses. Use of existing rights of way in the region may also have value for expediting the infrastructure needed for deep decarbonization, and many of skillsets needed for the oil and gas sectors are the same as those in CCS and hydrogen projects. Source: EIA, 2021 and Cambridge Systematics, 2008.

While unions have strong programs to reskill and upskill workers, it should also be noted that the skills needed for hydrogen and CCS transfer readily from the natural gas production, fossil fuel power generation, and oil and gas infrastructure skill sets already exist in the region. In addition, the Tristate Energy and Advanced Manufacturing (TEAM) has established an MOU between higher education institutions that defined career pathways in energy and advanced manufacturing and is working to modularize their training curriculum.[33]

Forming a new market will require collaboration and investment from multiple industries, labor, government, academia, and the public.

At the workshop, a frequently mentioned challenge for a hub was "what comes first." Companies considering hydrogen production or CO_2 capture are unsure where or when companies will start using hydrogen or building facilities to sequester carbon, and vice versa. This classic chicken and egg problem limits job creation and scale-up. Does one company take a large risk and create hydrogen supply without known demand? How does a company explain to shareholders that it is making a large investment in infrastructure without supply contracts? Yet, success requires initial deployment at commercial-scale. Costs must be reduced, and economies of scale achieved. The market formation needs to start somewhere, and trust and cooperation are needed. As it is very difficult for one party to take the first step, establishing a hydrogen and CCS hub will likely require a significant coalition of firms, governments, and non-governmental actors across the region.

Ms. Betsy McIntyre, of TEAM, shared that she saw progress from "getting people together with diverse agendas around the table in the spirit of 'coop-etition' [cooperation and competition]. When we work together, we can be more efficient, more effective, have a boarder impact. It sounds like rhetoric until you start doing it." One example of this approach can be found in the Ohio River Valley area, where there is an MOU on workforce development and universities now "share curriculum and transfer credits among competing institutions and across state lines."[34]

Mr. Mike Docherty, of In-2-Market, observed that "these companies coming together and demonstrating some sort of alliance and alignment is what it's going to take to attract the federal funding and get the legislature behind it." Regarding the first mover spirit that is so helpful to form a market, Mr. Rice, of EQT Corporation, stated during his panel discussion that EQT plans to build their first hydrogen plant in the region and are proactively looking for customers for inexpensive hydrogen.

The LEP study of CCS, *Building to Net-Zero: A U.S. Policy Blueprint for Gigaton-scale CO_2 Transport and Storage Infrastructure*, explains that, given the proximity of many stationary emitting facilities to robust permanent geologic storage resources, developing local networks of CO_2 infrastructure can enable significant emissions reductions in the region, create a large number of jobs, and increase associated economic activity. Aggregating emitters to form hubs can also align CO_2 sources with companies and entities capable of transporting and storing CO_2. Such strategic alignments can pave the way for business innovations—forming new industry consortia, sharing risk across actors, and leveraging skills from multiple industries.

The government's responsibility to support deep decarbonization includes enabling legislation and infrastructure investment to support carbon sequestration.

Alex Kizer, of EFI, reminded the audience of the urgency of decarbonization goals by beginning his presentation with: "We have 3,000 days to reduce emissions by three gigatons with economy-wide solutions." That goal cannot be met with business as usual—new government policies, incentives and investments will be needed.

Some U.S. federal policies have been proposed. Ms. Lee Beck, of the Clean Air Task Force (CATF), described the Biden Administration's proposed American Jobs Plan as "the largest ever proposed investment put forward by a single government into the commercialization of carbon capture and storage. It could expand U.S. carbon management by thirteenfold." The proposed American Jobs Plan includes $35 billion for climate innovation, $15 billion for climate demonstration projects, and has a goal of establishing 15 clean hydrogen demonstration projects and ten pioneer demonstration facilities using carbon capture retrofits. Other recent proposed legislation includes an expansion of the 45Q tax credit to ramp up deployment of carbon capture, as well as the SCALE Act. The SCALE Act would create a program called the CO_2 Infrastructure Finance and Innovation Act and allocate $2.1 billion over five years to the program. A direct air capture center in the Ohio River Valley region was included in the President's budget request 2021. As Senator Manchin reminded us, there is already government funding available in the Energy Act of 2020 that he stewarded into passage: $35.2 billion was authorized for use across all energy technologies with over $6 billion for CCS alone.

Mr. Richard Fruehauf, of U.S. Steel, brought out the challenges of working "across multiple counties and states" and the government's responsibilities for "legal changes related to permitting, liability for storing carbon and transmitting hydrogen, and pipeline siting." The federal government also needs to simplify permitting and draft enabling regulations to support the private sector to move towards developing these hubs.

"[It is] not one [national] clean energy transformation [that is] needed but many individual regional transformations."
– Lee Beck, of CATF.

Regional clean energy innovation ecosystems—active groups of geographically connected stakeholders that support the RD&D and deployment of clean energy technologies—are at the heart of clean energy innovation in the United States. This is in part due to shared interests in local economies, people, and environments. By aligning local interests and resources, stakeholders can create new businesses and jobs, encourage outside investment, improve air and water quality, and reduce the impacts of climate change.

