

The Appalachian Energy and Petrochemical Renaissance

An Examination of Economic Progress and Opportunities

June 2020



[This Page Intentionally Blank]

The Appalachian Energy and Petrochemical Renaissance

An Examination of Economic Progress and Opportunities

Prepared by

Department of Energy

With contributions by

Appalachian Regional Commission

Army Corps of Engineers

Department of Agriculture

Department of Commerce

Department of Labor

Department of Transportation

Small Business Administration

June 2020

[This Page Intentionally Blank]

FOREWORD

At the time of this report's original writing, much of Appalachia was on an economic upswing, albeit not at the same pace as much of the booming United States economy. Upon its release in June 2020, Appalachia, is in the early stages of economic recovery. In the intervening period, in early 2020, Appalachia, along with the rest of the world, endured the economic setback associated with the outbreak of the COVID-19 Pandemic.

Stay at home orders across the country, along with nationwide demand destruction for many manufactured products, consumer goods and energy disproportionately impacted the Appalachian region. In eastern Ohio, for example, the industrial share of manufacturing is more than 50 percent greater than the national average, the industrial share of coal, gas and other mining is 125 percent greater, and the industrial share for utilities is slightly over 100 percent greater.¹ As of the week ending on April 25, 2020, United States coal production was down 39.5 percent compared to a 2019.² As of April 21, 2020, the United States natural gas rig count was down 54.3 percent from the same time in 2019.³ While the Appalachian economy may be temporarily down, the abundance of its energy resources, the strong will of its citizens, and its future economic opportunity, persist.

A major component of the United States economic recovery will be the abundance of reliable, affordable energy to enable United States manufacturing and other sectors of the economy to reignite the pre-pandemic boom. Appalachia's economic viability during this recovery will serve as a key indicator of the prospects for, and overall health of United States economic recovery.

The opportunities for economic growth discussed in this report are especially timely and relevant in the new reality of a post-pandemic world that we face as a Nation. Economic recovery and growth are a priority, and outside of Appalachia, few other regions have the same potential for not only recovery, but for new growth at a scale not seen since the Industrial Revolution. Appalachia can expect to grow via energy resource production, next generation manufacturing, and petrochemical industry development and expansion.

Furthermore, the lessons learned from this pandemic experience underscore the importance of the United States petrochemical industry. The personal protective equipment (PPE) that protects first responders and health care workers are largely constructed from petrochemical feedstocks. From latex gloves to N95 masks and plastic face shields, petrochemicals play a key role. To put this in perspective, over 80 percent of the PPE used by firefighters are derived from petrochemicals.⁴ Life-saving medical equipment, vital communication equipment, home building materials, clothing, and transportation equipment all have components derived from petrochemicals. Increasing United States production capacity of these products via an Appalachian petrochemical and manufacturing renaissance will ensure that adequate supplies of these products exist, not just for emergencies like COVID-19, but enable a productive economy and increase the quality of livelihoods.

[This Page Intentionally Blank]

PREFACE

The United States has plentiful energy resources, including abundant supplies of coal, oil, natural gas, nuclear, and renewable resources. Energy producers in America have demonstrated a remarkable ability to harness innovation to cost-effectively unlock new energy supplies, making America a dominant energy force.

These energy supplies present tremendous economic potential. To fully realize this potential, the Nation needs infrastructure capable of safely and efficiently transporting energy to domestic residential, commercial, and industrial consumers and to international customers. Without this infrastructure, energy costs will rise, and the national energy market will be stifled; job growth will be hampered; and the manufacturing and geopolitical advantages of the United States will erode.

With this in mind, on April 10, 2019, President Trump issued Executive Order 13868 on Promoting Energy Infrastructure and Economic Growth. The Executive Order made it the policy of the United States to promote private investment in America's energy infrastructure through:

- Efficient permitting,
- Regulations that reflect “best practices” and “best-available technologies,”
- Timely governmental action on projects,
- Increased regulatory certainty,
- Effective stewardship of America's natural resources, and
- Support for American ingenuity, the free market, and capitalism.

The energy-rich Appalachian region is now the single largest natural gas producing region of the country and increasingly is becoming a major producer of natural gas liquids, including ethane, propane, and butane. The region also saw improvement in its coal production during 2017 and 2018 for the first time in a decade. Recognizing that the abundance of Appalachian energy resources is an engine for economic growth, the Executive Order directed the Secretary of Energy, in consultation with other agencies, to assess opportunities for promoting continued economic growth within the Appalachian region.

This report assesses economic progress and opportunities for growth in three sectors of the Appalachian economy that are driven by energy: the energy sector, the petrochemical sector which uses energy as its primary feedstock, and the manufacturing sector, which can use low-cost energy and petrochemical sector products as manufacturing inputs. Further, it examines the supporting public and private infrastructure required to accelerate economic growth in these sectors. Importantly, it documents the role of human capital in Appalachia and how best to develop a twenty-first century workforce.

Geographically, while Appalachia encompasses parts of 13 States, most of the natural gas and natural gas liquids are produced in Northern to Central Appalachia, including Pennsylvania, Ohio, West Virginia, and Kentucky. This area is also the heart of the Appalachian coal fields. This geographic area is the center of Appalachian energy production and, as such, is the principal focus of the report.

[This Page Intentionally Blank]

TABLE OF CONTENTS

Foreword.....	i
Preface	iii
Table of Contents	v
List of Figures	vii
List of Tables.....	vii
List of Boxes	viii
1. Executive Summary.....	1
1.1 Energy Sector	2
1.2 Petrochemicals Sector	4
1.3 Manufacturing Sector.....	5
1.4 Path Forward	5
2. Introduction	7
2.1 The Appalachian Economy	7
2.2 The Game-Changing Opportunity.....	9
3. Energy Sector	11
3.1 The Region Today.....	11
3.1.1 Natural Gas	11
3.1.2 Coal.....	14
3.2 Growth Opportunities.....	18
3.2.1 Natural Gas	18
3.2.2 Coal	19
3.3 Infrastructure Considerations	21
3.4 Workforce Considerations.....	23
4. Petrochemical Manufacturing Sector	24
4.1 The Region Today.....	25
4.2 Opportunities for Growth.....	29
4.3 Infrastructure Considerations	34
4.4 Workforce Considerations.....	35

5. Manufacturing Sector	37
5.1 The Region Today	37
5.2 Opportunities for Growth	38
5.2.1 Energy Intensive Manufacturing.....	38
5.2.2 Downstream Manufacturing	38
5.2.3 Advanced Manufacturing.....	39
5.2.4 Supporting the Growth Opportunities.....	40
5.3 Infrastructure Considerations	42
5.4 Workforce Considerations.....	43
6. Supporting Infrastructure.....	45
6.1 Rail	45
6.2 Waterways	46
6.3 Pipelines	48
6.4 Road	49
6.5 Broadband and Other Infrastructure.....	51
7. Concluding Remarks	53
8. Abbreviations and Units	56
9. References	58

LIST OF FIGURES

Figure 1. Driving Appalachian Economic Growth	2
Figure 2. The Economic Status of Northern to Central Appalachian Counties	8
Figure 3. The Geographic Location of the Marcellus and Utica Formations and Projections of Natural Gas Production	10
Figure 4. Number of Utica and Marcellus Wells	12
Figure 5. United States Natural Gas Production by Basin	12
Figure 6. Natural Gas Liquids Production by Fraction	13
Figure 7. Appalachian Coal Mines	15
Figure 8. Coal Production in Northern to Central Appalachia	15
Figure 9. Coal Industry Economic Status for Northern to Central Appalachian Counties	17
Figure 10. Coal Production in Appalachia	19
Figure 11. Natural Gas Value Chain and End Market Size (2018)	24
Figure 12. Appalachia Regional Infrastructure Map	28
Figure 13. Projected Growth in Natural Gas Production and NGL Production	31
Figure 14. Ethane Production and Estimated Rejection, 2010-2018	32
Figure 15. Typical Percentage of Olefin Output from an Ethane Cracker	33
Figure 16. Benefit to Industry from Program Participation	41
Figure 17. North-central Appalachian Railroads	46
Figure 18. North-central Appalachian Waterways	47
Figure 19. Pipeline Infrastructure	49
Figure 20. Appalachian Development Highway System	51

LIST OF TABLES

Table 1. Major Natural Gas Liquids Pipelines in Appalachia	27
--	----

LIST OF BOXES

Box 1. TEAM Consortium Workforce Development.....	22
Box 2. Enabling the Success of Small Businesses in Appalachia	40
Box 3. Mid-Atlantic Trade Adjustment Assistance.....	41
Box 4. Kentucky’s Shaping Our Appalachian Region	43
Box 5. The National Energy Technology Laboratory Regional Workforce Initiative	44
Box 6. Department of Transportation	46
Box 7. Ohio River System Upgrades.....	48

1. EXECUTIVE SUMMARY

Building on the foundation of the shale gas revolution, Appalachia is on the cusp of an energy and petrochemical renaissance. This renaissance has gained momentum over the past 2 years and it offers renewed promise to a region of the country that would benefit from further economic gains. There are also substantial opportunities in manufacturing.

As energy infrastructure expands in Appalachia, the manufacturers and consumers of the industrial Midwest, New England, and the East Coast have an opportunity to benefit from low-cost energy and energy-related products, such as petrochemicals, produced in Appalachia. This enables Appalachia and these surrounding regions to be more competitive in the national and global marketplace, create jobs and sustain a higher quality of life.

Because Appalachia is now the Nation's number one producing region of low-cost natural gas and a producer of high quality metallurgical and high-BTU thermal coal, Appalachia contributes to the strengthening energy security and the economy of the United States. It also has substantial energy export opportunities that further enhance the United States economy and contribute to global geo-political stability.

To fully realize the promise of this renaissance, the public sector (Federal, State, and local governments) must continue to work proactively to catalyze additional private capital investment within the region. Ultimately, the private sector powers the economy and creates family-sustaining jobs.

Federal, State, and local governments can help attract private sector capital by investing in:

- (1) A business environment that is supported by pro-growth tax policy, increased regulatory certainty, efficient permitting processes, and timely government actions;
- (2) Public infrastructure, such as roads, rail, locks, ports, and broadband, which enables commerce;
- (3) Workforce development, which provides a pool of skilled workers suited to today's and tomorrow's needs, and enables businesses, families, and communities to grow and thrive; and
- (4) Innovation, particularly with respect to early stage research and development (R&D) and public-private partnerships, that advance technology to the point where the private sector can carry it forward to the marketplace.

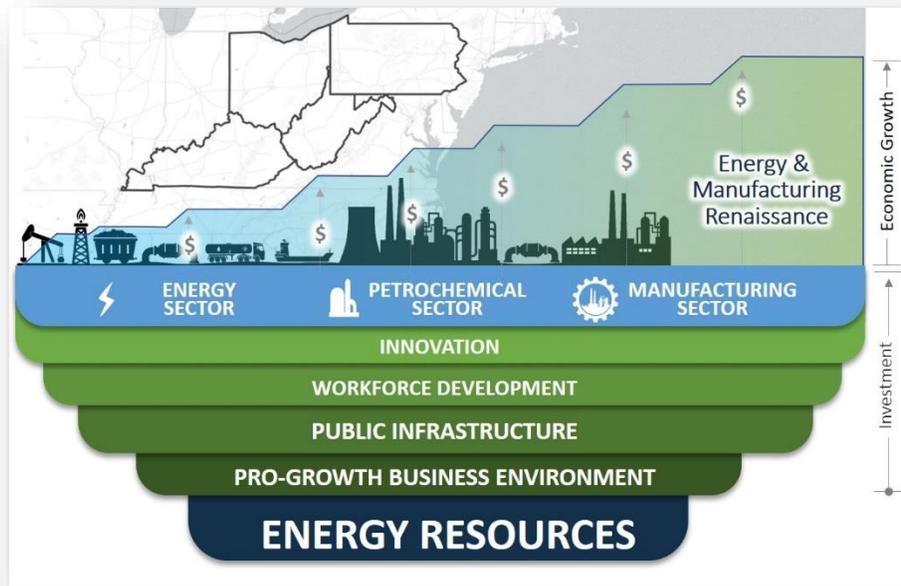


Figure 1. Driving Appalachian Economic Growth

The sheer magnitude of the shale gas revolution in Appalachia is illustrated by the fact that 85 percent of the growth in United States natural gas production over the past decade has occurred in Northern to Central Appalachia.

For decades to come, Appalachia is projected to far outpace all other United States gas producing basins in both production and production growth. This sustained abundance is anticipated to keep natural gas costs low in the region for the long term. Liquids are co-produced with much of Appalachian natural gas. Chief among these natural gas liquids (NGLs) are ethane, propane, and butane, which have many value-added uses.

The shale gas revolution has the potential to last for more than a century. This megatrend creates a wide range of opportunities for growth across the United States economy, but three specific Appalachian sectors have the most to gain: the energy sector, including energy production and power generation; the petrochemical sector; and the manufacturing sector. These three sectors are the focus of this report.

1.1 ENERGY SECTOR

Capitalizing on the benefits of the shale gas revolution requires maintaining the region's ability to drill, produce, and transport natural gas to domestic consumers and export markets. In Ohio, Pennsylvania, West Virginia, and Kentucky, most producible lands are privately held, and all of them have policies and permitting practices supportive of natural gas production. Because of its abundance and low cost, residential, commercial, and industrial consumers are creating significant market demand for natural gas.

With respect to export markets, the Federal Energy Regulatory Commission (FERC) and the Department of Energy (DOE) have moved expeditiously to authorize Liquefied Natural Gas (LNG) terminal capacity on the East and Gulf Coasts. However, both domestic and terminal-supported export markets face challenges in siting and permitting pipelines that supply them. This continues to limit the full potential of natural gas.

The Environmental Protection Agency (EPA) has revised its regulations governing Clean Water Act Section 401 certifications, which are important for the siting and approval of energy infrastructure projects.⁵ Additional, high-priority Federal Government actions include streamlining other regulations, developing road and broadband infrastructure, and accelerating R&D that offers the potential to as much as double shale gas wellfield productivity.

While shale gas and the associated NGLs are the principal energy resources driving new economic opportunity, parts of Appalachia's economy continue to rely heavily on coal, and there is no ready substitute for the economic activity generated by coal.

From 2009 to 2016, Appalachian coal production declined by over 40 percent. From 2017 to 2019, production realized a net 32 percent gain from 2016 production levels, driven in large measure by a shift to supportive Federal coal policies and to improved export markets for Appalachia's metallurgical and thermal coal.

Unfortunately, due significantly to electricity demand destruction driven by the COVID-19 Pandemic, as of the week ending on April 25, 2020, United States coal production was down 39.5 percent compared to 2019.⁶ Looking ahead, short-term production increases will depend heavily on post-pandemic restoration of coal-fired electricity demand, coal export potential, and competition from low-cost natural gas. Coal production will remain a priority to the region, as it continues to diversify its economy. This is particularly true for those communities in which the coal industry is the primary source of employment and considering that over half of the counties in this region are what the Appalachian Regional Commission categorizes as "At Risk" or "Distressed" economically.

Actions that could address this priority include forestalling premature retirements of coal plants; enabling the existing coal plant fleet to upgrade with modern efficiency and environmental controls without punitive re-permitting; investing in aging river lock and dam infrastructure critical to coal transport; developing a next generation of near-zero emission coal-fueled power generation technologies that can meet the emerging operational requirements of the eastern electricity grid; continuing development of durable coal-based products; extracting critical minerals and rare earth elements (REE's) from coal; ensuring fuel-neutral access to capital and insurance markets; and improving coal export opportunities.

