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The Roosevelt Project

A Low-Carbon Energy Transition in Southwest Pennsylvania

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A New Deal for Employment, Energy, and Environment

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May 2022

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A New Deal for Employment, Energy and Environment

About the Roosevelt Project

The Roosevelt Project takes an interdisciplinary approach to the transitional challenges associated with progress toward a deeply decarbonized economy. The project aims to chart a path forward through the transition that minimizes worker and community dislocations and enables at-risk communities to sustain employment levels by taking advantage of the economic opportunities present for regional economic development. The first phase of the project involved an analytical assessment of cross-cutting topics related to the transition. The second phase of the project assesses the transition through the lens of four regional Case, working with local partners on the ground in the Industrial Heartland, Southwest Pennsylvania, the Gulf Coast, and New Mexico. The project was initiated by former Secretary of Energy, Ernest J. Moniz, and engages a breadth of MIT and Harvard faculty and researchers across academic domains including Economics, Engineering, Sociology, Urban Studies and Planning, and Political Science.

REPORT SPONSOR

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The Roosevelt Project would like to thank the Emerson Collective for sponsoring this report, and for their continued leadership on issues at the intersection of social justice and environmental stewardship.

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THE ROOSEVELT PROJECT: A LOW-CARBON ENERGY TRANSITION IN SOUTHWEST PENNSYLVANIA

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Contents

Acronyms and Definitions

AEPS	Alternative Energy Portfolio Standards
AIST	Association for Iron and Steel Technology
AM	Additive Manufacturing
AMD	Acid mine drainage
AMLs	Abandoned Mine Lands
ARC	Appalachian Regional Commission
ARIPPA	Appalachian Region Independent Power Producers Association
ARM	Advanced Robotics and Manufacturing Institute at Carnegie Mellon University
AWEA	American Wind Energy Association
CCS	Carbon capture and storage
CCSI	Carbon Capture Simulation Initiative Toolset
CCU	Carbon capture and utilization
CCUS	Carbon capture, utilization, and storage
CDCs	Community Development Corporations
CHP	Combined heat and power
CMU	Carnegie Mellon University
CO2	Carbon Dioxide
DCED	Pennsylvania Department of Community and Economic Development
DCNR	Pennsylvania Department of Conservation and Natural Resources
DEP	Pennsylvania Department of Environmental Protection
DLI	Pennsylvania Department of Labor and Industry
DOE	U.S. Department of Energy
EDWIN	Exploration and Development Well Information Network
EIA	U.S. Energy Information Administration
EOR	Enhanced oil recovery
EPA	Environmental Protection Agency
EVs	Electric vehicles
FIRST	DOE program
FQHC	Federally qualified health centers
GHGs	Greenhouse gases
HVAC	Heating, ventilation, and air conditioning
IDAs	Industrial Development Authorities
IDCs	Industrial Development Corporations
LDAR	Leak detection and repair
LNG	Liquified natural gas
MLF	Marcellus Legacy Fund
MMT	Million Metric Ton
NAICS	North American Industry Classification System
NETL	National Energy Technology Laboratory
NGOs	Nongovernmental organizations
NPV	Net present value
NRDC	Natural Resources Defense Council
O&M	Operating and Maintenance
Pitt	University of Pittsburgh
PJM	Pennsylvania-New Jersey-Maryland Interconnection
PSC	Pittsburgh Supercomputing Center
PSU	Penn State University
PV	Photovoltaic
QCEW	Bureau of Labor Statistics Quarterly Census of Employment and Wages
RECLAIM	Revitalizing the Economy of Coal Communities by Leveraging Local Activities and Investing More Act
RGGI	Regional Greenhouse Gas Initiative
ROW	Right-of-way
RSG	Responsibly resourced gas

SMCRA	Surface Mining Control and Reclamation Act
SMR	Small modular reactor
SRECs	Solar rewnewable energy credits
TEAM	Tri-State Energy and Advanced Manufacturing Consortium
TMI	Three Mile Island
UPMC	University of Pittsburgh Medical Center
USDA	U.S. Department of Agriculture
ZECs	Zero-emission credits

Executive Summary

Southwest Pennsylvania has long fueled the U.S. energy and manufacturing industries. For over a century it has powered the nation with coal and steel, and today it is one of the nation's top natural gas producers, thanks to the development of the Marcellus and Utica shales. Yet, as the nation and the world seek new, more efficient ways to use energy without emitting carbon dioxide (CO_2) and other greenhouse gases (GHGs), Southwest Pennsylvania faces an important transition. How can the region continue its economic development without leaving workers and communities behind?

This case study shows the importance of taking an "all of the above" approach. The Commonwealth of Pennsylvania has enormous fossil fuel resources and related manufacturing and industrial sectors that are expected to grow under business-as-usual policies. Fossil fuel extraction, power generation, and manufacturing provide considerable income and relatively well-paying employment throughout the region, especially in rural areas. It is possible to lower carbon emissions in these industries while meeting growing global demand for energy and manufacturing. The commonwealth also has considerable capacity to contribute to other energy sectors, including wind, solar, and nuclear power, and to capitalize on emerging manufacturing opportunities, such as additive manufacturing and clean steel.

Many of these opportunities will take time to cultivate, as they require substantial investment and infrastructure development. Meanwhile, the region's energy and manufacturing sectors are already under pressure, and some changes in the energy sector will be felt by workers and communities in the near term. For example, several coal mines and steel mills have been idled in recent years. A smooth transition of the energy and manufacturing sectors in this region will require investments and policies that address the needs of communities and workers. Doing so now will set the region on a course for future economic development.

1. In the near term, the Commonwealth of Pennsylvania should undertake a large-scale effort at remediation of methane leakage from wells and pipelines, of water contamination, and of brownfield sites. Plugging and capping the over 400,000 legacy wells in the area will provide immediate employment for workers, reduce greenhouse gas emissions, and improve public health.
2. In the medium and long term, development of carbon capture, utilization, and storage (CCUS) and hydrogen will allow the region to continue the use of existing fossil fuels in ways consistent with the rising demand for low greenhouse gas production. CCUS and hydrogen will require construction of pipelines and storage infrastructure and retrofitting of existing facilities. The Commonwealth of Pennsylvania will need to develop CCUS and hydrogen plans now to take advantage of these opportunities.
3. For the short to longer term, other areas of energy production and manufacturing represent substantial employment and growth opportunities for the region. Energy efficiency and the grid are and will continue to be a large source of employment in the energy sector. Additional training programs are needed to meet the growing demand for these industries. Wind, solar, and nuclear energy have substantial potential and could advance with new momentum from the Bipartisan Infrastructure Law and Inflation Reduction Act . Shifts in state laws, such as loosening restrictions on community solar and the

expansion of carve-outs for renewables in the Alternative Energy Portfolio Standard, will support the attainment of some of this potential. Clean technologies for advanced manufacturing also hold considerable promise for the development of modern manufacturing industries in this region.

4. Under all scenarios for the future, the region will need an effective workforce development strategy. State public agencies should more strategically align their efforts toward economic development and job planning. Innovations in the energy sector will displace workers in traditional energy jobs, and emerging energy industries will require an appropriately trained workforce. Programs that engage local industry with area community colleges and local universities have proven very effective for helping workers adapt to the evolving job markets.

It must also be kept in mind that energy is just one of several key industries in the region today. Southwest Pennsylvania emerged from the decline of the steel industry in the 1990s with a much more diversified economy than it had in the past. In the 1990s, the region's political, civic, and economic leaders identified health care as an opportunity for the future direction of the economy. Health care is now the largest industry in the region. In fact, health care is the largest employer and largest source of income in all but one of the 13 counties in Southwest Pennsylvania. But health care is not alone: the region has substantial finance, higher education, tech, and manufacturing industries as well. The diversification of Southwest Pennsylvania's economy means that changes in the energy sector may not have as profound an effect on the region as they did in the past. The focus of this report is on energy, but the other sectors of the economy will also be important sources of employment for displaced fossil fuel energy workers and the creation of new economic opportunities.

The coming changes in the energy sector will require the Commonwealth of Pennsylvania and local political and economic leaders to identify successful models for adapting economic development and effectively deploying resources to impacted communities. Areas that have the highest dependence on fossil fuel extraction and power generation tend to be rural counties in this region. Economic development can be stimulated through regional infrastructure, especially transportation networks and broadband internet. There is a need to align the commonwealth's policies with public and industry demands. The commonwealth and the Southwestern Pennsylvania Commission should convene public-industry task forces and working groups that meet regularly to examine regional development in line with the needs of communities. It should be noted that the case analysis primarily reflects developments in the region as of mid-2021. As of this writing, developments in the region and at the national level were evolving rapidly.

The coming transition in global energy production presents Southwest Pennsylvania with a unique opportunity to cultivate entirely new industries out of existing resources, such as CCUS, hydrogen, and advanced manufacturing. Doing so will take time and investment. Fortunately, the region has a combination of assets that few other places in the world enjoy. It has the natural resources, the history, the know-how, and the people to help the world create a cleaner energy future.

Acknowledgements

This study is one of four case studies conducted by the Roosevelt Project to explore strategies for future energy development in the United States in the face of increasing demand for cleaner ways of generating power and manufacturing goods. The Roosevelt Project was founded by Ernie Moniz and is directed by Michael Kearney. This study is a joint effort of MIT and Harvard Universities. We are grateful to the presidents of Harvard and MIT, and to the Emerson Collective, for their support.

We benefited enormously from the wisdom and guidance of our advisory board: Brian Anderson, Tom Conway, Melanie Dickersbach, Earl Gohl, Katie McGinty, Michael McQuade, Stefani Pashman, Andrew Place, Sam Reiman, and Audrey Russo. We also wish to thank all of the people interviewed as part of this project for their time and insight. A complete list of people interviewed as part of this project is available in Appendix 1. Max Drickey, Henry Marshall, Carl Melle, Rachel Reolfi, Faith Rugut, and Will Schrepferman provided invaluable assistance in the research conducted.

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Chapter 1: Introduction

Southwest Pennsylvania has anchored energy production in the United States for almost two centuries. Fossil fuel extraction and related industries, such as steel and petrochemicals, are deeply rooted in the region's economy and culture. A global energy transition that will directly affect this region's energy-driven industries is already underway. Over the past two decades, the United States has seen significant growth in natural gas, wind, and solar energy and a massive drop in demand for coal. The United States and other nations increasingly favor energy generation technologies, industrial development, and products that have lower carbon emissions than occur with traditional fossil fuels. Given the changes that are occurring in energy systems, how can Southwest Pennsylvania adapt to, or even take advantage of, these changes without leaving workers and communities behind?

The challenges and opportunities that the region faces will unfold over the course of decades. There are near-term effects of the low-carbon energy transition that require immediate attention and solutions. Most notably, closures of coal mines, idling of steel facilities, and conversion of coal power plants to natural gas have displaced significant numbers of workers. There is an immediate need for new employment opportunities in the affected communities. These displacements, however, may just be the leading edge of deeper changes in the region's energy sector over the next 10 to 20 years. Consequently, the region has the opportunity now to develop strategies to manage the changes that will come over the medium and long term and possibly to create entirely new energy and manufacturing industries. The coming energy transition will be eased further because the Southwest Pennsylvania economy is built around numerous industries, including finance, health care, higher education, tech, and manufacturing.

This report focuses on just one of those core sectors of the economy—energy.

Today, energy is one of six key industries in Southwest Pennsylvania. Energy extraction, power generation, and related manufacturing account for up to 20% of the region's gross domestic product and roughly 10% of employment. Thanks to Southwest Pennsylvania's substantial energy industry, the commonwealth is the second-largest energy producer in the United States and an important source of energy for the nation. Notably, since 2005, the development of Marcellus Shale gas has driven a boom in energy extraction and is attracting related industries, such as petrochemicals.

The Commonwealth of Pennsylvania predicts continued expansion of natural gas extraction and related utilities and manufacturing industries over the next three decades. Southwest Pennsylvania will be central to that development. This assumes continued growth in national and global demand for natural gas. There is a growing likelihood that future demand for coal, natural gas, and oil, at least as we currently use them, will lessen. The region's political and industrial leadership should work together to develop strategies to anticipate this potential and take advantage of new opportunities.

Future demand for fossil fuel–generated energy and products from Southwest Pennsylvania faces four pressures. First, other parts of the United States are rapidly developing new energy sources, especially wind and solar power. These new energy resources will compete with natural gas and coal and will reduce demand for the region's energy resources. Second, public policies in other states (and possibly at the federal level), such as renewable portfolio standards and carbon taxes, will eventually lessen demand for fossil fuels from Southwest Pennsylvania. Third, other countries' carbon policies, such as the European Union's border carbon adjustment, will lower demand for metals, petrochemicals, and other products that are made with energy or materials from this region and that have high carbon emissions. Fourth, other regions of the country, notably Texas, are beginning to deploy technologies, such as CCUS and hydrogen, to reduce the carbon content of fossil fuels. Southwest Pennsylvania risks falling behind in these sectors.

Because the region has a very diversified economy, the impact of a shift away from fossil fuels is predicted to have a mild negative effect on the region's economy as a whole. The Roosevelt Project's REMI model predicts that, if there is a significant drop in demand for fossil fuels, the region can expect a 2% drop in employment, concentrated in the energy extraction, utility, and manufacturing sectors. The effect is expected to occur in 10 to 15 years and will be a lasting shift in the region's output and employment. Importantly, these projections are driven, in part, by a projected increase in fossil fuel energy prices and costs, and they do not incorporate the possibility of the region specializing in CCUS, hydrogen, utility-scale battery storage, or other new energy technologies. Such disruptive technologies could alter the region's trajectory.

The economic and social effects of decreased demand for the region's fossil fuels will be felt unevenly. The economic sectors and employment most closely tied to fossil fuel production tend to be concentrated in rural counties in Southwest Pennsylvania, such as Greene County, Fayette County, and Indiana County. Many of the fossil fuel industry jobs pay well, currently providing people without college educations with solid middle-class incomes. Loss of these jobs will place a burden on these counties in Southwest Pennsylvania and increase the income gap in the area.

We are confident in the ability of this region to navigate the coming energy transitions. The critical questions for Southwest Pennsylvania are: How can energy production and related manufacturing industries put themselves in a position to head off possible contraction in the future? How can the Commonwealth of Pennsylvania and regional planning organizations help workers and communities already being affected adapt to change? How can industry and research organizations take advantage of new economic opportunities that will arise with the energy transition?

The region has a history of navigating industrial transitions. Pittsburgh and the surrounding counties emerged from the decline of the steel industry in the 1990s with a much more diversified economy. Today, health care is the largest industry in terms of employment and gross product in the region, but the area also has substantial finance, higher education, tech, and manufacturing industries. Embracing health care was a conscious decision by local civic, economic, and political leaders who took stock of the region's assets in this industry, especially Pittsburgh's medical centers and universities. In urban and rural counties alike, health care is now the region's largest industry. More importantly, every county has several significant industries, rather than just one big employer or a single-sector economy.

The region has maintained and even strengthened its deep community of civic, economic, and government organizations. Local nongovernmental organizations (NGOs), such as community development corporations, industrial development authorities, universities, and foundations, are already focused on the challenges that the transition from traditional fossil fuel industries presents.

Unlike the transition following the decline of the steel industry, the region is in front of some of the changes that are occurring and are to come in the energy and manufacturing sectors. We are impressed by the large number of organizations that are focused on the region's future and the ability of the region to navigate changes in its economy successfully.

This report presents a case study of the energy transition in Southwest Pennsylvania: what is happening now and how the region can capitalize on key opportunities. It is not an exhaustive study of the region's economy. Rather, it focuses on energy and closely related industries and is organized around five topics: the organizational ecosystem, remediation, fossil fuels, diversification of energy and manufacturing, and workforce development. Each of the chapters of this report can be read as stand-alone analyses, as well as part of the whole.

One specific near-term recommendation recurs throughout this report. We recommend that stakeholders in the region, working through organizations such as the Allegheny Conference on Community Development, the Southwestern Pennsylvania Commission, or the Appalachian Regional Commission, establish a set of task forces, each focusing on a particular theme, such as technology pathways, remediation, or workforce development. These task forces should develop a region-wide plan for the particular topic under examination. The task forces should include a wide range of stakeholders, and they should conduct public meetings to listen to people in the region about how to address coming changes in the energy, industrial, and manufacturing sectors.

We see four organizational and political needs. First, there is a need for building organizational capacity in smaller communities. Many small towns lack the permanent governmental and civic organizations that continually invest in revitalizing downtowns and other essential economic development activities. Second, there is a need for streamlining planning processes. Third, there is a need for more region-wide planning and for coordination among the regional commissions, such as county planning commissions, the Appalachian Regional Commission, and the Southwestern Pennsylvania Commission. Finally, there is the need for political leadership to champion economic development programs in regions that will be hardest hit by a transition away from fossil fuel extraction and manufacturing.

In the near term (over the next 5 to 10 years), there is the need for investments that can stimulate commercial activity and provide well-paying jobs for those already experiencing dislocations due to decreasing demand for coal. Remediation of well leakage and soil and water contamination in Southwest Pennsylvania can provide a substantial and immediate economic stimulus in precisely the areas that have been hardest hit. Well capping and other forms of remediation, such as leak detection and repair, will also greatly reduce greenhouse gas emissions and other forms of pollution in the area.

The region's long history of fossil fuel production through coal mining and conventional well drilling has, in many places, left a deeply problematic environmental landscape. There are at least 400,000 wells in the region that require capping and maintenance to prevent leakage of methane and other pollutants. There are substantial employment, environmental, and public health benefits to remediation at natural gas and coal sites. There are also substantial challenges. Large numbers of these wells—perhaps most—were operated by firms that no longer exist and long preceded the current unconventional gas extraction brought about with hydraulic fracturing.

Ample reasonable opportunities exist to change and enhance the incentives for active fossil fuel operations to help correct past harms and prevent future ones. These include modifications to bonding requirements on wells and third-party leakage minimization certification programs for active extraction and transport operations. The commonwealth should expand databases of problematic sites and operations and create a "low-emission natural gas" certification for Pennsylvania natural gas. Natural gas with this certification can be sold at a small premium, with revenue going back into remediation work.

Research investments by area universities and industries in technologies for detecting and quantifying specific harms, like methane leakage, will help create new tools to direct remediation investments.

Brownfield sites, such as former coal-powered power plants, are opportunities for future development. However, potential investors face substantial uncertainties. Investing in site-specific promotional "playbooks"—and actively distributing them—can help reduce these uncertainties and unlock opportunities.

In the medium to long term, carbon capture, utilization, and storage (CCUS) can provide a way to continue the region's fossil fuel industries in line with rising demand for low-carbon energy. There are significant opportunities for substantial economic growth in fossil fuel energy and related manufacturing with the deployment of technologies to capture carbon from power generation or manufacturing processes and to store the waste carbon or use it in other applications. Ramping up a CCUS system in the region at scale may take 10 to 15 years because of the time horizons needed for planning, siting, permitting and building infrastructure. There is also a need for technological improvements to further reduce the costs of carbon capture and utilization. Hence, if the region is to become a hub for CCUS, it is important to take the first steps now.

The region is ideally suited for the creation of an innovation hub to meet global demand for new technologies for carbon management. Southwest Pennsylvania has the natural resources, existing industry, trained workforce, and research and development capacity—with the National Energy Technology Laboratory, Carnegie Mellon University, the University of Pittsburgh, and Penn State University—to develop, demonstrate, and deploy CCUS. An innovation hub in Southwest Pennsylvania focused on carbon management would help maintain U.S. leadership in the emerging industry and would stimulate growth locally.

Development of CCUS in the region may eventually support other industrial development. CCUS can be instrumental in reducing carbon emissions in the production of cement, steel and other metals, and petrochemicals. CCUS can also be used to produce hydrogen using natural gas (blue hydrogen) and support the development of hydrogen to transform transportation, industrials, and petrochemicals—perhaps the most economically viable options in the near term.

If the commonwealth chooses to develop CCUS to extend its fossil fuel industries, now is the time to plan for its deployment and to invest in core infrastructure. The commonwealth lacks a comprehensive plan for carbon capture and sequestration and has not laid the foundation for development of hydrogen. Texas has jumped into the lead in developing CCUS and hydrogen infrastructure, with the construction of CO_2 and hydrogen pipelines and storage facilities. ExxonMobil has announced the investment of $100 billion in the Gulf Coast for the development of carbon capture and sequestration. Development of the requisite infrastructure will take time, but to be competitive or even lead in this industry will require investment in the near term.

Deployment of CCUS at scale in this region will require the construction of a backbone or trunk CO_2 pipeline as well as branch pipelines that connect energy and industrial facilities to storage sites. It will also require construction and maintenance of underground CO_2 storage facilities. We estimate that the core infrastructure will cost in the neighborhood of $10 billion. If the region is to capitalize on this opportunity, industry and government will need to plan and invest in such infrastructure development in the near term.

Energy efficiency and grid development hold substantial promise for economic development and expanding employment. The development of wind and solar energy within the state is not expected to reach the same level as existing fossil fuel power generation or to replace existing fossil fuel jobs, but under the right circumstances, wind and solar energy sources have the potential to make significant contributions to Pennsylvania's energy mix.

Energy efficiency (especially heating, ventilation, and air conditioning) and grid jobs already account for the largest number of energy jobs and most of the growth in energy employment in Pennsylvania. Some of these jobs, especially construction of grid infrastructure, require skills similar to those needed in energy extraction and manufacturing. Energy efficiency and grid jobs are expected to grow considerably over the coming decades. Appropriate training programs are needed to meet growing labor demand for these sectors.

Forecasts by the Pennsylvania Department of Environmental Protection (DEP) predict no substantial production of energy from wind and solar power in the state over the next 30 years, under business-as-usual assumptions. However, some projections do foresee substantial development of these resources. The region has potential for wind development along the Appalachian ridges, and open farmland may be used for solar development. Our sense is that there is considerable room for growth of wind, solar, biogas, geothermal, hydropower, and other energy sources, but development of these sources has so far not received the same attention that development of fossil fuels has.

Development of solar and wind power on a large scale in Pennsylvania requires regulatory and policy changes, such as enabling legislation for community solar, and may depend on breakthroughs in utility-scale storage, including large battery storage. In the immediate future, the solar and wind workforce and industries could position themselves to support market growth in the region.

The Pittsburgh area is experiencing a surge in the development of new industries, especially in tech around robotics and artificial intelligence and in biomedical science around the university medical centers. These emerging industries will absorb some of the dislocation due to a transition away from energy, and their emergence will further diversify and strengthen the region's economy.

Carnegie Mellon University (CMU) and the University of Pittsburgh have been important engines for generating innovation in the Pittsburgh area. Innovations in robotics at CMU, for example, have led to the development of the university's National Robotics Engineering Center and the Advanced Robotics for

Manufacturing Institute. These, in turn, have created employment and new companies in the region. The area has excellent existing infrastructure for new manufacturing and innovation centers. Hazelwood Green in Pittsburgh is one such example.

An important challenge is to leverage the region's assets to attract more investment capital for manufacturing ventures in Southwest Pennsylvania. There is ample venture capital for ideas in the region, but there is less venture capital for development of new manufacturing, especially firms related to the region's innovation and technology centers.

Strategic decisions by political leaders locally and across the state can accelerate these new industries. Expanding the Industrial Development Authorities, which provide tax incentives for new industrial development, is one possible strategy. At the very least, there is the need for more aggressive political leadership regionally to attract investment in new manufacturing.

A central challenge for the region over the coming decades is to create good-paying jobs for people whose livelihoods currently depend on fossil fuel industries. The effects of decreasing demand for coal and, eventually, for natural gas will be felt most acutely in rural areas where fossil fuel extraction and utilities are among the most important industries, especially for workers who do not have college degrees.

Loss of fossil fuel jobs will likely exacerbate wage gaps. The typical fossil fuel–related job in this region pays approximately the median income in the area and requires a high school education. Currently, a typical job in any sector of the region's economy that requires a high school degree or less pays substantially less than a fossil fuel job. The loss of such jobs will likely add to inequities in wages and income.

Institutions—such as local community colleges, county governments, and planning commissions, like the ARC—are bracing for this transition. The most common strategy involves training programs to narrow the wage gap and ease the transition of coal field workers to other sectors. Such programs are difficult to operate successfully, because typically, they do not track workers into a specific job or industry that will definitely provide long-term employment at the end of the program. That said, we have encountered several promising successful models in the region. The most successful models are those that work with industry and offer people skill training that goes beyond just one specific job.

We recommend that industry, educational institutions, governments, and NGOs develop a regional strategy to improve workforce training. The Southwestern Pennsylvania Commission should convene a joint task force to improve physical infrastructure and broadband access to assist these training efforts.

Pittsburgh and Southwest Pennsylvania emerged from the decline of steel with a diversified economy and a resilient civil society. These are the core strengths of the region as it will face future transitions in its energy and manufacturing sectors. Some areas of the region, especially traditional coal-producing communities, are already experiencing dislocations. Immediate action is needed to help these communities. Now is also the time to develop strategies to adapt to changes in the energy industry that will come in the next decade. It can take years to implement a successful economic development strategy or to build the infrastructure needed to sustain emerging industries. Fortunately, Southwest Pennsylvania has the opportunity now to participate actively in the energy transition.

Chapter 2: Challenges and Opportunities for a Diversified Southwest Pennsylvania Society

Elizabeth Thom

Introduction

Southwest Pennsylvania is no stranger to major economic transitions. The region has engaged in coordinated planning efforts to tackle industrial, environmental, and infrastructure challenges for over 75 years. During the 1940s, concerns over air pollution and the need for economic diversification drove development plans; in the 1970s and '80s, declining demand for steel and coal resulted in strategies to invest in new industries and revitalized communities. Today, climate change and the forthcoming energy transition pose a new set of challenges to economic growth and prosperity in the region.

However, the current moment also presents Southwest Pennsylvania with an opportunity to capitalize on previous regional development successes. The area is well positioned to leverage its natural resources, dedicated workforce, world-class colleges and universities, and diverse institutional landscape to become a leader in the transition to a low-carbon future. As the Allegheny Conference on Community Development put it, "Reinvention is our pedigree."[1]

Indeed, the planning organizations and blueprints that steered Southwest Pennsylvania through previous transitions can be credited for the region's economic diversification relative to other former industrial or "rust belt" areas. This is especially true for the city of Pittsburgh, whose transformation from an industrial manufacturing center to a health care and technology hub has been well documented.[2] Insights from these previous periods of change and adaptation provide important lessons for the upcoming energy transition.

To start, successful outcomes are possible when stakeholders align and engage in regional planning with shared goals. During the steel industry collapse, political leaders, county commissioners, universities, and economic development groups, such as the Allegheny Conference, came together to assess the region's assets and craft a forward-looking plan. Among the region's primary resources were its many colleges and universities, including the University of Pittsburgh (Pitt) and Carnegie Mellon University (CMU). They formed a core part of the region's redevelopment plan, known as Strategy 21. The plan focused on investments in infrastructure and real estate and a joint partnership between CMU and Pitt to establish technology centers.[3] Billions in private investments and $400 million from the state facilitated the reimagination of the city as an engine for technology-driven innovation.[4]

Stakeholders also identified health care as another industry to invest in, given the area's network of universities, hospitals, and research centers. Today, the lifeblood of post-steel Pittsburgh consists of university-affiliated technology centers and medical services. Health care predominates outside of Pittsburgh and Allegheny County, too. Among the 13 counties in our study, the health care industry is the largest job creator in all but Greene County, employing about one in five workers.[5]

The success of tech and health care in Southwest Pennsylvania is a direct result of the region's coordinated planning efforts and shared strategic vision. Similar processes ought to be put in motion now in order for the region to get out in front of the energy transition and take advantage of its diversified assets. This time around, however, regional planning will have to contend with two new issues.

The first is that it will be critically important for regional planning to incorporate stakeholders from both within Pittsburgh *and* its surrounding counties. The economic benefits of Pittsburgh's transformation were not evenly distributed throughout the Southwest region. Absent from the regional planning model were clear strategies for assisting displaced workers from rural counties with roots in the coal and steel industries. Blue collar workers were largely left out of the city's reimagined medical and tech future, exacerbating the effects of steel-related income and revenue losses.

Southwest Pennsylvania's more rural counties will again face the immediate consequences of the next transition, perhaps even more so this time given the region's recent natural gas boom. While technology firms took hold in Pittsburgh, natural gas boosted rural economies. The industry offered opportunities for workers without college degrees and put money in the pockets of landowners to build wells on their properties. Local businesses benefited from increased traffic to the region, and gas companies invested heavily in local communities, sponsoring agricultural fairs and infrastructure projects. Both the state and local governments have profited from gas-related taxes and impact fees. In order to ensure inclusive prosperity during the energy transition, an even more diverse set of Southwest Pennsylvania stakeholders must come together to coordinate a new vision that takes into account the needs of all residents in the area.