Locally-oriented clean energy innovation is also motivated by subnational efforts to reduce carbon emissions. Over 3,800 businesses and investors, cities and counties, mayors, colleges and universities, indigenous tribes, cultural institutions, and other organizations stand by the goals of the Paris Agreement. These groups, representing $9.46 trillion in GDP and covering 48% of the U.S. population, have committed to reducing emissions and increasing the deployment of clean energy technologies.

Multiple speakers at the workshop emphasized that regional solutions are the best solutions. State and local governments working with regional energy mixes, natural resources, industries, infrastructure, and geology are most qualified to find optimal solutions for their parts of the country. "Place-based strategy is what we need," stated Ms. Shuler, of the AFL-CIO. Dr. Brian Anderson, of the National Energy Technology Laboratory, believes in "leveraging existing assets in each region and not having a one-size-fits-all approach for the country." He stated that, "We have to tailor the path forward for the decarbonized energy and industrial sector economic future based on existing [regional] assets." Ms. Beck, of CATF, commented that hydrogen and CCS "technologies enable individual energy transitions." In CATF's view "there is not one transition but there will be individual regional energy transitions to create economic opportunities, enhance regional energy security and job security, and keep productive assets in play."

Senator Manchin emphasized that "it is our collective responsibility to address global climate change. I am a strong supporter of all-of-the-above energy policy and a firm believer in innovation rather than elimination and use all of our bountiful resources in the cleanest way possible. Hydrogen and carbon capture and sequestration are a crucial part of any climate economic development goals."

Strategic alignments formed for developing hubs can pave the way for building trust across stakeholders, sharing risks and innovation, and leveraging skills from multiple industries.

The federal government has a unique capability to convene major emitters, midstream companies, geologists, economists, and regulators to facilitate commercial activity and public-private sector collaboration. For example, in a hydrogen and CCS hub, with geographic clustering of CO_2 sources, there is potential to create economies of scale through a CO_2 infrastructure hub. Public-private partnerships can enable hub formation where a single entity could develop the CO_2 infrastructure for use by emitting entities.

In this regard, the LEP CCS study noted that, "...interstate compact authority ... could assist with hub formation in the region," and "there are many examples of such compacts; they would likely require Congressional approval, although this approval could be quite broad, e.g., general authority for states to form such compacts. There are many relevant examples of interstate compacts formed to support environmental protections and issues that span multiple states." One such compact already operating in the region, the Ohio River Valley Water Sanitation Compact, was established "for the purpose of maintaining waters in the river basin in a satisfactory condition, available for use as public and industrial water supply after reasonable treatment, suitable for recreational use, and capable of maintaining healthy aquatic communities."[35]

One key challenge is sizing the CO_2 transport and storage infrastructure for future, large-scale capacity before commitments are made from all CO_2 sources. The government's role could be to approve a new financing program that could provide flexible, low-interest loans to CO_2 transportation project developers for initial excess capacity on new infrastructure to facilitate future growth. Ms. Anderson, of WEF, explained that the 12 global companies working together on the Humber industrial cluster in the UK "have come together to create a shared, sustainable, commercial, business model which allows them to unlock individual sustainable commercial business models in the region."

ACTIVE COLLABORATIONS TO BUILD ON IN THE OHIO RIVER VALLEY.

A strong foundation of industry collaborations and economic development initiatives in this region are well-positioned to support regional hydrogen and CCS development. Dr. Brian Anderson, of the National Energy Technology Laboratory, and Ms. McIntyre, of TEAM, discussed multiple Ohio River Valley groups that can rally people behind the hubs, including:

- TEAM: TriState Energy and Advanced Manufacturing Consortium is a partnership to support clear and accessible pathways to jobs in energy and advanced manufacturing in Ohio, Pennsylvania, and West Virginia.[36]
- Allegheny Conference: The Allegheny Conference on Community Development is the sole organization committed to improving the Pittsburgh region's economic future and quality of life bringing together public and private sector leaders across Pittsburgh to define and communicate a regional vision, build partnerships, and mobilize action to advance a shared vision for the future.[37]
- Tri-State Shale Coalition: A collaboration initiated by the Governors of West Virginia, Ohio, and Pennsylvania seeking to optimize downstream economic development pertaining to shale gas, especially modern manufacturing.[38]
- Marshall Plan for Middle America: The Center for Sustainable Business at the University of Pittsburgh has been leading a cross-sectoral research team to envision a strategy for tackling the concurrent challenges of climate change, social and environmental injustice, and economic crisis. With a charitable donation and scientific support from the Enel Foundation, the Marshall Plan for Middle America (MP4MA) Roadmap aims to build a regional, multi-sectoral coalition of stakeholders to drive investment in infrastructure and energy diversification that will catalyze more equitable economic recovery while laying a foundation for the Ohio Valley (including Upper Appalachia) to be a global leader in cleaner energy resources and circular economy practices.[39]

- In-2-Market: In-2-Market provides a new and unique collaboration model, bringing together world-class research, innovation communities and businesses in Ohio, Pennsylvania, and West Virginia to accelerate research and commercialization of transformative technologies and solutions in modern manufacturing, advanced materials, and energy.[40]
- The Roosevelt Project: The goal of the Roosevelt Project is to provide an analytical basis for charting a path to a low-carbon economy in a way that promotes high quality job growth, minimizes worker and community dislocation, and harnesses the benefits of energy technologies for regional economic development. The next phase of the Roosevelt Project will develop implementation plans for four specific regions, including the Industrial Heartland where the Ohio River Valley is located.[41]
- The region is home to a strong and politically active labor movement, and many of the firms and sectors that would be involved in a hub are unionized.