Generally, non-hydro renewables and nuclear power supply a small fraction of Appalachia's energy production and economy. The one significant exception is Pennsylvania, which sourced 39 percent of its electricity from nuclear in 2018.⁷ Avoiding premature retirement of any of these energy producing assets is important to significant segments of the regional workforce.

1.2 PETROCHEMICALS SECTOR

Appalachia was the birthplace of the United States petrochemical manufacturing industry in the early 1900s; however, the industry waned during the mid- to late-1900s, when the oil and gas industry grew in the Gulf Coast region. With Appalachia's new abundance of gas and NGLs, the industry is returning, and an Appalachian petrochemical renaissance is unfolding.

Current ethane production is 250,000 barrels per day (BPD) but 100 percent of that is exported out of the region. As this production grows to a projected 640,000 BPD by 2025, in-region petrochemical manufacturing capacity would maximize the economic benefit to Appalachia. Shell's petrochemical complex, which will convert ethane to polyethylene plastic resin, represents the first of what could be multiple facilities in the region. PTT's planned ethane cracker and its associated polyethylene production lines represent a potential second complex. Combined, these facilities represent \$16 to \$20+ billion in capital investment. Each project will require 6,000+ construction workers. Providing both plants become operational, combined, it is estimated by Shell and PTT that these projects combined will create 1,200 direct, on-site jobs.^{a 8} Accounting for the indirect jobs that would result from these projects, the total jobs created from these projects are in excess of 9,800.^{b 9}

Given the forecasted ethane production levels referenced above, a concerted effort to ensure similar mega-projects follow would result in transformational economic development for the region. With propane production levels expected to reach 300,000 BPD by 2025, there is also an opportunity to develop infrastructure to convert propane to polypropylene plastic resin. The story for butane, which feeds refineries, is similar. There are also significant regional opportunities for ammonia, urea, methanol, and ethylene production. These can be manufactured in-region from low-cost natural gas and NGLs and be sold as chemical derivatives to regional markets.

There are clear cost advantages for investors who build petrochemical plants in Appalachia. There are challenges, however, when it comes to attracting the tens of billions in private capital to construct those facilities. Among those challenges include a regional workforce smaller than that found within the Gulf Coast, Appalachia's hilly topography, and public infrastructure (roads, rail, barge, and broadband) which is more limited than in some other regions of the country. All of these challenges make public sector investments in workforce development, public infrastructure, and build-ready development sites very high priorities for Appalachia.

^a Shell officially states that once operational, the Monaca, Pennsylvania-based petrochemical facility will create 600 full time jobs. PTT estimates "hundreds" of full-time positions will be created once its proposed Belmont County, Ohio-based facility is operational. Authors assume that employment will be of similar scale to the Shell project based on size of the proposed plant.

^b The ACC estimates that for every direct job created in the chemical industry, 7.2 indirect jobs are created. Applying this multiplier to the direct jobs created at these facilities results in an additional 8,640 indirect jobs created, bringing the total jobs created from these projects to 9,840.

1.3 MANUFACTURING SECTOR

There are currently 630,000 manufacturing jobs in Northern to Central Appalachia, representing 13 percent of the overall direct jobs market in the region, as well as substantial additional support sector jobs. These include manufacturing jobs in automotive, electronic, furniture, food processing machinery, and packaging segments.

Building on this existing base, the opportunity for downstream manufacturing using petrochemical derivatives, such as ethylene or plastic resins, is enormous. For example, the Appalachian region annually produces over \$30 billion in plastic consumer goods using feedstocks largely imported to the region. In-region production of these feedstocks will provide for lower input costs, greater profitability, and a basis for manufacturing expansion.

Low-cost natural gas provides low-cost energy, directly as fuel gas and indirectly through gas-fired electricity generation. This can drive down production costs in existing manufacturing operations, thereby increasing competitiveness. A recent McKinsey study analyzed Appalachian energy-intensive manufacturing opportunities: it concluded that there are opportunities to attract glass, cement, and fabricated materials manufacturing, as well as the next generation of data centers required by high technology industries and e-commerce.

Manufacturing in Appalachia today is disproportionately concentrated in low-skilled, labor-intensive processes. This type of manufacturing is particularly susceptible to overseas outsourcing. Appalachian manufacturing would benefit from a shift in emphasis toward higher-value manufacturing and manufacturing that takes advantage of low-cost regional energy resources.

This shift is not without its challenges, including increased R&D as part of manufacturing modernization, workforce development and retention, and capital access for small- and mid-sized businesses. Progress addressing these challenges has already been made through SBA programs, the National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership (MEP), and other government and industry initiatives, but more work remains.

Actions that would improve growth opportunities for downstream manufacturing in Appalachia include investment in public infrastructure that facilitates commerce (roads, rail, and broadband); continued streamlining of regulations on small to mid-sized business; fostering growth in energy-intensive and other manufacturing that gains an economic advantage from the proximity to the region's low-cost energy resources; and creation of collaborative public-private partnerships focused on Appalachian petrochemical and broader manufacturing.

1.4 PATH FORWARD

Conducting business-as-usual in the public sector is not sufficient to help Appalachia fully realize the benefits of an Appalachian energy and manufacturing renaissance. Federal, State, and local governments must act, in close alignment with the private sector and other stakeholders.

In some cases, the public sector will need to step back and allow free markets to work more effectively; in other cases, the public sector will need to streamline and accelerate its role. In

still others, targeted public sector investments and policies will be needed to incentivize development, without government overreach. If such actions are taken, a surge in private capital will enter the Appalachian region, energy resources will be stewarded in an environmentally responsible manner, and the Appalachian economy and quality of life will be improved.

Looking across the three sectors, energy, petrochemicals, and manufacturing, there are three areas where public sector investment is critical: (1) creating a pro-growth business environment, (2) developing public infrastructure, and (3) supporting workforce development. In addition, government has an important role to communicate the economic opportunity to help mobilize and align public- and private-sector efforts.

2. INTRODUCTION

2.1 THE APPALACHIAN ECONOMY

Northern to Central Appalachia—the geographic focus of this report—is home to the Marcellus and Utica shale formations, the Appalachian coal fields, and a significant stretch of the Ohio River Valley. It is characterized by counties that are largely rural. The region is known for its abundance of natural resources, which have provided the foundation of industries such as forestry, mining, farming, traditional manufacturing, and energy production.

This part of Appalachia has not seen these resources and industries translate into the same economic growth that the United States has experienced. The continued evolution of trade and the shift toward high technology has challenged the region’s natural resource-based industries, leaving its economy struggling.¹⁰

However, there are promising signs. Thanks to the presence of some high-quality educational institutions, the region graduates Science, Technology, Engineering, and Mathematics (STEM) trained students at a rate above the national average. But the region has trouble keeping them. Appalachia retains those graduates at one of the lowest rates in the Nation.

The region has a long tradition of hard work and self-reliance, and it abounds with examples of communities re-inventing themselves and attracting new business investment. Unfortunately, these successes have not occurred at a scale or on a sufficiently widespread basis to uplift the region-wide economy.

Although this region has seen exponential growth in shale gas production, many counties do not fully share in the Nation’s economic prosperity. More must be done to realize a full economic transformation for the region.

The Northern, North Central, and Central subregions of Appalachia, as defined by the Appalachian Regional Commission (ARC), are principally within Pennsylvania, Ohio, West Virginia, and Kentucky.^c There are 193 Appalachian counties in this part of Appalachia. ARC annually assesses the economic status of these counties considering the unemployment rate, per capita income, and poverty rate.¹¹ “Distressed” counties are the bottom 10 percent of all United States counties and “At Risk” counties are the bottom 10+ to 25 percent of all United States counties.¹² Almost half the counties in this part of Appalachia are defined as “At Risk” or “Distressed,” while only seven counties are in the top 10+ to 25 percent (Competitive), and the rest are “Transitional.” See Figure 2.

Other indicators paint the same picture, showing that many of these Appalachian counties are below United States averages across the board. The percentage of adults with bachelor’s degrees in Northern to Central Appalachian counties is 16.4 percent, compared with 30.9 percent across

^c While not the primary geographic focus of this report, seventeen counties located in southern New York and the Maryland panhandle are also within the Northern and North Central subregions of Appalachia.

the United States. Similarly, the average household income is \$15,000 less than the United States average, and the unemployment rate is 1.7 percent higher than in the rest of the United States.

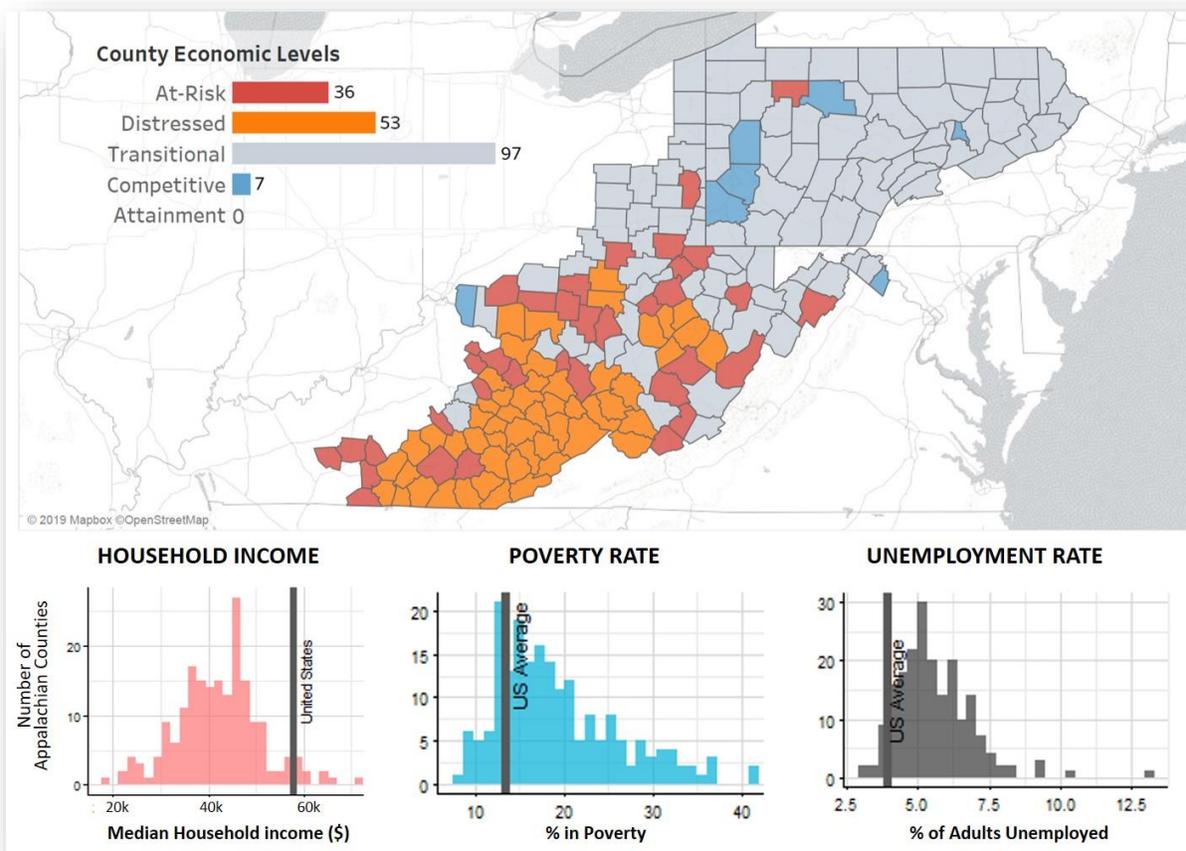


Figure 2. The Economic Status of Northern to Central Appalachian Counties ¹³

The Appalachian economy has historically depended on its natural resources. That dependence continues in many counties today. In 2018, Appalachian counties in Kentucky had seven times the coal, gas, and other mining activity as average United States counties, while counties in Ohio and West Virginia had four times the activity.¹⁴ While Northern to Central Appalachia has significant coal, gas, and mining activity, these industries employ a rather small share of Appalachians—1.4 percent in 2018. Most natural resources are extracted and exported out of the region. Consequently, jobs associated with processing these natural resources into derivatives and final products are “exported” along with the resources. In contrast, 20.6 percent are employed by the health care and social services industries. Other large industries in the region include retail, which employs 14.6 percent, and manufacturing, which employs 12 percent.

2.2 THE GAME-CHANGING OPPORTUNITY

The shale gas revolution is a global game changer—economically and geopolitically. Technological improvements in drilling and hydraulic fracturing have greatly enhanced the extraction of natural gas in the Appalachian region over the last decade. Appalachia’s resources, with the Permian Basin’s resources in Texas, have positioned the United States as a net exporter of natural gas for the first time since 1957.¹⁵ The abundance of natural gas in the United States has driven residential, commercial, and industrial gas prices to among the lowest levels in United States history.

The shale gas revolution can be a long-term economic game changer for Appalachia, but only if the public and private sector work together to capitalize on it. The energy resource potential of the Marcellus and Utica formations make the Appalachian basin one of the largest gas basins in the world.

By 2050, the Energy Information Administration (EIA) projects that Eastern natural gas production will nearly double from its 2019 level of 27 billion cubic feet per day (bcf/d) to 54 bcf/d, at which point it will make up more than 45 percent of United States production.¹⁶ See Figure 3. Further, much of Appalachian natural gas is rich in NGLs, including ethane, propane, butane, iso-butane, and pentanes. Production of NGLs is projected to more than double by 2050, reaching production levels of 1.7 million BPD. Supported by a well-executed economic development strategy, a substantial portion of the value associated with production and conversion of these gas and NGL resources can be captured and retained within the region. Absent a strategy, the resources will almost exclusively be exported from the region via pipeline.

As an example, ethane supply in the region could support multiple world-scale ethane crackers without disruption to current ethane exports from the region. The market could also support multiple polypropylene, ammonia, and methanol production facilities. Each of these anchor facilities would produce petrochemical derivatives, which are building blocks for a wide variety of chemicals, plastics, solvents, synthetic rubbers, antifreeze, pharmaceuticals, and other products produced by downstream manufacturers.¹⁷

As a second example, low-cost energy provides an opportunity for glass, steel, aluminum, and cement manufacturers to increase their competitiveness and expand. Low-cost natural gas as a primary fuel and gas-fueled electricity generation is providing a financial edge to these manufacturers, enabling them and other manufacturers to be more profitable and to expand in Appalachia.

The low-cost regional supply of natural gas and NGLs is one advantage in the economic growth equation for Appalachia. Another advantage is Appalachia’s proximity to the domestic customer base for chemical derivatives and finished manufactured products. For example, the epicenter of the NGLs producing area is within a day’s drive of 70 percent of the downstream manufacturing demand for polyethylene resin and within 500 miles of more than 40 percent of the United States population. Multiple anchor facilities producing petrochemical derivatives will be positioned to provide feedstocks to hundreds of new and existing downstream manufacturers who can flourish.