Second, the region will have to contend with an institutional ecosystem that looks a lot different than previous transitions. Historically, the Southwest Pennsylvania region has tended to rely on one big industry or employer for jobs and revenue. Energy and energy-adjacent industries have often filled this role. However, thanks to the success of the region's transition away from steel, the institutional environment today is much more diffuse. Put simply, there are many more players with stakes in the region's continued economic development. Previous transition formulas will be mostly obsolete given this new institutional environment, which presents both challenges and opportunities for coordinated regional planning.

This chapter surveys the current institutional ecosystem in Southwest Pennsylvania, examining the interconnectedness of various groups and industries, while revealing gaps to be filled in regional planning processes. Then, it discusses how the ecosystem is currently addressing regional development issues by highlighting a few illuminating examples. With these insights in mind, the chapter considers how the ecosystem could be leveraged to address five main proposals in our report: CCUS pipeline development, environmental remediation, sustainable diversification, and workforce retraining. We conclude with some additional recommendations for how the region can build upon its proven track record of innovation and reinvention.

Today's Institutional Ecosystem in Southwest Pennsylvania

Southwest Pennsylvania consists of a dense network of regional assets that sets it apart from neighboring states and other parts of Central Appalachia. Many of these are legacy institutions that have formed a critical part of the region's social fabric for decades, while others are new organizations that have been born out of dedicated investment in the area. To summarize, these assets fall into four broad categories: (1) diversified economic activity, (2) planning and development capacity at various levels, (3) financial resources, and (4) good hardware. We discuss each in turn, examining how they might be able to coordinate effectively to address the energy transition.

Asset 1. Diversified Economic Activity

For much of the twentieth century, the Southwest Pennsylvania economy relied on a handful of industries. Today it is home to an increasingly diverse set of companies, entrepreneurs, nonprofit organizations, manufacturing facilities, and educational institutions. Major industries include healthcare, tech, finance, insurance, robotics, artificial intelligence, autonomous vehicles, arts and entertainment, energy, utilities, universities and research institutions, advanced manufacturing, philanthropies, tourism, and a growing small business ecosystem. We highlight a few of these in order to call attention to ways they could be utilized to offset the anticipated effects of the energy transition.

1. Educational Institutions for Research and Training

A key feature of Southwest Pennsylvania's institutional ecosystem is its dense network of public and private colleges and universities. There are 14 community colleges in the Commonwealth of Pennsylvania and 5 of them are located in the southwest region. The Community College of Allegheny County is the largest among them, with a total of 40,000 students enrolling annually across all programs.[6] There are also community colleges in Beaver, Butler, and Westmoreland Counties, and the Pennsylvania Highlands Community College has satellite campuses throughout the southwest. Private and for-profit technical schools in the area offer additional opportunities for associates degrees and training.

Several of Pennsylvania's public universities also have a strong presence here. Penn State University (PSU), the commonwealth's land grant university, has five satellite campuses in the region, including one in New Kensington that we highlight later on in this chapter. The University of Pittsburgh is a major part of the city's institutional ecosystem, with a 132-acre campus and roughly 33,000 students.[7] It is the top employer in Allegheny County, thanks to its affiliated hospitals and research centers. Historically, the university has played a key role in guiding the region through economic changes, and we expect it will continue to do so. In addition to Pitt and PSU, California University of Pennsylvania, Indiana University of Pennsylvania, and Slippery Rock University enroll thousands of students in the counties surrounding Allegheny.

Dozens of private colleges and universities are based in the region as well. Carnegie Mellon University is well known globally for its programs in science and technology, especially robotics and artificial intelligence. It consistently ranks as one of the top schools in the country for computer science and engineering, and its focus on innovation has helped it attract companies such as Google, Uber, GE, and Intel to Pittsburgh.[8] CMU students themselves have also created their own companies, contributing to the region's growing start-up culture. The university has been a major driver of the city's transformation into a technology hub, and it will certainly be a leader in the region's response to the technological and social challenges of the energy transition.

Other prominent private institutions in the area include Robert Morris University, Chatham University, Duquesne University, Waynesburg University, and Washington and Jefferson University, to name a few. All serve critical roles in their respective communities, attracting tens of thousands of talented students to the region and educating 21st-century workforces.

2. Health Care Networks

A pillar of Southwest Pennsylvania's diversified economy is its health care infrastructure. As we have already noted, health care is the leading industry in nearly all of the counties in the southwest region. Hospitals, doctors' offices, and outpatient facilities serve important functions in these communities, providing opportunities for employment, as well as offering much-needed medical care to an aging population. The largest provider in the region is the University of Pittsburgh Medical Center (UPMC), a $23 billion institution that operates 40 academic, community, and specialty hospitals in the area.[9] It is the largest nongovernmental employer in the Commonwealth of Pennsylvania, with more than 90,000 employees. UPMC contributes hundreds of millions in state and local taxes and gives about $1 billion each year to the Southwest Pennsylvania community through investments in charity, health programs, and medical research.[10]

Smaller regional facilities form another important piece of the health care network. Many of them are located in more rural communities that otherwise would face barriers to accessing care. The southwest region is also home to dozens of community-based federally qualified health centers (FQHC), which provide primary and preventative care to individuals regardless of their ability to pay. There are 27 such centers in Pittsburgh alone.[11] Their deep community ties make them invaluable assets for both the economic and physical well-being of Southwest Pennsylvanians.

3. Technology and Innovation

Thanks in part to the region's rich ecosystem of research universities, Southwest Pennsylvania is a national and global leader in technology and innovation across a range of fields. Carnegie Mellon University leads the way in artificial intelligence, machine learning, and robotics, with the number one AI program in the nation. Advancements by CMU faculty and students in supercomputing, AI, autonomous vehicles, cybersecurity, biotech, and medical devices have attracted $141 million in computer and information science R&D funds.[12] In 2017, CMU received $250 million to launch the Advanced Robotics and Manufacturing Institute (ARM). The institute is part of the Department of Defense's efforts to invest in advanced manufacturing and collaborative robotics research.[13] Today, the facility is headquartered in Mill 19 of Pittsburgh's Hazelwood Green site, a former abandoned steel mill that is being redeveloped as a hub for the area's next chapter in manufacturing.[14] We discuss Hazelwood Green in more detail later on in this chapter.

CMU has also teamed up with Pitt on several joint technology research ventures, most prominently the Pittsburgh Supercomputing Center (PSC). The center receives federal, state, and private funds to support high-performance computing, communications, and data analytics for scientists and engineers.[15] With the help of a $5 million grant from the National Science Foundation, PSC recently launched Neocortex, a supercomputer designed to "revolutionize scientific AI research" in fields such as medical imaging, genomics, climate research, and computational fluid dynamics.[16]

Attracted by these growing research centers and a large pool of talented graduates, private tech companies and start-ups have also found a home in Southwest Pennsylvania. Google, Amazon, and Facebook are capitalizing on the region's AI technology, while Uber is taking advantage of advancements in sensors for autonomous vehicles. A stream of homegrown start-ups have also been very successful. Duolingo, the language-learning platform, is Pittsburgh's first “unicorn” start-up, reaching a valuation of $1.5 billion in 2019.[17] Pitt graduate Bryan Salesky founded the self-driving technology company Argo AI, which has partnered with Volkswagen and Ford to use its lidar sensors to get commercial autonomous vehicles on the road in the coming years.[18] Together, these companies form a new section of Pittsburgh’s business district, affectionately dubbed “Robotics Row.”

The region is also home to the National Energy Technology Laboratory (NETL), which is part of the U.S. Department of Energy’s national laboratory system. With offices in Pittsburgh and Morgantown, West Virginia, the government-owned and -operated lab specializes in energy and environmental research, especially in the areas of coal, natural gas, and oil technologies.[19] Established partnerships between the lab and other research institutions in the Southwest Pennsylvania ecosystem make the region an ideal center for developing new technologies for carbon management in the energy transition.

4. Finance and Venture Capital

Access to capital for these innovative and entrepreneurial activities comes from a diverse set of financial institutions and venture capitalists with deep roots in the region. PNC Bank was founded in Pittsburgh in the 1850s, and its corporate headquarters has been located at the same city intersection for more than 160 years.[20] The former Mellon Financial Corporation, now Bank of New York Mellon, maintains an important presence in the region’s financial sector, too.

Other sources of investment include groups such as Innovation Works and the Pittsburgh Technology Council. Both focus on helping tech entrepreneurs gain access to capital and resources for business growth. Innovation Works is the largest seed-stage investor in Southwest Pennsylvania, contributing $113 million to more than 700 companies. Meanwhile, the Pittsburgh Technology Council focuses on growing technology clusters in the area by connecting companies with the region’s workforce and advocating for public policies that foster business development.

With so much entrepreneurial activity taking place in the region, it comes as no surprise that venture capital is now a major component of the institutional ecosystem. The Pittsburgh Venture Capital Association is the primary membership organization for over 200 firms and investors in western Pennsylvania.[21] The group sponsors investor events such as the 3 Rivers Venture Fair and helps coordinate funds toward promising deals. With a mix of both large corporations and small entrepreneurs, there is a steady flow of capital investment in Southwest Pennsylvania.

5. Foundations and Nonprofits

The economic activity of the region is anchored by a dense network of foundations and nonprofits with deep histories and commitments to Southwest Pennsylvania. In the greater Pittsburgh metro area, there are an astounding 3,955 foundations and grantmaking organizations, totaling $20 billion in assets.[22] The most prominent among them are private foundations such as Heinz Endowments, the Richard King Mellon Foundation, the Claude Worthington Benedum Foundation, PNC Foundation, the Pittsburgh Foundation, and the Hillman Family Foundations, to name a few.[23] Each has its own mission and favored causes, spanning public health, education, workforce readiness, economic development, environmental conservation, the arts and more.

The RK Mellon Foundation is the largest in the region and among the biggest in the world, with an endowment of $3.1 billion.[24] In January 2021, the foundation revealed its new strategic plan, including a commitment to invest $1.2 billion in the area by 2030. Signaling its commitment to this mission, in May 2021, the foundation approved $150 million—the largest grant in its history—for CMU to build a revolutionary science facility on its Oakland campus and two new centers in Hazelwood Green, one a robotics innovation center and the other focused on advanced materials and manufacturing.[25] And in April 2021, Heinz Endowments committed a historic $30 million to CMU in order to create the Center for Shared Prosperity, which will focus on establishing community-university partnerships to address socioeconomic inequality in the area.[26] Both examples illustrate how various institutions in Southwest Pennsylvania's ecosystem can come together to tackle important issues in the community.

There are thousands of smaller nonprofits in the region that provide critical resources to the community, too, including unions, community health organizations, educational groups, religious institutions, community development organizations, and recreational clubs. Together with the foundations, they are essential components of Southwest Pennsylvania's social fabric and a key feature of the region's ecosystem that sets it apart from other areas in Central Appalachia.

6. Manufacturing

Southwest Pennsylvania has a rich history of using its natural resources to manufacture the materials that have built and powered cities around the world. This is how Pittsburgh earned its reputation as an industrial capital and its nickname, "Steel City." Manufacturing remains a dominant industry, ranking among the top employers in 11 of the 13 counties in our study. There are over 2,800 manufacturing establishments in the area, producing materials ranging from heavy metals, lighting, and bottling to computer systems, cryogenic pumps, and hydrocarbons.[27]

The region's manufacturing history and infrastructure, along with its many universities and research centers, position it well to take advantage of continued innovation in advanced manufacturing capabilities. CMU's National Robotics Engineering Center and its Advanced Robotics for Manufacturing Center in Hazelwood Green focus closely on how to incorporate robotics systems into manufacturing. Meanwhile, Pitt's Ansys Additive Manufacturing Lab focuses on additive manufacturing processes of metal, polymer, and composite materials.[28] The concentration of these innovative manufacturing techniques and approaches has, in turn, attracted to the region new investment and companies that are eager to take advantage of these assets. There is perhaps no better example of the kind of advanced manufacturing clusters that could grow in Southwest Pennsylvania, given its existing infrastructure, than Neighborhood 91 at the Pittsburgh International Airport campus. We discuss how the ecosystem mobilized for that project in the next section of the chapter.

7. Energy and Utilities

Lastly, a key part of the region's diversified economic activity is the utilization of its natural resources: today, most prominently, the Marcellus Shale. While a handful of coal mines remain open in the southwest corner of the state, natural gas has taken over as the primary driver of the region's energy economy. This is especially true in the more rural counties surrounding Pittsburgh, where the region's gas supply powers much of the East Coast. Virtually all major fossil energy companies are present in the region, although most are headquartered elsewhere. Shell is currently building a major, multi-billion-dollar new ethane cracker plant in Beaver County on property that was once a steel mill.[29] The company plans to take advantage of its proximity to the shale resource in order to streamline plastics-manufacturing processes.

There are solar and wind companies in the region, although they operate on a much smaller scale than the fossil energy firms and are less visible in the regional ecosystem. Nevertheless, the region's diverse natural resources, landscape, and inland location are all important assets to take into account when trying to find ways to get out in front of the next energy transition.

Asset 2: Planning and Development Capacity

In addition to a diversified economy, Southwest Pennsylvania's institutional ecosystem also features a dense network of regional, state, and local planning and economic development organizations. They range from major federal agencies, such as the Appalachian Regional Commission, to local-level community development corporations and industrial development authorities. In the greater Pittsburgh area, there are 144 local community development corporations with combined assets of $81 million.[30]

Throughout the region as a whole, these sorts of planning organizations are responsible for devising economic development strategies, finding ways to finance new projects, and attracting regular investments. We view them as vital assets for the forthcoming energy transition because of their ability to identify local needs, engage with their communities, and find innovative solutions to pressing challenges. In the table below, we highlight several of these organizations at the regional, state, and local levels. This is not an exhaustive list but rather a way to illustrate the kinds of planning activities already happening in the region.[31]

Table 1: Planning and economic development groups.

Multistate or Federal	Pennsylvania	Regional	Local
Appalachian Regional Commission	Southwestern Pennsylvania Commission	Allegheny Conference on Community Development	Industrial Development Authorities (IDAs) and Industrial Development Corporations (IDCs)
Great Plains Institute	Southern Alleghenies Planning and Development Commission	County-level economic development commissions	Community Development Corporations (CDCs)
Midwest Regional Carbon Initiative	Dept of Community and Economic Development (DCED)	Foundations	Mon Valley Alliance
Marcellus Shale Coalition	Keystone Innovation Zones (DCED)	Sustainable Pittsburgh	Fay-Penn Economic Development Council
U.S. Economic Development Administration	Pennsylvania Industrial Development Authority		Pittsburgh Economic & Industrial Development Corporation
Reimagine Appalachia	Regional Industrial Development Corporation		Economic Growth Connection of Westmoreland
Great Lakes Metro Chambers Coalition	Team Pennsylvania		Pittsburgh Technology Council
The Progress Fund	Keystone Economic Development and Workforce Command Center		
TriState Energy and Advanced Manufacturing (TEAM) Consortium	Pennsylvania Economic Development Association		
BlueGreen Alliance			

Asset 3: Financial Resources

There is a wealth of financial capital across the many economic activities and planning groups in the Southwest Pennsylvania ecosystem. Potential access to investments from well-endowed universities, research centers, foundations, nonprofits, venture capitalists, and economic development groups sets the region apart from other former industrial centers. As strategies and plans for the energy transition come together, these financial assets will be critical for funding new industries and investing in workforce development.

Asset 4: Good Hardware

Lastly, thanks to its industrial roots, Southwest Pennsylvania has a well-organized infrastructure system to support a diverse set of economic activities. Four interstate highways intersect the region, along with over 1,000 miles of freight railway.[32] An extensive inland port and international airport connect the region to the rest of the country and world. The Southwestern Pennsylvania Commission also recently launched a new regional transit plan called SmartMoves that takes into account the technological, environmental, and economic changes already taking place in the region. The plan is designed as a chance to connect communities in the southwest corner of the state by increasing physical mobility via public transit and virtual connectivity through expanded broadband access. It outlines investments in highways, roads, and trails that will form a more integrated transportation system.[33] Following through with this plan will present new possibilities for regional development.

Connections and Gaps in the Regional Ecosystem

Overall, Southwest Pennsylvania's diversified ecosystem is a valuable asset and offers many opportunities for planning around the energy transition. First, the involvement of multiple stakeholders suggests there will likely be several pathways for workers and industries to move beyond traditional fossil fuel approaches. The diverse industry landscape in the region can help attract future investments and provide the foundation for building out existing capabilities. In addition, current stakeholders are committed to the region's success and share a deep commitment to the area, providing a basis upon which to overcome differences and build out relationships. Having numerous players also means there will be possibilities for new collaborations to emerge, as was the case with CMU and Pitt in the 1980s. Today, these partnerships represent some of the strongest connections between institutions in the ecosystem.

Nevertheless, there are some challenges that come with a more diverse and diffuse institutional landscape. To start, it will be difficult to ensure that everyone who wants to be at the table has an invitation. Previous transition processes were very Pittsburgh-centric and did not effectively incorporate voices from the surrounding rural counties. Leaders involved in the planning process will have to engage in outreach efforts and build partnerships with a diverse set of stakeholders.

This will be especially important given that the rural counties in Southwest Pennsylvania are the ones closest to the energy and manufacturing industries that will be hardest hit by a transition away from fossil fuels. On top of that, the economies of these rural counties are generally not as diversified as the Pittsburgh metro area's and are further removed from rising tech and venture capital investments. Of particular note when it comes to industry support is the fact that while there is plenty of venture capital for ideas in the region, there is less for the development of new manufacturing, which would benefit blue collar workers. Attracting more diverse investments to the area—and especially to rural counties most impacted by a transition away from fossil fuels—should be a high priority for regional planning.

The commonwealth already appears to be working toward this end. In 2020, the Department of Community and Economic Development launched a venture capital program to "invest primarily in lower middle-market manufacturing and business service companies" in communities that do not traditionally attract those kinds of investments.[34] This represents an important step toward filling the gap in capital flows across communities and accelerating new industry development.

Tackling the distribution of capital flows would also help address the broader challenge of how to diversify rural economic development. The Appalachian Regional Commission often invests in small businesses, nonprofits, and workforce training in rural communities in the region, along with foundations such as Benedum. However, it remains difficult to attract continuous investments for new ventures and redevelopment in smaller communities. One of the limitations is scale—it is challenging to develop projects on a small scale without appropriate resources. Regional planning organizations at the local level are often committed to solving this issue; however, they also face their own capacity limitations.

While Southwest Pennsylvania has a rich network of planning organizations at various governmental levels, it is not obvious to what extent they coordinate among themselves to achieve region-wide goals. For example, how engaged are the regional planning commissions, such as county planning commissions, the Southwestern Pennsylvania Commission, and the Appalachian Regional Commission with one another in planning for the energy transition? There appears to be a degree of fragmentation across these groups. When it comes to crafting a new blueprint for the region's future in a low-carbon energy environment, it will be beneficial to increase coordination among various economic development organizations, align on a shared vision, and streamline planning processes. This would also help, in part, with the need to build organizational capacity in smaller towns and engage more with rural communities in the energy transition.

Lastly, it is notable how disconnected renewable energy firms are from other major players in the institutional ecosystem, especially compared with fossil energy and utility companies. This may be due partly to the fact that many of the wind and solar companies are based outside of the United States. However, if they are to play a key role in the energy transition in Southwest Pennsylvania, they will need to get more involved in the economic, political, and community fabric of the region.

In sum, the region overall is rich in the kinds of resources and infrastructure needed to weather and thrive in yet another major economic transition. However, it will have to contend with ensuring a more even distribution of resources and development across Pittsburgh and rural communities and more effective coordination across planning organizations.

Insights from Three Innovative Regional Developments

We turn next to a brief discussion of three projects that demonstrate how the regional ecosystem can be activated to incentivize new developments.

1. Penn State New Kensington

Situated to the northeast of Pittsburgh in Westmoreland County is the city of New Kensington, a prototypical rust belt town that was the birthplace of the Alcoa Corporation. The city is like many others that surround Pittsburgh and Allegheny County—it has experienced population loss and shrinking investments in local infrastructure and economic activity. However, it happens to be home to one of Penn State University's 21 branch campuses, and Penn State New Kensington's chancellor, Dr. Kevin Snider, saw this as an opportunity to transition the city from the rust belt to the digital belt. He believed fostering innovation could be a way to help prepare students for a 21st-century workforce while also revitalizing the city's downtown.

In order to do so, Snider spent several years building relationships with a diverse set of actors in the local community, including political leaders, chambers of commerce, community groups, foundations, corporations, school districts, and other local colleges. He listened to their needs and interests, while sharing with them his vision to build a coworking space and "corridor of innovation" to foster entrepreneurship in New Kensington. The goal was to establish "a living, learning laboratory for developing innovative solutions to the challenges faced by small rust belt towns."[35] The plan attracted investments to renovate parts of the city's downtown to build the coworking space and revitalized corridor. Today, the coworking space, called the Corner, is a multifunctional work space, and construction is underway for the "Digital Foundry," a state-of-the-art innovation and manufacturing lab. The recent redevelopments have attracted new companies and small businesses to the area. The Penn State New Kensington experience highlights how educational institutions, business groups, foundations, and community leaders can come together to diversify and revitalize economic development outside of major cities.

2. Hazelwood Green

The redevelopment of Pittsburgh's Hazelwood section along the Monongahela River is an excellent example of the way former industrial brownfield sites can be remediated and repurposed for public parks, renewable energy sites, and advanced manufacturing facilities. The Hazelwood site was once home to the Jones & Laughlin Steel Company and became a major industrial hub during World War II.[36] The plants closed in the late 1990s as a result of the steel industry collapse. In 1999, a nonprofit organization called Riverlife created a redevelopment plan for Pittsburgh's waterfronts. Named "Three Rivers Park," the plan envisioned a 15-mile stretch of industrial redevelopment and green space.[37] Since the plan's launch in 2000, there has been $4.2 billion in investment in the downtown riverfront area.

Hazelwood Green constitutes a fraction of these investments. A group of foundations got together to purchase the property with a commitment to using the site for sustainable community development. After environmental remediation and several rounds of neighborhood plans, the site began attracting investments from CMU and Uber, who used part of the land as a test track for self-driving cars. Today, the 178-acre site is divided into three districts, each with its own development purpose. In the Mill District, continued funding from RK Mellon has encouraged additional investments to build CMU's Advanced Robotics for Manufacturing Institute and Manufacturing Futures Initiative, which are housed in the former steel company's historic Mill 19 building. The River District features residential and business developments, while a good portion of the Flats District is dedicated to open public space. Together, these riverfront developments demonstrate how a community vision can come to life with sustained investments and stakeholder buy-in.

3. Neighborhood 91

The third example is Pittsburgh International Airport's Innovation Campus, called Neighborhood 91. The 200-acre campus, which is situated adjacent to the airport's airfields, is home to a growing additive manufacturing hub. At the hub's core is a group of 3D printing supply chain businesses that aim to take advantage of proximity to the airport (for seamless transport), research and grads from Pitt, easy access to AM components, on-site production of new and recycled argon, and a microgrid powered by local natural gas resources.[38] The development provides an excellent blueprint for how the region can leverage its natural resources, manufacturing legacy, skilled workforce, affordable land for development, and connections to research universities to foster innovative approaches to manufacturing and economic development.

How the Ecosystem Could Engage Our Proposed Developments

With these insights in mind, we now turn to how the Southwest Pennsylvania ecosystem may coordinate to advance the proposed energy-related developments we put forward in this report.

Development of CCUS Pipeline Infrastructure

Southwest Pennsylvania is ideally suited for the creation of a carbon capture innovation hub. The region has the natural resources, existing industry, workforce, and research capacity—with CMU, NETL, Pitt, and PSU—to develop and deploy carbon capture, storage, and utilization technologies. An innovation hub in Southwest Pennsylvania focused on carbon management would help maintain U.S. leadership in the emerging CCUS industry and would stimulate growth locally. If Pennsylvania chooses to develop CCUS, now is the time to devise a systematic plan to invest in the core infrastructure it requires. Deployment of CCUS will necessitate the construction of major pipelines to connect energy and industrial facilities with storage sites. It will also require construction and maintenance of underground CO_2 storage facilities. Such plans will need to be set in motion by local, state, regional, and federal planning agencies.

Remediation

Several federal, state, and local groups will need to coordinate strategies to address issues associated with environmental remediation. To start, federal support will be essential for guaranteeing reliable funding sources. The Pennsylvania Department of Environmental Protection (DEP) should maintain a state approved list of contractors and a database of remediation sites, among other related initiatives. The Pennsylvania Department of Community and Economic Development (DCED) could be utilized to expand remediation playbooks, along with the help of other organizations in the state, such as the BlueGreen Alliance. The Marcellus Shale Coalition and the Pennsylvania Public Utility Commission could unite to sponsor a certified gas program. Meanwhile, leaders in remediation technologies, such as NETL and PSU, should work toward improved technologies to seal wells with advanced monitoring sensors. Lastly, unions should mobilize to ensure that wages and benefits in remediation remain high enough to support workers and their families.

Lower-Carbon Industries and Sustainable Development

A cohesive regional strategy is also needed to support lower-carbon industries and more sustainable development in the region. The Allegheny Conference could work with the Southwestern Pennsylvania Commission or the Appalachian Regional Commission, as well as with state agencies, to mobilize (1) targeted, direct investments; (2) workforce programs with more hands-on training opportunities and programming for certification in electrician licensing; and (3) joint industry-educational efforts to connect with decarbonization and modernization initiatives.

Workforce Development

Local community colleges, county governments, and planning commissions are bracing for the effects the energy transition will have on workers. Educational institutions, governments, and NGOs will need to develop comprehensive regional strategies to improve workforce training. The most successful models are those that work with industry and offer people-skills training that goes beyond just a specific job, such as training in general communication and teamwork skills. The Tri-State Energy and Advanced Manufacturing (TEAM) Consortium offers a good example of building workforce development programs and partnerships.

Recommendations Summary

We see four ways to engage in successful regional and economic development in order to get out in front of the energy transition:

1. Capacity Building

There is a lot of human energy and social capital for economic development in Southwest Pennsylvania; however, smaller communities need assistance and a continuous flow of resources to more fully take advantage of these assets. Targeted efforts to encourage broad engagement in the continued health of local communities is essential to maintaining vital towns and cities in the region, especially as the industrial base transitions from traditional fossil fuel activities.

2. Resource Deployment

The region has access to an enormous amount of capital, but it needs to be more evenly distributed across Pittsburgh and surrounding communities. Reducing the physical and virtual distance between these communities with improved transit and broadband would help bridge this gap.

Additionally, local communities need support in realizing their economic development plans. The Commonwealth of Pennsylvania provides resources through industrial development authorities and economic development tax credits. However, the PA DECD should also consider ways to supplement those funds in communities that will be hardest hit if there is a continued transition away from coal and, eventually, from natural gas.

3. Coordination

There are hundreds of planning groups and organized interests in the region, but they need to be able to align and streamline their strategies to address the pressing demands of the energy transition. We see a much larger role for organizations such as the Southwestern Pennsylvania Commission and the Allegheny Conference as venues for coordinating groups and devising shared goals.

4. Champions

All proposed developments and strategies require champions who can engage in activities to build partnerships and attract investments to the region. Political and community leaders need to take on more direct roles to ensure that Southwest Pennsylvania is able to take advantage of the opportunities that the energy transition presents. Doing so would ensure the region maintains its position as a national and global leader in energy, technology, and manufacturing.

Profile: Stephanie Tyree and the West Virginia Community Development Hub

Stephanie Tyree arrived at community and economic development work by way of environmental justice policy and advocacy. Upon receiving her law degree from New York University, she worked for an environmental justice organization in New York City before moving to West Virginia, where these issues have complicated and deep roots. It was through her experiences with environmental justice projects that Stephanie came to understand the importance of leveraging community-based assets and local leadership to achieve redevelopment goals.