Although hub development has already begun in several parts of the world, there is still potential for the United States to build global competitive advantage in decarbonized heavy industry.

Around the world, many carbon dioxide capture projects in development are part of hubs, where geographically clustered emissions sources share carbon dioxide pipelines and geologic storage sites. A CCS hub in development in Norway is planning to form a joint industry venture that will share costs, responsibility, and liability across multiple companies. This venture includes companies from cement, oil and gas, and waste management industries. The Humber industrial cluster in the United Kingdom plans for multiple hydrogen production facilities with CCS, low-carbon steel and chemicals, shared carbon dioxide and hydrogen pipelines, and offshore carbon dioxide storage. In May of this year, the UK government announced a £167 million competition to support, "the build out of carbon capture technologies, greenhouse gas removal and hydrogen." The program is aimed at supporting the UK's goal of reducing greenhouse gas emissions by 78 percent—compared to 1990 levels—by 2035.

Speakers saw U.S. potential for global leadership despite a head start in Europe. Mr. Rice, of EQT Corporation, said, "We have a tremendous amount of emissions here [in the Ohio River Valley], about 50 million tons per year [of carbon dioxide]. To put that into perspective, that is about all the carbon capture that is taking place right now in the world, about 50 million. So, there is also a tremendous opportunity to make an impact right here."

Several speakers commented on global competitiveness. Ms. Beck, of CATF, said, "The U.S. must continue to globally stay ahead in commercializing these technologies to ensure that it will be a leader in clean energy manufacturing," and Ms. McCarthy, the White House National Climate Advisor, asserted that "Clean energy tech is the pathway to harness the global lead in industry and innovation again." A CCS and hydrogen hub in the Ohio River Valley could be important for maintaining the industrial base and the electricity system that supports it—important for both the region and a test case for the country, while also helping us meet the urgent need for deep decarbonization.

Impact Report for the Workshop

PARTICIPATION

144 participants tuned in for the live virtual event. To date, the YouTube recording of the event has 570 views. View the full-length recording here.

SOCIAL MEDIA OUTREACH

Regarding promotional, event, and subsequent posts, there were over 14,762 impressions on EFI's Twitter with an additional 2,462 impressions on Secretary Moniz's Twitter. On LinkedIn, over 8,083 views were received on the Secretary's account. There were an additional 3,047 impressions from the EFI LinkedIn account and across all EFI social media platforms; the event garnered over 28,354 impressions.

NEWS ARTICLES:

Sherrod Brown News (7/12):
Brown Highlights Ohio's Future as Leader in Next-Generation Energy Manufacturing

The New York Times (7/13):
Hydrogen is one answer to climate change. Getting it is the hard part by Stanley Reed and Jack Ewing

Embargoed until Sept. 21, 2021

Building Upon the Workshop: Next Steps

The Labor Energy Partnership's inaugural document, *Energy Transitions: The Framework for Good Jobs in a Low-Carbon Future*, summarizes ten key areas of analysis that the LEP believes will help guide an effort to create a clean energy economy that is more equitable for all Americans and can be sustained across our diversity of political views, regional differences, and economic challenges for the next 30 years. This document identifies ten key areas that are critical to creating a unified path forward for the implementation of climate solutions in the United States and requires unbiased analysis that identifies challenges, opportunities, needed investments, and policy options.[a]

Included in these ten critical elements are half that are directly relevant to the focus of the July 12, 2021 Ohio River Valley Workshop on Hydrogen and CCS Hub Market Formation:

1. A national action plan for the deployment of carbon capture, utilization, and sequestration technology.
2. A priority energy infrastructure analysis that provides a roadmap for key energy infrastructure, financing mechanisms, and approval and permitting pathways in a deeply decarbonized economy.
3. Development of technology and policy pathways for the use of natural gas consistent with meeting climate goals.
4. An analysis of the economic challenges and cost benefits of the development of hydrogen fuels' alternatives for the transportation, power, and industrial sectors.
5. A roadmap for implementing carbon dioxide removal at scale.

This workshop was a forum to launch a dialogue and set of actions that can help develop new markets to benefit the Ohio River Valley through economic revitalization, creation of high-paying union jobs, regional industrial partnerships, bolstering the innovation ecosystem, and mitigating climate change. The LEP is committed to building upon the success of this workshop and convening multi-stakeholders to continue the momentum that was created on July 12th.

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