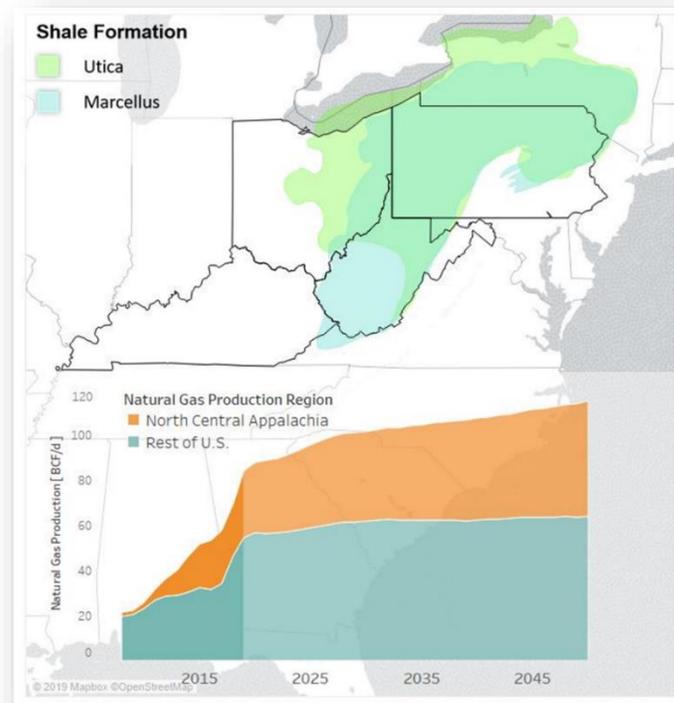


Figure 3. The Geographic Location of the Marcellus and Utica Formations and Projections of Natural Gas Production

The trifecta of potential growth in energy, petrochemical manufacturing, and other energy intensive and advanced manufacturing brings the promise of a renaissance to the Appalachian region. According to the American Chemistry Council (ACC), the opportunity in the petrochemical sector alone could result in an economic expansion of \$28 billion per year and result in the creation of over 100,000 jobs in the region.¹⁸

These economic opportunities can be facilitated by public sector investments that catalyze increased private sector investment in the region. These public sector developments would include: (1) creating a pro-growth business environment, (2) developing public infrastructure, (3) supporting workforce development, and (4) investing innovation. Public-sector leaders, at all levels of government, must effectively communicate the substantial economic opportunity, within and outside the region, to energize public- and private-sector participation.

This report seeks to communicate the economic opportunity, in order to accelerate an energy and petrochemical renaissance in Appalachia. Such a renaissance will benefit the region and the Nation by facilitating long-term sustainable growth.

3. ENERGY SECTOR

Northern, North Central and Central Appalachia have provided immense energy resources to the rest of the country for centuries. Coal was first mined in this region during the colonial era.¹⁹ Petroleum has been actively produced in Appalachia since 1859, when oil was discovered in northwestern Pennsylvania at the Drake well. Coal and oil fueled the Industrial Revolution and the growth of the United States economy throughout the subsequent decades. More recently, the Marcellus and Utica shale formations have supplied the Appalachian shale gas revolution. Wind and solar electricity production are a modest, but growing, fraction of the region's energy production. Pennsylvania and Ohio are also home to 11 nuclear power plants, providing a significant share of Northern Appalachia's electricity. But shale gas and coal remain the two forms of energy that have the greatest potential to impact the Appalachian economy—each in different ways.

3.1 THE REGION TODAY

3.1.1 NATURAL GAS

With the introduction of horizontal drilling and hydraulic fracturing in the Utica and Marcellus shale formations, Appalachian natural gas production over the past decade has transformed the U.S. energy landscape. Eighty-five percent of the United States growth in natural gas production over the past decade originated from these shale formations. Production was driven by the remarkable growth in the number of horizontal wells, increasing by more than 14,000 new wells—from less than 800 prior to 2010, to more than 14,800 in 2019. See Figure 4.²⁰

Appalachian natural gas production far surpasses that of every other region, producing twice as much natural gas as the Permian Basin region in Texas, the next largest producing region. See Figure 5.²¹

The growing production volume of Appalachian shale gas has altered the directional flow of natural gas within the country over the past decade. Natural gas used to flow predominately from the southwest toward the northeast. But since 2015, natural gas has flowed outward from Appalachia in all directions, including to the Gulf Coast for domestic and international use, and to the Cove Point, Maryland LNG export terminal.²² That supply has enabled the United States to become a net exporter of LNG to global markets.

Appalachian natural gas has also fueled an increase in natural gas-fired electricity generation, which provides a low-cost source of electricity for households and businesses. Natural gas-fired power plants, which can quickly ramp up and down, are also an important buffer for intermittent wind and solar electricity generation, which has a small but growing role in the region.²³

The chemical composition of natural gas produced varies across Appalachia. Dry gas is mainly produced in northeastern Pennsylvania. Dry gas is predominantly methane (CH₄) and requires minimal processing before it goes to market via pipeline. In contrast, natural gas produced in the southern Pennsylvania, West Virginia, and eastern Ohio is predominantly wet gas. Wet gas contains NGLs, which are non-methane hydrocarbons that are coproducts of natural gas

production. NGLs should not to be confused with LNG, which is natural gas that has been cooled to a liquid state for transport.

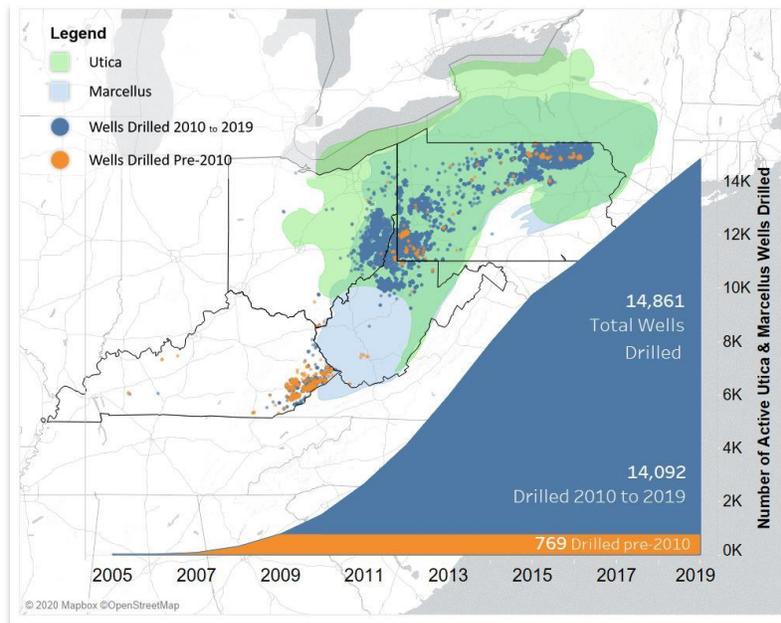


Figure 4. Number of Utica and Marcellus Wells

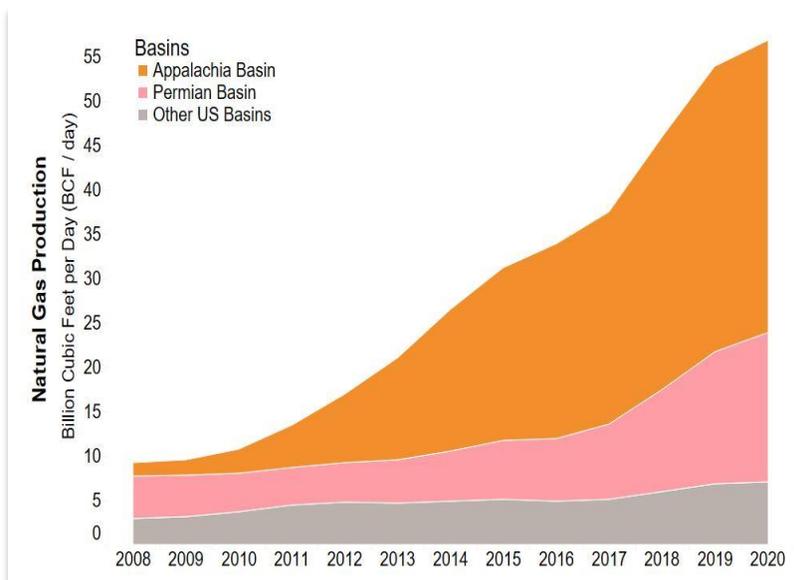


Figure 5. United States Natural Gas Production by Basin

NGLs are primarily comprised of ethane (C₂H₆), propane (C₃H₈), butane (C₄H₁₀), and natural gasoline (C₅H₁₀₊). To meet transport specifications on many pipelines, some of these liquids

must be removed. The removed NGLs, referred to as Y-condensate, can be further separated and sold for various uses. Those include propane for space heating and cooking fuel or petrochemical feedstock, butane for blending into vehicle fuel, and ethane for use as a petrochemical feedstock.

Ethane may be left in the natural gas to be sold as fuel (i.e., a methane/ethane mix). The practice of leaving NGLs in natural gas is referred to as rejection. Ethane is typically rejected when there is an insufficient or inaccessible market demand for pure ethane. There are limits to the amount of ethane than can be rejected into an otherwise dry gas, because it boosts the heat content of the natural gas above acceptable pipeline transportation limits. Propane can also be rejected in small amounts, but it is not a common Appalachian practice.

NGL production doubled in the United States, and by 2019 Appalachian production grew to more than 20 times the 2010 production level. See Figure 6. While non-ethane NGLs generally find a market, there is a surplus of ethane in Appalachia due to limited regional demand. As a result, ethane rejection in Appalachia is a common practice. In 2018, 277,000 BPD of ethane was produced and sold to market. It is estimated that an additional 150,000 to 685,000 BPD was produced and rejected.²⁴

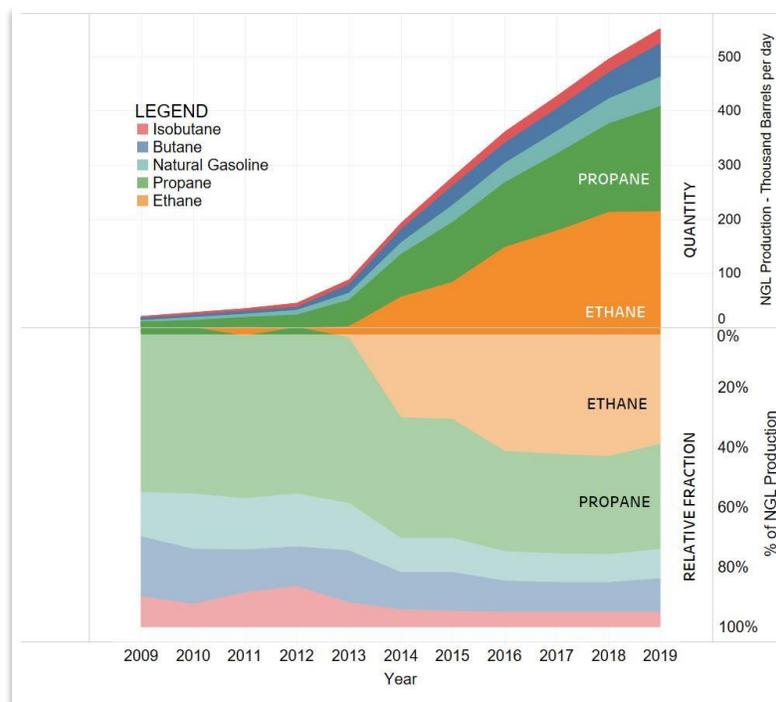


Figure 6. Natural Gas Liquids Production by Fraction

While Kentucky is widely known for its coal production, the state also saw an increase in natural gas production through the early 2000s from resources located in the eastern part of the state. Natural gas production in Kentucky peaked in 2010 but has since declined due to a decrease in natural gas prices.

Even with these declines, the commonwealth of Kentucky is well within the top 20 producing states in the United States. While Kentucky currently does not produce as much natural gas as other neighboring Appalachian states, primarily because the Utica and Marcellus formations fall outside of Kentucky's borders, shale formations in the State (e.g., the Rogersville formation) may be future producers. Much of the natural gas produced in the region travels through Kentucky, making the region a significant exporter of natural gas to the rest of the country. More than 90 percent of the gas entering Kentucky flows to other states, primarily Tennessee, Indiana, and Illinois. In addition, Kentucky has 23 underground natural gas storage facilities that can hold 2.4 percent of the total United States storage capacity.²⁵

3.1.2 COAL

Coal mining has long been an important source of employment in Appalachia, providing high-wage jobs that sustained entire communities. Even though coal production has declined in recent decades, coal mines are still operating throughout the region. See Figure 7. Many exist in rural counties that do not have other significant economic opportunities.

Coal production in Northern to Central Appalachia declined by more than 40 percent, from 210 million short tons (MMst) in 2009 to 124 MMst in 2016.^d See Figure 8.²⁶ In 2017 this decline was reversed, with growth occurring in 2017 through 2018 due to improving export markets and more favorable policies toward coal. In 2019, coal production experienced a slight decline from 2018 levels, from 171 MMst in 2018 to 164 MMst in 2019. However, compared to a baseline low point in production in 2016, overall production still experienced a net increase of 32 percent over the 3-year period that followed.

This significant decline through 2016 was part of a national trend towards declining coal production and demand driven by three factors:

- Low natural gas prices that gave an economic advantage to natural gas-fired generation over coal-fired generation, coupled with flat demand growth for electricity;
- Increased regulatory barriers to combusting coal for power generation and mining, including stricter environmental regulations and state policies favoring renewable energy resources; and
- Weakened demand for coal in international markets between 2013 and 2016, primarily attributable to policies in other countries aimed at slowing the growth of coal consumption and stiff competition from other coal exporting countries.

^d The production figures represented here in Pennsylvania, Ohio, West Virginia, and Eastern Kentucky, which closely represent the geography of the ARC-defined North Appalachia, North Central Appalachia, and Central Appalachia subregions.

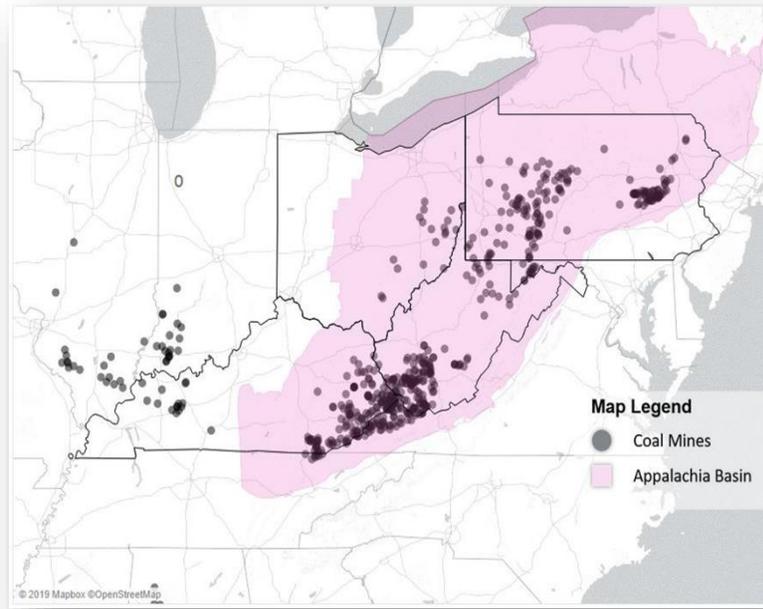


Figure 7. Appalachian Coal Mines

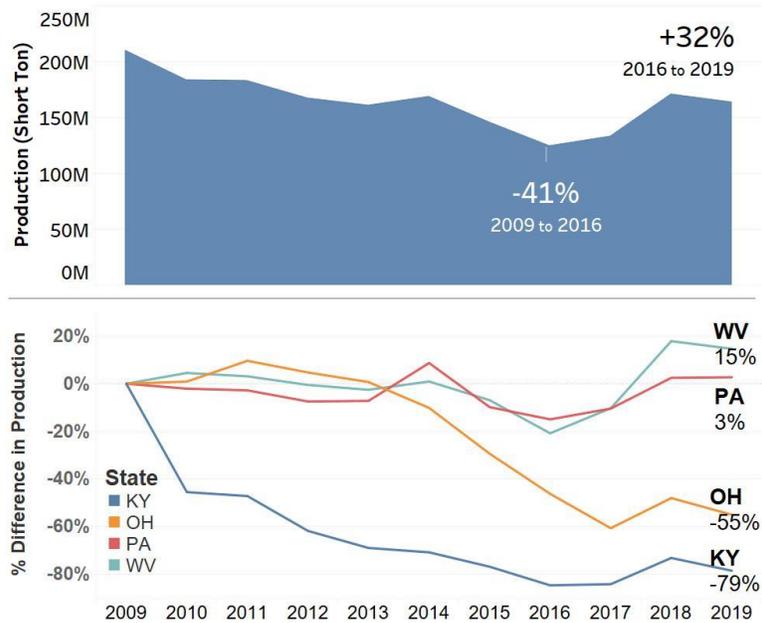


Figure 8. Coal Production in Northern to Central Appalachia^e

^e Kentucky production represents only Eastern Kentucky. Western Kentucky is not formally part of Appalachia.