Today, Stephanie is based in Charleston, West Virginia, where she is the executive director of the West Virginia Community Development Hub, affectionately nicknamed "the Hub." The organization is a statewide community development nonprofit that works with small rural communities to design and execute local redevelopment projects. The Hub uses an innovative coaching- and accompaniment-based model to support West Virginia communities. Local leadership teams apply to the Hub and are matched with a coach who works alongside them to realize their development goals. Coaches build relationships with the community leadership teams and help them devise strategies to move their projects forward. Regular check-ins and monthly visits ensure that coaches are continuously engaging with the team and offering individualized support so that communities can meet their goals. These efforts take time and commitment. Most projects, especially ones that involve physical redevelopment, take between 5 to 10 years to complete.

The Hub's coaching model helps West Virginia communities overcome common challenges in rural redevelopment. In many cases, residents are committed and eager to engage in planning and economic development but lack the resources and capacity to do so. Financing is a major obstacle, especially for capital projects such as building renovation and site redevelopment. There are few community development corporations in West Virginia for communities to turn to for help. In addition to coaching—which addresses some capacity limitations—the Hub provides local teams with access to funding to help kickstart their redevelopment plans.

The Hub's innovative approach leads to projects that are unique to each town's history and culture. For example, leaders in Princeton, in the southwest corner of the state, focused on using the arts as a basis for revitalizing the town's business district. Local artists created 30 murals in what was once a crime-ridden section of the town, and the local theater is currently under renovation. In Buckhannon, toward the center of the state, community leaders developed a plan called Create Buckhannon, which has resulted in a revitalized Main Street, with new buildings and office spaces. Downtown and Main Street redevelopment remains a common goal for many rural towns that have experienced economic downturns.

Revitalizing these physical properties and restoring community spaces will require large-scale investments from government, the private sector, foundations, and other nonprofit organizations.

For Stephanie and her colleagues at the Hub, the aim is to "grow the pie together" by partnering with groups who share their commitment to local community development approaches. The Hub's coaching model offers important insights into how to achieve rural redevelopment goals while centering the unique identities and needs of local communities. Doing so at an even larger scale will require additional investment in resources, time, management, and community engagement.

Chapter 3: Regional Remediation Opportunities for a Job-Driven Cleaner Environment

Alison Hu, Dustin Tingley

Introduction

Pennsylvania—home to a recent boom in natural gas production, as well as a largely legacy coal and oil industry—faces a range of environmental problems. Chief among them are contaminated soil and water, in part due to years of fossil fuel extraction that was unregulated or under-regulated. Recently, more attention has been paid to another problem: leakage of methane from wells. As a result, Pennsylvania and other states in the region, such as West Virginia, routinely score very poorly compared to other states on a variety of environmental metrics.

Fortunately, this does not have to be the case. Pennsylvania has made regulatory progress in the past; there is a substantial desire among many currently operating in the fossil fuel sector to improve the situation (Pennsylvania is the second-largest producer of gas in the nation);[39] there are ample opportunities for market-based approaches to the problem; and there exists a combination of ingenuity and a hard-working ethic that could turn this situation around. In this chapter, we focus on the methane and abandoned or orphaned well problem, as well as the myriad challenges associated with soil and water contamination. While at times related, each poses unique challenges requiring different solutions.

Over 150 years of oil and gas production has resulted in wells littered across the landscape, many of which release methane and other chemicals into the region's air, soil, and water.[40] Methane is of particular concern. It comprises 10% of greenhouse gas emissions, but it is much more potent than carbon dioxide.[41] Methane absorbs 86 times more heat than carbon dioxide in the span of two decades and over 25 times more in the span of a century.[42] Methane release is a major contributor to global warming. Human activities account for over 25% of atmospheric releases of methane,[43] and energy-related activities are the second-largest contributor to methane emissions in the United States.[44] The rate of methane emissions is accelerating.[45]

Actively utilized wells have methane leakage problems, especially from older operations.[46] These emissions can be dealt with using appropriate approaches, including standards and regulations and tax incentives. These practices do generate costs for companies, but the benefits can be sufficient to make remediation cost-effective. The broader benefits to society of responsible extraction are even more substantial, given the greenhouse potential of methane and health effects of other pollutants.[47]

Abandoned and orphaned natural gas wells pose a larger and more difficult problem. Abandoned wells are wells that have not been in active production for a certain period of time and may be plugged, unplugged, or improperly plugged. Orphaned wells are abandoned wells whose legal owner cannot be found. Wells become orphaned for a variety of reasons—most often when the owners of a well go out of business.[48] Neglect typically results in leakage of pollutants into the atmosphere and groundwater. With no one liable for an abandoned well, responsibility for remediation to prevent further pollution becomes difficult to establish.

In addition to methane leakage, fossil fuel activities can pollute land and water. Coal-mining practices; abandoned coal mines, some of which date to colonial times; coal-related industries, such as iron and steel production; and coal-fired power plants have all led to soil and water contamination in the region.

Of particular concern are abandoned mine lands (AMLs). These lands were once used for coal mining but were not properly reclaimed. Water that flows through AMLs picks up chemicals found in coal that when mixed with water, create toxic solutions and can lead to clogged streams and polluted runoff.[49] In turn, this increases the chance of flooding in regions with AMLs. Rising acidity levels in waterways from acid mine drainage (AMD) also lead to imbalances in—or completely destroy—biodiversity in aquatic ecosystems and their surrounding communities.[50] Abandoned coal mines also create other safety and environmental issues. For example, underground mine fires, formed from coal and waste remains lit either naturally or by human activity, are a major source of greenhouse gas emissions and air pollution.

Addressing these problems is not only an environmental necessity but also an economic opportunity for a region that has relied heavily on extractive fossil fuel industries. Reclaimed lands can be used for other industrial purposes, for agriculture, or to attract tourism. Brownfield sites, such as Washington's Landing, can become promising locations for new industrial developments or urban redevelopment.

Scope of the Problem

Abandoned or orphaned wells account for an estimated 7 to 10% of Pennsylvania's methane emissions.[51] The amount each well emits is not uniform but varies greatly based on a number of factors, including well depth, age, and proximity to other wells.[52] Although plugged wells may still emit methane, unplugged wells in general are much higher emitters and are the main contributors to associated environmental problems. In fact, as little as 10% of all wells, deemed super emitters, contribute over three-quarters of total greenhouse gas emissions from extractive activities.[53]

Methane can also contaminate water. Wells may penetrate aquifers, underground layers of rock that contain groundwater, or oil and gas reservoirs and carry contaminants throughout the surrounding area.[54] Leakages from unplugged wells may seep into groundwater sources.[55] Processes involved in hydraulic fracturing, when carried out in close proximity to abandoned wells, may only exacerbate the groundwater pollution problem.[56]

The scope of the problem is at once immense and uncertain. There are around 8,700 documented orphaned wells, but several estimates suggest that there are over 500,000 abandoned or orphaned wells in Pennsylvania.[57] Well drilling in Pennsylvania commenced over 100 years prior to the establishment of permit requirements in 1955.[58] Records for wells drilled in the 19th century are long lost, and many wells were drilled in the 20th century under minimal regulatory oversight. The total cost of plugging 500,000 wells could exceed $18 billion. [59] Typical estimates for the effectiveness of a plugging job range from 50 to 100 years, but neither states nor the federal government have regulations in place to enforce methane emission monitoring.[60]

These challenges are not unique to Southwest Pennsylvania. There are an estimated 2 to 3 million abandoned wells around the country,[61] emitting over 280 kilotons of methane annually. [62] That is the equivalent of the emissions from 16 million barrels of oil in 2018. Many states face environmental challenges similar to Pennsylvania due to methane leaks from abandoned wells.[63]

Methane releases from abandoned wells are not the only environmental issue facing the region. Earlier eras of coal extraction have created a range of land- and water-based environmental problems. Like oil and gas drilling, most coal mining occurred in eras with no environmental regulation. In 1977, Congress passed the Surface Mining Control and Reclamation Act (SMCRA), the first formal legislation to address the environmental effects of mining.[64]

Mine reclamation is particularly important for Pennsylvania. Today, one-third of the nation's abandoned mine lands are located in Pennsylvania.[65] In the past, many coal-mining operations would simply move on after exhausting a coal seam. Soil that had been removed was not put back in place. Runoff from these areas pollutes one in three of Pennsylvania's streams. Over 5,500 miles of waterways are contaminated by acid mine drainage, which negatively affects recreation, agriculture, wildlife, and human health.[66] One source estimates that Pennsylvania has 40 active mine fires, which are polluting the air and beyond.[67]

Across the nation, an estimated $11 to $21 billion is needed to clean up AMLs, with an additional $5 billion more to be added before 2050. At current fee levels set in place by the SMCRA, only $0.7 billion will be collected in the same time period, leaving a funding shortfall of over $25 billion. Pennsylvania is home to an estimated 41% of AMLs to be reclaimed.[68] As with abandoned oil and gas wells, these numbers are based on known sites and thus likely underestimate the true extent of the problem.

Finally, Pennsylvania's rich industrial history has left a legacy of contaminated sites. Examples range from former steel factories to tanneries. These brownfields require extensive (and job-supporting) remediation. For example, a recent EPA grant of $3.7 million covers eight sites.[69]

Remediation Landscape

The landscape of remediation opportunities and approaches is vast. The activities include engineering, construction, and monitoring.

When a well goes out of production, it needs to be sealed in order to prevent liquid or gas leakages. Permanently sealing a well involves a series of steps, including removal of debris (e.g., collapsed walls), removal of well casing, and plugging with cement to separate geological layers. Properly plugging a well is key. A faulty job can lead to contamination of groundwater, as well as continued methane leakage. This process typically involves some heavy equipment, which can make access difficult in wooded and hilly regions. Water used in this process needs to be captured and remediated. In cases where there also exist coal seams, a vent (with flaring) is required to prevent explosions.

Many methods and technologies for water and soil remediation have been developed. They include removal, where contaminants are treated at the contamination site (in situ); separation, where contaminants are physically removed from the soil or water and treated off-site (ex situ); destruction, whereby contaminants are treated via chemical or biological processes (in or ex situ); and containment, where contaminants are immobilized and controlled (in situ).[70]

For water sources affected by acid mine drainage, alkaline materials are often inserted into the environment in an attempt to neutralize the contaminated land. Contaminated water may also be treated with treatment plants or artificial wetlands.[71]

In order to determine which strategy to use, sites are evaluated using a number of criteria, such as feasibility, effectiveness, cost, extent of contamination, and physical properties.[72] The methods for cleaning up soil tend to be more straightforward than those addressing groundwater, in part because sources of groundwater pollution are much harder to trace.[73]

Causes of Problems

Historical Legacy

For most of its history, fossil fuel extraction in the region was largely unregulated. Wells date back all the way to the late 1800s. Few, if any, records exist on where older wells were located and what types of wells they were. This makes identification of wells that need to be plugged extremely difficult. And even if a well is identified, the lack of records on the type of well it is and other information that supports successful capping are nonexistent.

Similarly, coal mining in the region was historically under-regulated, with some operators having minimal environmental safeguards in place. On top of this, as mines became less productive or as coal became less competitive, mines were simply abandoned. This has generated the need for programs like the Abandoned Mine Reclamation Program in Pennsylvania.

Incentives

A reasonable principle is that "the polluter pays." Unfortunately, this has not always been the case. There are a range of incentive problems that create a situation where those profiting from extraction do not pay the costs of pollution.

One challenge starts at the very beginning of the extraction process. When a new well is to be drilled, companies are required to put down a bond. This bond is designed, in part, to cover the costs of properly closing down the well once production ends. However, for this incentive scheme to work, the bonds need to be appropriately priced. Current bonding requirements are not appropriately priced, with actual cost of plugging more than ten times the bond price.[74] This is not just a state problem. The bonding requirements set by the Bureau of Land Management for federal lands have not been adjusted to account for inflation since the 1950s and 1960s.[75] Addressing this concern is important, especially if federal funding for well capping is seen as a bailout for fossil fuel producers.[76]

The Pennsylvania government has resisted efforts to reprice bonds, and some individuals described this as a nonstarter for the industry. they argue that opposition to higher bonding requirements has traditionally been driven by conventional well owners and operators that do not require hydraulic fracturing stimulus funds, especially firms that have been buying older, less productive wells. Others are slightly more optimistic, suggesting that as more capitalized firms are established, there will be more willingness to change requirements. While some firms have made settlements to change the bonding requirements,[77] many indicate this is insufficient given the scope of the problem.[78]

Nonconventional operators are required (under the 2012 Act 13) to pay impact fees.[79] Counties can then apply to use these funds for a variety of purposes. One way these funds are distributed is through the Marcellus Legacy Fund (MLF). However, applications are rarely made to the MLF for the purposes of well capping. One estimate indicates that only 1% of these funds have gone toward plugging wells.

Another challenge is that individual property owners do not have incentives to report abandoned wells, due to property value implications. If reporting an abandoned well is seen as a liability, then this can adversely impact property values. If there were a financial motivation (e.g., qualifying for offsets), property owners might be differently incentivized.

Related issues have also confounded water and soil remediation. In the coal industry, for example, low bonding requirements give companies little incentive to put in place environmental guards for when their operations cease.[80] The current system of "self-bonding" allows companies to appease regulators while bypassing payments. Some may simply sell off their permits to other companies.[81] In West Virginia, a coal company with 100 holdings filed for bankruptcy, leaving behind abandoned mines that the state estimates will cost more than $230 million to clean up.[82] Across the Appalachian region, there are an estimated 490,000 acres of mined land that have yet to be restored, with substantial bonding shortfalls.[83]

Private sector–driven development of brownfield sites, such as shuttered coal power plants, represents a substantial opportunity. Power of 32, an initiative led by the Allegheny Conference on Community Development, highlights the impact that such private investment can have on revitalizing brownfield sites and creating future investment opportunities.[84] However, such investment faces uncertainties about the suitability of a given site and any liabilities that might come with it. Putting this discovery work entirely on the shoulders of potential investors can be a major deterrent. As discussed below, developing site-specific playbooks can help.

Limited Government Investments

Efforts to deal with this problem to date are limited compared to the size of the challenge. While the Pennsylvania Department of Environmental Protection (DEP) has put in place some programs,[85] legislative engagement has not led to an overhaul or any substantial progress, and funding allocated to well plugging has diminished. Currently, the DEP is capping 10 to 12 wells per year, with a budget of about $400,000 annually.[86] This contrasts with neighboring Ohio, which plugged 131 wells in 2020 and is budgeting $25 million annually.[87]

As a result, there is not a deep bench of established firms in the plugging and abatement business. One company, noting that they are one of the largest in the region, has approximately 50 employees, and plugging and abatement is only part of their business. Other existing or future operators may be smaller, and quality assurances will be a challenge, given the distributed nature of the problem.[88]

Soil and water remediation face similar challenges. Like the scope of abandoned wells, the scale of brownfields and contaminated properties is difficult to quantify, but current estimates put Pennsylvania's land in need of remediation at over 287,000 acres.[89] Remediating a site, from the site assessment through the cleanup process and later monitoring, can be extremely costly. According to the Bureau of Abandoned Mine Reclamation, which oversees the Abandoned Mine Reclamation Program under the DEP, it would take $15 billion and over a century of work to clean up the state's AMLs at existing levels of support.[90] Additionally, the current structure of fee collection is set to expire this year; if federal support is not renewed, the state will potentially lose $750 million of funding and over $28 million in economic benefits to communities that are impacted by AMLs.[91]

Even at current levels of funding, Pennsylvania has historically been a leader in this space, with the DEP being one of the first state agencies in the United States to establish funds directly targeted at brownfield remediation, in 1995. The state's Land Recycling Program sets regulatory standards and provides liability protection and funding to private individuals, groups, or companies who would like to remediate a site.[92] Other incentives also spur voluntary cleanup, such as the Key Sites Initiative, which employs state-funded contractors to assess remediation sites and associated costs and encourage the reuse process.[93] Pennsylvania has been able to garner funding from federal sources as well.[94]

Nevertheless, securing sufficient economic resources for brownfield cleanup remains a challenge, as the current structure for tax incentives may not cover enough of the cleanup costs to properly incentivize such efforts. In addition, as the state faces growing problems in other areas, such as abandoned wells, more resources and staffing will be needed to sustain progress in this space.[95]

Limited Discovery, Monitoring, and Enforcement Capacity Relative to Scope of Problem

The location of many abandoned wells is not known due to their establishment in the distant past. Furthermore, drilling over the past 120 years has taken place over broad swaths of land, and this region has a highly variable landscape. Finding and documenting these wells is challenging.

Even when a well is known (and even when it is in use), estimating the extent of methane leakage and potential soil and groundwater contamination can be challenging. Solutions for detecting atmospheric release that are being explored in some regions[96] might not work as well in others. As discussed below, research on leak detection and repair (LDAR) technologies is an opportunity for further development.

Unfortunately, the monitoring challenge can be even more vexing. Even if a well is plugged, it needs to be done correctly. Especially with older wells with little documentation, plugging can be challenging and requires deep background knowledge and even custom equipment to deal with well technologies that are multiple decades old. As such, even with well-intentioned plugging operations, the job can be difficult to complete and require resources for quality implementation.

If there was sufficient monitoring and enforcement capacity to evaluate the quality of well capping, poor-quality well-capping jobs could be reduced. However, at present there are around three inspectors in the DEP that do this type of work. This is greater than the number of inspectors in West Virginia according to one interviewee. Given this, even if there was a large investment in well capping, there is at present insufficient state capacity to take advantage of such an investment fully and effectively. This is problematic because incorrectly capped wells could not only be ineffective at curtailing emissions, but they could also exacerbate groundwater contamination.

Similarly, accurate assessments of the locations and extent of AMLs are nonexistent. As a result of inadequate funding, the initial federal inventory of AMLs was incomplete and remains incomprehensive, especially as more lands become abandoned every year.[97] Since the 1980s, resources in Pennsylvania have shifted from discovery to reclamation.

As with plugged wells, ensuring remediated soil or water sites remain clean is challenging at current state capacities. Regulatory agencies have been slow to implement more automated, remote-sensing systems that would help to fill the need for manpower, due to their still-high costs.[98] As more mines become abandoned, sites are at greater risk of becoming contaminated again, leading back to the initial challenge of identifying the source of contamination.

Economic Opportunities

Activities aimed at well discovery, capping, and monitoring would have a near-term impact on job opportunities, especially for individuals with experience in the oil and gas industry. Estimates here range from 14,000 to as many as 120,000 jobs per 500,000 wells for capping, plus thousands more for discovery and monitoring.[99] A study conducted in Pennsylvania specifically estimates that with $1.2 billion in federal investment, over 9,000 jobs will be created annually in remediation, with over one-third of those coming from well capping.[100] Employment in the leak detection and repair space may be relatively high paying as well.[101] Workers in the conventional well-drilling space likely have many of the required skills—but also expertise and institutional knowledge—to work in this space, a point emphasized by a number of individuals interviewed.

Effective remediation is important for ensuring a positive public and political evaluation of the natural gas industry as a whole. Opposition to natural gas production based on environmental considerations has already led to bans on drilling in some regions.

Some firms seem to recognize that minimizing methane leakage makes good business sense. Indeed, a burgeoning industry involves firms going through certification processes that examine operations from extraction to shipment. Given a set of standards, third-party assessors can evaluate operations, which can often identify cost savings above and beyond environmental savings.[102] Recently, Chesapeake Energy, a major gas operator in the region, partnered with one such organization.[103] And a major utility company, Xcel, announced plans to purchase natural gas from a certified party.[104] As discussed below, these market-based approaches can be coupled with a small surcharge system, such that consumers can pay slightly more for natural gas that is produced in ways that minimize environmental damage due to extraction and shipment processes. These funds can then be distributed by the state for remediation of abandoned wells, as well as other remediation opportunities that will provide quality jobs. Several stakeholders we spoke to were excited about these market-driven opportunities.

Responsibly sourced gas is not just pertinent for U.S. domestic markets. In 2020, France barred liquified natural gas (LNG) exports from the U.S. firm NextDecade due to concerns about methane emissions from the extraction, processing, and shipment stages. This effectively blocked a multiyear deal with French gas distribution firm Engie.[105] Such considerations will become even more binding as the European Union considers targeting methane release as part of its broader climate goals.[106] Economic consequences like this are helping to animate various industry groups focusing on methane emissions, such as OneFuture.[107] This all becomes more pertinent for the broader region if LNG export terminals, such as the Gibbstown, NJ, facility, move forward.[108]

Land-based remediation is of substantial value as well.[109] The broader restoration economy is estimated to generate nearly $25 billion and over 220,000 jobs, and many of these employment opportunities are in rural or low-income communities.[110] For restoration of oil and gas extraction lands, estimated environmental benefits of $21 billion far outweigh costs of $7 billion.[111] Reclamation of known and existing AMLs is estimated to generate up to 170,000 employment opportunities. These jobs would, in turn, stimulate supporting industries and surrounding communities.[112] Ultimately, remediation will improve area property values.[113]

Beyond direct job creation, activities in the restoration sector can help increase biodiversity and agricultural productivity, slow land degradation, tackle greenhouse gas emissions, and improve overall quality of life. If all AMLs were reforested, they would have the potential to sequester over 232,000 metric tons of carbon dioxide annually; reforestation would also help address many of the environmental issues associated with AMLs mentioned previously by reducing acidic water runoff and decreasing flood risk.[114] Mine lands and surrounding areas have also been repurposed for a number of different uses (e.g., solar plants and wind farms, recreation areas, and commercial developments).[115] One example of a coal site reclamation in Pennsylvania, funded by the U.S. Economic Development Association, is estimated to generate nearly 200 jobs and over $120 million in private investment.[116] Another brownfield remediation example is Mill 19 in Pittsburgh, a former steel mill undergoing renovations to become a community center and site for robotics and artificial intelligence innovations.[117] Other projects like Power32 provide additional examples that leverage a broader regional ecosystem.[118]

Recycling waste from coal-mining operations may also generate income, particularly through the extraction of rare earth elements. According to the National Energy Technology Laboratory (NETL), global demand for rare earth elements was 149,000 metric tons in 2015, of which the United States comprised 11%.[119] Currently, the United States imports most of its supply from China, which raises national security concerns. In collaboration with NETL and the U.S. Department of Energy, the West Virginia Water Research Institute is researching efficient rare earth element extraction from acid mine drainage. Previous research found that acid mine drainage from treatment sites in West Virginia, Pennsylvania, Maryland, and Ohio combined could produce up to 2,200 tons of rare earth elements annually.[120] Similar efforts around the use of coal refuse are also promising (e.g., the West Virginia University's Mid-Appalachian Carbon Ore, Rare Earth and Critical Minerals Initiative).

Some economic opportunities may create tensions between emissions reduction and land or soil remediation. For example, this region is the world's epicenter for using coal refuse to create energy by circulating fluidized bed boilers. Coal refuse is a major source of water and land pollution, but it can still be leveraged to produce energy. The world's largest coal refuse–burning plant in the world is a facility in New Florence, Pennsylvania. Refuse coal plants are said to generate upwards of 10% of power in the region, with a variety of employment and revenue upshots.[121] Unfortunately, a variety of emissions-related consequences are created by this opportunity. Finding appropriate ways to take advantage of coal refuse—and thereby helping clean up soil and water pollution problems—in an emissions-friendly manner will be a challenge and an opportunity.

In summary, these economic opportunities can tap into the substantial knowledge base and skills of individuals currently employed in fossil fuel extraction. Experience with well drilling can in some contexts prove beneficial for well-capping efforts. Experience with operating a mine may help with various land remediation and reclamation efforts. Such skill-adjacent opportunities, even if they are not perfect, could help transition some workers into new economic opportunities.

Policy Options for the Region

This region faces a range of possible approaches to enhance environmental quality and reduce emissions of methane and other gases. We discuss these approaches in terms of incentives, processes, research investments, and stakeholder engagement. Some can be pursued at the state and local level and complement federal initiatives. Some do not directly require government and can be led by industry. For clarity, we discuss methane release separately from soil and water contamination. In some cases, it makes sense to think about both problems together.

Methane Release

Incentives

- Increase bonding requirements for wells while aiming to reduce inadvertent economic consequences that would put smaller, often conventional well operators out of business. These changes in bonding requirements would apply to both existing and future wells. In order to minimize economic impact, especially on older wells run by smaller operators, different strategies—for example, a process of phased increases—could be used. As discussed above, there exists precedent for increasing bonding requirements on existing bonds.
- Establish third-party responsibly sourced gas (RSG) certification for natural gas produced by minimizing methane leakage from in-production operations. These certifications will complement existing regulations and existing efforts by firms to minimize methane release. Establish a gas premium charge, approved by the Public Utility Commission, for gas produced and shipped in a way that has been certified. This surcharge will raise funds for plugging abandoned wells, for other remediation activities, or for research on preventing methane leakage. Use the RSG certification to brand Pennsylvania gas exported to other states or overseas.
- Establish a voluntary additional charge on current extraction, shipment, and storage operations. These funds then go to cleanup operations in the regions the company works in. Voluntary contributions by companies will be publicly reported as a percentage of economic activity. Firms not contributing will appear in these public records. While voluntary programs historically have found it difficult to raise substantial funds, such a program would enable firms committed to environmental quality to be better recognized for these contributions. These contributions would be above and beyond money raised through existing levies.
- Maintain a list of companies vetted and approved for doing remediation work in Pennsylvania. These companies are then eligible to bid on remediation projects. Assess projects for quality, and make membership on the list dependent on effective quality. This decreases the tendency to underbid and do poor-quality remediation work.
- Establish consistent streams of funding for remediation projects.[122] In addition to increasing efficiencies, this will also help incentivize individuals to switch into this industry.
- Explore incentives for property owners to report abandoned wells. For example, carbon offset funds could be used to properly compensate landowners once remediation occurs.

- Make permanent calculations of the social cost of methane that recognize the higher potency of methane compared to carbon dioxide as a greenhouse gas. Current measures are interim. Build in a social cost of methane as part of an integrated cost of greenhouse gases policy.[123]

Processes

- Invest in improving existing data and data processes for keeping track of wells by funding an expansion of the Exploration and Development Well Information Network (EDWIN) program. This would enable more detailed access to information about wells and their locations, which will enhance remediation efforts but also prevent unintended harms from new drilling operations.
- Identify ways to improve the predictability of various permitting processes spanning a range of operations, including remediation. Work with industry, regulatory, and community stakeholders to ensure commonly held values around protecting the environment and economic livelihoods.
- Expand the DEP's monitoring and inspection capabilities around all forms of remediation. This will include, for example, a focus on quality of well capping so as to avoid both groundwater contamination and atmospheric release due to poorly executed jobs.

Research Investments

- Invest in detection and quantification research. Methane leakage detection is a fast-moving area in the development of sensors and also in strategies of deploying sensors (drones, continuous-time sensing). Quantification is one of the biggest investment opportunities, because the scale of emissions in a site is critically important. Quantification will help identify super-emitter sites and the scale of capping needed. Industry, federal, and state funds should be used for research on remote methane leak detection that recognizes that different producing regions will have different challenges. Similarly, sustained research in other techniques for identifying abandoned wells, such as aeromagnetic techniques, warrants continued exploration.[124]
- Encourage industry-led investments in the creation of a common database where firms can report problems that lead to inadvertent leakage from in-production facilities. This enables identification of potentially common problems so any firms using similar equipment and practices can be proactive. This enables focus on prevention, given the relatively low percentage of places where there is accidental release. By "engineering out" solutions to common challenges, industry can take the lead in prevention.

Stakeholder/Public Engagement

- Encourage the formation and flourishing of industry groups, and nurture their existence and effectiveness in the remediation space. While industry groups like the Marcellus Shale Coalition exist on the active extraction side, these relationships are less established around remediation. This can be facilitated by regional foundations. Encourage the involvement of local and regional companies and workers. This will help build up a community that can advocate for itself.
- Promote the importance of well-capping efforts as part of the broader remediation and environmental quality effort. This will help well-capping projects achieve greater public awareness and make community-driven proposals for funds to the Marcellus Legacy Fund more likely. Currently other, more visible, projects get prioritized by applicants. For example, Act 13 (Impact Fee) Funds for Greenways/Trails totaled $87 million in 2019–20, whereas plugging abandoned wells totaled $1.7 million from a handful of applicants.

Soil and Water Remediation

Incentives

- Establish a *predictable* stream of funding for soil and water remediation. This will help the private sector and civil society make longer-term investments in workers and equipment. A major source of this funding can be existing programs. Release funds from the existing federal Abandoned Mine Lands Fund to jump-start high-priority cleanup jobs. As laid out in the Revitalizing the Economy of Coal Communities by Leveraging Local Activities and Investing More (RECLAIM) Act, this money could be allocated immediately.
- Identify and prioritize areas located in former mining regions that can be repurposed for renewable energy locations. This includes locating solar and wind installations at former open-air mining locations that are less likely to have other productive economic opportunities. This also includes strategic repurposing of facilities like coal-powered plants that take advantage of their access to rail, energy grids, and contiguous land.
- Increase bonding requirements on active fossil fuel extraction operations. This includes coal mines. If possible, this should be part of a federal program, so as to ensure that no particular region, like the Appalachian region, is disadvantaged due to policies in other states.
- Expand the set of brownfield sites that have state-commissioned playbooks.[125] These sites can be great investment opportunities, but investors might be intimidated by the due diligence process and potential liabilities that come with these sites. By producing playbooks ahead of time, these uncertainties can be reduced and site-specific opportunities highlighted. Ensure these playbooks are promoted and utilized.
- Power plants that use coal refuse should be incentivized to be first in class when it comes to emissions mitigation. Using coal refuse to produce energy reduces water and soil pollution, but these power plants emit a range of airborne pollutants and greenhouse gases.[126] The relevant industry association, ARIPPA, notes that coal refuse fires, which are scattered across the region, are even more pernicious. Existing tax credits that these plants receive could be adjusted to incentivize further emissions mitigation.[127] Large, more recently built facilities might be used as carbon sequestration pilots, if appropriate.

Processes

- Invest in data collection and oversight resources needed to accurately document AMLs. In particular, the existing federal AML inventory can be used as a baseline but should be updated and expanded upon. Thorough assessments of sites can then be used to tackle highest-priority areas and yield more accurate cost estimates.
- Highlight and support the bipartisan Congressional efforts around abandoned mines and reclamation coming from legislators in this region. This includes reauthorizing the Abandoned Mine Land act but also other initiatives such as the RECLAIM Act. With bipartisanship rare in the U.S. Congress, job-producing efforts that clean up the environment for all are a win-win for America and the region. This support extends beyond Congressional leaders to a variety of civic associations, such as Trout Unlimited and related organizations.[128]

Research Investments

- Fund research on groundwater contamination due to underground gas leakage.[129] This has been a challenge, in part due to the complexity of measurement and source identification. Research is needed in methods to properly identify sources of soil or groundwater contamination.[130] More research is needed to make remediation methods for groundwater and soil more cost efficient and scalable.[131] This could entail investments in remote sensing and even robotics technologies.[132]

- Research on reclamation of trace metals from coal tailings and coal ash could help unlock value from otherwise hazardous waste from years of coal mining. Emerging needs around rare earth and trace metals for various industrial applications require research and development support to achieve proof-of-concept demonstrations all the way up to processes that can achieve required scale economies. This work can be done in conjunction with industry partners.[133]

Stakeholder Engagement

- Given the labor-intensive nature of much soil and water remediation work, it will be important to ensure that jobs created by investing in this area pay a respectable wage. In part, this can be facilitated by involving unions, including those representing existing coal workers. For instance, although AML workers' wages are generally above the poverty line, they are often below a livable wage; tying wage regulations to AML jobs can help to raise workers' pay.[134]
- Private sector leadership—ranging from the energy sector to industrial sectors to other organizations, including local Chambers of Commerce—will be key, given the expansive set of challenges. Making sure these groups are aware of various funding streams and real business opportunities, including from land developers, will be important. To facilitate this engagement, the state should invest in more playbooks for additional sites (see discussion in Chapter 5).
- Prioritize training, hiring, and funding of workers from historically marginalized groups. Many of the areas experiencing economic hardship from declining coal activity face issues related to race- or gender-based disparities.[135]

Profile: Brandon Dennison and Coalfield Development

In 2020, Coalfield Development celebrated its 10th anniversary as an organization devoted to rebuilding the Appalachian economy from the ground up. Based in southern West Virginia, the nonprofit is led by area native Brandon Dennison, who envisioned a new entrepreneurial future for workers and communities once dependent on coal mining. Recognizing the need to diversify local economies, invest in infrastructure, and retrain workers, Dennison developed an innovative model that rests on three core capabilities:

1. Investments in employment-based social enterprises,
2. Support for personal, professional, and academic development, and
3. Community-based real estate development.

This three-pronged approach allows the nonprofit to tackle economic and social issues that are deeply intertwined. To start, there is a need to connect employers with workers who are equipped with appropriate personal and professional skills. Coalfield Development helps workers change careers, pick up new skills, and advance their education through its unique workforce development model called 33-6-3. Participants in the program are offered a 2.5-year contract in which they complete, per week, 33 hours of paid work, 6 credit hours of higher education, and 3 hours of personal development. The model recognizes that workers cannot afford to take time off to retrain without being paid. Training is completed while earning wages to support families. This model also takes into account the fact that the 21st-century workforce demands not just technical skills but also project management, communication, and interpersonal capabilities. This is where the hours spent on personal development and education come in. By the end of the 2.5 years, Coalfield Development has prepared participants to contribute to the workforce and their respective communities.

Next comes the challenge of connecting successful participants with good, quality jobs. By investing in employment-based social enterprises and community-based real estate development, Coalfield Development is able to help bridge the gap between employers and labor. Many program participants go on to work in construction, clean energy, agriculture, woodworking, and related fields that are supported by these development projects and social enterprises. The projects also serve the dual purpose of diversifying local economies and revitalizing towns and neighborhoods. Renovating and rehabbing local downtowns makes the region more likely to attract future investments.

To date, Coalfield Development has created over 250 new jobs in southern West Virginia, trained over 1,200 people, capitalized on over $20 million in new investment, and refurbished over 200,000 square feet of property. Perhaps most importantly, the nonprofit is a catalyst for encouraging future growth and development in the region. Its model serves as an example for how to involve, invest, and grow Appalachian communities once reliant on traditional energy industries.

Chapter 4: Carbon Management and the Future Development of Fossil Fuel Resources in Southwest Pennsylvania

Stephen Ansolabehere, Heidi Li

Coal, oil, and natural gas from southwest Pennsylvania have been critical energy resources for the United States for the better part of two centuries. With the rise of the Marcellus and Utica Shale gas industries since 2005, fossil energy production in the region has witnessed a renaissance. The Pennsylvania Department of Environmental Protection forecasts a doubling of gas production between 2020 and 2050 and, with that, the promise of attracting other industries, such as petrochemicals, to the region.

The global transition of energy industries to lower-carbon emissions, however, will alter the region's energy, manufacturing, and industrial sectors. The expansion of natural gas production in the near term will help reduce greenhouse gas emissions, as natural gas has much lower carbon intensity than coal. Eventually, however, the use of natural gas will itself be in tension with increased consumer demand for cleaner energy and with public policies and goals.[136] The projections of the Roosevelt Project's REMI model indicate that a shift in demand toward lower-carbon energy will result in a permanent contraction in energy extraction, industrials, and manufacturing in the region unless new ways of using fossil fuels are deployed.

Carbon management is a logical strategy for southwest Pennsylvania. Core technologies and processes for carbon management include carbon capture, utilization, and sequestration , or CCUS. Carbon dioxide and other greenhouse gases (GHGs) can be captured during power generation or other industrial and manufacturing activities. Waste carbon may then be sequestered underground or used as an input for other products, such as cement or steel, in ways that prevent it from escaping into the atmosphere. In its *2020 Flagship Report*, the International Energy Agency identifies CCUS as the "only group of technologies that contributes both to reducing emissions in key sectors directly and to removing CO_2 to balance emissions that are challenging to avoid—a critical part of 'net' zero goals."[137]

Carbon management offers southwest Pennsylvania a plausible way to reduce its greenhouse gas emissions from fossil fuels. The region has excellent geology for storage of waste carbon, natural gas, and hydrogen. The region has the requisite industry, expertise, and workforce to build and operate CCUS infrastructure, as well as extensive existing infrastructure, some of which may be used as part of a carbon management system.

Potentially larger opportunities for southwest Pennsylvania can emerge with the development of a CCUS innovation hub. Such a hub would connect the region's fossil fuel energy facilities to carbon storage facilities. It would also serve as an incubator for research and development of commercially viable technologies for CCUS. There is growing global demand for cost-effective technologies that can be deployed on a large scale to reduce carbon emissions from existing and new fossil fuel power plants, agricultural processing facilities, industrial production, and manufacturing processes. There will also be demand for new technologies to store waste carbon underground or to use carbon as an input to other industrial processes.[138]

Carbon capture is not a matter of *if* but *where*. The United States is currently the global leader in CCUS technology. Half of all large-scale carbon capture and storage projects in the world are in the United States.[139] United States development of CCUS is also beginning to attract very large investments.[140] CCUS technologies are the subject of intense investigation worldwide, and this technology is beginning to attract significant investments from leading energy companies.

Southwest Pennsylvania can become a global leader in CCUS technology. The region has the research and development capacity to become an innovation hub for CCUS. The U.S. Department of Energy's fossil fuel research lab—the National Energy Technology Laboratory (NETL)—has campuses in Pittsburgh and in Morgantown, West Virginia. The region also has world-class research universities, including Carnegie Mellon, the University of Pittsburgh, Penn State University, and nearby universities in West Virginia and Ohio. With its natural resources, industry and workforce, and research capabilities, southwest Pennsylvania is extremely well positioned to create an innovation hub for the development of CCUS.

Carbon capture and sequestration infrastructure in the region can eventually support the production of hydrogen, which can be used as a fuel or as a feedstock to produce fertilizers, ammonia, and other petrochemicals. When coupled with CCUS, hydrogen produced using natural gas, called blue hydrogen, can have minimal GHG emissions, bringing it in line with environmental goals and policies. Commercial development of blue hydrogen will require further technological innovations and infrastructure, but the technology offers an option for the region to develop its natural gas industry over the long run.

Large-scale commercial deployment of CCUS requires a clear plan for regional deployment, championed by political leaders in the region and in the commonwealth. We recommend the following:

1. Establish a carbon management task force. The task force should develop a regional plan for carbon transportation and storage and should represent the views of the community, industry, government, and research institutions. It should meet regularly to discuss public concerns, regulatory issues, and industrial development strategies.
2. Expand the region's research and development capacity for carbon capture, utilization, and storage. The federal government should authorize the National Energy Technology Lab to establish a new program devoted to carbon management and should increase funding for research on CCUS and hydrogen.
3. Double down on demonstration projects for underground carbon storage and for carbon capture at industrial scale. Demonstration projects should be designed and operated by NETL and affiliated U.S. research universities as part of the initiative on innovation in and optimization of carbon management.
4. Assess the potential for hydrogen. The state's Department of Environmental Protection and Department of Conservation and Natural Resources, working with industry, should produce their plan for development of hydrogen infrastructure, especially pipeline and storage facilities.
5. Develop a region-wide planning process for the management of underground assets. The relevant state agencies of Ohio, Pennsylvania, and West Virginia should conduct a joint study of the below-surface assets of the region, such as deep saline formations, and how they can be managed efficiently and equitably.
6. Develop environmental and safety standards for CCUS and hydrogen. The Commonwealth of Pennsylvania should develop clear environmental and safety

standards for CO_2 and hydrogen sources, pipelines, and storage facilities. The commonwealth should increase the capacity of state and federal agencies for monitoring pipelines and storage facilities and enforcing standards.

Context

Energy production is one of five key industries in the highly diversified economy of southwest Pennsylvania.[141] Energy extraction and power generation account for 9% of the gross domestic product of the region. Manufacturing, which depends heavily on energy, adds another 10%. Although they contribute greatly to the domestic product, energy extraction and utilities account for only about 2% of employment.[142] The reason for the discrepancy between gross product and employment is that much of the value of energy extraction is from export of fuels, especially natural gas, to other states.

Coal remains the primary fuel for electricity generation. Compare approximately 7 gigawatts of generating capacity from coal with 3.5 from natural gas and 1.8 from nuclear power. Another 7.5 gigawatts of power are generated using coal in a handful of power plants in areas of Ohio and West Virginia that border Southwest Pennsylvania. That said, coal mining in Southwest Pennsylvania is in decline, with the largest number of jobs in Greene County, Pennsylvania.

The development of natural gas in the Marcellus Shale in the early 2000s transformed energy production and related industries in the region. Almost all energy extraction in the region is now natural gas. In 2019, Pennsylvania produced nearly 7 trillion cubic feet of gas, making the state the second-largest energy producer in the nation[143] and one of the top three energy exporters in the United States.[144] Most of the gas from this area goes to New York, New Jersey, Maryland, Ohio, and West Virginia.[145] The Pennsylvania Department of Community and Economic Development (DECP) views Marcellus natural gas resources as central to future economic development of the state, including power generation and downstream manufacturing.[146]

Fossil energy has long attracted other industries to the region, such as steel. Pennsylvania's Marcellus Shale gas is beginning to attract development of petrochemicals and other manufacturing.[147] Shell is constructing an ethane cracker plant in Beaver County, Pennsylvania , to produce ethylene. This plant is projected to employ 600 to 800 people when operational. Three other plants are under consideration in Ohio and West Virginia, though specific plans for those facilities are still uncertain.[148] In Clinton County, Pennsylvania, KeyState Agri is raising capital to build a chemical facility to produce, among other things, ammonia and fertilizer from natural gas.[149]

The economic impact of energy extraction and utilities varies within the region. In Greene County, mining, quarrying and oil and gas accounted for 18% of employment in 2018; in Armstrong, Fayette, Indiana, and Washington Counties, energy extraction activities accounted for approximately 5% of employment; in Allegheny, Beaver, Butler, Cambria, Lawrence, and Westmoreland Counties, energy extraction was less than 1% of employment.[150] The development of Marcellus Shale gas has generated the equivalent of 25,000 additional jobs annually in the region.[151] Gas operations have resulted in substantial increases in income and employment and in county government revenues, especially in outlying parts of the region: notably in Fayette, Greene, and Washington Counties, to the southwest of Pittsburgh, and in Armstrong and Indiana Counties, to the northeast of Pittsburgh.[152]

Income from the natural gas industry has been a windfall for state and local governments. The Commonwealth of Pennsylvania imposed a gas impact tax, called the Impact Fee, in 2012. That fee has generated approximately $200 million per year for the commonwealth. Of those revenues, over half goes directly to the county and local governments in areas where there is gas extraction. Those revenues have helped improve schools and roads in these counties. Approximately 20% goes to counties for parks and bridges; 15% goes to statewide environmental funds; and 9% funds state agency oversight.[153] These funds are a particularly important source of revenue for local governments in the counties where the Marcellus development has occurred.[154]

The rise of Marcellus gas has also had two negative impacts on the region. First, there has been an increase in air and water pollution. An extensive study, conducted by researchers at Princeton and Carnegie Mellon Universities, of the economic benefits and health costs of the first decade of shale gas development to the Appalachian region concluded that the benefits net the costs have been a wash. The health effects associated with air pollution, when monetized, have cost $23 billion and produced $21 billion in direct economic benefits to Ohio, Pennsylvania, and West Virginia. Furthermore, the net benefits have been far greater than the costs in rural counties, but the health care costs have far exceeded the economic benefits in Allegheny County.[155]

Second, development of Marcellus gas has driven down the price of natural gas, leading to a steep drop in demand for coal. Some parts of central Appalachia have enjoyed an economic windfall from gas, but other parts of the region are experiencing economic dislocations due to the drop in demand for coal. We focus on Southwest Pennsylvania, though other areas of Appalachia have been much harder hit by recent declines in coal mining.

Policies designed to reduce greenhouse gases will also affect specific activities. Electric power generation accounts for the lion's share of the greenhouse gases that are emitted *inside the region*. Most of the carbon attributed to energy production in the region is emitted *outside* the region. Most of the natural gas extracted in Southwest Pennsylvania goes to other states, especially Ohio, New York, New Jersey, and Maryland. In 2018, the GHG content of fuels exported from (rather than energy generated or products made in) the region amounted to 336 MMT of GHGs—more than five times the GHG emissions associated with all economic activity inside the region.[156] If the neighboring states decarbonize their energy and industrial sectors, there could be a significant decrease in demand for natural gas from Southwest Pennsylvania, at least as long as carbon capture, utilization, and sequestration (CCUS) is not available.

Carbon Capture and Hydrogen

There are two pathways for continued use of the region's fossil fuels with significantly lower carbon emissions: (1) carbon capture, utilization, and sequestration (CCUS) and (2) hydrogen from natural gas. These two pathways work in tandem. Carbon capture can be used in processes that use natural gas to produce hydrogen, called blue hydrogen.[157]

Southwest Pennsylvania has a number of assets that can support deployment of these technologies. The geology of the region has extensive deep underground saline formations that are suitable for large-scale permanent storage of carbon or temporary storage of hydrogen fuel. The promise of hydrogen storage, which we view as of particular importance 20 to 30 years in the future, means that the underground assets of the region can have long-term economic value if managed properly. The region has extensive expertise in fossil fuel generation, including a skilled workforce and local companies capable of large-scale industrial development. The region also has research and development capacity, with the National Energy Technology Laboratory and the area's university research laboratories. Such expertise will be necessary for systems analysis and planning as well as improvement in chemical and industrial processes.

Carbon capture and hydrogen at scale will require government agencies and private companies to make choices that shape the industry. The region will need to plan, site, and construct pipelines and storage facilities suitable for carbon dioxide and hydrogen. The commonwealth will need to establish and enforce appropriate environmental, safety, management, and ownership rules. Many of the opportunities in the region cross state boundaries. Federal involvement or regional cooperation is essential to realize the full value of carbon capture and hydrogen pathways.

Carbon Capture Pathway

Carbon capture is a suite of technologies and associated infrastructure that allows for the extraction of CO_2 from fuel directly or during combustion or chemical processing. There are three phases to this process: carbon capture, transportation, and sequestration .

Industry in Southwest Pennsylvania provides a wide variety of opportunities for carbon capture, including power generation and manufacturing of industrial products, such as petrochemicals and steel. Power generation is perhaps the most obvious large-scale application for carbon capture. Capture may occur precombustion or postcombustion. Capture technology is well known but remains expensive, and current U.S. Department of Energy (DOE) research is focused on reducing costs. Investment in carbon capture research is vitally important to an economically successful deployment of this technology at a regional scale.

Postcombustion capture separates carbon dioxide (CO_2) from the flue gas stream produced by conventional fossil fuel combustion. The CO_2 is separated from nitrogen in the flue gas and can be stored underground or used for other purposes. The cost of postcombustion capture is estimated to be approximately $50 per metric ton of carbon from coal and $70 per metric ton of carbon from conventional natural gas. (See Appendix 2.)

Pre-combustion capture converts a feedstock, such as coal, into a gas that is a mixture of hydrogen, carbon monoxide, carbon dioxide, and other elements. This synthesis gas, or syngas, can be separated into hydrogen for fuel and carbon dioxide. The CO_2 can be separated and later used for other purposes or stored as a pollutant. Under today's commercially viable technology, the cost of CO_2 capture in power generation is around $60 per metric ton of CO_2.[158] While carbon capture is cheaper for each ton of carbon captured from coal than it is from natural gas, it must be kept in mind that the carbon density of coal is much higher, making the cost of capture per unit of *energy* produced cheaper for natural gas than for coal.

To make carbon capture feasible on a national, or even global, scale, it is essential to reduce the cost of the technologies. Current DOE research at NETL is focused on multiple technologies to improve the efficiency and lower the cost of pre-combustion and post-combustion capture.[159] Such research will likely need to be expanded.

Carbon capture can also occur in manufacturing processes, either in the generation of power for the process or in manufacturing itself. The Shell ethane cracker facility nearing completion in Beaver County, Pennsylvania, can be retrofitted for carbon capture, as can processes involved in iron and steelmaking in the Mon Valley in Allegheny County. The costs for capture from such heavy industrial processes are typically higher than for power generation using coal or gas. The capture technologies are expensive to retrofit to existing facilities, and they also require energy to operate .

New electricity generation and manufacturing technologies are being developed and deployed with the aim of improving the ability to capture carbon dioxide and other pollutants without significant loss in efficiency. One of the most promising recent developments is the Allam cycle natural gas power plant design. This process can operate at 59% efficiency, almost the same as the most efficient conventional gas power plants (at 62%), and the Allam cycle captures 100% of the carbon dioxide.[160] North Carolina–based NET Power has constructed a 50 MW Allam cycle demonstration plant in La Porte, Texas, and, in collaboration with Exelon, is expanding that facility to a full-scale, 300 MW operation.[161] The Allam cycle is an example of a promising new technology that will improve the efficiency of carbon capture.

The second part of the problem is what to do with the captured carbon. In the near term, sequestration underground is perhaps the most immediate option at a very large scale. This involves pumping CO_2 underground, a task that requires substantial deep underground geologies that are sufficiently stable and nonporous to allow for permanent storage without high risk of leakage. Deep underground saline formations are ideal for CO_2 sequestration .

Pennsylvania has such formations in abundance. A 2009 report of the Pennsylvania Department of Conservation and Natural Resources estimates that Pennsylvania's geology has the capacity to store roughly 300 years' worth of CO_2 emissions at current rates, which would correspond to a total of almost 90 billion metric tons of CO_2.[162] The potential for deep underground storage is greatest in western Pennsylvania, exactly the region most at risk of economic dislocation with deep decarbonization.

Industrial production in the Southwest Pennsylvania region has the potential to create a robust market for carbon as an industrial input. A market for carbon as an input will create a price on carbon that makes capture more economical. Common current uses of carbon dioxide are in beverages and in enhanced oil recovery (EOR). [163] One promising possibility is cement. Cement manufacturing is one of the most carbon-intensive industrial activities. Use of captured carbon from power generation in cement production can further reduce carbon emissions from cement production, and the cement itself can become a medium for storage of the carbon.[164]

CCUS may be especially important for the decarbonization of industrial production, which has been the slowest sector to decarbonize. According to the Pennsylvania Department of Environmental Protection, the industrial sector accounts for approximately 80 MMT CO_2 annually, 31% of all emissions in the commonwealth. That amount has not declined since 2000. By comparison, carbon emissions from electricity production have declined by almost 40% since

2000.[165] Developing a large-scale carbon capture, storage, and utilization system in Southwest Pennsylvania can help reduce the carbon intensity of the industrial sector and protect the region's industrial production from becoming uncompetitive in the event that there are stricter regulations on carbon or increased demand for low-GHG products.

To fully develop a carbon capture and storage system will require significant planning and investment in infrastructure. Existing coal- and gas-fired power plants will need to be retrofitted with capture technology, and plants using new designs, such as the Allam cycle, may be built. Other industrial facilities, such as steel, petrochemical, and cement plants, will also need to be retrofitted for capture. In addition to capture technologies, the region will need to develop appropriate pipelines and storage facilities.

The region has taken some initial first steps toward developing CO_2 infrastructure. The states of Ohio, Pennsylvania, and West Virginia have conducted extensive geological studies of the suitability and feasibility of carbon storage.[166] The U.S. Department of Energy's National Energy Technology Laboratory, American Electric Power Services Corporation, and the State of West Virginia collaborated in a successful 15-year deployment of commercial-scale carbon capture and sequestration at the Mountaineer Power Plant in Mason County, West Virginia.[167] Working with NETL in this development as part of the Department of Energy's Coal FIRST program, Consol plans to build a zero-emission coal power plant in Washington and Greene Counties. This facility will be capable of capturing nearly all of its carbon emissions.[168] Those projects establish a foundation for CCUS in the region.

As of now, there are no large-scale CO_2 storage sites and no CO_2 pipelines in Southwest Pennsylvania, eastern Ohio, or West Virginia.[169] Nor are there any below-ground storage facilities or containers in the region dedicated to CO_2.

What would a carbon capture and storage (CCS) system at scale look like?

A handful of studies have examined large-scale development of CCS in this region. In 2009, the Pennsylvania Department of Conservation and Natural Resources prepared a study of carbon capture and storage for the largest emitting coal-fired power plants in Southwest and central Pennsylvania.[170] This study scoped out a CO_2 pipeline system running from Armstrong and Indiana Counties to Montour County in the center of the state. NETL has studied CCS in neighboring parts of Ohio. But to our knowledge, the commonwealth has not done a subsequent study of CCS at scale.[171]

We have conducted an assessment of CCS at scale in this region based on analysis of four recent studies of carbon capture, transportation, and storage elsewhere.[172] We envision a pipeline and storage network that would run east–west, connecting power plants in Indiana and Armstrong Counties in Pennsylvania to Coshocton, Ohio, and north–south, connecting Beaver County to Greene County and extending into West Virginia. This plan would bridge the proposed development considered by the State of Pennsylvania in its 2009 report and the development in Ohio proposed by NETL.

Our estimates of the costs of a CCS hub in the region have three components. First, we gauge the scale and costs of capture at all industrial facilities in Southwest Pennsylvania. Second, we estimate the cost of constructing a CO_2 pipeline through the region and of transporting CO_2. Third, we estimate the cost of building and operating large-scale storage facilities.

First, to calculate the approximate carbon capture costs, we examined all major industrial and electricity point sources for greenhouse gases in Southwest Pennsylvania. Using the U.S. Energy Information Administration (EIA) database of energy facilities, we located each facility with more than 100,000 Mt CO_2 emissions annually in the 13 counties in Southwest Pennsylvania. We further identified the fuel source and production technology used, as the capture costs vary considerably by fuel source. Using estimates from CarbonSafe, McCoy and Rubin, and Schmeltz et al., we computed the cost to retrofit each facility and the cost of capturing CO_2 from each source.

The capture costs per ton of carbon vary by type of fuel used and process. The total cost for this portion of the project came to $500 million. Averaging across studies, levelized costs of capturing a ton of carbon dioxide are $51 per ton for a coal-fired power plant, $73 for a natural gas–fired power plant, and $122 for cement manufacturing. The cost of capture may be offset with tax incentives, such as 45Q, and prices for carbon as an input to other processes.

Second, to calculate the approximate transport costs, we assumed that there would be a backbone CO_2 pipeline connecting eastern Ohio, northern West Virginia, and Southwest Pennsylvania. This pipeline would run from Coshocton, Ohio, to Indiana County, Pennsylvania, and from Beaver County, Pennsylvania, to Morgantown, West Virginia. We chose Coshocton, Ohio, as that is the location of a carbon capture and enhanced oil recovery site proposed by a team of researchers at NETL. Connecting Beaver County and Morgantown would connect the Shell ethane cracker plant in Beaver to coal-generating facilities in West Virginia. To estimate the cost of such a pipeline, we rely on figures published by Kinder Morgan and NETL for pipeline development in mountainous terrain.

Third, to calculate storage costs, we assumed that three storage facilities would be constructed in the area, at suitable locations. This would require construction of pumping stations and aboveground short-term storage, as well as operation and maintenance costs.

The total cost over 30 years for a pipeline and storage system for this region would come to approximately $8.2 billion. This is an approximate estimate based on existing recent research and modeling of the costs of carbon transportation and storage.

Hydrogen Pathway

Hydrogen offers a second possible pathway for the development of low-carbon fuels and technologies in this region. Large-scale hydrogen development requires a reliable supply of water, access to energy (preferably non-carbon-emitting), and safe storage for hydrogen fuel produced. Southwest Pennsylvania, eastern Ohio, and West Virginia have these resources in abundance and are perfectly suited for region-wide industrial development of hydrogen.[173]

Several large-scale hydrogen facilities in the region are planned or under construction.

- KeyState Agri and Frontier have announced plans for and are raising the funds for the construction of a $500 million synthesis gas plant in Clinton County, Pennsylvania. The company plans to "extract natural gas and capture CO_2" in the manufacturing process, producing (1) low-carbon hydrogen for fuel, (2) low-carbon ammonia, (3) low-carbon nitrogen fertilizer, and (4) exhaust treatment for power plants and diesel engines to reduce emissions from those processes.[174]

- Long Ridge Energy Terminal in Hannibal, Ohio (90 miles from Pittsburgh), in collaboration with New Fortress Energy and GE Gas Power, is building a 485 MW combined-cycle power plant that will run initially on a gas-hydrogen mix but will transition to 100% hydrogen. Long Ridge is also locating a 300 MW data center campus at that site.[175]
- Ember Partners and Mitsubishi are developing a 1 GW power plant in Harrison County, Ohio (70 miles from Pittsburgh) that will initially burn a mix of 70% gas and 30% hydrogen and eventually transition to 100% hydrogen. That partnership is also planning a 485 MW gas-hydrogen power plant in Lackawanna County, Pennsylvania.[176] Similar facilities are under development in New York, Virginia, Utah, and Florida.