Low-cost natural gas has been the principal driver for the decline in United States demand for coal. Due to declining natural gas prices and electricity producers switching from coal to gas-fired power generation, the electric power sector has become the largest consumer of natural gas—greater than the industrial, residential, or commercial sectors.²⁷ The shift away from coal has also been caused by environmental regulations such as the EPA’s Mercury and Air Toxics Standards (MATS). MATS targets reduced emissions from coal- and petroleum-fired power plants, required stringent emission reductions, and provided a short time-frame for compliance. The cost of compliance and the lower cost of natural gas forced the owners of many coal-fired plants to make a choice. In many cases, they chose to retire the plants rather than incur costs for installing emissions control technologies.

Direct employment in the coal mines of Appalachia followed a declining trend similar to that of production, going from nearly 50,000 in 2009 to a low of 22,238 in 2016. Since then, employment has grown as mines hired additional workers to meet higher demand. During 2017 and 2018, Appalachia added 2,352 mining jobs.²⁸ It is estimated that for every one coal mining job created, five indirect jobs are created.^{f 29} Using this multiplier, the uptick in Appalachian coal production since 2016 has likely created over 14,000 jobs.

In 2018, the ARC published a series of reports that explored the economic impact of the coal industry in Appalachia. The first of those reports found that the impact of coal’s long-term decline has not been spread evenly across the region.³⁰

ARC analysts examined several economic indicators to rate the economic health of Appalachian coal industry and the businesses that supply it and benefit from it. The industry in Appalachian counties was rated as either Hardship, Depressed, Vulnerable or No Impact. These ratings were based on a combination of a county’s dependence on the coal industry for employment (Dependence), changes in employment as coal production in the county has declined (Impact), and the risk of future declines in coal production negatively impacting employment (Risk). Vulnerable counties had high Risk scores; Hardship counties had high Dependence, Impact, and Risk scores; and depressed counties had high Dependence and Impact scores, but no longer scored high on Risk because the coal industry had largely already left the county. See Figure 9.³¹

^f This estimate was produced using a recent multiplier developed by the Economic Policy Institute, and Washington, D.C. based non-profit in 2019. The supply chain sector multiplier for coal mining is 3.3, the induced job multiplier is 1.7, for a total of 5 indirect jobs for every mining job created.

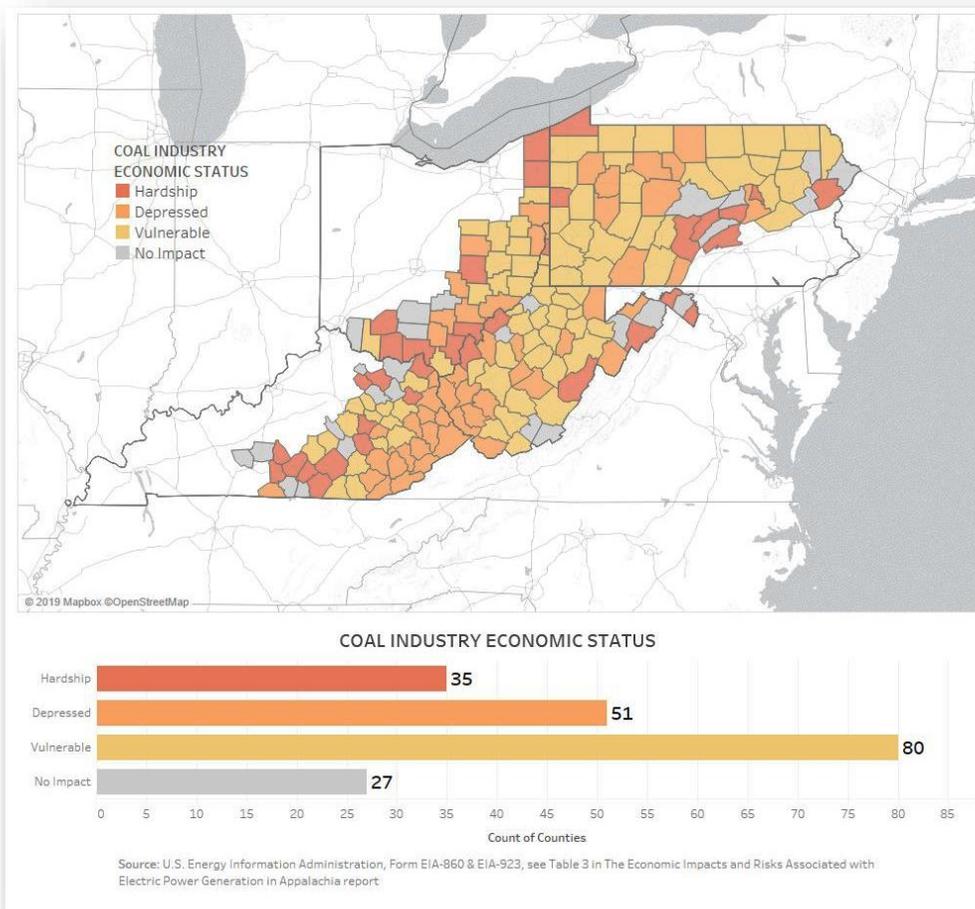


Figure 9. Coal Industry Economic Status for Northern to Central Appalachian Counties

The impact of the decline in coal production may not seem as large as it could be when the region is viewed as a whole. It has resulted, however, in devastating losses for isolated communities throughout the region. Because of the limited number of industries that employ workers with skills similar to those of coal miners, these isolated communities have been unable to absorb laid-off workers into the job market.³² This points to the importance of public-sector policies and actions that can sustain coal production while the economy of these counties diversify and while coal-to-products manufacturing opportunities (i.e., alternative, non-combustion uses for coal) are developed.

For example, the Assistance to Coal Communities program, administered by the Department of Commerce Economic Development Administration (EDA), assists communities and regions facing displacement. The program, currently funded at \$30 million for FY 2020, provides grants to support economic diversification, job creation, capital investment, workforce development and re-employment opportunities. The program helps coal communities create new businesses and jobs in a variety of industry sectors, including, but not limited to, advanced manufacturing,

agriculture, energy, information technology, health care, telecommunications, tourism and recreation, transportation, and cultural and natural assets.

3.2 GROWTH OPPORTUNITIES

3.2.1 NATURAL GAS

The EIA projects that Appalachian natural gas production will continue to grow in the coming decades. The Annual Energy Outlook (AEO) 2020 projects that production in EIA's Mid-Atlantic and Ohio region will continue to be a major exporter of natural gas to other regions of the United States, doubling its shipments to the Northeast, Southeast, and Midwest from 10 bcf/d to 20 bcf/d by 2035.³³

This growth is driven by the continued expansion of Utica and Marcellus production. It is also driven by technological advancements and progress in industry practices, which the EIA predicts will increase production volumes and reduce production costs. However, other studies predict that growth will be much more modest, arguing that the impact of technology on well productivity will be much smaller^{34 35} or that an aggressive growth scenario such as that in the AEO would require higher natural gas prices to fund an increase in operations, additional regional demand growth, and aggressive increases in pipelines to downstream markets.³⁶

The latter view highlights the importance of continuing to invest in technology and continuing to implement a pro-growth policy and permitting environment that supports development of wellfield, midstream gas processing, and pipeline infrastructure, so that continued growth of the industry is not dampened. Further, opening up Northeast market access with additional pipeline capacity would further boost market demand.

The shale gas industry was founded on technological advancements in horizontal drilling and hydraulic fracturing. The industry continues to improve the effectiveness of that technology using longer lateral wells, some now reaching several miles from the vertical well bore, as well as improvements in hydraulic fracturing techniques. It remains the case, however, that only about 10 percent of the original gas-in-place is produced with today's technology. Substantial opportunity exists for further technological advancements that provides expanded access to the resource.

In the current age of precision sensors, producers have the ability to collect massive data sets for drilling and reservoir performance, and the ability to analyze this information using today's computational capabilities. They can use that information to improve well design and increase productivity. A second wave of the shale gas boom could well be unleashed if the digital age is fully embraced by the industry. Economic impacts resulting from such improvements would further help to transform not only Appalachia, but the United States economy as a whole. For instance, in a recent study, it is estimated that the increase in United States unconventional natural gas production over the 2008–2018 period resulted in an economic savings for the United States of over \$1 trillion.³⁷

3.2.2 COAL

Coal mined in Appalachia serves two primary end-use markets: thermal and metallurgical. Thermal coal is used for power generation. Metallurgical coal is used in steelmaking.

Coal-fired power generation in the United States and some of the region’s traditional export markets, such as Germany, declined through 2016. Starting in 2017, there has been an uptick in global demand for coal, driven by higher thermal coal exports and increased demand for metallurgical coal. Appalachia benefited from this increase in global demand. Higher global prices in 2017 and 2018 also improved United States coal’s competitiveness in international markets.³⁸ Although coal production experienced a slight decline in 2019, coal remains a staple of global energy production and significant contributor for the United States economy.

Under EIA’s 2020 AEO base case scenario, Appalachian coal production is projected to decline through 2020, increase in 2021 and 2022, decline slightly in 2025, then effectively stabilize through 2035.³⁹ See Figure 10.

In an analysis published a year earlier, the ARC forecast a modest increase in regional coal production through 2035.⁴⁰ These different estimates could be explained by differences in the assumptions upon which the projections are based or simply analytical uncertainty in the projections. As noted in the Foreword, these projections were prepared pre-COVID.

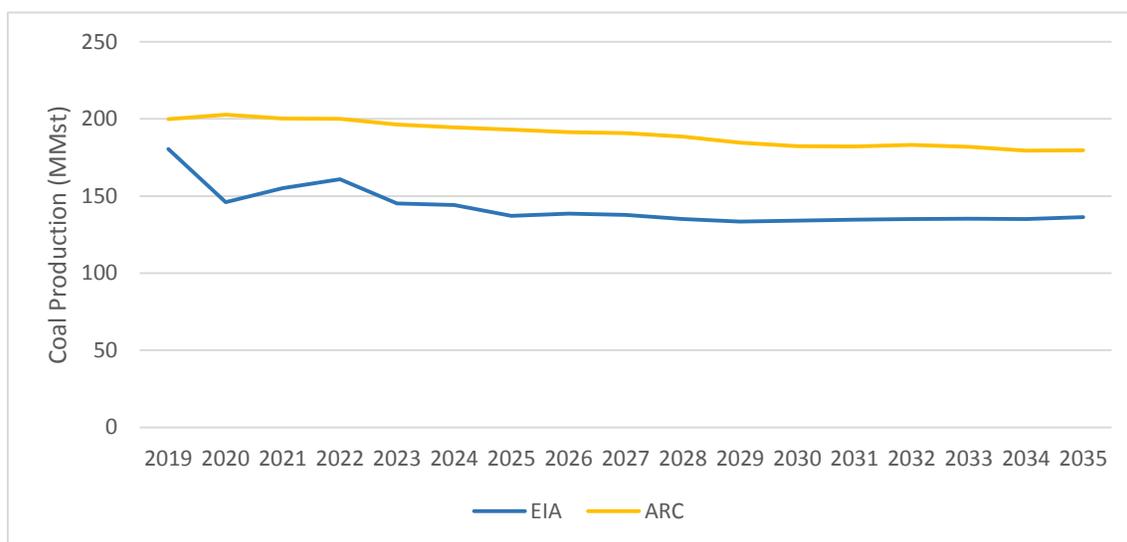


Figure 10. Coal Production in Appalachia

While moderate stability is projected, at best it is a fragile stability that could be negatively affected by the out-year price, by the availability of competing natural gas, or by changes in international market demand. This, coupled with the fact that the economic fortunes of many Appalachian communities will remain dependent on coal production, means that Federal and state policies are needed to support the coal industry and coal communities.

Given the importance of export markets to the stability of United States coal markets, there are several steps that could be taken to improve coal exports. The National Coal Council (NCC), a multi-stakeholder advisory committee to DOE, released an assessment of coal exports in 2018 that recommended increased funding for maintaining inland waterways and enhancing coal export terminal and port capacity.⁴¹

The NCC also recommended updating the existing coal-fired power generation fleet with the latest efficiency and emission controls equipment, without excessive permit modification. Policies that benefit domestic steel manufacturing, such as the Administration's anti-dumping policy measures, are other avenues that can help stabilize domestic coal demand.

To help ensure a continued role for coal, the NCC assessment also expressed support for the development of advanced coal technologies. One major United States effort to develop advanced coal technology is Coal FIRST. Launched by DOE in 2016, Coal FIRST aims to develop the next generation of coal-fueled power generation technologies that are near-zero emissions. Coal FIRST plants are designed to operate flexibly in conjunction with intermittent resources such as wind and solar.⁴²

Apart from coal's role in energy production, extraction of critical minerals and rare earth elements (REE's) from coal also presents a significant opportunity for economic growth in Appalachian communities. Critical minerals and REE's play a significant role in today's economy and in national defense. They are used in goods such as computers, batteries and cell phones, in components of renewable energy technologies, and in military equipment such as GPS, night vision, guidance systems and other defense electronics that enable a United States military strategic advantage.

Currently, the United States is largely dependent on foreign sources of critical minerals. The United States is more than 50 percent import-reliant for thirty-one of the thirty-four mineral commodities identified as critical by the Federal Government. This issue has gained attention of the White House, and as a result Executive Order 13817, "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals", was issued in 2017, establishing that the policy of the Federal Government regarding critical minerals is to "reduce the Nation's vulnerability to disruptions in the supply of critical minerals."⁴³

A potential domestic source of interest for these mineral commodities and REEs is coal. DOE is leading research on ways to identify and extract critical minerals and REEs from our vast coal reserves, coal byproducts, and coal wastes. DOE estimates that recoverable coal reserves in the Appalachian region could produce nearly 5 million metric tons of REE's alone. To put this in perspective, in 2013 REE consumption in the United States was 18,500 metric tons.⁴⁴ If processes to extract critical minerals and REE's from coal are made economic through R&D, accessing these markets could serve as a significant economic driver for the Appalachian region.

Another pathway to help sustain coal markets, and thus coal communities, is the development of new products that are made from coal. Possibilities include certain lightweight, high strength building materials and other carbon-based products. DOE estimates that the demand for carbon fiber, graphite, and graphene, which can all be derived from coal, will experience double digit annual growth in the years ahead.⁴⁵ In another recent analysis undertaken by the NCC, it was

concluded coal usage for coal-to-products manufacturing could potentially grow to the same order of magnitude as coal usage for power generation.⁴⁶ The Administration's Fiscal Year (FY) 2020 and FY 2021 budget requests propose to increase R&D funding in this area.

The NCC also recommended providing incentives for private sector investment in the coal-to-products production and manufacturing sectors. These incentives would include establishing public-private partnerships, expediting environmental and permit approvals for projects, providing tax incentives similar to those provided for renewable energy technologies, and using coal communities as economic revitalization zones for new coal-to-fuels and coal-to-products production and manufacturing centers.⁴⁷ Coal-to-products manufacturing can develop in the coal communities that supply the raw material, much like the petrochemical industry is attracted to the Appalachian region due to the NGLs produced.

3.3 INFRASTRUCTURE CONSIDERATIONS

Transportation infrastructure is an important linchpin in the future growth of the Appalachian energy sector. In the case of natural gas, the ability to site and permit pipelines in a timely manner is the biggest challenge that must be tackled.

Multiple major pipeline projects have been delayed or canceled in recent years. For example, a 2-year delay to the in-service date of the Atlantic Coast Pipeline, designed to move natural gas from the Utica and Marcellus in West Virginia to the east coast through Virginia, has been announced. The delay is due to permitting lawsuits and has added more than \$2 billion in cost.⁴⁸

In another instance, the Sweden Valley Project, a pipeline from Pennsylvania to Ohio, was cancelled due to delays in the Federal permitting process.⁴⁹ Situations like these make clear the need for more streamlined permitting processes that protect human health and the environment while simultaneously providing timely permitting decisions. The tremendous cost of delay is ultimately borne not by only energy customers, but also by landowners, construction workers, investors, and Americans generally.

EPA's recent effort to reform and update its Clean Water Act Section 401 regulations to reduce delays in issuing water quality certifications is one example of effective streamlining. A continuation of the Administration's systematic review of existing regulations affecting pipelines, underground gas storage, power generation, and electricity transmission could identify further opportunities for regulatory streamlining.

To continue growing exports, FERC and DOE should continue to place a high priority on timely authorization of LNG export applications so that industry has the needed certainty to invest in

Box 1. TEAM Consortium Workforce Development

The Tri-State Energy & Advanced Manufacturing (TEAM) Consortium provides credentialed education and training that leads to jobs in the Appalachian energy & manufacturing sectors.

Launched in 2017, the Consortium serves 27 Appalachian counties through community colleges and higher education institutions in the region. The consortium members offer five tiers of workforce development, which each have a pathway to employment: (1) foundational skills training, (2) three-week training, (3) certificate programs, (4) associate degrees, and (5) bachelor's degrees.

This workforce development model has proven highly successful in the region. It is a candidate for scaling to other parts of Appalachia. Long-term financial sustainability is based on a combination of foundation, industry, government, and tuition funding. The financial support to support the launch was provided by Chevron, the Benedum Foundation, the Appalachian Regional Commission, and Beaver County Community College and other regional educational institutions.



Photo credit: ShaleNET

LNG infrastructure. While the natural gas industry makes substantial investments in the roads it uses, Federal and state programs that help local communities upgrade their roads and bridges are essential as well.

In numerous cases, over and underpasses built many decades ago are simply underrated or have height restrictions prohibiting vital equipment shipments that support the energy sector's economic growth. And in the emerging age of the "digital gas field," broadband service (and sometimes even basic cell service) needs to be developed.

The needs of the coal industry are somewhat different, with rail and waterway infrastructure being the most important. Shipments of coal out of the region are reliant on a robust rail and waterway network.

Appalachia has a rail network developed during the height of Appalachian coal production. It is capable of transporting coal from mines to power plants and industrial centers such as those serving the steel industry. In addition, an extensive lock and dam system was built many decades ago along the Allegheny, Monongahela, and Ohio Rivers, and it is still used today for shipping coal out of the region.

Some rail and waterway infrastructure are old and deteriorating. The Upper Ohio (river) Navigation study revealed that three locks are structurally unsound and will reach a 50 percent probability of failure by 2028. On the Monongahela River, the lock

and dam at Elizabeth, Pennsylvania, has far exceeded its design life at 111 years old and it is highly unreliable. Infrastructure on the Allegheny River face similar challenges.

Expanded West Coast export infrastructure would improve the competitiveness of United States western coal in the international market. If more western coal can find economic outlets overseas, the demand for coal from Appalachia will grow.

3.4 WORKFORCE CONSIDERATIONS

The Bureau of Labor Statistics reports that the total 2018 wages associated with natural gas drilling and extraction in Northern to Central Appalachia amounted to \$1.1 billion.⁵⁰ The economic impact of the natural gas industry reaches well beyond direct employment from drilling and extraction. More broadly, the American Petroleum Institute (API) estimates that the natural gas and oil industry supports more than 260,000 jobs in Ohio, 320,000 jobs in Pennsylvania, and 71,000 jobs in West Virginia—well over 650,000 jobs combined.^g Estimated wages associated with these jobs are more than \$14.7 billion, \$23.0 billion, and \$3.5 billion respectively. These jobs include those directly related to natural gas activities, like drilling and extraction, as well as supporting activities such as construction, transportation, and banking, among others.⁵¹ In addition, API estimates more than \$90 billion in total economic activity in these states associated with oil and natural gas industry operations.

The construction of pipelines throughout Appalachia also represents significant investment in the region that stems from the natural gas industry. Twelve federally regulated pipeline projects in Northern, North Central, and Central Appalachia are either approved or currently under construction.

A decade ago, when the shale gas industry first emerged, there was a significant shortage in the trained workforce. Over the past decade a solid base workforce has been built. This is due, in significant measure, to a range of industry and government training programs. These programs, such as the example cited in Box 1, will need to continue if the region is to be positioned for future growth. In the coal industry, the existing workforce is highly trained and as production increases, the market is able to readily fill positions. For those who have been displaced, re-training for workforce opportunities is the leading priority.

^g Data are unavailable for Kentucky.

4. PETROCHEMICAL MANUFACTURING SECTOR

Petrochemicals are chemical products derived from processing hydrocarbon feedstocks, such as petroleum-based liquid feedstocks (e.g., naphtha), NGLs, or dry natural gas. One common processing technology is steam cracking of liquid feedstocks into a slate of chemical derivatives, such as olefins (ethylene, propylene and butylene) and aromatics (benzene, toluene, xylene, and others). Olefins and aromatics are used to manufacture products: plastics, resins, fibers, elastomers, lubricants, and gels. See Figure 11.

There are also catalytic processes, such as dehydrogenation that directly convert NGLs to single olefins. For example, propane dehydrogenation (PDH) produces a single product, propylene. Further, there are processes, both thermal and catalytic, that convert dry natural gas to chemical derivatives such as ammonia and methanol that are used to manufacture fertilizers, antifreeze, paint-thinner, and fuel additives.

Each of these production technologies represents an opportunity to establish anchor petrochemical facilities in Appalachia that produce chemical derivatives which can subsequently be converted by downstream manufacturers into consumer and industrial products.

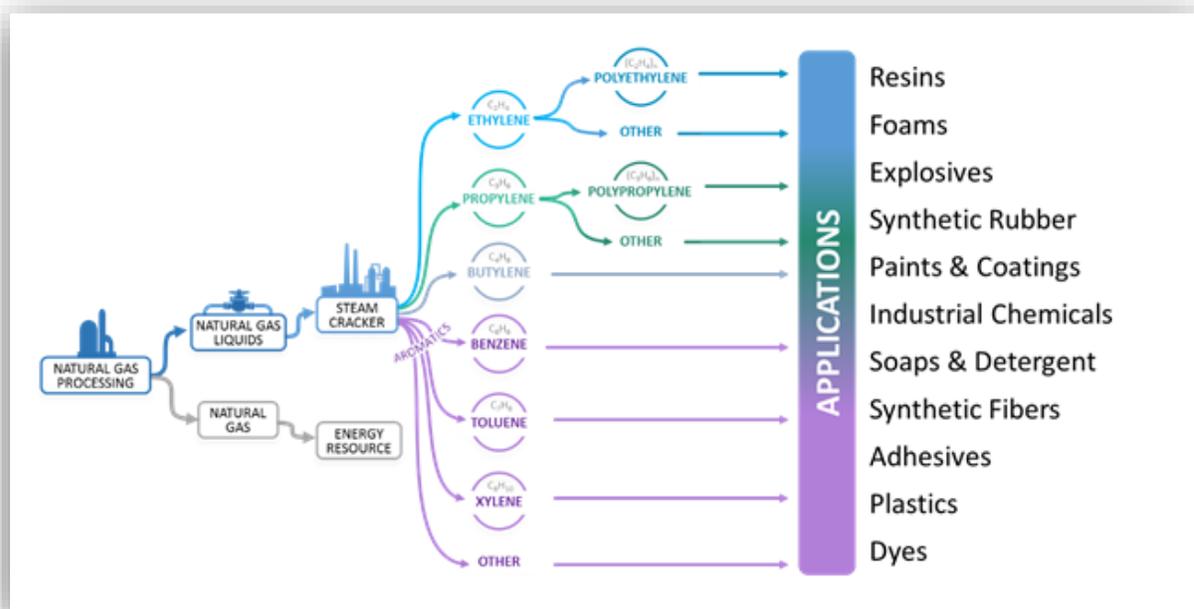


Figure 11. Natural Gas Value Chain and End Market Size (2018)

The price difference between petroleum and natural gas is important to the global competitiveness of the United States petrochemical industry.^h Due to low United States natural gas prices over the past decade, and projected into the foreseeable future, the United States remains at—and expects to retain—a global competitive advantage in petrochemicals production.⁵²

4.1 THE REGION TODAY

Appalachian natural gas production infrastructure has rapidly expanded since 2010, and the region is experiencing growth in the associated processing capacity throughout the entire value chain. As raw natural gas is extracted from the wellhead, it is transported to a processing plant that removes impurities, such as water and carbon dioxide (CO₂), and separates NGLs from “dry” natural gas (methane).

Appalachia’s gas processing capacity increased nearly tenfold between 2010 and 2016, growing from 1.1 bcf/d to 10 bcf/d.⁵³ While practices vary from plant to plant, when NGLs are separated as an aggregate stream (known as Y-grade), some of the ethane is left behind in the natural gas (a practice called rejection), because there is no other market outlet for the ethane. Thus, Appalachian dry natural gas often has residual NGLs (notably ethane).

After being separated at the processing plant, the Y-grade NGL stream is transported to centralized midstream facilities that separate the Y-grade into its distinct components: ethane, propane, normal butane, isobutane, and natural gasoline. This process is called fractionation. Appalachia has experienced exponential growth in fractionation capacity since 2010, surging from just 41,000 BPD in 2010 to 1.1 million BPD in 2019.⁵⁴

The 2018 average volume of NGLs sold to market was approximately 683,000 BPD. This includes 277,000 BPD of ethane, 240,000 BPD of propane, and 166,000 BPD of other NGLs. Additionally, it is estimated that somewhere between 150,000 BPD and 685,000 BPD of ethane were produced at the wellhead but were rejected into natural gas sold to market. The practice of rejection represents a very low-value use for the ethane and a missed opportunity for higher-value utilization.

The most cost-effective way to transport NGLs is through pressurized pipelines. Due to Appalachian pipeline capacity limits, however, a significant share of production must be moved via rail. While rail can be cost competitive for propane, butane and isobutane, it is extremely costly for ethane, which requires either cryogenic temperatures or very high pressures to remain in a liquid state. As a result, rail shipments of ethane are generally considered impractical in Appalachia due to poor economics.

^h When the ratio of the price of oil versus natural gas is above 7.0, United States petrochemicals production, much of which is based on natural gas-based feedstocks, is generally competitive with European and Chinese petrochemical production, much of which uses oil-derived naphtha as a feedstock. The ratio of the price per barrel of Brent crude oil to the Henry Hub price per million BTUs of natural gas has been above 7.0 since 2009.

As of April 2020, there are seven major pipelines, either operating or nearing construction completion, which have the potential to transport NGLs out of Appalachia. The combined total capacity of the pipelines is 900,000 BPD, and through increased pumping and operational changes (i.e., achieved without additional pipe) that capacity could be substantially increased.⁵⁵ Table 1 shows the region's major pipelines, capacity, and destination. Figure 12 illustrates the location of pipeline and other NGL infrastructure in the region. These NGL pipelines were developed or repurposed to transport the products out of the Appalachia to downstream consumers such as crackers, refineries and other petrochemical complexes, as well as to domestic distributors and exporters. Table 1 does not include major NGL pipelines, such as Cornerstone, which move NGLs exclusively within the region. Capacity ratings should not be confused with actual shipment volumes out of the region through the pipelines.

In the region, one of the most significant NGL pipeline developments is the planned completion/re-purposing of the three Mariner East pipelines. In the recent past, the Mariner East I pipeline has transported ethane and propane in batches. Once remaining operational issues are resolved on the Mariner East II pipeline, it will carry propane and will have receipt and distribution points along its route, giving producers and consumers new transport options.

Once fully operational, Mariner East II will free up Mariner East I exclusively for ethane shipments, increasing the amount of ethane it has historically carried from an estimated average of 35,000 BPD to 70,000 BPD. Once Mariner East IIX is commissioned, it will provide additional capacity for NGLs and other products including condensates. The particular NGL that the pipeline owner, Sunoco Logistics, decides to transport will shape regional product flows significantly. With respect to ethane, approximately 250,000 BPD is currently being produced for sale to the market (i.e., not rejected). Of this 250,000 BPD, approximately 20,000 BPD is transported by the Appalachia-to-Texas Express (ATEX) pipeline to Kentucky. The remaining 230,000 BPD is transported via pipelines out of the region: ~70,000 BPD to Canada via the Utopia and Mariner West pipelines, 125,000 BPD to the Gulf Coast via the ATEX pipeline, and ~35,000 BPD to Marcus Hook, Pennsylvania, for export to Europe. These quantities are all estimates of private business transactions.

With respect to propane, in 2019, Appalachia produced 194,000 BPD. Unlike ethane, propane moves by rail and pipeline, so shipments out of the region are not easily estimated. In-region demand, principally for fuel, is strong, but steady production and seasonal demand patterns result in outbound summer exports and inbound winter imports to the region.

The TEPPCO pipeline is noteworthy. It sends about 30,000 BPD of Appalachian propane to Selkirk, NY for use in New York, New England, and Northern Pennsylvania. Substantial propane subsurface storage is located along the TEPPCO route to Selkirk. Also of note is the Marcus Hook, Pennsylvania liquefied petroleum gas (LPG) facility that exports propane and butanes.

Table 1. Major Natural Gas Liquids Pipelines in Appalachia

Pipeline	Capacity (BPD)	In-Service Date	Destination	Product
Mariner West	50,000 ⁱ	December 2013	Sarnia, CN	Ethane
Utopia	50,000 ^j	January 2018	Windsor, CN	Ethane
ATEX	145,000 ^{k,1}	January 2014	Mont Belvieu, TX	Ethane
TEPPCO	60,000 ^m	January 2014	Selkirk, NY	Propane
Mariner East I	70,000 ⁿ	September 2015 ^o	Marcus Hook, PA	Ethane
Mariner East II	275,000 ^p	December 2018	Marcus Hook, PA	Propane/Butane
Mariner East IIX	250,000 ^q	TBD	Marcus Hook, PA	TBD ^r

ⁱ Between Mariner West and Utopia, it is estimated ~75,000 BPD of ethane is delivered to Canada based on usage of ethane near the pipeline terminus. As these shipments involve private business transactions, the exact total transported and split between the two pipelines is not publicly available.