Hydrogen also can serve as a transportation fuel, especially for large vehicle fleets, with centralized fueling stations. Pennsylvania has been a first mover in the development of alternative fuels, such as compressed natural gas, hydrogen, and other alternative transportation technologies. The U.S. Department of Energy has selected two locations in Pennsylvania for the development of alternative fuels corridors (I-80 and the I-78/I-81 corridors). Penn State University, Carnegie Mellon, and NETL have significant research activities in hydrogen fuel cells and alternative-fuel vehicles. We leave the question of hydrogen and transportation to the Industrial Heartland case study, which examines the energy transition and the automotive industry.

The emergence of hydrogen for power, transportation, and manufacturing provides near- and medium-term economic benefits for Southwest Pennsylvania. Each of the planned hydrogen facilities in the region will employ hundreds of people locally. The KeyState Agri facility, for example, will employ 150 to 200 people. The location of new hydrogen facilities in areas where there has been a loss of coal-mining jobs or the closure of steel- or coal-generating facilities can help offset some of the employment hit that the energy extraction and industrial sectors have taken over the past two decades.

Natural gas is critical to the development of hydrogen. For projects such as the Ember-Mitsubishi facilities, natural gas is a bridge fuel. Initially, these plants will burn a mix of natural gas and hydrogen, but eventually they will burn hydrogen produced from solar, wind, or another power source with zero GHGs. Natural gas is necessary in the near term to allow for scaling up the use of hydrogen.[177] These facilities will increase demand for hydrogen, raising the price of the product and making production of hydrogen from gas, wind, solar, and other means more economical.

Large-scale deployment of hydrogen, however, will require a substantial infrastructure investment. Hydrogen alone will require development of a transportation network, including pipelines and storage facilities. Deployment of hydrogen with natural gas at an industry-wide scale will likely require a carbon capture and storage system as well as an additional system of hydrogen pipelines and storage. Given the wide range of hydrogen technologies, from fertilizer production to fuel cells to power generation, it is difficult to give a simple estimate for the cost of infrastructure needed.

In the long term, the hydrogen for fuel may be produced using technologies, such as nuclear, solar, or wind, that have no GHG emissions. Such green or related hydrogen could become the feedstock for an entirely carbon-free power and industrial sector in the region. The near- and medium-term prospect is that hydrogen mixed with gas or produced from gas with carbon capture provides the pathway to transition to zero-emissions electricity generation and manufacturing.

The location of hydrogen facilities can also reduce the economic impact of the decline of coal mining or the eventual decline of natural gas extraction. As an industrial, workforce, and remediation strategy, it makes sense to locate new hydrogen facilities at or near fossil fuel facilities that are decommissioned or inactive. Those facilities have the infrastructure to support large-scale power generation, such as transmission lines and real estate, and a labor pool experienced in working with energy. Reuse of such sites will lessen the environmental impact of new energy and industrial development in the state.

What's Needed?

To create an innovation hub and to support CCUS deployment will require substantial investment in research on CCUS and hydrogen at NETL and university labs. Innovations in entire systems, such as the Allam cycle, and in materials that more effectively remove carbon from flue gas will improve the cost-effectiveness of carbon capture. New methods for developing carbon fibers and related materials from carbon will improve the value chain for carbon, making carbon capture commercially attractive.[178] These innovations come directly from investments in lab research. The federal government and industry should increase their financial commitment to research, development, and deployment of CCUS.

A system of CO_2 or hydrogen infrastructure will raise a complex set of management issues. Stakeholder deliberations concerning CCUS development elsewhere in the United States have identified six key issues.[179]

1. Regulation and enforcement of underground injection control. The U.S. Environmental Protection Agency oversees the Underground Injection Control program. The state of Pennsylvania will need to request and be granted by EPA primacy over class 6 wells for permanent storage of CO_2 or hydrogen in order to move forward with CCS.
2. Long-term liability. Liability associated with leakage or failure of a storage facility creates uncertainty and risk for the public and that makes firms unwilling to commit to storage. A rigorous evaluation and clear standards are needed to ensure that these risks are minimal, both for the health and safety of the public and to clarify long-term liabilities.
3. Pore space access. The underground space is an important resource, and there may be competing uses, such as the injection of other gases. The management of underground CO_2 must be developed in a way that allows for multiple intended uses. Furthermore, there may be problems of "subsurface trespass," when carbon migrates to other spaces.
4. Unitization. Because underground storage space is an aggregate, a natural problem is how to treat leasing rights underground. Some states treat the entire underground formation as a unit and negotiate pooling agreements among the private interests using the underground resource. Developing clear unitization rules will create greater certainty about storage.
5. Eminent domain. Development of pipelines and underground storage caverns will likely require state legislation asserting eminent domain for purposes of siting.

6. Fiscal incentives. Tax incentives, such as the federal credit for CO_2 sequestration, help make CCUS commercially viable. Especially in the early phases of CCUS, tax incentives, direct grants or loans to CCUS projects, allowing utilities to pass on costs to ratepayers, and clean energy standards are all likely necessary.

These issues need to be considered and resolved by stakeholders in the region, especially state and local governments, companies, and people involved in or directly affected by the development of CCUS.

The Commonwealth of Pennsylvania has taken several important initial steps to develop CCUS and related hydrogen and petrochemical industries. For example, the commonwealth has joined several multistate agreements and initiatives, such as the Midwest Regional Carbon Initiative and the Great Plains Institute, to reduce carbon emissions. These multistate collaborations are driving the development of CO_2 pipeline development and storage systems.[180]

First, we recommend creating a carbon management task force that includes representatives of companies; local, state, and federal governments; NGOs and foundations; universities and research labs; and the public. The task force should meet regularly to consider in detail the six key issues identified above and related issues; to negotiate specific proposals to resolve these issues, including proposed rules and legislation; and to present plans for regional and state development of CCUS to the governor and legislative leaders of the State of Pennsylvania.

Second, we recommend that the Pennsylvania Department of Environmental Protection, the Pennsylvania Department of Conservation and Natural Resources, and the National Energy Technology Laboratory collaborate on the development of at least three region-wide proposals that focus on siting of carbon dioxide pipelines and storage facilities.

Third, we recommend that the Commonwealth of Pennsylvania conduct a series of public engagements to learn what sort of carbon transport and storage developments people in the region as a whole want and what their concerns are. One such model is the deliberative polling used by the Texas Public Utility Commission in the late 1990s when planning their electricity development.[181] Public input should guide decisions about the scale and location of developments, monitoring and enforcement of environmental impact of CO_2 and hydrogen infrastructure, and safety and liability.

A final critical issue is who pays for and who owns CCUS infrastructure. There are many possible models, from complete public finance and management to complete private finance and management, and there are examples of each currently operating in the United States.[182] It is likely that there will need to be a public-private partnership for the development of pipelines and storage facilities. An immediate, practical difficulty for Southwest Pennsylvania, and Central Appalachia generally, is that there has been little or no private development in carbon transportation and storage. Public financing and management may be necessary to jump-start the development of CCUS in Southwest Pennsylvania and to achieve economies of scale. The carbon management task force should propose a financing and management model that works for this region.

Conclusion

By all accounts, the economic opportunities for Southwest Pennsylvania created by the development of Marcellus natural gas will continue to grow for the next 5 to 10 years. All scenarios considered by the Roosevelt Project and by other studies predict increases in gas production in the region in the near term.

Beyond that time, the trajectory for the region's energy and industrial sectors is less clear. These sectors are highly dependent on other states' policies. Most of the natural gas produced in the region is exported to other states, including New York, New Jersey, Ohio, and Maryland. If other states adopt low-carbon requirements or develop alternative energy sources, the demand for Pennsylvania natural gas will fall. That is precisely what drives the pessimistic forecasts of many models of the future energy industry in the state, including the REMI forecast of the Roosevelt Project.

Carbon capture and hydrogen offer southwest Pennsylvania two extremely promising pathways for the long-term development of fossil fuel resources in line with increasing global demand for low-carbon fuels and products. The region has the opportunity to create an innovation hub that will foster entirely new industries around CCUS and hydrogen production. Setting a new course for the development of natural gas and coal use in Pennsylvania will take foresight, planning, and investment, and those efforts will need to begin soon for the region's fossil fuels to remain competitive in a carbon-constrained world.

Profile: Kevin Snider and Penn State New Kensington

Kevin Snider came to New Kensington—New Ken, as it is affectionately called—to take on running a satellite campus of Penn State University. However, he really chose to relocate because he saw New Ken as a place where he could make an impact. Dr. Snider isn't from the Pittsburgh area, or even from Appalachia. He got his PhD in political science from American University in Washington, D.C., where he became an expert on U.S. foreign policy. He followed a path into academic administration, directing a research institute at Indiana State University and eventually becoming chief of staff to the president.

Terre Haute, Indiana, had long-standing tensions between the town and the university. The city was in decline, and the university seemed to be in its own bubble, with expanding enrollment and growing revenues. Then the university moved its business school into a post office building that was soon to be closed. That development helped revitalize restaurants and shops in the neighborhood, and it opened the door to constructive engagement between the university and the city. This was Dr. Snider's "Aha!" moment.

New Kensington, Pennsylvania, was the birthplace of ALCOA Corporation. It is only a half hour down the Allegheny River from New Ken to downtown Pittsburgh, but Pittsburgh's renaissance in health care and tech has barely touched New Ken. When Dr. Snider arrived, the downtown was quiet, and block after block had boarded up and abandoned storefronts. The decline of the downtown wasn't the only obstacle. Students at Penn State New Ken work, on average, more than 30 hours a week. They have neither the time nor the resources to take their ideas and explore the entrepreneurial possibilities.

Dr. Snider's model focused on the place and the people. The key to rebuilding the downtown community was to build a model of engagement around the physical space, to get people to become emotionally, as well as financially, invested in the place. As in Terre Haute, he would move some of New Ken's activities into an abandoned building in the heart of New Ken. Partnering with the city, the county, the Appalachian Regional Commission, and other foundations, corporations, governments, and organizations, he raised more than $1 million to develop the coworking and lab space, now called the Corner Launchbox. The success of the Corner helped him raise funds for capital improvements to surrounding buildings, with the vision of creating a New Kensington corridor of innovation.

In addition to the physical space, Dr. Snider sought to give New Ken's students the opportunity to explore their ideas and develop workable business plans. Ultimately, it would be the university's community of students and staff that would drive the revitalization, not with their money or labor but with their ideas and innovations. Support from the Chambers of Commerce and Westmoreland County, as well as others, provided the funds to support programs in entrepreneurial development and coworking. Students would generate and refine their ideas, and the university would help nurture and fund them. The Launchbox wasn't just a piece of urban redevelopment; it was the place where people could prove new business ideas, such as applications in computing, sensors, and data analytics in specialty manufacturing. Those ideas would, in turn, lead to further local area development.

Penn State New Ken's latest project is the Digital Foundry, a state-of-the-art innovation and manufacturing lab. In collaboration with the Richard King Mellon Foundation, the Digital Foundry will serve as a digital makerspace for entrepreneurs and small to medium-sized manufacturing companies to receive training in the latest manufacturing equipment and software. Penn State students will have the chance to collaborate and learn alongside the companies about the latest technological advancements. The goal is twofold: to assist companies in the area and to equip students with 21st-century skills. Construction of the Foundry is expected to be finished in 2022, adding yet another revitalized space to the city's Main Street.

All of these efforts have proven incredibly successful for downtown New Kensington. However, it took many years of building relationships, meeting with stakeholders, developing plans, adjusting curricula, and raising funds to pull it off. New businesses are beginning to open in downtown New Ken, and long-time residents, many of whom were initially skeptical of yet another redevelopment plan, are enthusiastic.

Currently, Dr. Snider is working to scale up the New Ken model. This sort of program development is unusual for universities, colleges, and even technical schools. Building partnerships between communities and educational institutions takes consistent engagement, time, and patience. The New Ken experience shows how removing institutional barriers and working with communities toward shared goals can unlock a powerful driver for economic revitalization and innovation.

Chapter 5: Revitalizing Communities with Diversification in Clean Energy and Related Advanced Manufacturing

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Introduction

If 19th-century Pittsburgh industrialists George Westinghouse or Andrew Carnegie looked at southwestern Pennsylvania today, they would see a region that has led industrial booms in steel, coal, oil, nuclear power, and natural gas. The currently diversified economy is led by health care, but energy and manufacturing are significant. The region has the potential to leverage the adaptive capacity of its workforce, research and educational hubs, and entrepreneurial ecosystem to take advantage of the low-carbon transition that is underway.[183] Clean energy and related advanced manufacturing are the sectors that will be most directly affected by energy and environmental policies, so they are examined here. The clean energy sector will grow as low-carbon policies come online. The manufacturing sector is more complex. Much existing manufacturing, such as metals and petrochemicals, may be adversely affected by low-carbon policies, but other sectors, such as advanced and additive manufacturing, have potential to get a boost. How the region positions its energy and manufacturing bases as low-carbon priorities evolve remains to be seen. A key will be to prime the region's workforce expertise and supply chain strategically with the markets that are emerging.

This chapter focuses on the status, potential, and what may be needed for clean energy and related advanced manufacturing in the region for the next 30 years. For the purposes of this analysis, *clean energy* includes renewables, nuclear energy, grid modernization, efficiency, and weatherization. Related *clean and associated advanced manufacturing* includes traditional manufacturing or newer manufacturing that integrates less carbon-intensive processes and/or less inputs. The chapter begins with clean energy and is followed by related manufacturing.

Clean Energy

Solar Power

Solar power is booming in the United States, and the trends are no different in Pennsylvania.[184] In the last decade, installed solar power capacity increased nationally by an average annual rate of 42%, while within Pennsylvania, similar capacity grew by more than a factor of five from 2010 to 2020,[185] representing about 6% of the state's renewable electricity in 2019.[186] During this time, Allegheny County became a leading solar county for installations and installed capacity, as the market grew across the state.[187] Large retailers, including IKEA, Johnson and Johnson, and Crayola, as well as cultural-educational centers, such as the Philadelphia Eagles Stadium, are among local solar power adopters.[188] Penn State University, the University of Pittsburgh, and the city of Philadelphia now have power purchase agreements for solar power.[189] Farmers, including the Amish, are also notable among those adopting solar power.[190]

Closer inspection of Pennsylvania's solar market shows that nearly half of Regional Transmission Organization PJM's approval queue is solar projects.[191] Pennsylvania's solar industrial base also currently consists of 395 companies, with clusters in southwestern Pennsylvania and southeastern Pennsylvania, and jobs estimated at 4,310.[192] The industrial base appears to be comprehensive; however, there is not enough in-state labor to support a larger boom,[193] so a review and realignment of training programs is recommended.

Potential areas exist for repurposing with solar power, for instance, at retired power plant sites, where the power infrastructure ready for is "plug and play" use. To attract new investment, the Pennsylvania Department of Community and Economic Development has been developing playbooks to provide redevelopment assessments for former power plant sites.[194] The former Talen Coal Plant site in Sunbury is one example where a 300 MW solar project is being built.

In policy terms, at the state level, there is a net-metering program and solar renewable energy credits (SRECs).[195] There is also a limited solar carve-out of 0.5% with the Alternative Energy Portfolio Standards (AEPS). With the current AEPS legislation, a constructive policy step would be to increase the share of the carve-out, to be more in line potentially with other states. To date, Pennsylvania utility rules also do not allow community solar installations.[196] However, in March 2021, bipartisan state legislation was introduced to allow such projects.[197] Analysis by Pennsylvania State University indicates that new construction of community solar projects would generate roughly $1.8 billion in economic gains, create over $793 million in labor income, and support over 11,000 jobs in various sectors across the commonwealth. Once operational, these projects would annually generate about $83+ million in economic output and support 520 full-time jobs in Pennsylvania, plus an additional $574,260 in annual property tax collections for municipalities in 48 rural and urban counties.[198]

In September 2021, Pennsylvania cleared one of the final hurdles to join the Regional Greenhouse Gas Initiative (RGGI), a regional cap-and-trade system that sets a limit and utilizes a market for trading GHG emissions certificates.[199] Joining RGGI provides conditions that would allow low-carbon energy, like renewables and potentially nuclear, to thrive in Pennsylvania. However, the measure is challenged by political gridlock and what may be described as the favoring of the natural gas industry.

Beyond RGGI, Governor Wolf also announced one of the largest state government procurement commitments to solar energy as part of his GreenGov challenge. Pennsylvania will source 50% of the state government electricity from solar power (361,000 MWh/year; 191 MW); the project is expected to be operational by January 1, 2023.[200]

The above measures align with the federal policy support in 2021 by the Biden administration for 100% carbon-free power by 2035; a mandate for system modernization; R&D for demonstration; renewable tax credits/investment tax credits to attract investment in large transmission projects to electricity demand hubs (at least 20 GW of high-voltage capacity power lines), connecting regions with solar and wind resources to electricity demand hubs; and the removal of fossil fuel subsidies and tax incentives.[201] This support continues to take shape in the Infrastructure Investment and Jobs Act and the Reconciliation package.[202]

Wind Power

Similar to solar power, the wind power industry is broadly experiencing rapid growth globally and nationally. Despite the COVID-19 global pandemic, the global wind industry recorded its strongest year ever in 2020, with a record 93 GW of new capacity additions, equal to a 53% increase.[203] In the United States, wind power has grown by more than a factor of 50 between 2000 and 2020, to 338 billion kWh.[204] The United States is also home to one of the largest and fastest-growing wind markets in the world.[205]

Specific to Pennsylvania, the commonwealth has a manufacturing hub that includes 30 manufacturing facilities that are focused on components.[206] Pennsylvania also has an estimated 1,459 MW of wind power generation installed and 90 MW under construction.[207] At least 27 wind farms provide electricity to power nearly 350,000 Pennsylvania homes, with almost 3,000 people employed in the wind energy field.[208] Beyond Pennsylvania's existing base, there is potential within the commonwealth to expand its onshore wind market from the currently installed capacity of approximately 1,500 MW to 109,000 MW, in addition to targeting a much broader market in the eastern U.S. region.

If energy-related policy support for infrastructure and jobs is implemented, alongside additional policy for offshore wind (detailed below), a surge in wind power adoption is expected, particularly within the eastern United States. The commonwealth's wind industry and adjacent industries in steel, materials, and coatings are positioned to support such increased demand. Even if the in-state adoption remains flat, new expansion in the broader East Coast region and nationally allows Pennsylvania to export equipment, components, lubricants, and services to out-of-state customers.

Offshore Wind Deployment Potential: The United States is primed for considerable near-term development in offshore wind. Based on significant technical potential,[209] falling technology costs, energy demand linked to high population centers, plus limited onshore space, the East and West Coasts of the United States are recognized as key markets for growth.[210]

The region surrounding Pennsylvania has been actively engaged in developing offshore wind projects, including the Great Lakes region, which Pennsylvania borders.[211] Recognizing the enormous opportunity for jobs, industry, and clean energy, the Biden administration launched an ambitious plan to catalyze the nascent offshore wind industry with a goal to generate 30 GW of offshore wind by 2030. With it, the administration aims to streamline and accelerate permitting, invest in R&D, provide low-interest loans to industry, and fund changes to ports.[212] For the offshore wind market, Southwest Pennsylvania could leverage its capabilities in steelmaking and materials; deploy electrical experts; and produce components, materials, coatings, and lubricants. Joint ventures with already engaged companies, like many in New Jersey, would provide Pennsylvania industries an on-ramp to the market that has been developing for years. Pennsylvania workforce strategies should also leverage unions across the Eastern Seaboard states for reskilling and points of access.

Onshore Wind Deployment Potential: There is limited policy in place today to support wind power deployment in Pennsylvania. In terms of adoption targets, the AEPS (as noted with solar power) could be expanded. The most promising policy driver at the commonwealth level currently is entry into RGGI.

Looking back at an earlier wind power surge in Pennsylvania from 2005 to 2012, the state had engaged in targeted outreach to companies to site their facilities in-state. Today, this type of strategy would be advantageous to mobilize both local capabilities in manufacturing of wind technology components, materials, and lubricants and a local workforce to support the build-out in the regional markets. The region's union and technical capabilities could be leveraged in the anticipated regional and national wind build-out. If national/regional transmission modernization and expansion occur in connection with offshore wind and/or other infrastructure aims, Southwest Pennsylvania's unions and capabilities could enable such efforts.

Hydropower

As with solar and wind power, Pennsylvania is home to a hydropower hub. The state has two global manufacturers of hydroelectric equipment: Voith Hydro and Weir American Hydro,[213] and as of 2015, the commonwealth was a base for 250+ companies in the hydroelectric industry supply chain, accounting for over 5,000 jobs.[214] The locally based hydropower hub positions Pennsylvania to supply equipment for an increase in hydropower demand or modernization that may be driven by clean energy priorities. While most domestic hydropower expansion tapered off since the 1990s, prospective domestic capacity growth could occur with efficiency improvements at existing dams, the expansion of pumped hydro storage, and the installation of power-generating equipment at existing locks and dams that were constructed for other purposes (e.g., river navigation, flood control, etc.).[215]

Pennsylvania also has untapped potential for hydropower from its 83,000 miles of streams and rivers, as well as its existing infrastructure for industry and water treatment.[216] Currently, Pennsylvania has 892 MW of conventional hydropower and 1,583 MW of pumped storage hydropower capacity.[217] A 2014 DOE study by Oak Ridge National Lab found that Pennsylvania ranked sixth nationally in terms of hydropower potential, with an estimated 679 MW of untapped capacity available by using existing water control infrastructure.[218] Such projects include the Allegheny Lock and Dam No. 2, for which the University of Pittsburgh committed to purchasing 100% of power output.[219] Importantly, the above potential doesn't account for hydropower applications at municipal or privately owned dams, conduits, and other water features. It also does not include increases in efficiency and generating capacity at existing powered dams.

According to the Army Corps of Engineers and National Hydropower Association, there are 24 non-powered dams (used for non-electric purposes) in the Pittsburgh area alone, located along the three major rivers—the Allegheny, Monongahela, and Ohio Rivers—which had been estimated to have the potential to generate a total of 904 MW of hydropower capacity. Within this, approximately 520 MW is deemed economically feasible.[220]

Specific to Southwest Pennsylvania in 2021, Allegheny County and the University of Pittsburgh are committing to new hydropower. Allegheny County expects to buy roughly 40% of the electricity that is generated from a 17.8 MW plant that Rye Development will build at the Emsworth Locks and Dams on the Ohio River around Pittsburgh.[221] This reflects new hydropower on existing dam infrastructure. The University of Pittsburgh also plans to purchase all the power that will be produced by an 11 MW Rye plant planned for the Allegheny River near the Highland Park Bridge.[222] In total, Rye will develop 10 hydropower projects in the region.[223]

Nuclear Energy

Nuclear energy has played a critical role in the commonwealth's long-standing history as a technology leader. Pennsylvania is the home of the first commercial U.S. nuclear power plant, in Shippingport.[224] The Keystone State is also the headquarters for Westinghouse, a major global player in nuclear technology, which has been restructuring after emerging from bankruptcy. The company's strategic focus today centers on new builds with the AP1000 design and commercializing the eVinci microreactor design. Westinghouse was recently also listed as a DOE contract vendor, among a pool of vendors selected to support deactivation, decommissioning, and removal services for a 10-year period and a maximum award value of $3 billion.[225]

Looking beyond its first commercial nuclear plant and Westinghouse, the Pennsylvania nuclear ecosystem consists of key actors from national labs and academia. It is home to the Bettis Atomic Power Lab/Nuclear Naval Lab, a U.S. leader in creating the nuclear navy. In addition, Penn State has one of the earliest nuclear engineering programs in the country,[226] supporting the workforce needs of utilities, national labs, and the broader industry, with recent programming adapted to include safeguards, nuclear medicine, etc.

In March 2021, nuclear generation was the second-largest fuel in Pennsylvania's electricity mix at 33% of the total (Appendix). Despite a strong track record for nuclear energy, Pennsylvania has been experiencing, along with other states, early retirement of nuclear plants that are based within competitive markets. Such plants are being shut down ahead of the end of their licensed life because relatively low-cost natural gas and increasingly competitive renewables (without subsidies) are outcompeting nuclear energy.[227]

To some observers,[228] the nuclear industry in Pennsylvania is riding out a downturn, tied in part to the premature closure of Three Mile Island (TMI) Unit 1 and a national slowdown of nuclear adoption. The Pennsylvania nuclear industry sought state support with zero-emission credits (ZECs), similar to ones used in New York and Illinois, to value the stable and low-carbon baseload power that nuclear energy supplies. Pennsylvania's decision to pass on the ZEC support means the industry is functioning, but below the radar.

Despite the downturn, there are signs of traction for nuclear energy in new applications and research and development. Bitcoin mining, for example, is an industrial application that is emerging in Pennsylvania in connection to nuclear energy. Joint ventures are being formed between cryptocurrency companies and nuclear plant owners to provide electricity that is necessary to run the energy-intensive computer centers that mine the virtual currency.[229] Integrated nuclear systems are also receiving attention for applications, such as with hydrogen production, utilization, and storage.[230] Exelon, for example—the nation's largest nuclear power generator, with plants in Pennsylvania and other states—was awarded $7.2 million in partnership with Nel Hydrogen to demonstrate an integrated facility at an existing nuclear plant site.[231] Beyond cryptocurrency mining and hydrogen production, an international competition is underway to commercialize advanced nuclear technology with small modular reactor (SMR) and microreactor designs.[232] Pittsburgh-headquartered Westinghouse has one of the designs to watch in this potentially disruptive playing field. In 2020, Westinghouse was awarded $9.3 million by the DOE Advanced Reactor Demonstration Program to advance eVinci's design of a heat-pipe-cooled microreactor to support demonstration by 2024 and to develop an economically viable refueling process, among other factors.[233]

A development of relevance to Pennsylvania's nuclear industry may be seen in coal-rich Wyoming. Like Southwest Pennsylvania, Wyoming is a state that is encountering challenges with declines in coal mining. In November 2021, Wyoming announced that it would site a demonstration project for TerraPower's

SMR design in Kemmerer, Wyoming, at a former coal plant.[234] Terrapower was awarded $80 million in initial funding by the DOE in October 2020 to construct and demonstrate its advanced nuclear reactor design.[235] Pennsylvania, with its existing nuclear hub and history, may diversify its nuclear technology activity with SMR/microreactor demonstration.

In policy terms, Pennsylvania passed on support of the local nuclear industry with zero-emission credits, yet if the commonwealth joins RGGI, the remaining eight nuclear plants may be left in operation. In fact, the announced closure of the twin-unit 1,872 MW Beaver Valley Nuclear Power Station in Shippingport, Pennsylvania, that employs 1,000 people was reversed by Energy Harbor Corporation when Governor Wolf announced his intention for Pennsylvania to join RGGI.[236] This industry and market are by no means written off but are ones to watch.

Bioenergy

Pennsylvania produces several forms of bioenergy: biomass- and biogas-based combustion for heat and power production, as well as biofuels for transport. As a state with agriculture as a cornerstone of its economy,[237] Pennsylvania's production and use of bioenergy leverages its agricultural strengths.

Pennsylvania ranks among the top states for electricity generated from biomass.[238] Pennsylvania also ranks ninth for biogas production potential, up to 45.54 billion cubic feet of renewable methane from biogas each year. For the period from 2000 to 2018, Pennsylvania biogas production increased by a factor of eight.[239] Biogas is produced with anaerobic digesters at dairy, poultry, and swine farms; at water resource recovery facilities; with food scrap systems; and with gas at landfills where flaring is done. [240] Penn State was recently awarded a U.S. Department of Agriculture (USDA) grant with Iowa State to conduct research on ways to optimize this agriculture-energy process.[241] In Southwest Pennsylvania, biogas production occurs on farms. As is discussed in a later section on urban-rural considerations, there is potential for expansion in biogas production.

Specific to its biofuels profile, Pennsylvania's single ethanol production plant is the largest on the East Coast, with a capacity of about 128 million gallons per year.[242] As of May 29, 2021, Pennsylvania has 1 biodiesel fueling station (20% biodiesel and above) and 146 E85 (85% ethanol) fueling stations.[243] The commonwealth ranks sixth in annual fuel ethanol consumption: 488 million gallons. [244] Within Pennsylvania, ethanol consumption increased by a factor of 35 from 2000 to 2018, primarily driven by the ethanol mandate provision in the Energy Independence and Security Act of 2007.[245] Pennsylvania also has two biodiesel manufacturing plants that can produce 90 million gallons annually, and it is the 11th-largest biodiesel-consuming state at nearly 40 million gallons a year.[246]

Specific to policies and research, the commonwealth has measures in place to encourage bioenergy development. It has blending mandates for biodiesel and cellulosic ethanol based on specific fuel production attainment schedules; an alternative fuel tax; and an alternative fuels incentive grant program.[247] In the Pittsburgh region, drivers in the summer must use motor gasoline that has lower evaporative emissions, which is favorable for biofuels.[248] Specific to industrial and university research, Erie-based biodiesel company Hero BX has invested in Penn State's Advanced Manufacturing and Innovation Center for a biofuels lab.[249] As Pennsylvanian ethanol imports have been increasing, farmers in Southwest Pennsylvania may have the potential to scale their output for biofuels production.