^j Kinder Morgan, the Utopia pipeline owner, indicates the line could be expanded to 75,000 BPD with additional pumping and could potentially carry propane in addition to ethane.

^k Enterprise Product Partners, the owner of the ATEX pipeline, is currently soliciting pipeline users to gauge their interest in a 50,000 BPD capacity expansion. The pipeline is generally known to be operating at capacity.

¹ Approximately 20,000 BPD of the ATEX capacity is used to support the steam cracker and PVC manufacturing plant in Calvert City, Kentucky. The remaining 125,000 BPD of product is delivered to Texas.

^m Approximately half of this capacity, on this segment, is used for Appalachian propane and the remainder is received from the Gulf Coast point of origin. As there are receipts and withdrawals at various points along the pipeline, and these receipts and withdrawals are confidential, private-sector sales transactions, this is an estimate.

ⁿ This pipeline has historically transported ethane and propane in batch shipments. It is currently being converted to ethane-only use. Historically, DOE estimates that an average of ~35,000 BPD of ethane was transported via this pipeline.

^o This line was commissioned for ethane use in September 2015. It was originally commissioned as a gasoline pipeline in the 1930s.

^p Based on the engineering of the pipeline, as much as a doubling of this capacity may be possible with increased pumping and operating refinements.

^q Based on the engineering of the pipeline, as much as a doubling of this capacity may be possible with increased pumping and operating refinements.

^r Multiple possible products have been publicly mentioned by Sunoco Logistics, the pipeline owner.

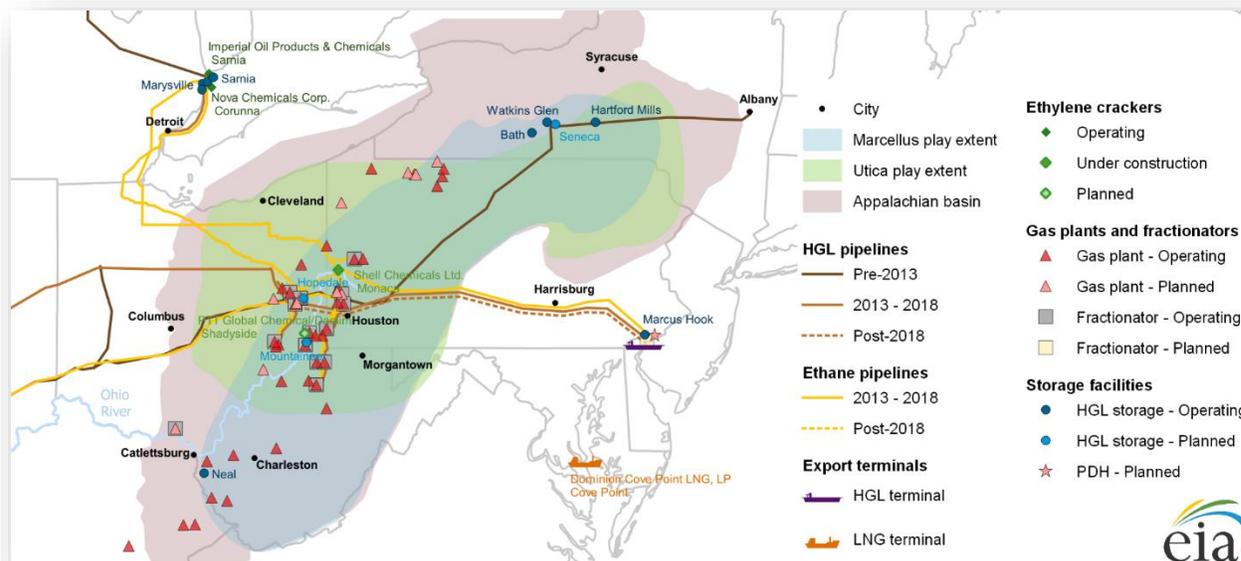


Figure 12. Appalachia Regional Infrastructure Map^s

The total cost of producing and transporting ethane from Appalachia to the Gulf Coast usually exceeds the realized price of ethane at Mont Belvieu, the Gulf Coast trading hub.^t Effectively, some producers are selling ethane at a loss in order to manage excess ethane that they cannot otherwise reject. This practice is currently a necessity as there is no Appalachian market for most ethane that is co-produced with shale gas.

Currently, the Appalachian region has one world-scale ethane cracking complex under construction and one that is nearing Final Investment Decision (FID). Shell Chemicals Appalachia, LLC is constructing a petrochemical complex in Beaver County, Pennsylvania, which will include 95 miles of ethane pipeline, seven ethane cracking furnaces, three polyethylene production lines, and a 250-MW natural gas-fired power plant to supply site electricity.

The project had a peak construction workforce of 8,500 predominantly union employees.⁵⁶ The demand for union employees is so large that the project draws from union halls throughout the region and the Nation, creating broad economic benefit.

In a second project, Thai-based PTT Global Chemical is approaching an FID to construct a \$10 billion petrochemical complex in Belmont County, Ohio. This project would create an estimated

^s In the Figure's legend, Hydrocarbon Gas Liquids (HGL) storage refers in aggregate to NGL (alkane) storage and olefin storage.

^t Mont Belvieu, Texas is a major delivery point and storage location for the Gulf Coast and is therefore used as a pricing point of NGL commodities in the Gulf Coast.

6,000 construction jobs. Once operational, it is estimated to be a workforce of similar size as the Shell project, supporting 600 full-time positions. Combined, the Shell and PTT projects are estimated to create approximately 1,200 direct onsite jobs, and over 9,800 indirect jobs that will span across multiple sectors of the United States economy.

The region's only existing petrochemical cracker is Westlake Chemical's Calvert City, Kentucky plant. The plant's cracker is about 20 percent the size of Shell's cracker and withdraws approximately 20,000 BPD of ethane from the ATEX pipeline. The facility converts ethane into ethylene, and subsequently converts the ethylene to PVC resin, which is then extruded or molded into plastic pipe, vinyl building siding, and other products. Prior to 2014, the plant used propane as a feedstock, but with the availability of low-cost ethane from the ATEX pipeline, the plant has converted to using ethane feedstock and was able to expand its production capacity.

As the petrochemical industry expands in Appalachia, NGLs storage becomes an increasingly vital component of NGL infrastructure. Storage enables the industry to manage the variability of supply and demand of NGLs, which can be caused by any number of factors, including wellhead production variability and downtime at fractionators and crackers. Due to the volume of storage necessary at each storage location (millions of barrels for each type of NGLs or NGLs-derivative stored), geologic caverns are best suited to the task. Y-grade, ethane, propane, butane, and NGL derivatives like ethylene and propylene are all candidate liquids for storage.

Within Appalachia, there is limited geologic storage, and what exists is dedicated to specific facilities. Examples include the one-million-barrel hard-rock butane storage cavern that supports Marathon's Catlettsburg, Kentucky refinery, the hard-rock storage cavern that is integrated with Braskem's polypropylene production in Marcus Hook, Pennsylvania, and the four hard-rock storage caverns that Sunoco repurposed for NGL storage at its export/processing facility in Marcus Hook, Pennsylvania. One exception is the propane storage caverns in New York, which service multiple customers.

This contrasts with other areas of the country, most notably Mont Belvieu, Texas, which has a storage hub. The hub consists of numerous storage caverns owned by multiple companies, as well as supply and distribution lines connecting them to the marketplace. Total storage capacity is estimated at over 240 million barrels.

In Appalachia, there are multiple geologic storage projects under development that would service multiple customers the way Mont Belvieu does, albeit on a much smaller scale (that is, millions to tens-of-millions of barrels of capacity). While the market will ultimately decide which Appalachian storage projects advance to completion, there are enough active projects to expect that one or more will commence operations in the early- to mid-2020s and that these projects will interconnect with pipelines in the region.

4.2 OPPORTUNITIES FOR GROWTH

Due to its proximity to low-cost natural gas, NGLs, and light tight oil (LTO) resources, and its proximity to market demand for petrochemicals derived from these resources, Appalachia has a competitive advantage for petrochemical manufacturing. Illustrative of this advantage, IHS

Markit estimates that when compared with the the Gulf Coast, identical greenfield manufacturing facilities in Appalachia could produce polyethylene for 23 percent less, ammonia/urea for 12 percent less, propylene for 10 percent to 11 percent less, and methanol for 26 percent less.

Additional opportunities exist for other chemicals, such as ethylene oxide, ethylene glycol, ethylene dichloride (EDC), vinyl chloride monomer (VCM), polyvinyl chloride (PVC), chlorine, caustic soda, and others.

The ACC estimates that more than 100,000 permanent jobs could be created in Ohio, Kentucky, Pennsylvania, and West Virginia from a build-out of the petrochemical industry. Beyond this, a host of existing downstream manufacturers who make products from petrochemicals would have an opportunity to grow, and new manufacturers would be attracted to the region. Capturing this growth opportunity, however, will require a cooperative effort between the public and private sectors to attract private capital to the region.

The foundation for the economic opportunity was created by the newfound abundance of NGLs that are co-produced with shale gas. The region's unique natural gas composition, consisting of nearly 40 percent wet gas, creates the large supply of NGLs.

EIA projects continuing growth in Appalachian natural gas production and natural gas plant liquids (NGPL)^u production through 2050. At the end of that forecast period, 2050, production is still growing. Figure 13 presents EIA's projection for all major regions of the country. Note that Appalachia is the principal driver for the "East" production region. The *sustained* abundance of gas and NGLs in Appalachia is a prerequisite to private-sector investment in petrochemical infrastructure, because the facilities are long-lived assets that must earn a financial return.

^u "NGL" stands for natural gas liquids, which refers to the total resource in the region. "NGPL" stands for Natural Gas Plant Liquids, which refers to the liquids (NGL's) separated from produced gas at processing plants and fractionators. In some contexts, the difference is subtle.

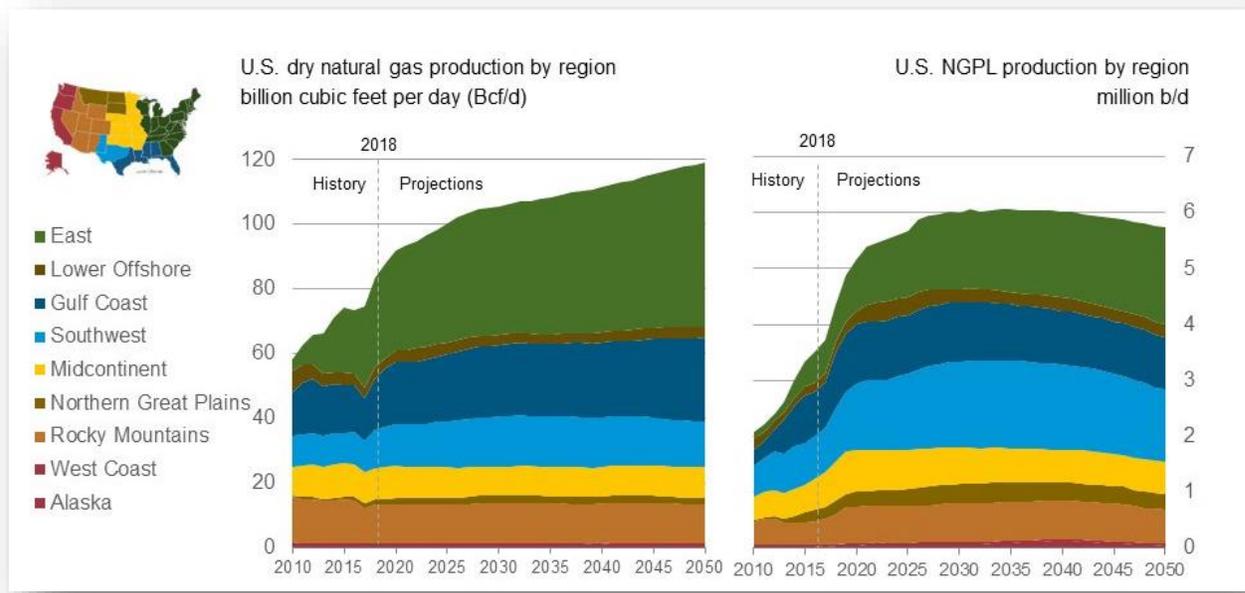


Figure 13. Projected Growth in Natural Gas Production and NGL Production ⁵⁷

Of all the NGLs produced at the wellhead, ethane is currently the most underutilized. Current ethane production of 250,000 BPD is projected to reach 640,000 BPD by 2025 and 950,000 BPD by 2050. At 640,000 BPD, the existing pipeline network that carries ethane out of the region and four world-scale ethane crackers^v could be supported by 2025. Given the time-to-construct, as a practical matter, only Shell and PTT could be on-line by 2025. But there is clearly adequate ethane resource available for other plants to follow in the 2025 to 2030 timeframe. This is all prior to accounting for the ethane that is currently rejected.

^v A world-scale ethane cracker is assumed to consume ~90,000 BPD.

Figure 14 provides EIA’s estimates of production and ethane rejection for 2010 through 2018. Prior to 2014, when the first pipeline capacity for transporting ethane commenced operations, 100 percent was rejected.

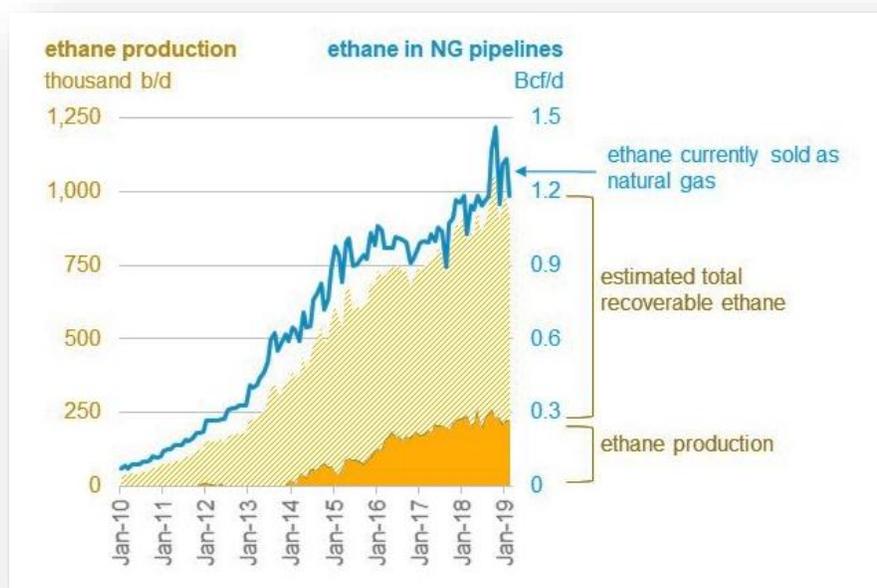


Figure 14. Ethane Production and Estimated Rejection, 2010-2018 ⁵⁸

In 2018, it is estimated that a minimum of 150,000 BPD and as much as 685,000 BPD of recoverable ethane was rejected due to the lack of another market. This ethane was simply mixed with natural gas and consumed as fuel—a very low-value use. The region’s projected growth in ethane production and in the creation of value-added uses for the rejected ethane provides an immense opportunity for petrochemical producers and for Appalachia.

Ethane steam cracking is vital to economic growth because it transforms ethane into principally ethylene.⁵⁹ These basic petrochemicals serve as molecular building blocks for downstream manufacturers. In the case of the crackers already under development (i.e., Shell and PTT), downstream polyethylene production lines are co-located at the cracker site.

Polyethylene is the most common polymer produced from ethylene. The polymer (commonly called a plastic resin) is subsequently converted by other downstream manufacturers into a wide variety of products (e.g., films, tubes, plastic automotive parts, and plastic consumer products). Figure 15 shows the typical steam cracker yields for ethane and propane feedstock. The “other” output represented by the blue bar in Figure 15 includes aromatics that support downstream manufacturers in the production of specialty chemicals used in plastics, rubbers, and other chemical derivatives. Lanxess and Covestro are examples of two downstream specialty manufacturers operating in the region. Butane and other NGLs can also be cracked, yielding a similar slate of products but in different proportions.

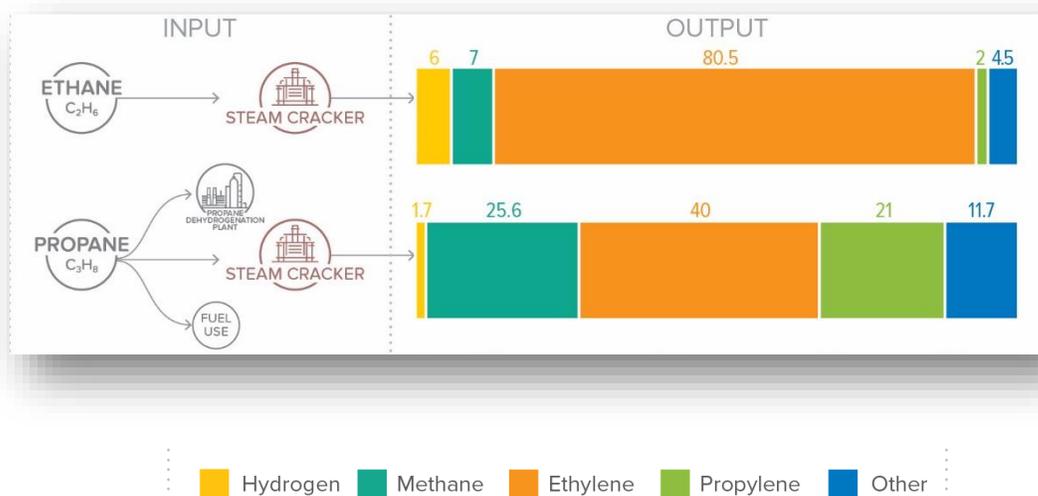


Figure 15. Typical Percentage of Olefin Output from an Ethane Cracker⁶⁰

There are numerous steam crackers around the country, but most of the United States capacity is located in the Gulf Coast region. As ethane has become more abundant nationally, more steam crackers are using low-cost ethane as the feedstock of choice. The result is lower yields of propylene, butylene, and aromatics as compared to that historically produced from other feedstocks. This situation is driving the petrochemical industry to use PDH facilities to create propylene.⁶¹

More than 2 million metric tons/year (MMtpy) of new PDH capacity has come online in North America since 2010, another 1.6 MMtpy is under development, and propane/propylene economics may well support still more capacity being built by the mid-2020s. Given Appalachia's abundant supply of propane and proximity to propylene markets, the region would be a good candidate location for PDH facilities. Presently one is being considered for construction at the Marcus Hook petrochemical complex.

Major petrochemical projects have lengthy development and construction schedules—5 to 10 years being common. It is most likely that as NGL production grows, pipeline capacity will also grow to enable the export of more NGLs from the region. The practice of rejection will likely continue, in parallel with the development of petrochemical projects.

As new infrastructure—a pipeline or a petrochemical plant—comes online, each project “locks-in” another increment of NGL demand. Therefore, it is imperative that, if Appalachian States want to ensure maximum in-region economic development, there is a swift move to attract private petrochemical investment to the region. If a higher capacity pipeline network is installed prior to in-region petrochemical complexes, Appalachia's growing NGL production will simply be exported from the region along with many prospective jobs and economic benefits.

Beyond the NGLs play in Appalachia, the shale formations in the region are producing some quantities of LTO. In particular, southeast Ohio has seen an increase in this unconventional oil

production. The Ohio Department of Natural Resources reports nearly 5 million barrels of oil in the first quarter of 2019 produced from the Utica shale play.⁶² This situation also presents an opportunity for more aromatics production, which can be done through reforming NGLs and LTO.

Expanding beyond existing regional refining capabilities would enhance the economic value derived from the available regional energy resources. LTO refineries produce LPG, consisting of propane or butane. LTO refineries are also capable of reforming natural gas to produce aromatics. A petrochemical industry would benefit from having the option of refined petroleum-based feedstock or NGLs, which would give producers the ability to produce both fuel and feedstocks for chemicals, creating an additional economic advantage.

Attracting that capital involves a considerable economic development effort to communicate the investment opportunity. That effort has to be built on a foundation of data and information that prospective investors can use for making what will often be multi-billion-dollar investment decisions. Substantial progress has been made by the Tri-State Shale Coalition, Shale Crescent USA, the commonwealths of Pennsylvania and Kentucky, the states of Ohio and West Virginia, and the DOE to communicate the opportunity. But tens of billions in private capital will not materialize overnight. It will require a decade-long communication effort, pursued with alacrity, where the outreach to prospective investors is targeted and buttressed with current information on market economics, workforce readiness, data on the short- and long-term availability of the energy resource, development site availability, the availability of transportation and communications infrastructure, supply chain information, permitting requirements, and other business-decision making information. Further, Federal and State regulatory policies and incentives that create a positive business environment will be essential for enticing investment capital to the region.

4.3 INFRASTRUCTURE CONSIDERATIONS

For the major petrochemical facilities such as crackers, river access is a prerequisite. Managers of large capital projects will source components (e.g., process vessels, furnaces, and prefabricated pipe racks) from across the United States and from international manufacturers. These components are so large that the Mississippi-Ohio river system is the only viable transportation route. This includes reliable and adequate Gulf Coast port capacity at entry points to the river system.

This is one of the reasons why upgrading the lock and dam infrastructure managed by the United States Army Corps of Engineers would be beneficial to attracting large petrochemical facilities. Rail and highway access are important, as well. Appalachian waterway, rail, and highway infrastructure has been sufficient, but key parts of the infrastructure show its age and many locks may be undersized. Continued investment in this infrastructure to bring it up to modern standards would be beneficial to attract maximum private investment to Appalachia. Some of these improvements include upgrading lock infrastructure that is nearing 100 years old; widening roads to support commercial heavy traffic; upgrading underpasses, overpasses, and bridges that have weight and clearance limitations; and expanding rail access at a fair market price.

Contrary to a common misperception, large (350- to 1,000-acre) river-accessible development sites that are suitable for major petrochemical complexes are available in Appalachia. Large flat sites, however, are more limited in number than the Gulf Coast where most United States petrochemical infrastructure has historically been built. Often, Appalachian sites require brownfield redevelopment or land re-contouring that might not be typical in some other parts of the country. Using large development sites that are set back from river frontage with access provided by short heavy haul roads from barge unloading facilities is also an option. Smaller sites (tens to a hundred acres) for smaller facilities are abundant.

In some cases, advance site preparation (e.g., consolidation of multiple tracts, razing of existing industrial infrastructure and providing a pathway to indemnification from the acts of prior owners) would make some Appalachian sites much more attractive investment locations. The public and private sector should work together to take advantage of Federal and State programs, such as the Department of Interior's Abandoned Mine Land (AML) program, Pennsylvania's brownfield site redevelopment program, and similar programs to establish build-ready sites. A database of available petrochemical development sites in the region that could be used as a communication tool to prospective investors would be valuable and does not uniformly exist at present.

As in the case of the energy sector (discussed in the previous chapter), broadband infrastructure to facilitate commerce does not always have consistent coverage in Appalachia. Further, streamlining of regulations, particularly as they apply to pipelines, would facilitate growth of the petrochemical sector.

Finally, while major regional infrastructure garners most of the attention, community level infrastructure (e.g., water, sewer, roads, and schools) can be stretched beyond capacity by major projects. It would not be uncommon for an Appalachian county to have an annual budget of \$5 to \$25 million. While a \$10 billion petrochemical facility would be welcomed, the influx of >5,000 construction workers, followed by operations staff, supply chain employees, and others creates an immediate demand for community infrastructure—sometimes many years—before incoming tax revenues to support local infrastructure improvements materializes. There is an opportunity for State and Federal Governments to help fill this need through a range of existing public infrastructure investment programs—for example, the Department of Agriculture (USDA), Office of Rural Development, Department of Transportation, and the Appalachian Regional Commission programs.

4.4 WORKFORCE CONSIDERATIONS

Upstream projects (i.e., gas production), midstream projects (i.e., gas processing and pipelines), and the construction of Shell's petrochemical complex have clearly demonstrated that an adequate workforce can be mobilized to successfully deliver projects in Appalachia. These projects, however, have been successful as a result of a concerted effort by the private sector—often in partnership with the public sector, academic institutions, unions, and foundations—to recruit, train, and foster a talented workforce. Further, a significant portion of the construction workforce consists of travelers who come to the region temporarily from other parts of the

country. Operators are more likely to be local or permanently move to the region. Transitioning to a sustainable workforce that employs a higher percentage of in-region hires will require a concerted, long-term workforce development effort.

A construction workforce that is more regionally based will largely be driven by two factors: a steady series of infrastructure projects that enables in-region construction careers, and a concerted training and education efforts that creates pathways for Appalachians to enter the workforce.

Appalachia currently has limited basic petrochemical production; however, there is a robust upstream oil and gas production industry, and robust downstream manufacturing that consumes basic petrochemicals to make derivative chemicals and products for other downstream manufacturers, as well as finished end-use products. In fact, 68 percent of total United States employment related to petrochemicals (principally downstream) is within a 500-mile radius of Pittsburgh. Ohio and Pennsylvania represent over 12 percent of petrochemical industry employment.⁶³ So, there is an existing workforce in the broader region. An Appalachian petrochemical renaissance fills in the middle of the value chain with new basic petrochemical facilities and new economic opportunity.

The TEAM consortium discussed in Box 1 that serves 27 Appalachian counties, and regional union training centers, are two complementary, non-profit models for advancing workforce development. Making these and other equally meritorious models successful ultimately depends on durable public-private partnerships.

5. MANUFACTURING SECTOR

The shale gas boom creates additional significant opportunities for Appalachia in manufacturing. Low-cost natural gas and gas-fueled electricity can drive growth in energy-intensive manufacturing. Further, as basic petrochemicals become more abundant, the region has an opportunity to expand downstream manufacturing. Downstream manufacturers have an opportunity to convert basic petrochemicals into derivative chemicals and products for use by other downstream manufacturers, as well as finished end-use products.

5.1 THE REGION TODAY

There are currently 630,000 manufacturing jobs in Northern to Central Appalachia, representing 13 percent of the overall direct jobs market in the region. The major subsectors of the manufacturing industry in Appalachia include automotive, electronic components, wooden and upholstered furniture, food processing machinery, and packaging equipment companies.⁶⁴ Manufacturing in Appalachia today emphasizes lower-skill, labor-intensive manufacturing, and only 3 percent of manufacturing facilities engage robotics.⁶⁵ This type of manufacturing is particularly susceptible to challenges from imports.⁶⁶

In 2015, the Appalachian region produced \$32.1 billion in plastic consumer goods, accounting for 17 percent of United States industry.⁶⁷ Feedstocks for this manufacturing were largely imported to the region. In many cases, in-region production of these feedstocks could provide reduced delivery times for feedstocks and lower feedstock costs. That would create a basis for enhanced competitiveness and manufacturing growth.

The upholstered furniture sector is the most integrated manufacturing sector within the region. At least 50 percent of the raw material inputs come from within the region and over 80 percent of the finished products are sold within the region.⁶⁸ Driving down raw material costs and improving efficiency in manufacturing processes will challenge imports and maintain market share for domestic products. At the other end of the spectrum, the automotive industry is the least integrated from a supply chain perspective and presents an opportunity to bring more of that business to the region.

Appalachia, and more generally the United States, cannot match foreign labor costs, and it has historically been disadvantaged by some international trade agreements. As a result, there is an urgent need to improve manufacturing efficiency and ensure trade policies are equitable.

The Appalachian region is uniquely positioned to grow by taking advantage of its low-cost energy supply; its leading edge R&D in automation and advanced manufacturing which is being developed in parts of Appalachian industry and academia; and opportunities for increased production of goods and equipment directly related to energy production (e.g., wellfield equipment, midstream processing equipment, and electronic controls).

5.2 OPPORTUNITIES FOR GROWTH

5.2.1 ENERGY INTENSIVE MANUFACTURING

Low-cost Appalachian energy can drive down production costs in existing manufacturing operations, thereby increasing competitiveness, and attract new businesses. A recent McKinsey study analyzed Appalachian energy-intensive manufacturing opportunities. It concluded that there are opportunities for the region to expand and attract glass manufacturing, fabricated materials manufacturing, and cement manufacturing, as well as the next generation of data centers required by high technology industries and e-commerce. To elaborate on the opportunities:

- *Glass*: Electricity accounts for roughly 30 percent of total glass production costs. Low-cost electricity can offer a regional production advantage for a glass market that is growing due to an emerging global consumer class. Strong end markets for glass include the construction, automotive, and electronics industries.
- *Fabricated Materials* (i.e., machine shops): This sector fits well within the legacy steel and metalwork industry in the region. The total market for fabricated materials in the U.S. is \$140 billion. General and precision fabrication is expected to grow 2.5 percent per year for metals and 8 percent per year for plastics through 2025.
- *Cement*: There is sufficient capacity to meet cement supply needs in the near-term. However, by 2025, demand growth will require that new plants come online. Pennsylvania is already the fourth largest U.S. supplier of cement. As electric power represents about one-third of the total operating cost of cement manufacturing, low-cost energy provides a basis to expand an existing industry.
- *Data Centers*: The market for data centers will grow at greater than 5 percent per year through 2025 due to the increasing proliferation of the Internet of Things. Large data centers are industrial-scale operations that can use as much electricity as a small town. Electricity comprises 20 to 30 percent of total data center costs, which means low-cost electricity will be a competitive differentiator. This energy resource advantage, combined with the region's high-technology expertise, could make it a magnet for network operations and data centers.

5.2.2 DOWNSTREAM MANUFACTURING

There are near-term prospects for significant in-region supply growth of polyethylene, polypropylene, other cracker byproducts, and increasing volumes of natural gas-derived primary chemicals (e.g., methanol and ammonia). Appalachia also offers close proximity to end-use markets for finished products; that means there is a significant opportunity for growth in downstream manufacturing.

This growth will manifest itself in the expansion of existing manufacturing capacity and the development of new regional businesses. Manufactured products could include plastic

automotive parts or even finished automobiles, polymer components of medical devices, self-repairing tires, agricultural products, films, specialty chemicals, water pipes, and other finished products that businesses and consumers use every day. Each step of the manufacturing value chain that is retained in the regional economy creates jobs and benefits; it also helps diversify the economy of the region. With more of the manufacturing value chain housed in Appalachia, shorter lead times between manufacturers often enables companies to hold less inventory and reduce feedstock transportation costs. Established industry lines (e.g., automobile manufacturing) have an economic incentive to build or remain in Appalachia. The build-out of the value/supply chain is an evolutionary process where steady progress and patience is required as the region works toward increased, long-term economic growth.