Hydrogen

As has been discussed earlier,[250] hydrogen production is a potential game changer, especially for hard-to-decarbonize industries. Whether the aim is to reduce emissions associated with hydrogen production in existing applications or to introduce hydrogen as an energy carrier or industrial feedstock in new applications, hydrogen can be produced from fossil fuel (blue hydrogen, if done with carbon capture and sequestration), renewables (green hydrogen), and nuclear energy (pink hydrogen).

In 2021, the first green hydrogen plant will be built in Pennsylvania's Lancaster County on the Susquehanna River.[251] Plug Power is partnering with dam operator Brookfield Renewable Partners to use power from hydroelectricity and Susquehanna River water to produce 15 metric tons of liquid hydrogen per day. This is reportedly enough to power 1,500 heavy-duty trucks. In line with Penn State University's Hydrogen Energy Center and the above activity, Pennsylvania has elements for becoming a hydrogen leader. It should competitively pursue proposed funding from the Biden administration for climate research, development, and demonstration that includes hydrogen. With such funding, Southwest Pennsylvania could engage in production of hydrogen by leveraging hydropower or nuclear power in the region. More broadly, Pennsylvania could leverage its nuclear, hydrogen, combined heat and power, and steelmaking (discussed below) capabilities to test and optimize an integrated system of low-carbon steel, clean energy, and related co-benefits.

Grid Modernization and Build-Out

By 2030, the United States may require between $30–90 billion in new investment for grid robustness, flexibility, and resilience and $200–600 by 2050, according to a Brattle Group study.[252] Specific to Pennsylvania and the broader PJM power market, modernizing the grid is increasingly necessary as transmission equipment continues to age. As of 2019, two-thirds of transmission is more than 40 years old, over one-third is more than 50 years old, and some local equipment approaches 90 years old.[253] Modernization is made more urgent by extreme weather and increased penetration of electric vehicles (EVs) and renewable energy sources. [254] To that end, PJM has initiatives designed to enhance reliability and cost-effectiveness. PJM is planning for the connection of microgrids, distributed energy resources, and offshore wind generation, reporting that $6.4 billion in onshore grid upgrades will be required to accommodate the planned 15.6 GW of offshore wind projects. [255] PJM also plans to increase charging infrastructure for the expected rollout of EVs in the next 5–10 years.[256] With such build-outs, modernization, and/or upgrades, opportunities exist for Pennsylvania and its southwestern region in the production of the grid infrastructure materials, as well as the construction and servicing of the grid.

Efficiency, Weatherization, ENERGY STAR, HVAC, and Geothermal Heating

Additional clean energy potential exists with efficiency and associated work in ENERGY STAR products; weatherization; heating, ventilation and air conditioning (HVAC); as well as geothermal heating.[257] Prior to the onset of the pandemic, energy efficiency was the fastest-growing job sector in the U.S. energy industry, accounting for nearly half of all new energy industry jobs in 2018.[258] Trends in Pennsylvania align with this tendency, with 10% growth in energy efficiency jobs between 2016 and 2018. In the commonwealth, 14% of all construction jobs are involved in energy efficiency. The majority of Pennsylvania's nearly 69,000 energy efficiency jobs fall into servicing tied to HVAC (34,994), ENERGY STAR appliances and efficient lighting (14,286), and building materials and insulation (13,105).[259] Primary types of efficiency jobs in Pennsylvania include energy auditors, retrofit installer technicians, crew leaders who manage, and quality control inspectors, among others.[260] For the 13 counties in Southwest Pennsylvania, energy efficiency represented over 16,100 jobs in 2019.[261] Specific to the ENERGY STAR program that is sponsored by the U.S. government, Pennsylvania has more than 519 businesses and organizations participating, including a manufacturing hub with 81 manufacturers.[262] In Southwest Pennsylvania, this area had nearly 2,350 jobs in 2019.[263] As demand for these products increases, nationally and/or within the state, more job opportunities are expected. The HVAC field includes installation, servicing, and repair for residential, commercial, and industrial buildings. In 2019, traditional HVAC work had roughly 4,635 jobs in Southwest Pennsylvania. This is seen as a long-term area of service need, with low entry barriers and flexibility in which to train and work.

Another key area of clean energy build-out is geothermal heating. Geothermal energy has potential to be tapped in Pennsylvania for direct heating and heat-pumping systems.[264] Geothermal resources can be utilized for newer and redeveloped residential and commercial buildings, as well as campuses, to heat or cool a building or water without burning any fuel or releasing emissions. Large-scale geothermal heat-based systems have been installed in the commonwealth to replace campus district heating.[265] The installation of geothermal heat systems or pumps is done generally by skilled contractors who could also work in HVAC systems, weatherization, and other forms of energy efficiency. This clean and efficient heat presents another flexible job track, especially when done with efficiency or HVAC work.

Rural-Urban Considerations

Among the 13 counties of this study, Allegheny, Beaver, and Westmoreland are classified as urban, based on population density, with the remaining 10 counties being rural, namely Armstrong, Butler, Cambria, Clarion, Fayette, Greene, Indiana, Lawrence, Somerset, and Washington.[266] This report recognizes that decarbonization and other changes in the regional economy are affecting urban and rural communities differently. Among the differences, the urban counties appear to have diversified more than the rural counties in recent years.[267] This report nonetheless sees opportunity for both types of communities. Rural counties can be sites of innovation to build out energy co-production on underutilized farmland. This can be done with solar and wind energy, geothermal heating, biofuel feedstock production, and biogas from farm animal methane, based on optimal leveraging of area natural resources. Urban counties, in turn, are seen as having greater development opportunities with municipal gas, green roofs, modernization and decarbonization of public transport, hydropower and solar energy in areas with good resources, and integrated energy systems on campuses. Both types of counties can benefit from improved building efficiencies and weatherization.

Outlooks: *Near to medium term (1 to 10 years):* Looking at clean energy jobs in the near term, two recent studies (2020–21) of the state's clean energy industry and workforce identified important insights:[268]

- Pennsylvania is a strong manufacturing hub for wind energy technology and ENERGY STAR products;

- Eight out of ten Pennsylvanian clean energy employers indicated challenges finding qualified applicants at the end of 2019. Reasons included the lack of applicant experience or industry-specific knowledge and employer competition for applicants.
- As the economy recovers from the pandemic, a share of employers has indicated that project development pipelines are behind. This presents an opportunity for greater hiring of skilled workers.

Seven clean energy jobs were identified as being high-growth occupations prior to the pandemic in Pennsylvania. Table 1 summarizes their wages, education/training, and common certifications.

Table 1: Clean energy workforce.[269]

Job	Wages	Entry-Level Education	On-the-Job Training	Common Certification
Assemblers or Fabricators	$12.00–24.41	High school diploma or equivalent	Moderate-term on-the-job training	Coil Processing FMA Certification, Soldering Certification, Electronics Assembly IPC Certification
Insulation Workers	$15.35–32.80	No formal educational credential	Short-term on-the-job training	EPA Asbestos Training, Energy Appraiser Certification
HVAC Mechanics, Installers, or Technicians	$18.90–39.42	Postsecondary nondegree award	Long-term on-the job training	EPA 608 Certification, Local Licensing, North American Technician Excellence Certification, HVAC Excellence Certification
Solar Photovoltaic Installers	$13.86–23.35	High school diploma or equivalent	Moderate-term on-the-job training	North American Board of Certified Energy Practitioners, Occupational Safety and Health Administration 10
Energy Auditors	$21.04–50.91	Bachelor's degree	None	Certified Energy Auditor (CEA), Certified Energy Manager (CEM), BPI Building Analyst
Electricians	$19.93–46.23	High school diploma or equivalent	Apprenticeship	Local Licensing, NABCEP
Plumbers, Pipefitters, and Steamfitters	$19.50–46.52	High school diploma or equivalent	Apprenticeship	n/a

These jobs all represent potential for near-term transitioning by the clean energy workforce that will be covered more fully in Chapter 6, on the workforce. In addition to the above positions, there is opportunity in the near to medium term for expansion of regional clean energy industry development with ramped manufacturing of wind and solar equipment components and materials for the regional market; manufacturing, installation, and servicing of grid infrastructure in the region; build-outs of in-state geothermal heating, efficiency, biogas, and biofuel production; plus replacement and adaptation of the retiring nuclear workforce.

Medium to longer term (6–30 years): Looking further ahead, the level of grid build-outs and upgrades, particularly for an emergent offshore wind market and expansion of electric vehicles, can be expected to be ongoing at least for the next 15 years. In addition, there is growth potential with advanced nuclear which will require lead time for a specialized nuclear workforce, particularly at the intersection of nuclear and cyber capabilities.[270] If Westinghouse is successful with its microreactor design, this could translate to new in-state manufacturing jobs.

What Is Needed to Leverage Diversification Opportunities in Cleaner Advanced Energy?

The implementation of federal policy for infrastructure, jobs, and clean energy and RGGI participation for Pennsylvania are likely to be two of the most important catalysts to spur in-state clean energy jobs and related advanced manufacturing. For on- and offshore wind, siting will also need to be addressed in order for the substantial and untapped opportunity to be leveraged. Moreover, passage of a state-level community solar law and expansion of the AEPS carve-outs are critical to allow new growth by interested customers. Finally, to close the skills gap for clean energy jobs, state public agencies, including the Department of Environmental Protection (DEP), the Department of Labor and Industry (DLI), and the Department of Community and Economic Development (DCED), should partner with regional leads, such as the Southwestern Pennsylvania Commission, Allegheny Conference on Community Development, and the Appalachian Regional Commission, to more fully align efforts on training/certification centers and programs that connect course offerings with skills demand, streamline the modes of access, and use a share of the stimulus and/or jobs funding to support members of the unemployed workforce with training that may have a net zero cost with capability gains.

Additional Diversification with Associated, Cleaner, and Advanced Manufacturing

Cleaner and advanced manufacturing presents another area for revitalizing Southwest Pennsylvania with traditional or newer manufacturing that integrates less carbon-intensive processes and/or less inputs.

Combined Heat and Power/Cogeneration

Combined heat and power/cogeneration holds considerable potential for added efficiencies in a diversifying economy. Pennsylvania's long-standing strengths in manufacturing are naturally suited for process streamlining and optimization by capturing industrial heat that is often a waste, then utilizing it through combined heat and power (CHP)/cogeneration. CHP-based companies are able to add a revenue stream by producing electricity for on-site use or to send to the grid. The Mid-Atlantic CHP Technical Assistance Partnership estimates that Pennsylvania has significant untapped potential in CHP relative to other regional states.[271] This finding is supported by estimates by the U.S. Department of Energy with further breakdowns of potential by manufacturing industries.[272] Southwest Pennsylvania's industrial, commercial, and institutional utilization of CHP is an area to evaluate more fully for economically viable energy co-production.

Advanced Manufacturing, Materials, and Robotics: The commonwealth also has a long history of steel and glass manufacturing.[273] Building on the region's strong manufacturing base, universities, government laboratories, and industry have been conducting research and investing in innovative technology to improve products, processes, and materials. In 2018, the Allegheny Conference reported that growth in advanced manufacturing is one of Pittsburgh's most significant innovation assets.[274] This area, combined with advanced materials and robotics, represents an avenue for specialization. The region is drawing attention and investment from large corporations, such as Dow, that are interested in leveraging local capabilities. As noted earlier, project sectors of relevance range from medical devices and energy to consumer goods.

Robotics: Robotics is a field that can be disruptive for industries from manufacturing to health care. The Boston Consulting Group estimated global growth potential for robotics from $15 to $67 billion in the period from 2010 to 2025.[275] As discussed earlier in this report, Pittsburgh is a pioneering hub for the robotics field with work done at Carnegie Mellon (CMU) and the University of Pittsburgh. The schools produce graduates with many of the skills the robotics industry demands in programming, project management, and engineering. Importantly, robotics expertise aligns well with the health care strengths of the region. Medical device production, for example, could be advanced with strategic adaptations.

Autonomous vehicles: The pool of engineering graduates in robotics and automation from CMU and the University of Pittsburgh has spilled over into autonomous vehicles. This emerging industrial cluster has drawn companies to invest in the region. Argo AI, Delphi, Aptiv, and Aurora (which recently acquired Uber's Advanced Technologies Group) are leading companies that are posting job openings.[276] To continue the momentum of this emergent cluster, Pittsburgh must retain and grow the talent pool it creates (*see* Venture Capital section). In 2019, Pittsburgh outlined its expectations for safe autonomous vehicle testing in its autonomous vehicle principles. This preemptive move may help Pittsburgh maintain its position at the vanguard of the industry, as incoming companies have a clear set of guidelines to follow and can be sure of their welcome in the region.[277] With development of autonomous vehicles, Southwest Pennsylvania could leverage overlapping strengths in manufacturing materials and components for electric vehicles; this is covered more fully in the Roosevelt Project Industrial Heartland case study.

Advanced Materials: Southwest Pennsylvania's capabilities in coatings, glass, materials, and petroleum lubricants position it to be a supplier of advanced components and lubricants for electric and autonomous vehicles, wind turbines, and solar panels. The traditional automotive region around Detroit will likely maintain its automotive manufacturing lead with EVs. Nonetheless, Pennsylvania is geographically well situated and has strong manufacturing capabilities to support the heartland's supply chain.

Additive Manufacturing: Additive manufacturing, which uses 3D printing to electronically design and produce physical objects with additions of material layers, is viewed as a disruptive field of development. The global additive manufacturing market has been projected to grow to $6 billion by 2022.[278] Pittsburgh has had recent investment in this area by Alcoa, CMU, University of Pittsburgh, and Robert Morris University. Before the pandemic, the Pittsburgh region evidenced some of the fastest job growth for this field (128% year-over-year growth vs. 9% for the United States). The majority of the jobs for the region skewed toward chemical engineering, reflecting prominent materials manufacturing with Alcoa, Arconic, and PPG. The Pittsburgh region produces not only finished products but also the underlying materials that drive the sector.

Low-Carbon Steel: Decarbonizing the industrial sector is in line with broadly increased climate mitigation ambition and targets. Steel, iron, cement, and chemicals manufacturing are some of the most challenging areas to decarbonize.[279] Steelmaking is a long-standing expertise of Southwest Pennsylvania, so it is the primary focus here.

Recent analysis of decarbonization in steelmaking indicates that integrating CCS or CCU (carbon capture and utilization) technology into blast furnaces may add roughly $122 (€100) per ton for crude steel, and hydrogen-based steel production could cost roughly $207 (€170) per ton of crude steel.[280] Pennsylvania has not yet made such investments, though there is stated interest in cleaner steel.[281]

For the steel industry in the United States, the best pathway to decarbonization may be improvements in sorting and collection of scrap metal, combined with renewable energy–powered electric arc furnaces. In theory, steel is 100% recyclable, but scrap metal is often found with contaminants that are severely detrimental to material performance. The industry would be well served in both economic and environmental benefits by improvements in the pipeline for clean, high-quality scrap metal.

Another option could leverage advanced nuclear technology, which is naturally suited for extremely high temperatures and is being developed for new industrial applications, like energy-intensive sectors.[282] As indicated earlier, Pennsylvania has key capabilities to test and demonstrate clean and advanced energy and manufacturing with integrated energy systems that include nuclear, hydrogen, CHP, and low-carbon steel. Nuclear engineering experts at Penn State and the University of Pittsburgh could partner with industry and CMU experts in iron and steelmaking to develop this opportunity.

Specific to Southwest Pennsylvania, the region has a unique opportunity for technology leadership in low-carbon steel. U.S. Steel, which is headquartered in Pittsburgh, committed to leading steel and steel manufacturing to a sustainable future with a target to reduce greenhouse gas emissions intensity by 20% by 2030 versus 2018 baseline levels.[283] In June 2021, U.S. Steel also announced a collaboration with Equinor to explore potential opportunities with CCS and hydrogen development in the Pennsylvania, Ohio, and West Virginia region.[284] With the company's scale of operations, it is a primary player in the region. The Biden administration also proposed creating a climate research agency with goals that include "decarbonizing industrial heat needed to make steel, concrete, and chemicals."[285] Research funding support for universities or university-industry partnerships could help technology experts in the Pittsburgh area identify and test scalable, clean steelmaking processes. Steel suppliers and producers in the Association for Iron and Steel Technology (AIST) are already moving to create a committee dedicated to understanding the pathways toward decarbonization for the industry as a whole. Similar shifts toward prioritizing decarbonization can be seen in the aluminum industry (its biggest player is Alcoa, also headquartered in Pittsburgh).

A Challenge for Pittsburgh: Labs, Incubators, and Venture Capital: The Pittsburgh region has a mixed outlook for new advanced manufacturing. The city is well positioned with universities, producing a talented workforce. Relevant labs and incubators, such as U-PARC @ Pitt and CMU Hazelwood Green, mentioned earlier in the report, foster the innovation system. Resources are also relatively abundant. Yet there is a venture capital problem. Ample funding exists for ideas. However, the talented graduates often leave the state for other regions, thereby creating a gap between the early ideas and the supply chain. Autonomous vehicle sensors illustrate this point: the technology was invented at CMU, but it is now being produced elsewhere. This is a challenge for Pittsburgh that may not have a simple solution. Nonetheless, it is part of the diversification playing field that may shape the economy.

Outlooks for Cleaner and Advanced Manufacturing:

Near term: Looking ahead for the near term, CHP presents one of the only mature technology paths for clean and advanced manufacturing in the region. Additive manufacturing appears to be a promising disruptive path.

Mid to longer term: The EV supply chain, autonomous vehicles, and low-carbon steel are areas to watch. If CCUS is scaled for the fossil fuel industry, carbon management could also be integrated into traditional manufacturing to sustain in the decarbonized economy. If done in a way that innovates the process, the companies could lead nationally or internationally with products and processes that serve an increasingly carbon-conscious business environment.

Clean Energy and Associated Advanced Manufacturing Recommendations

Looking across the prospects for clean energy and associated advanced manufacturing in southwestern Pennsylvania, the **region** would benefit from a considerably more cohesive strategy that pools the resources as well as the expertise of the Allegheny Conference, the Southwestern Pennsylvania Commission, and the Appalachian Regional Commission. The focus of this strategy should be to amplify and more fully connect reskilling with prime employer needs in high-growth areas, while also bringing new visibility to local strengths. At the **commonwealth** level, initiatives could be backed by state agencies, including DEP, DCEP, and DLI, in a more integrative fashion with respect to attracting regional investment and closing the skills gap. Second, joining RGGI and possibly implementing a more robust clean energy standard could foster new growth in renewables, nuclear, hydrogen, clean steel, and CHP. Updating the AEPS with an increased carve-out for renewables would strengthen the local business playing field for these industries. Passing enabling legislation for community solar would also allow interested customers to act in a new market. Similar legislation to clarify wind siting would broaden promising local opportunities. At the **federal** level, the passage of the Infrastructure Investment and Jobs Act and potential passage of the Reconciliation package with measures to support transmission development and clean energy, as well as to extend the 48C Advanced Energy Manufacturing Credit, taking special account of rural communities, has the potential to catalyze nearly all options covered in this diversification section. Finally, added policy support and cross-jurisdictional streamlining for transmission build-out, especially for offshore wind, would enable a major regional market to emerge and Pennsylvania to engage through its supply chain and grid service jobs.

Profile: Betsy McIntyre and the Tri-State Energy and Advanced Manufacturing Consortium

The Tri-State Energy and Advanced Manufacturing (TEAM) Consortium is a public-private partnership that helps provide accessible pathways to jobs in energy and advanced manufacturing in Ohio, Pennsylvania, and West Virginia. The organization was founded by a group of regional leaders with the purpose of addressing the mismatch between the growing number of jobs in these industries and the existing skills and training of area residents. The group found that workers in the region were unsure of how to access education and training to better position themselves for well-paying jobs.

The Consortium developed a partnership-based model to connect companies with local workers and educational institutions in order to (1) communicate what knowledge and skills employers need for in-demand occupations, (2) share this information in a timely way with educational and training partners, (3) deliver relevant curricula across state and institutional boundaries, and (4) connect students and trainees with internships, apprenticeships, and jobs. This partnership-based model overcomes some of the challenges associated with workforce development, including how to communicate across various stakeholders, how to certify that training meets occupational demands, and how to ensure that workers who invest in training will find gainful employment in the end. TEAM's website even includes a search page where job seekers can explore employment opportunities in the tri-state region based on industry, education or training requirements, and starting wages, providing potential employees with essential information about what jobs are available and how to prepare for them. Participating educational institutions adopt a stackable credentials model that supports locational flexibility and customization to the needs of potential employers.

Today, the TEAM Consortium consists of an institutional network of 41 higher education institutions, 16 economic development partners, 11 workforce development boards, and dozens of companies of all sizes. The group has been co-chaired by the Community College of Beaver County and Chevron and will transition to new college and corporate co chairs at the annual meeting in October 2022. Financial support comes from partner institutions, as well as foundations and government agencies, such as the Claude Worthington Benedum Foundation and the Appalachian Regional Commission. TEAM's founding director, Betsy McIntyre, is committed to developing additional curricula and programming, expanding the network's reach, and continuing to raise awareness about jobs anticipated in a future clean energy transition. She speaks of the importance of "coopetition": encouraging groups that compete against each other to cooperate and achieve greater impact. The organization's model is a promising one for training the 21st century's energy workforce.

Chapter 6: The Region's Workforce in a Clean Energy Transition

Valerie Karplus, Kathy Araújo, Yiran He

A low-carbon energy transition will imply changes for the workforce of Southwest Pennsylvania in the coming decades. Individuals' employment choices reflect their unique histories, identities, aspirations, and contexts. This chapter discusses the composition of the region's present workforce and considers its relationship to activities that emit GHGs. It then considers how clean energy growth and economic diversification will affect jobs and wages.

Our analysis suggests a regional strategy that embraces multiple paths to deep decarbonization could create new jobs in clean energy and less energy-intensive economic activities. Low carbon pathways that rely on natural gas may result in less near-term disruption in the extractive and energy-intensive manufacturing industries, which are important sources of regional employment.

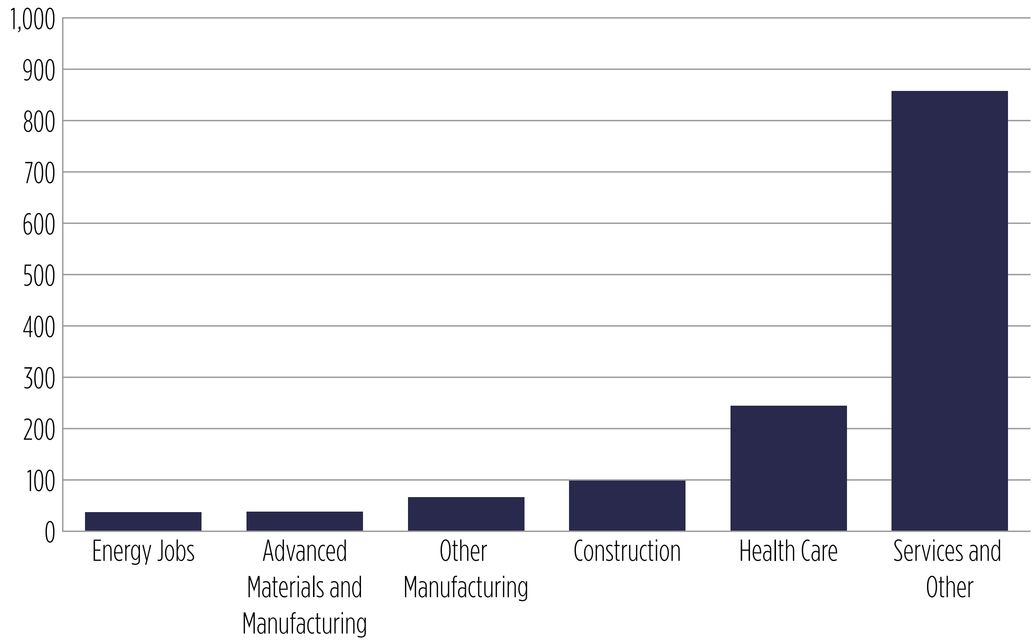
Key findings are summarized as follows:

1. **Coal mining and coal-fired power generation** are already feeling the effects of transition. Natural gas has displaced coal in the region's electric power sector for economic and environmental reasons. The transition path for these workers will differ by age cohort: older workers may prefer retirement, while younger workers may develop adjacent or new skills that lead to employment in other industries.
2. In **oil and (mainly) natural gas production**, job opportunities locally will depend on developments in the market for natural gas nationwide and globally. In the near term, natural gas demand may persist under climate policy as it substitutes for coal, which has a higher carbon content. Over the long term, natural gas use may persist, if any associated CO_2 emissions are captured and sequestered underground. Carbon capture and sequestration could create new jobs with skill sets akin to those required for traditional oil and natural gas-related jobs. Career pathways for oil and natural gas workers.
3. Efforts to **decarbonize energy intensive industries** via process changes that reduce energy requirements, increase reliance on recycled materials, or support the use of alternative fuels has the potential to create new jobs. The economic viability and future scale of an expanded chemicals industry in the region is highly uncertain, especially under climate constraints. Despite access to inexpensive natural gas feedstock, the region faces difficulty competing with the Gulf Coast and other locations. However, the region does have an opportunity to develop its comparative advantages in manufacturing. As discussed earlier in this report, low-carbon steel and industrial robotics are two options.
4. **Economic diversification** can generate new jobs that provide substitute or supplemental employment for workers likely to be most affected by the transition. These jobs will be especially needed in heavily rural or industrial counties. Most importantly, workers will need information on how they can access retraining programs and certainty that skills acquired will help them secure high-quality jobs in the future. These initiatives are also important to broaden opportunity for all workers, not just those in energy.

6.1 Today's workforce: Composition and trends

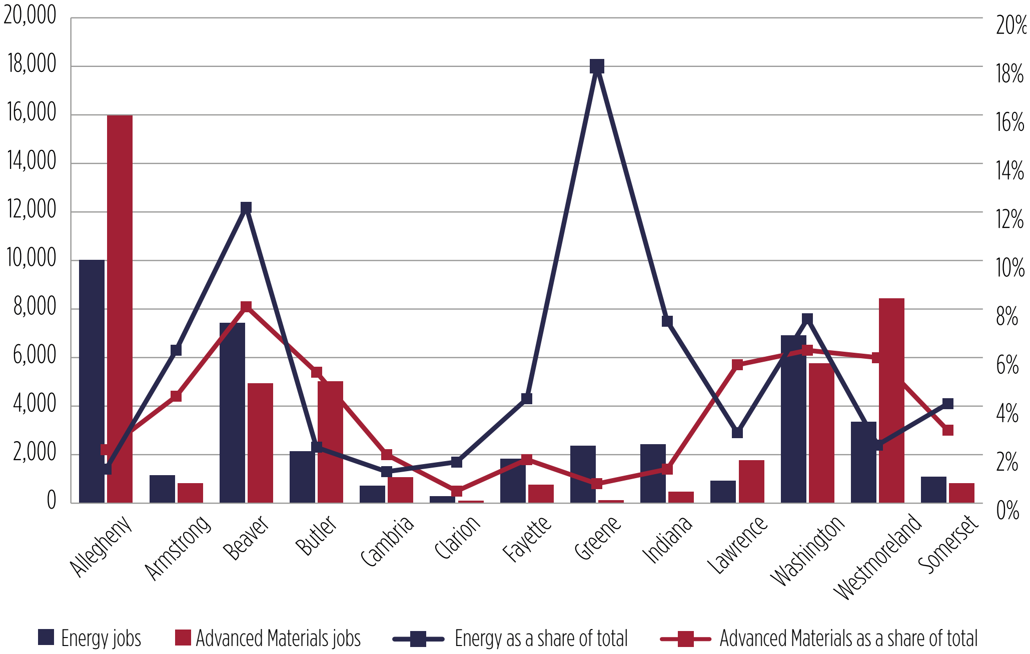
While numerically a small share of the workforce, fossil energy has a long history in the region and represents a culturally important contribution to the region's economy. A snapshot of the region's job composition in 2021 is shown in Figure 6.1.[286] Energy and manufacturing, which have the highest CO_2 intensity, account for relatively modest shares of the region's workforce as a whole. Manufacturing (the total of the advanced materials, advanced manufacturing, and other manufacturing categories) accounted for an additional 8% of total employment in 2021. Economic composition varies widely across counties. Health care accounted for the largest share of the region's employment in 2021in the 13 counties, ranging from 10-20% of total employment across counties. With the Services and Other category, "Technology, Innovation, and Support Services" and "Hospitality, Leisure, and Entertainment" accounted for the largest shares; the former accounted for a much higher share in Allegheny County (16%) relative to the other 12 counties (2.2%–11.5%), while the latter was broadly similar across counties (5.7%-9.2%). Technology and financial services jobs were most strongly represented in Allegheny County, largely reflecting Pittsburgh's diversified urban economy.

Figure 6.1: Jobs in the 13-county region in 2021. Data from the Pennsylvania On Target Dashboard and Emce Burning Glass, 2021.



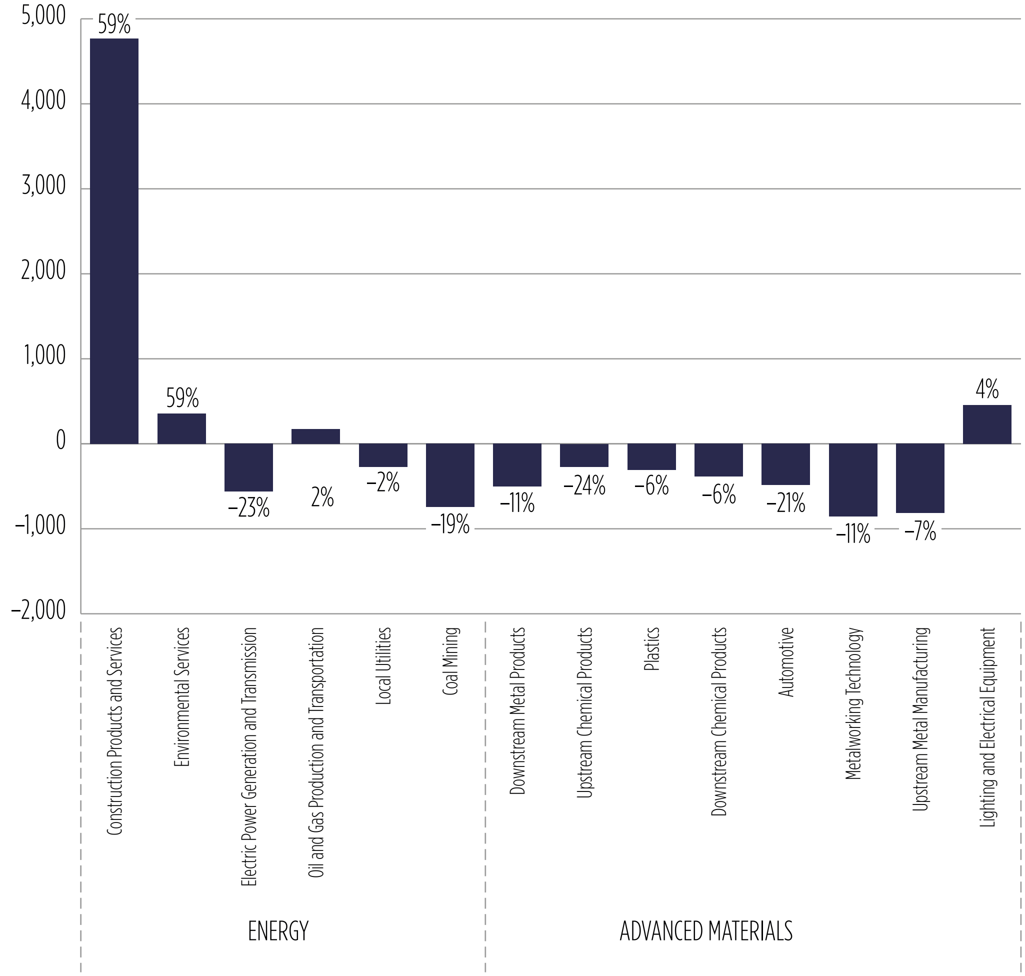
As shown in Figure 6.2, the share of jobs in the energy sector is highest in Greene, Beaver, Washington, and Indiana counties. Greene county's 18% share reflects mainly jobs in bituminous coal mining and natural gas production. Jobs in natural gas production are highest in Washington County. Jobs in the advanced materials sector, which includes the most energy- and carbon-intensive industrial activities, account for the highest employment shares in Beaver, , Washington, Westmoreland, and Lawrence Counties (see Figure 6.2). Beaver County's high energy-related employment is driven almost entirely by the ongoing construction of the Shell Petrochemicals Complex. Westmoreland County's high level and share of advanced materials jobs is due in large part to the manufacturing of plastics, metalworking, and lighting. Access to cost-competitive energy sources and proximity to related manufacturing activities support the continued operation of these industries as part of the region's energy and manufacturing clusters.

Figure 6.2: Total jobs (bars, left axis) in energy (blue) and advanced materials (orange) and shares of total (lines, right axis), by county, from the 13-county region in 2021. Data from the Pennsylvania On Target Dashboard and Emce Burning Glass, 2021.



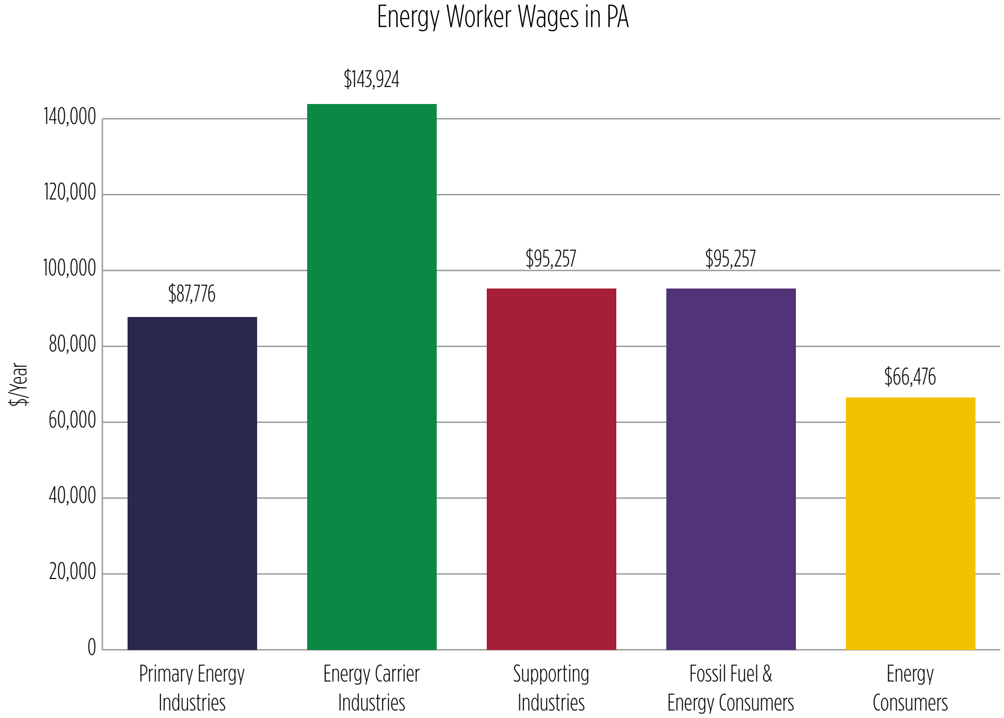
Labor market trends reflect a clean energy transition already underway. Figure 6.3 shows changes in jobs from 2016 to 2021 in the 13-county region for the industries within the broader categories of energy (left) and advanced materials (right). Electric power generation has been affected by the closure of coal power stations, with employment falling by 23%. Coal mining has likewise dropped by 19%, affected by reduced local and regional demand for coal power generation. The largest job growth by sector in both absolute and relative terms is the "Construction Products and Services," almost all of which is due to an increase in jobs in "Oil and Gas Pipeline Construction" in Beaver county, where the Shell Petrochemicals Complex is near completion and expected to become operational in the early 2020s. "Environmental Services" also experienced substantial growth (47% between 2016 and 2021) from a much smaller base.

Figure 6.3: Trends in jobs in energy and advanced materials in the 13-county region, 2016-2021. Data from the Pennsylvania On Target Dashboard and Emce Burning Glass, 2021.



According to state-level data on energy worker wages, summarized in Figure 6.3, levels of compensation for the energy and advanced manufacturing workforces are high relative to the state average (industry categories are described in Appendix 6.1). In particular, utility workers (in the energy carrier industries) are highly compensated, with average salaries in the $140,000s.

Figure 6.4: Average wages in 2018 for major categories of the energy workforce in Pennsylvania. Data are from the Bureau of Labor Statistics Quarterly Census of Employment and Wages (QCEW, 2019).[287] Categories are described in Appendix 6.1).



Impacts of the Transition on Fossil Energy Jobs

While transition pressure may be greatest for activities that directly emit GHGs, upstream (supplier), downstream (buyer), and adjacent or supporting industries will also be affected. For instance, the transition may increase the variable cost of downstream industries that rely on energy carriers, such as electricity and heat. Employers may respond by adjusting wages or reducing their workforces. Finally, industries, especially in services, that coexist alongside fossil energy activities will face new pressures. For example, if coal plants close, firms that exclusively serve coal-fired power plants (for instance, those that produce or service air pollution control equipment) will face pressure to downsize or pivot to new activities.

Coal Jobs

For coal power, the energy transition is already underway. Multiple plant closures have occurred in the region and its neighboring states (Warner, 2021).[288] Prior closures have occurred largely due to pressures unrelated to decarbonization, including lower natural gas prices, higher coal costs, and local environmental regulation.

For example, the 2013 closure of two FirstEnergy plants, the Hatfield's Ferry Power Station in Washington County and the Mitchell Power Station in Greene County, resulted in approximately 400 layoffs and had far-reaching effects on a range of jobs in industries that support the plant, including equipment maintenance and coal transport. Most of these job losses were concentrated in Washington, Greene, and Fayette Counties. While recent employment numbers by plant were not available, these facilities are estimated to employ a few thousand individuals and support several thousand jobs in related and supporting industries.

Our interviews revealed that it is important to communicate early and consistently around plant closures and to have transition assistance in place at the time a closure is announced. Many expressed that there is a general fear that jobs will disappear "overnight" as a result of the transition. Here, early, consistent, and supportive communication could go a long way.

Some counties face outsized exposure to potential future closures. Beaver and Indiana Counties have the largest shares of employment in the utility sector, at 2.7% each (see Appendix 4). The Conemaugh plant (2.0 GW), Homer City Generating Station (2.0 GW), and Seward plant (585 MW) are important local employers in Indiana County. Capacity factors of these facilities are already relatively low. The larger facilities (e.g., Conemaugh) could be candidates for carbon capture and storage, although substantial investment would be required to train workers and develop suitable systems. Given that the pressures that led to the region's earlier plant closures are likely to persist, and that the decarbonization imperative only adds to them, it will be important to plan well in advance to retrain or otherwise transition workers at these facilities.

Table 6.1: Coal plants operational or retired within the past ten years in the region, with coal source, ordered by operating status and capacity.

Coal Power Plant	Capacity	Status	Coal Source
Conemaugh Generating Station	1951 MW	Operational; retirement expected 2028 due to new wastewater rules	Bituminous; Bailey Mine (Consol), Lowry Mine (Rosebud mining), Cumberland Mine (Contura), Ernest Mine (Gulf), Mast Mine (P&N Coal), Fieg Bros (RFI), Tasara Strips (RFI), Laurel Sand and Stone Mine (Kacey Material Handeling), Mine No 1 (RFI), Hoover Job Mine (RFI)
Keystone Power Plant	1872 MW	Operational; retirement scheduled for 2028 due to new wastewater rules	Bituminous; Amerikohl Strips (Amerikohl), Bailey Mine (Consol), Mcclure strip (P&N Coal), Lowry Mine (Rosebud mining), Ben Hal Strips (Trade Energy), Cumberland Mine (Contura)
Homer City Station Plant	510 MW	Operational	Bituminous; Blacksville 2 Mine (Murray), Mellon 5 Mine (Unionvale Coal), Loveridge 22 Mine (Murray)
Seward Plant	585 MW	Operational	Waste coal; RES Mine 33
Colver Project Power Plant	118 MW	Operational; retirement planned but unclear	Waste coal; N.A.
Ebensburg Power Plant	58 MW	Operational	Waste coal; RES Mine 33
Bruce Mansfield Plant	2742 MW	Retired 2019	Bituminous; Marshall County Mine; Powhatan No. 6 Mine (Murray American Energy)
Hatsfields Ferry Power Station Plant	1728 MW	Retired 2013	N.A.
Cheswick Power Plant	637 MW	Retired 2022	Bituminous; Tunnel Ridge Mine (Murray); Shoemaker Mine (Alliance)
Elrama Power Plant	510 MW	Retired 2014	N.A.
Armstrong Power Station Plant	326 MW	Retired 2012	N.A.
Mitchell Power Station Plant	299 MW	Retired 2013	N.A.
AES Beaver Valley Partners Beaver Valley Plant	149 MW	Retired 2015	N.A.
Cambria Cogen Plant	98 MW	Retired 2019	Waste coal; PA coal refuse sites

Notes: Data from Global Energy Monitor (2022).[289]

Coal plant closures have and will continue to reduce the demand for coal, much of which is mined in the region or its neighboring states, with impacts on mining jobs. Understanding which jobs in a clean energy economy will have the closest skills matches for these workers, while maintaining or increasing workers' wages and benefits, will be important to supporting workers in coal mining and power generation.

Natural Gas Jobs

While natural gas extraction has been a major growth industry and source of public revenue, its role in generating benefits for local workers and their families is multifaceted. When it comes to jobs, Pennsylvania's Department of Labor and Industry estimates that natural gas extraction supports between 20,000 and 50,000 jobs in the state, including related and supporting industries. The 13 Southwest Pennsylvania counties account for a substantial fraction of this total. Interviews suggested that, while hard to classify precisely, many of these jobs are occupied by workers relocated from out of state, although supporting industries, such as transportation, largely employ local residents. In the 13-county region, around 10,000 jobs are associated with "Oil and Gas Production and Transportation" (Pennsylvania On Target Dashboard and Emce Burning Glass, 2021). This total includes a mixture of in-state and out-of-state workers. These jobs have already come under pressure as the economics of natural gas extraction in the region grows more challenging. A decade ago, studies claimed the industry would create 450,000 jobs in Ohio, Pennsylvania, and West Virginia, but only a fraction of these jobs have materialized. High GDP growth due to the expansion of shale gas development was not paralleled by a substantial expansion in employment; job growth in the counties involved barely kept pace with the state average. In 2019, CNX, EQT, and Range Resources—major players in natural gas extraction in the region—reportedly reduced their workforces by 400 jobs, and Chevron announced that it was exiting the region.[290]

The future viability of natural gas extraction in the region will depend on developments in domestic and international export markets. Achieving carbon neutrality globally by mid-century is expected to reduce demand for unabated uses of natural gas. Although wellhead costs of natural gas drilling in the Marcellus are low relative to other parts of the United States, the transport costs make it difficult to compete with other U.S. sources. Given this uncertainty, important questions include: what is the potential for natural gas jobs to be preserved with investments in hydrogen and carbon capture and sequestration? How can employers signal early and consistently around any potential closures or layoffs? How can local governments and nonprofits anticipate transition assistance and retraining needs?

Clean Energy Jobs

A low-carbon energy transition may generate new job opportunities, some of which may appeal to the region's fossil energy workforce. Our interviews suggested that it is important not to assume that clean energy jobs will displace fossil energy and related jobs. Instead, understanding the attractive attributes of existing fossil energy jobs (wages, benefits, flexibility) as well as worker skills and aspirations will be crucial to supporting today's workforce during the low carbon transition. We consider several categories of potential employment.

First, demand for construction jobs will increase for the duration of the low carbon transition—for example, to install renewable energy, to build pipelines and wells to facilitate carbon capture and storage, to retrofit buildings for efficiency, and to build electric charging (and perhaps eventually hydrogen refueling) stations. Construction jobs will almost certainly be required regardless of the technology pathways emphasized. While skills needed will depend to some extent on the type of project, major categories of construction skills—plumbers, electricians, surveyors, masons, iron workers, concrete specialists, roofers—are likely to be in demand. In Pennsylvania, the majority of construction jobs are unionized.

Second, there will be demand for the operation of clean energy assets (e.g. solar installations, CCS facilities) and monitoring of energy performance (e.g. building or industrial energy efficiency). These are likely to be service jobs that will add to the region's workforce, assuming that activities take place within the region. It is important to consider the workforce impacts of relying on energy sources imported from outside the region, as opportunities for the displaced workforce will need to be developed in adjacent or new activities.

An open question is: what share of the clean energy jobs are likely to be well-paying, unionized positions? Given that jobs vary widely in the existing and expected union presence in the industries involved, the answer to this question will depend largely on state policy and evolving requirements. Traditional energy jobs in the state have historically paid well and offered attractive benefits, whereas salaries for non-college-educated workers are comparatively lower in emerging clean-energy industries (e.g., for solar technicians or energy efficiency auditors).

Third, methane remediation (e.g., well-capping) and reclamation of abandoned minelands could provide an opportunity to expand clean energy employment in rural areas. A federal or state funded cleanup program could provide a viable near-term pathway for workers, especially those in mining and the power sector, to gain new skills in activities that require substantial skills in handswork and equipment operation. However, it should be noted that these jobs will largely depend on government support and therefore the focus should be on equipping workers for long-term employment in the clean energy economy. To the extent that public support can be deployed to address not just the trajectories of individual workers, but gaps in community services, social safety nets, and support networks, it will lay a broad foundation for easing transition challenges across the region and especially outside of the urban centers.

Beyond Energy Jobs

As discussed above, the health care, technology, and manufacturing sectors are important contributors to employment in the region. Jobs are concentrated in Allegheny County, but workers commute frequently from surrounding counties. Across these sectors, dynamics are very different: health care and technology businesses are growing, while manufacturing still accounts for a substantial share but is in decline. The result is an increasingly diversified economy, with skills requirements that differ substantially from the historically dominant industries. Helping workers from a wide variety of employment backgrounds and socioeconomic groups from urban as well as rural settings connect with opportunities in an increasingly diverse economy is important to realizing steady and long-term regional growth and community health.

Several waves of industrial transition and offshoring have dramatically transformed the region's, and especially Pittsburgh's, employment base. In 2019, the region's manufacturing employment reached its lowest level at 82,000 (7% of the total), a 78% decline from peak manufacturing employment of 382,000 in the 1950s. Today, the economy has migrated far from its traditional industrial roots, with the city of Pittsburgh gaining 26,000 positions in what has been dubbed the "super creative core." These are largely jobs in tech and corporate headquarters. Economic diversification has meant new bottlenecks to workforce development, with many interviews suggesting that managerial and professional skills, not technical skills, are most often in short supply.

Many have focused on the potential of a regional chemicals hub to create high-quality union jobs for local employees, including those who might be displaced from other sectors in a transition. However, the chemical industry will need to decarbonize, and existing facilities will need to invest in carbon capture and sequestration or purchase CO_2 offsets. A Shell ethylene cracker plant is proving an early test of the viability of the chemicals hub concept. Slated for completion in 2022, after delays related to COVID-19, the Shell cracker plant would emit 2.25 million tons of carbon dioxide, in addition to substantial local pollutants. It is projected to create 600 permanent jobs, in addition to near-term construction jobs, many of which are relatively high paying (e.g., in welding).

Economic diversification has the potential to provide new sources of livelihoods that do not depend on high-emitting activities and go beyond one-size-fits-all, "big" industry solutions. Within our 13-county region, Pittsburgh (Allegheny County) is an important example of how cooperation among foundations, universities, industry, and local government can broaden the economic base: health care and now tech/AI have grown as export-oriented manufacturing declined. This has contributed to a shift in the city's identity but has exposed tensions between those who see the city's future in industrial megaprojects (e.g., the Shell cracker plant) and those who envision it as a leading tech and medical hub.

An important challenge involves building collective momentum around a diverse mix of activities, which can be easier to do in the case of large projects with numerous, well-organized beneficiaries. Here, a viable path forward will need to resonate with individuals' economic and cultural identity. In the case of our 13 counties, this identity has historically involved fossil energy and the industrial growth it enabled. However, engaging communities in smaller and rural towns in reimagining and diversifying their economies will help them to take ownership and buffer the jobs impact of a low-carbon transition. At the same time, by broadening opportunities for the region's workforce, individual and community identity and price may evolve with it, as it has begun to do in Pittsburgh.

If transition can occur "in place" in the region's towns and rural areas, it could allow residents to continue living where they are from, which we found in our interviews was an important consideration for many. Diversification in rural areas is likely to look very different from urban examples. Our interviews reveal the importance of the informal economy, of being able to do "hands work," and of enabling entrepreneurial activities that connect with rural culture. Interviewees pointed out that one of the region's greatest strengths stems from the "values and work ethic" of prospective employees. Training programs that help candidates obtain managerial, professional, and leadership skills can combine with these pre-existing enablers to produce powerful examples of success. For instance, Solar Holler is a solar energy company that reflects its rural roots, from its name to its workforce to its market focus. The efforts of local entrepreneurs like Brandon Dennison, founder of Coalfield Development, can provide a model for strengthening rural communities and creating diverse employment possibilities at the same time.

Looking to the future, in our interviews, we heard that the region has an opportunity to build on its historical strength in manufacturing and combine this with its emerging strengths in the innovation economy. For instance, advanced robotics is one area where the region has the potential to become particularly strong; investments are already in place in the form of Hazelwood Green, local offices of large tech companies, and the computer science and engineering strengths of Carnegie Mellon University. Decarbonization of integrated steel production may offer another opportunity to combine a similarly diverse set of local strengths. Federal grant programs, public-private partnerships, and innovative financing arrangements could help to expand these activities to the point where they preserve or create new jobs and career paths anchored in the region.

Preparing the Workforce

Our interviews suggested that if governments and employers can anticipate workforce needs in a transition, work with employees to develop and adjust viable transition assistance plans, and consistently and effectively communicate to employees around implementation, it could help substantially to mitigate worker dislocation in a transition. Any transition assistance or retraining program should consider the diversity of situations involved: needs will differ depending on career stage and the degree to which a job category faces pressure in a transition. At the same time, any programs must integrate into the economic fabric of each community and county and their links to the region.

Table 2 shows examples of transition paths depending on the career stage of the worker and the GHG intensity of their respective industry at the outset of the transition. The table reveals that there is no one-size-fits-all approach to workforce transition in the region. Even within categories, options will hinge on GHG mitigation actions and will materialize over very different time scales.

When it comes to the existing workforce, a jobs gap could emerge in the near term if decarbonization leads to the displacement (noncreation) of jobs in the hydrocarbon-oriented sectors. For local workers involved in these sectors, there is a need for training options followed by relatively concrete opportunities. In Table 2, this challenge affects employers primarily in mid-career GHG-intensive and GHG-adjacent industries. It is here that training programs—for instance, those offered by regional community colleges—could usefully focus, in order to provide a bridge to careers with adjacent skills. Our interviews reveal that potential skills matches include remediation of emissions from oil and gas wells, jobs in HVAC and landscaping, and jobs in construction. An important open question is how to make these jobs attractive for employees, especially union workers, given that salary and worker protections may currently be less attractive for these activities.

Table 6.2: Interventions to strengthen regional workforce development as a function of worker career stage and GHG intensity of activities.

	GHG intensive	GHG adjacent	GHG independent
Early career	Training in "low-carbon fossil": emissions abatement, H_2, CCS	Training in remediation, HVAC, landscaping, etc./longer term in clean steel, clean energy manufacturing	Need incubators, venture financing, inclusion of rural areas
Mid-career	Retraining for "low-carbon fossil," shift to GHG adjacent	Reskilling to focus on remediation, HVAC, landscaping, etc.	Reskilling to focus on entrepreneurship, health care, gig economy
Late career	Retirement with generous severance	Mobility limited; focus on repurposing fossil-linked jobs	Opportunities for seniors: volunteering, arts and culture

The impact of plant closures on workers and communities varies depending on how the transition is handled. In past coal plant closures, targeted transition assistance has played an important role in connecting workers with retraining opportunities and the support needed (cost-of-living stipends, transportation, childcare, class materials, and housing) to take full advantage of the opportunities. Developing guidance on transitioning workforces and redeveloping coal plant sites is currently underway and has the potential to improve outcomes by learning from past transitions involving coal plant closures in the broader Appalachian region. A similar approach could be taken for employees of GHG-intensive manufacturing facilities (e.g., coking) and, as needed, for local employees in natural gas drilling.

Broadening the set of options for workers deemed to be "at-risk," including that with the growing knowledge economy and entrepreneurship, can help to reinforce the reality that the region's economy is diversifying. Further understanding the role that gig economy jobs, revenue streams to landowners (e.g., from natural gas extraction or wind farms), allocation of jobs within families, the informal economy, and combining jobs might play in shaping the possible paths to maintaining and growing household income will also be important to designing acceptable transition strategies.

Recommendations

Based on the observations developed in this chapter, we outline several recommendations to help the region's workforce transition:

Create a Council for Regional Career Transitions. Bring together representatives of large employers, unions, community colleges, and incubators in Southwest Pennsylvania and the tri-state region to support and guide the creation of a free skills-matching service for employees and trainees , bringing multiple existing and needed functions under a single umbrella. This service would provide information to employers on employee skills and goals, while at the same time helping employees to identify a broader range of future career paths that are compatible with an economy that is diversifying away from fossil fuels. Certificate and apprenticeship programs could be designed with a strong understanding of the skills of the existing workforce and emerging needs in a clean energy economy. Paths could also include options for holding multiple part-time jobs (which is common in rural areas) that together represent attractive compensation.

Develop Best Practices for Managing Career Transitions in Industries Facing Transition Pressure. Provide state assistance to employers to allow paid leave for new skills acquisition, with the support of federal grants or innovative funding mechanisms linked to climate policy.

Strengthen Entrepreneurship in Rural Areas. Expand mentorship and seed capital opportunities for rural entrepreneurs, those connected with both clean energy and broader economic diversification. Messaging should avoid a focus on remote concepts such as "decarbonization" and instead on the potential for workers to contribute to local community revitalization and building connections to the broader national and global economy. Broadband infrastructure expansion will be important to enable this integration.

Explore Opportunities at the Intersection of the Manufacturing and Knowledge Economy. Explore the potential to revitalize manufacturing (e.g., in high-quality green iron and steel) in the region, through a combination of additive methods and clean industries that can draw on historic strengths in manufacturing and emerging strengths in robotics, artificial intelligence, and health care.

Conclusion

The global transformation of energy systems presents both challenges and opportunities for Southwest Pennsylvania. The region's energy and manufacturing industries, which are driven primarily by coal and natural gas, account for 20% of domestic product and 10% of employment in the 13-county region. If there is a significant global reconfiguration of energy production, industrials, and manufacturing, as many now anticipate, demand for Southwest Pennsylvania's energy and manufacturing products may decline. The energy transition presents opportunities to develop entirely new industries around emerging energy and manufacturing technologies.

This report has examined ways that the Commonwealth of Pennsylvania and stakeholders in Southwest Pennsylvania can anticipate and adapt to potential changes in the energy sector. As coal, and later gas, are displaced in energy markets, many workers and communities will need to find new economic opportunities. Industrial, civic, and government leaders will need to pursue strategies that reposition the energy and manufacturing industries for the long run. Now is an ideal time to begin to set a new course for the energy and manufacturing sectors.

In the near term (5 to 10 years), the commonwealth should undertake a substantial environmental remediation program that focuses on well-capping, brownfields, and water contamination. Any effort to reduce the region's greenhouse gases will have to address the leakage from over 400,000 wells in Southwest Pennsylvania. Almost all of these wells and pipelines are legacy wells from a century and a half of gas exploration.

The commonwealth should stand up a substantial well-capping and well-monitoring program. Similarly large projects should target brownfield sites and water pollution, as these are major environmental and public health problems. These efforts will require the commonwealth to support workforce training programs, develop and enforce standards, and create incentives and commit resources to sustain a significant remediation program. Addressing well leakage, brownfields, and water contamination will help the commonwealth meet its environmental and climate goals and create significant employment in the region.

In the medium to long term (10 to 30 years), the commonwealth can reposition its energy and manufacturing sectors along two tracks.

The first track is to deploy carbon capture, utilization, and storage (CCUS) at region-wide scale in order to maintain the competitiveness of the region's gas and coal sectors and fossil-fuel-driven industrials and manufacturing. CCUS and hydrogen are game-changing technologies for fossil fuels. They have the potential to alter the way we use gas, coal, and oil from a system in which the fuels are combusted for energy and the waste is sent into the atmosphere and water into one in which the fuel is transformed into a low-carbon fuel—natural gas or coal with all or most of the greenhouse gases extracted—or into a new clean-burning fuel—hydrogen—that can be used for electricity, transportation, and industrials.

Quite apart from its potential for clean energy production, CCUS represents a substantial new industry for this region. As the world races to meet international carbon emissions targets, there is growing global demand for technologies and systems that can help companies reduce greenhouse gases from their existing power generation, industrial, and manufacturing processes. Southwest

Pennsylvania's political and industrial leaders should work with NETL and area research universities to establish a research-driven industrial hub for the development of CCUS technologies for energy and manufacturing.

A second track for the development of clean energy and manufacturing in Southwest Pennsylvania is to develop energy sources that have little or no carbon emissions, including wind, solar, and nuclear power, as well as energy efficiency and grid development. Surprisingly, efficiency and the grid account for many more jobs in the region than does fossil fuel extraction, and these sectors are growing quickly. There is an immediate need in the region for development of a workforce with skills specific to energy efficiency and grid employment.

The region has nascent wind and solar industries. Capturing the potential of these resources will require changing regulations, such as restrictions on community solar, and development of industrial-scale storage. Existing industries in the Pittsburgh area can supply these needs, including steel, glass, and coatings, and in recent years, they have attracted increasing numbers of firms working on these and other energy platforms.

In addition, the region has a significant nuclear power industry, along with substantial nuclear research capability. Nuclear power provides roughly 20% of the commonwealth's electricity, and this resource is predicted to be a steady presence in the electricity mix through 2050. As new nuclear technologies are beginning to be explored and developed,[291] the Pittsburgh area, home to Westinghouse and the nearby Naval Nuclear Lab/Bettis Atomic Power Lab, may experience a renaissance in the nuclear industry.

Finally, it should be stressed that Southwest Pennsylvania has a robust, diversified economy, with strengths in health care, education, tech, and finance, and emerging strengths in robotics, autonomous vehicles, artificial intelligence, and additive and advanced manufacturing. Energy and traditional manufacturing (including metals, petrochemicals, glass, and coatings) are a significant part of the industrial mix in the region. The strength of a diversified economy will make it possible for the region to adapt to a changing energy industry.

With these observations in mind, we have the following recommendations.

1. Establish a substantial remediation program with the objective of cutting greenhouse gas emissions from leaking wells in half within 10 years.

   The natural gas industry and the Commonwealth of Pennsylvania should develop standards for methane emissions and well leakage. The commonwealth and industry, working together, should develop a sufficiently well-financed program for well-capping to provide for remediation of legacy wells, as well as active wells. The commonwealth, working with industry and communities, should conduct an evaluation of environmental and other regulations that bear on remediation in order to streamline regulations and accelerate remediation efforts.

2. Develop a region-wide infrastructure for carbon capture and storage and, eventually, hydrogen at industrial scale.

   The Commonwealth of Pennsylvania, working with industry, research labs, communities, and other state governments, should plan and develop CO_2 pipeline and storage facilities with the aim of connecting to other carbon storage infrastructure being developed or planned in neighboring states. Over the next three years, the commonwealth, with NETL, industry, communities, and partners in other states (such as the Great Plains Institute and the Midwest Regional Carbon Initiative) should conduct comprehensive studies of carbon capture and storage and of hydrogen with the objective of proposing feasible CCUS and hydrogen infrastructure to develop at scale. The commonwealth should reach consensus on plans by establishing a task force of stakeholders that meets regularly to identify key issues and obstacles to CCUS and develop strategies for its implementation. Finally, the Department of Environmental Protection, working with the U.S. EPA, should develop standards for carbon capture and storage. The agency should have the power and staff to monitor facilities and level significant fines for leaks or other pollution. As part of this standard-setting effort, the Commonwealth of Pennsylvania should develop standards for low-carbon fuels and low-carbon products to aid in the commercialization of its energy and products manufactured in line with carbon reduction initiatives.

3. Establish a research-driven CCUS innovation hub in Southwest Pennsylvania.

   The U.S. Department of Energy should establish a carbon management program within the National Energy Technology Lab. The federal government should increase research funding for capture technologies, carbon utilization processes, and systems analysis for carbon storage. These investments should prioritize lowering the costs of carbon capture and deploying capture and storage technologies. This research hub should proceed in consultation with industry in order to develop technologies that feed directly into the energy, manufacturing, and industrial sectors in the region.

4. Develop a comprehensive approach to wind, solar, biofuels, nuclear power, and other energy sources in order to build a more diverse energy portfolio.

   One concern with the emerging energy picture of the region and the commonwealth as a whole is that it is projected to become increasingly dependent on natural gas. A more diversified energy sector would be more robust in relation to price changes, technology shifts, or supply disruptions. The Department of Environmental Protection should conduct a study to gauge the potential contribution of each of these energy sources and the regulatory obstacles to their deployment. The commonwealth should remove regulatory barriers to community solar and streamline regulations that slow the development of its wind industry.

5. Launch a workforce development initiative.

   Regional stakeholders should create a Regional Council for Career Transitions that regularly brings together large companies, unions, community colleges, employers, and other stakeholders to discuss the region's employment and workforce needs and identify successful models and programs. The Commonwealth of Pennsylvania should adapt workforce programs that align with the findings and recommendations of the regional council. The commonwealth should expand satellite campuses of Penn State University and community colleges and locate these capacity-building hubs of the education and training system in areas where there will be the greatest future need.

6. Invest in developing the capacity of local communities.

   Foundations and regional planning councils, such as the Appalachian Regional Commission and the Southwestern Pennsylvania Commission, should invest resources to build the physical capital and the human capital of communities throughout the region. Improve regional transportation networks to expand people's job opportunities; extend broadband infrastructure throughout the region to improve communication and create opportunities to work and learn remotely as well as to bridge the digital divide that isolates many communities. Invest in programs that help people understand how they can improve their own towns and neighborhoods.

Southwest Pennsylvania sits on a golden egg. It is not the trillions of cubic feet of natural gas in the Marcellus Shale. Rather, it is the incredible adaptive capacity of its communities. In past economic transitions, the region's communities—its civic organizations, government leaders, companies, universities, foundations, and other organizations—have come together to remake the region. Southwest Pennsylvania has reaped the reward: today it has a rich, diversified economy.

The lesson of past transitions is that, although it is tempting to seek the one key solution or the next big thing, strength is to be found in pursuing many different possibilities. There is not one single industry around which to build the region's future economy or even one way to transform the energy sector. We have offered what we see as the obvious opportunities for the creation of new clean energy and manufacturing sectors for Southwest Pennsylvania. In navigating the coming changes in energy and manufacturing, we encourage the region to continue its course of developing a wide range of opportunities to maintain a strong, diversified economy.

Note: Max Drickey and Rachel Reolfi provided excellent research assistance for chapter 6.

Appendix 1: List of People Interviewed

Last	First	Organization
Althoff	David	PA DEP Energy Programs Office
Anderson	Brian	National Energy Technology Laboratory
Anderson	Loren	Marcellus Shale Coalition
Ban	Heng	University of Pittsburgh
Blumsack	Erin	Penn State University
Blumsack	Seth	Penn State University
Bright	Hillary	Blue Green Alliance
Brinley	Denise	PA DCED
Burke	Brandon	Business Network for Offshore Wind
Campbell	Kerry	PA DEP Energy Programs Office
Carter	Kris	PA DCNR
Charlton	Alex	Exelon
Chen	Kevin	University of Pittsburgh
Conway	Tom	United Steelworkers
Dennison	Brandon	Coalfield Development
Deutch	John	Massachusetts Institute of Technology
Eichenbaum	Pam	Carnegie Mellon University
Fidler	Jacquie	CONSOL
Giovannitti	Jen	Benedum Foundation
Gohl	Earl	Appalachian Regional Commission
Gohn	Andrew	Clean Power/AWEA
Gould	Ross	Business Network for Offshore Wind
Harr	Heather	Reimagine Beaver County
Harstein	Roy	Responsible Energy Solutions
Hunt	Mary	Benedum Foundation
Kang	Mary	McGill University
Kelly-Pitou	Katrina	University of Pittsburgh
McIntyre	Elizabeth	TEAM Consortium
McQuade	Mike	Carnegie Mellon University
O’Brien	Kiera	Students for Carbon Dividends
Pelepko	Seth	PA DEP
Pillar	Sharon	PA Solar Center
Pistorius	Chris	Carnegie Mellon University
Place	Andrew	Clean Air Task Force
Plants	Luke	Plants & Goodwin, Inc.
Robertson	Kathy	Exelon
Rusco	Frank	U.S. Government Accountability Office
Schuldt	Rhonda	PSU New Ken/Synergos

Last	First	Organization
Siger	Rick	Carnegie Mellon University
Sinclair	Jessica	University of Pittsburgh
Smith	Phil	United Mine Workers of America
Smith	Zach	CONSOL
Snider	Kevin	PSU New Kensington
Stewart	Susan	Penn State University
Szybist	Mark	NRDC
Taylor	David	PA Manufacturers Association
Tedesco	Dominic	Marcellus Shale Coalition
Teeter	Valerie	Exelon
Tyree	Stephanie	WV Community Development Hub
Webler	Bryan	Carnegie Mellon University
Winfield	Cindy	Just Transition Foundation

Appendix 2: CCUS Calculations in Appalachian Pennsylvania

The purpose of this appendix is to describe the process for calculating the cost of a carbon capture and storage (CCS) system for industrial and power plants in the case study's 13-county region. Calculations in this analysis are based on estimates for the region and CCS plans for nearby states Ohio and West Virginia.

The calculations were divided into four steps: (1) identifying high-emitting plants that could be retrofitted with CCS, (2) estimating the cost of installing CCS on each plant type, (3) estimating the component of levelized cost of CO_2 abated associated with transporting CO_2, based on pipeline design capacity and distance to storage site, and (4) estimating storage cost based on storage capacity and geology. For each step, Equation 1 computes the levelized cost of CO_2 abated by comparing the NPV of a similar project with and without CCS, then dividing it by CO_2 reduced by that CCS project.[292]

Cost of CO_2 abated ($/t$CO_2$):

$$\frac{(\mathrm{NPV})_{\mathrm{low-C}} - (\mathrm{NPV})_{\mathrm{ref}}}{(\mathrm{tCO_2})_{\mathrm{ref}} - (\mathrm{tCO_2})_{\mathrm{low-C}}} \quad \text{(eq 1)}$$

The incremental NPV (change in NPV) of a CCS project was derived by rearranging Equation 1 so that the CO_2 reduced by CCS is multiplied by the cost of CO_2 abated. Equation 2 gives the change in NPV.

Incremental NPV ($):

$$\frac{\$}{\mathrm{tCO2}} \left[(\mathrm{tCO_2})_{\mathrm{ref}} - (\mathrm{tCO_2})_{\mathrm{low-C}}\right] \quad \text{(eq 2)}$$

The incremental NPV references plants that will have a carbon capture system retrofitted to the existing infrastructure.

Step 1: High-Emitting Plants

In this study, "high-emitting" is defined as any facility (industrial or electricity generation plant) emitting over 100,000 tons of CO_2/year. This is the lower bound for facilities in the Carbonsafe study, which finds CCS is not economically viable below this threshold.[293] Therefore, this study looks into Pennsylvanian facilities around the same size (emitting above 100 kt of CO_2/year) to ensure that the levelized cost of CO_2 abated are comparable to the Carbonsafe study. To identify facilities to include, the study used the Pennsylvania Department of Environmental Protection's (DEP) Air Quality Reports, a database of facilities and their annual emissions.[294] The focus of this study includes facilities that exceeded the "high-emitting" threshold of 100 kt of CO_2/year in 2019 in the southwest, northwest, and north central regions, which could be connected via a single CCS transport and storage infrastructure.

The final list includes 44 facilities emitting a total of 60 Mt CO_2/year. Facilities belong to the following NAICS industry classifications: fossil fuel electric power generation (both coal fired and natural gas combined cycle), manufacturing (iron and steel mills and ferroalloy manufacturing; lime manufacturing; ethyl alcohol manufacturing; rolled steel shape manufacturing; reconstituted wood product manufacturing; and gypsum product manufacturing), electric bulk power transmission and control, petroleum refineries, and natural gas extraction. Cost calculations are customized for each of these industries. Nine facilities could not be matched with a corresponding capture cost estimate from the Carbonsafe or Schmelz et al.[295] studies, so these plants were omitted, resulting in 35 facilities in the analysis.

Differences in plant size and associated emissions can affect CCS cost estimates. The Carbonsafe and Schmelz et al. studies focus on high-emitting facilities emitting above 1.7 Mt CO_2/year and assume a 50 Mt storage capacity over 30 years. The present study applies a similar approach for the nine high-emitting plants that are above this threshold. There are nine of these high-emitting plants that are within the same scale as the cost estimates used in most of the studies (Carbonsafe, McCoy and Rubin, and Schmelz et al.[296]). Therefore, these cost estimates should more accurately represent the true system cost.

Figure 1: DEP air quality map of high-emitting plants (emitting above 100 kt CO_2/year) in the northeast, north central, and southwest areas of Pennsylvania.

Step 2: Carbon Capture Costs

The literature values for levelized capture costs of CO_2 abated (hereby referred to as levelized capture costs) describe the cost per ton needed for just the capture process. These values were taken from the Carbonsafe study and Schmelz et al. studies. These literature values are broken down by facility type and are presented in Table 1 below.

Table 1: Process type and levelized capture cost. Numbers were taken from the Carbonsafe study or Schmelz et al. or averaged. Underlined are the numbers that were used to calculate the levelized cost, which are averages of these studies for fossil fuel generation or the ones determined from the Carbonsafe study for manufacturing processes. The values are all in United States short tons and adjusted for inflation for 2018$.

Process type	Levelized capture cost of CO_2 abated (2018$ / ton of CO_2 captured)
Fossil fuel generation: coal	54 (Carbonsafe) 47 (Schmelz) 51 (average)
Fossil fuel generation: natural gas	70 (Carbonsafe) 76 (Schmelz) 73 (average)
Fossil fuel generation of unknown fuel type	62 (average of the coal and natural gas average)
Cement manufacturing	122 (Carbonsafe)
Steel manufacturing	95 (Carbonsafe)
Natural gas processing	17 (Carbonsafe)

The Carbonsafe study provides 30-year levelized capture costs by power generation type and manufacturing or refining processes with 85% capture capacity, according to that study's Table 4 and 5 of Attachment 3. More detailed assumptions are listed in Table 7 of Attachment 3 in the Carbonsafe report, including the total plant cost, fixed Operating and Maintenance (O&M), variable O&M, fuel consumption costs capture rate, and CO_2 captured. The literature did not specify a discount rate, but the underlying project NPVs used to calculate levelized capture cost imply a discount rate (as in Equations 1 and 2). Since the facilities studied in the Carbonsafe study are the more common type of fossil fuel generation facilities, capture costs of the 13-county region facilities were approximated using these values. Also, because the plants were based in Ohio and near Pennsylvania, general electricity, energy, and labor costs can be approximated to have similar values.

Schmelz et al. gave similar cost estimates for the natural gas and coal electricity-generating retrofit carbon capture technology, in 2018 dollars per U.S. ton of CO2, as reported in Table 1. Schmelz et al. examined the top 138 largest emitters among the 343 electricity-generating power plants but did not report the magnitude of emissions from individual plants. The 343 plants they reported produced a total of 409 Mt CO_2/year, which comes out to an average of 1.2 Mt CO_2/year per plant. Nonetheless, without knowing the distribution of these plants' emissions, it is hard to determine if their parameters match our plant size and type. Also, this report considered plants in both the Midwest and Northeast regions of the United States, leading to an underestimate of northeastern average energy prices and labor costs.

The incremental NPV associated with retrofitting each facility type with CCS was found using Equation 2 and the framework presented by Schmelz et al. The 30-year levelized cost of CO_2 abated at each facility type was multiplied by 85% (capture capacity) of the total amount of CO_2 emitted. Finally, the numbers were adjusted for inflation to 2018, as the Carbonsafe study reported numbers in 2015 dollars.

For all plants emitting above 100 kt CO_2/year (high-emitting plants), the final capture cost comes out to be 2.8 bn 2018$/year, and the 30-year incremental NPV comes out to 83 bn 2018$. Following the same framework for plants emitting above 1.7 Mt CO_2/year (top-emitting plants), the capture cost is 2.2 bn 2018$/year, and the 30-year incremental NPV comes out to 66 bn 2018$.

Step 3: Transport Costs

Literature values from McCoy and Rubin were used to estimate transport via pipeline costs. The cost estimates depended on pipeline distance, design capacity (how much transported), and pipeline size parameters. The first step was to find the distance from the plants to a potential storage facility. The one proposed in the Carbonsafe study found optimal storage geology in Coshocton, Ohio. Most of the high-emitting plants run across the northern border of Southwest Pennsylvania and along the Ohio-Pennsylvania border. Connecting these plants, the predicted pipeline system in Pennsylvania should run from Pittsburgh to Coshocton (200 km pipeline) and include another pipeline that branches from the bigger one, connecting Beaver to Greene County (130 km pipeline). Pipeline capacity of 5 Mt and 10 Mt were both considered, as capacity of pipelines depends on the CO_2 capacity at the storage sites.

Schmelz et al. used natural gas pipeline data to calculate CO_2 pipeline transport costs, due to similarities between the two types of infrastructure. The study cited pipeline parameters of 8–15 in. diameter and pressure of 15.3 MPa and provided cost estimates of materials, labor, right-of-way (ROW), and miscellaneous charges. The levelized transport cost of CO_2 abated (referred to as levelized transport cost) describes the cost per ton needed for just the transport via pipeline process. These estimates are presented below:

Table 2: Levelized cost of storage in 2018 \$/ton CO_2 stored. Literature values were taken from Schmelz et al. and adjusted for inflation.

Levelized transport cost (in 2018 \$/ton CO_2 stored)	5 Mt/year	10 Mt/year
130 km length	$2.41	$2.16
200 km length	$3.01	$2.05

Because the cost estimates were relatively similar, pipeline costs were averaged across capacity size and length for an average levelized transport cost of 2.18 2018$/ton. To find the total cost for all 35 high-emitting plants using Equation 2, the levelized transport cost was multiplied by 85% of the 30-year total emissions. For the high-emitting plants, the cost of transport via pipelines came out to be 103 mn 2018$/year, and over 30 years, the incremental NPV is 3.1 bn 2018$. For the top-emitting plants, the average distance was assumed to be about the same as the average distance for the high-emitting plants. These numbers come out to 83 mn 2018$/year and a 30-year incremental NPV of 2.5 bn 2018$.

Step 4: Storage Costs

To calculate storage costs, literature values from Schmelz et al. were used. For this, assumptions were made about similar geology characteristics that Carbonsafe concluded for Coshocton, which included onshore storage with oil and gas depleted and saline reservoirs, as well as an injection capacity of 30 years. This models closely to the geology in Pennsylvania, where there are both saline reservoirs and depleted oil and gas reservoirs. The study reported levelized storage cost of CO_2 abated (referred to as levelized storage cost) which describes the cost per ton needed for just the storage process. The study found that depleted oil and gas reservoirs cost $5 per ton of CO2, and this value was used to calculate the levelized storage cost. According to Schmelz et al., the storage capacity under these costs was at 2.9 Gt CO_2 but only increased slightly for higher capacities, which are negligible for our purposes.

Using Equation 2 and multiplying levelized storage cost by 85% of the total CO_2 emissions (adjusted for capture capacity) to estimate the amount reduced, the cost of storage for the 35 high-emitting plants comes out to $236 mn $2018/year and a 30-year incremental NPV of 7.1 bn $2018. For the top-emitting plants, the total cost of storage becomes 189 mn $2018/year, and the 30-year incremental NPV is 5.7 bn $2018.

Summary of Cost Analysis

Table 4: Summary of levelized costs per ton by facility type. The levelized cost of CO_2 abated was calculated by adding the levelized cost of capture, transport, and storage for each facility. The capture costs factored in the different costs for each facility, but the storage and transport cost were the same across facility type.

Facility type	Levelized cost of CO_2 abated (2018$ / ton of CO_2 captured)
Coal-powered generation plant	58
Natural gas–powered generation plant	80
Fossil fuel generation of unknown fuel type	70
Cement manufacturing	130
Steel manufacturing	102
Lime manufacturing	129
Natural gas processing	24

The values shown in Table 4 compare similarly to EIA estimates for levelized cost of CO_2 capture[297] for coal and natural gas generation facilities, which are 40–80 $2018/ton of CO_2.

Table 5: Annual costs. High-emitting facilities are those that emit >100 kt CO_2/year, and top-emitting are ones that emit >1.7 Mt CO_2/year. The capture costs factored in the different costs for each facility. Total cost was calculated by multiplying total costs by 85% of total annual emissions to account for 85% capture capacity.

	High-emitting facilities total annual cost (in millions of 2018$)	Top-emitting total annual cost (in millions 2018$)
Capture	2,770	2,190
Transport	103	83
Storage	236	190
Total	3,110	2,470

Table 6: 30-year incremental NPV. High-emitting facilities are those that emit >100 kt CO_2/year, and top-emitting are ones that emit >1.7 Mt CO_2/year. The capture costs account for the different costs of each facility type. Total cost was calculated by multiplying total costs by 85% of total 30-year emissions to account for 85% capture capacity

	High-emitting facilities total 30-year incremental NPV (in billions of 2018$)	Top-emitting total 30-year incremental NPV (in billions of 2018$)
Capture	83	66
Transport	3.1	2.5
Storage	7.1	5.7
Total	93	74

Other Calculation Methodologies

The scale of a CCS system in Pennsylvania was calculated from literature values and Equations 1 and 2. Not all the discount rates were reported, but the NPV can be derived from the levelized cost per ton of CO_2 abated for 30-year capture, pipeline, and storage project lifetime.

NETL released simulations that estimated costs for CCS along the value chain. Some of these simulations include CCSI toolset[298] and SimCCS[299][8]. CCSI looks at a material's behavior within the CCS system, and SimCCS is an open-source tool for optimizing CO_2 capture, transport, and storage infrastructure.

Conclusion

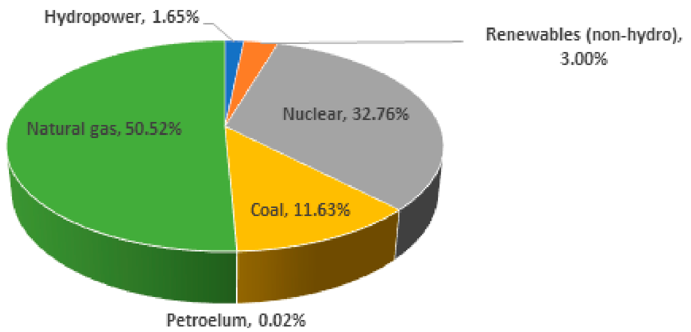
Most literature on carbon capture rarely estimates total cost, because it focuses on describing a representative plant rather than making an estimate of cost for retrofitting a specific plant population. There are frameworks that explain reporting methods, like Roussanaly et al.[300] and Rubin et al.[301] However, given the lack of data availability that would be needed to gain a more accurate CCS cost analysis, this report generates rough cost estimates. Creating a CCS system connecting the high-emitting plants across 30 years would cost approximately $93 bn 2018$. This estimate does not account for scaling factors based on individual plant emissions amounts. A more accurate estimate can be generated for CCS systems connecting the top highest-emitting plants. For the highest-emitting plants, the NPV of a CCS system is approximately $74 bn in 2018 dollars across 30 years. Since most studies only focus on these highest-emitting plants and suggest lower costs for these facilities, it makes sense to prioritize connecting the highest-emitting plants first.

Appendix 3: Pennsylvania Power Generation

Table 1: Net electricity generation for Pennsylvania and the United States.[302]

	Pennsylvania			U.S.
Fuel type	March 2021 monthly (1000 MWh)	% net generation	Change vs. March 2020	Change vs. March 2020
Hydropower	319	1.65%	(7.2%)	(9.5%)
Non-hydro renewables	579	3.00%	1.5%	29.6%
• Wind	N/A	N/A	N/A	34.0%
• Solar thermal and PV	N/A	N/A	N/A	43.8%
• Wood and wood-derived fuels	N/A	N/A	N/A	0.2%
• Other biomass	N/A	N/A	N/A	(4.7%)
• Geothermal	N/A	N/A	N/A	(16.6%)
Nuclear	6,318	32.76%	0.2%	(0.5%)
Oil	4	0.02%	(38.2%)	40.2%
Coal	2,242	11.63%	25.5%	22.5%
Natural gas	9,741	50.52%	4.7%	(14.8%)
Total net generation	19,283	18,398	4.8%	1.0%

Figure 1: Share of Pennsylvania's net generation, March 2021.



Appendix 4: Employment data

Figure 1: Visual representation of relevant energy industries using NAICS code classification.

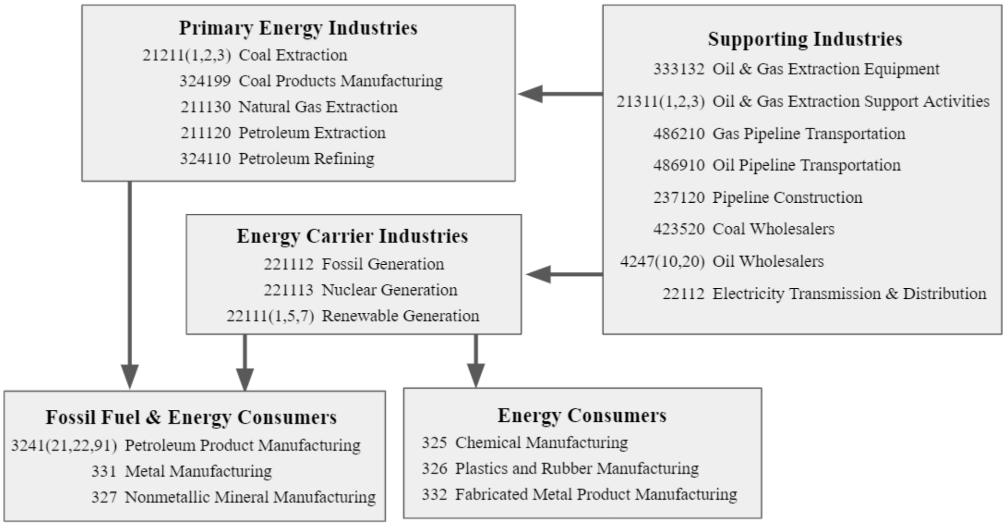


Table 1: Number of workers and wages in relevant industries in Pennsylvania (2018).

Industry category	Average annual employment (# workers)	Average annual pay ($/year/worker)
Primary energy industries	13,571	$87,776
• Coal coking	2,024	$54,548
• Coal extraction	4,973	$74,742
• Natural gas extraction	4,225	$125,266
• Oil extraction	270	$82,791
Energy carrier industries	6,460	$143,924
• Fossil power generation	2,742	$140,532
• Nuclear power generation	3,516	$148,335
• Renewable power generation	202	$143,584
• Oil refining	2,079	$127,603
Supporting industries	44,928	$95,257
• Coal mining support activities	483	$63,009
• Coal wholesalers	286	$130,245
• Electricity T&D	9,751	$120,340
• Gas pipeline transportation	1,857	$96,307
• Natural gas distribution	4,940	$104,828
• Oil and gas extraction equipment	356	$67,592
• Oil and gas extraction support activities	13,028	$85,804
• Oil pipeline transportation	535	$138,816
• Oil wholesalers	3,163	$73,747
• Pipeline construction	10,529	$102,847

Industry category	Average annual employment (# workers)	Average annual pay ($/year/worker)
Energy consumers	163,094	$66,520
• Chemical manufacturing	40,807	$80,822
• Fabricated metal product manufacturing	82,181	$57,036
• Plastics and rubber manufacturing	40,106	$59,141
Fossil fuel and energy consumers	58,576	$66,476
• Metal manufacturing	35,754	$71,346
• Nonmetallic mineral manufacturing	20,766	$59,950
• Petroleum product manufacturing	2,056	$69,238
Grand total/average	**286,629**	**$82,522**

Note: Source data from BLS Quarterly Census of Employment and Wages for 2018.

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