5.2.3 ADVANCED MANUFACTURING

Increased emphasis on advanced manufacturing would better insulate Appalachia from foreign competition and create more growth opportunities. This transition is not without its challenges. Advanced manufacturing refers to any process that improves the efficiency or quality of a product and generally includes robotics, automation, artificial intelligence, and additive manufacturing (3D printing). It is distinctly separate from traditional manufacturing methods, which include manual or mechanical machining and joining. While advanced manufacturing technologies do eliminate some low-skilled jobs, they support higher paying jobs, improve efficiency and flexibility, inspire innovation, and promote the growth of companies overall.

It is estimated that by 2025, consumption in emerging markets will more than double from 2010, meaning that manufacturing companies will need to anticipate where the demand will be and what it will look like.⁶⁹ This transition is not without its challenges. McKinsey reports that United States manufacturing companies face fractured markets and accelerated product cycles.⁷⁰

These changes require manufacturing companies to adapt by embracing smart technologies and developing new production methods. In addition to technology, capital access for small- and mid-sized businesses and workforce development is a persistent challenge. Progress addressing these challenges has already been made through SBA programs, the National Institute for Standards and Technology Manufacturing Extension Partnership, and other government and industry initiatives, but much work remains.

To thrive in a global economy with diverse markets, successful companies will need to invest in complex, adaptable facilities, capable of fabricating a wide range of products and seamlessly engaging multiple product lines to meet fluctuations in demand. Advanced manufacturing creates efficiency by incorporating automation, advanced materials, and sensors. These technologies can be implemented in all manufacturing facilities, regardless of size or sector.

The United States plastics manufacturing sector alone has the potential to replace two-thirds of activities with automation, resulting in almost \$10 billion in savings.⁷¹

These savings can be reinvested in companies to build out more advanced facilities or increase R&D. They can be used to increase hiring or to implement incentive programs to attract skilled workers to the region, and they can be captured as increased profitability.

Automation, constant monitoring, and analytics all generate tremendous amounts of data. Data centers allocate between 20 and 30 percent of their operating budget to electricity. As software, artificial intelligence, and data analytics become critical tools at future manufacturing facilities, the Appalachian region can emerge as a desirable place to develop.⁷²

5.2.4 SUPPORTING THE GROWTH OPPORTUNITIES

American manufacturing companies are shifting their primary focus from basic consumer goods to more complex, high-value goods, and initiating this transformation remains costly and time-consuming for established companies. These difficult transitions, however, are critical to remain competitive, and there are already resources in the Appalachian region to facilitate this transition. These resources can be the link to commercialize technologies that enable job creation and manufacturing growth.

The Appalachian region has the unique advantage of being on the leading edge of advanced manufacturing, with substantial investment from technology industry giants such as Google, Uber, and General Electric. These large companies are embracing the challenges of innovation and can leverage the talent and research at the universities within the region.

Small business is essential to ensuring that industries and a skilled labor force will prosper in Appalachia. The SBA was created to provide critical support and resources to help small businesses grow and create jobs. The majority of businesses in Appalachia are small businesses, many of which provide products and services to the energy, petrochemical, and manufacturing sectors. Assistance is provided to new and existing small businesses through access to capital, counseling, contracting, exporting, and investment in innovation. See Box 2.

Box 2. Enabling the Success of Small Businesses in Appalachia

SBA has a variety of programs well-suited to the needs of Appalachian businesses serving the energy, petrochemical, and manufacturing sectors. Among SBA's successes:

- In 2019, through a \$224,000 SBA Express loan, Specialty Ice Distribution, Inc. was able to acquire a cold storage facility. This capital enabled the company to increase production, hire more employees, and expand ice deliveries to the Marcellus Shale well sites.
- New Way Excavating LLC., an 8-year-old transportation service company, was selected to attend SBA's 2019 Emerging Leaders Program. As a result, New Way Excavating made the needed connections to grow their business, thereby expanding into mine reclamation services for the shale industry.
- After receiving \$388,000 through an SBA lending partner, SEDA-COG, Hawbaker Engineering, a Pennsylvania family-owned company founded in 1952, benefited from the Marcellus Shale industry by expanding to 44 counties in Pennsylvania with a footprint covering parts of New York, West Virginia, and Ohio. The expansion allowed Hawbaker Engineering to sustain a revenue stream during a time of recession, eventually increase employment by approximately 300 technicians, and obtain the ability to increase capital investments for resources and future development.

MEP is a Federal program funded through NIST, dedicated to helping manufacturing companies develop products and connect with new markets. The MEP has a special focus on small- and medium-sized companies.

According to its 2018 survey, the top three challenges for small manufacturing companies are cost reduction, growth, and employee recruitment.⁷³ The MEP has demonstrated value to the manufacturing industry by increasing jobs and sales and helping companies decrease their costs.⁷⁴ See Figure 16.



Figure 16. Benefit to Industry from Program Participation

The Department of Commerce Economic Development Administration’s (EDA) Trade Adjustment Assistance for Firms (TAAF) program funds a national network of 11 Trade Adjustment Assistance Centers (TAACs) across the U.S. to help strengthen the competitiveness of American companies that have lost domestic sales and employment because of increased imports of similar goods and services. The Mid-Atlantic TAAC (MATAAC) serves companies in the Mid-Atlantic region of the United States to make them more competitive. Based on the size of current grant funds, qualifying businesses are typically small- to mid-sized enterprises in virtually every manufacturing industry segment. Typically, MATAAC seeks to identify manufacturers throughout the region who may have experienced declines in revenue from United States customers due to imports and who could benefit from industry experts and financial grants to make improvements. See Box 3.

Box 3. Mid-Atlantic Trade Adjustment Assistance

A precision analytical equipment manufacturer was in its second year of decline with sale volumes down by 25 percent, negative earnings, and productivity down by more than 40 percent, when it was introduced to the Department of Commerce Economic Development Administration’s Mid-Atlantic Trade Adjustment Assistance Center (MATAAC). Through resource evaluation, R&D, market research, and web services, facilitated through MATAAC, the company saw revenue grow by 26 percent, operating earnings returning to positive, and a 26 percent increase in jobs at the company.

America Makes is a public-private partnership organization based in Youngstown, Ohio. It has over 200 members who engage in some way with additive manufacturing.⁷⁵ Its strong member base includes Federal partners such as the Air Force Research Lab and the DOE; private industry, including General Electric, the Ford Motor Company, and 3M; and many universities. America Makes invests in projects that promote knowledge-sharing and technical advancements. Members grow their businesses with access to partner research, the organization's Innovation Factory Laboratory for R&D prototyping, advisory groups, and a network providing access to R&D funding opportunities.

Advanced Robotics for Manufacturing (ARM) in Pittsburgh is another institute with a mission to modernize United States manufacturing. Established in early 2017, this strategically located organization brings together over 190 small and large manufacturing companies, academic institutions, nonprofits, and suppliers to accelerate the use of industrial robots. With a starting budget of \$250 million financed by the Department of Defense (DOD) and partner institutions, ARM draws attention to Appalachia with access to research in artificial intelligence, automation, and other emerging technologies, all with the goal of improving the affordability of industrial robots.⁷⁶ While these groups are providing key resources to their members, the real value lies in the strength of their networks.

5.3 INFRASTRUCTURE CONSIDERATIONS

For manufacturers who may want to locate in Appalachia, road, rail, and utilities (water, sewer, power, natural gas, and broadband) are high priority infrastructure. The importance of inland waterways depends on the type of manufacturing operation and its geographic location. It is noteworthy that while Northern to Central Appalachian counties have no coastline, 5 billion dollars of manufacturing industry products are exported overseas from these counties. Typically, these products are transported to ports in New York City; Buffalo, New York; Norfolk, Virginia; or Charleston, South Carolina. Electronic components, which are responsible for 30 percent of Appalachian exports, rely primarily on-air transportation.⁷⁷

While certain areas of Appalachia have very robust infrastructure, in other areas it is decidedly lacking. Basic cell service, and certainly broadband coverage, can be quite limited, partially driven by hilly topography and low population density that discourages privately funded broadband expansion. Larger energy companies and manufacturers often address their own broadband challenges through dedicated communication lines and towers. Limited broadband, however, disproportionately disadvantages small- to mid-size businesses that rarely have the financial means to develop their own infrastructure.

There are Federal programs to help develop rural infrastructure in relation to telecommunications and broadband capabilities, as well as water, sewage, and energy distribution. Notable programs exist within USDA's Rural Utilities Service, which provides loans and grants to make improvements or to build where there is no infrastructure in place.

State-level programs, such as Kentucky's SOAR program, are making strides to address economic development issues, including broadband. They often leverage public and private funds. See Box 4.

Box 4. Kentucky's Shaping Our Appalachian Region



Since 2013, Shaping Our Appalachian Region (SOAR) has been dedicated to transforming rural Kentucky by introducing broadband connectivity and leveraging it to create jobs. With a diversity of partners, SOAR has created 2,200 job placements and generated an estimated \$49.2 million in economic impact. SOAR has been financially supported by the commonwealth of Kentucky, the Appalachian Regional Commission, USDA's Office of Rural Development, private companies, foundations, and educational institutions.

There are, however, communities in need of infrastructure that do not qualify for these programs or do not have the financial capacity to cost share the development of infrastructure. Qualification requirements, cost-sharing, and application writing assistance are areas that could be examined to more effectively target available public funds. In some cases, this may require statutory refinements.

Economic analysis indicates that investments to build out critical non-highway infrastructure have supported manufacturing growth outpacing growth in mining, farming, and agriculture.⁷⁸ Additional investment in the region's highways is estimated to add a total of 80,500 jobs by 2035.⁷⁹

An evaluation of smaller scale infrastructure projects funded by the Appalachian Regional

Commission's Infrastructure and Public Works program showed that water and sewer system projects resulted in the highest business and family retention rates compared to other projects such as business incubators, industrial sites, and access roads.⁸⁰ While infrastructure investments should be selected and funded based on long-term impact, there are secondary benefits to consider, including the large number of jobs associated with construction.

5.4 WORKFORCE CONSIDERATIONS

Of the 630,000 manufacturing jobs in northern to central Appalachia, almost 70 percent are at large companies with more than 500 people, about 15 percent are with mid-size businesses, and about 15 percent are in small businesses with 50 employees or fewer.⁸¹ Large companies often provide more job opportunities and larger budgets for capital expansion, R&D and other investments required to adapt to a changing market. But small businesses are often more agile. Small and mid-size businesses also frequently provide critical elements of the supply chain required by the large companies. While most large companies are resilient enough to withstand fluctuations in the economy, they often face quarterly pressures from shareholders, which encourages increased profitability and drives outsourcing to cheaper imported components versus purchasing from a domestic supply chain. Economy-wide, United States-made content has fallen by almost 15 percent since 2000.⁸²

Currently, regardless of company size, only about 15 percent of jobs in the manufacturing industry require a bachelor's degree or higher, whereas over 50 percent require a high school equivalent or less.⁸³ Meanwhile, there has been substantial improvement in the percentage of the population graduating from high school, and it is clear that with supplemental training, there are

non-college pathways to the workforce. The Appalachian region, however, still lags behind the rest of the United States when it comes to higher education.

As industry diversifies to include advanced manufacturing, there will be a higher demand for skilled workers in science and engineering fields. Analysis of STEM education trends shows that Pennsylvania, West Virginia, and Ohio all produce STEM graduates at a higher rate than the national average; however, of the students who receive advanced degrees, those in STEM fields leave the region at the highest rates.⁸⁴

This is a clear indication that talent is available, but retention is part of the challenge. As advanced manufacturing grows, new opportunities for retention will open up among educated young people looking for work in innovative and challenging fields. Younger, more diverse populations are especially adaptable and typically learn new skills faster to keep up with changes in technology. Box 5 provides one example of an initiative that seeks to expose young people to innovative developments in energy and manufacturing.

Overall, Appalachian unemployment remains well above the national average, but at the same time, employers have difficulty filling open positions.

Companies currently report difficulty finding candidates with basic math and reading skills, or those with the ability to operate machinery. It is projected that by 2025, there will be 80,000 unfilled jobs in Pennsylvania alone.⁸⁵ This situation indicates a persistent misalignment of skills with needs, which creates an imperative for public and private workforce development programs. Companies can begin to reverse this situation by offering internships or other forms of engagement to college students. The trades have an opportunity to engage with students and their educators⁸⁶ to create pathways to employment. The common myth that college is the only pathway to a family-sustaining career must be dispelled if maximum opportunity for everyone in the workforce is to be created.

Box 5. The National Energy Technology Laboratory Regional Workforce Initiative

To accelerate the deployment of DOE-funded energy and manufacturing technologies, DOE's National Energy Technology Laboratory established a Regional Workforce Initiative (RWFI). RWFI focuses on "educating the educators," such as individuals running training programs at technical and community colleges. This approach has multiplying effect, in that each RWFI participant subsequently exposes many other individuals to DOE-funded energy and manufacturing technologies. More than 400 individuals from 137 organizations across academic, industry, governmental, and non-governmental organizations have participated in the initiative. Due to the multiplying effect, thousands of individuals have undoubtedly been exposed to emerging energy and manufacturing technologies through the initiative.



Photo credit: National Energy Technology Laboratory

6. SUPPORTING INFRASTRUCTURE

Infrastructure investment and development will be vitally important if Appalachia is to capture economic growth opportunities in the energy, petrochemical, and manufacturing sectors. For the growth potential in these sectors to be fully realized, the separate areas within the region must be more connected to each other and better connected to markets outside the region. Infrastructure is a principal mechanism for achieving this connection; it will enable commerce and foster growth.

There are many regions of the country that are in need of infrastructure investment. Two factors elevate Appalachia to the top of the list:

- A short time horizon in which upgraded infrastructure can accelerate the pace of economic development in Northern to Central Appalachia. Absent improved broadband, road, rail, and waterway improvements, a disproportionate fraction of the region's resources will be exported along with corollary economic opportunities, rather than enabling sustainable economic growth.
- The Appalachian economy has significantly improved over the past 2 years; however, for decades, many Appalachian economic growth indicators have lagged those of the Nation's. The region deserves an equal opportunity to accelerate its growth.

Some infrastructure, such as pipelines, the rail system, and broadband in more densely populated areas, depend largely on private capital for improvements. In these cases, policies that create a pro-growth business environment, such as streamlined permitting and tax policy, can enable the flow of substantial capital into infrastructure. Direct public funding should be more limited and should be highly targeted.

Investment in the highway system, waterway infrastructure, rural telecommunications, and local community infrastructure principally results from public policy and investment.

6.1 RAIL

North-central Appalachia's railroad infrastructure was principally built to transport coal and timber to power plants and industrial centers (see Figure 17); it has transported goods produced by the manufacturing industry for more than a century.

The decline in coal production has decreased the traffic on railways in the region. An ARC-commissioned study found that Appalachia is experiencing threats to its rail transport capacity as a result, although the losses to rail transport access are not expected to be catastrophic.⁸⁷ Service has been discontinued on several lines, but as railroad stakeholders adjust to this downturn in rail traffic, they have not made decisions that would be difficult to reverse, such as abandoning track, selling lines, or abandoning terminals.

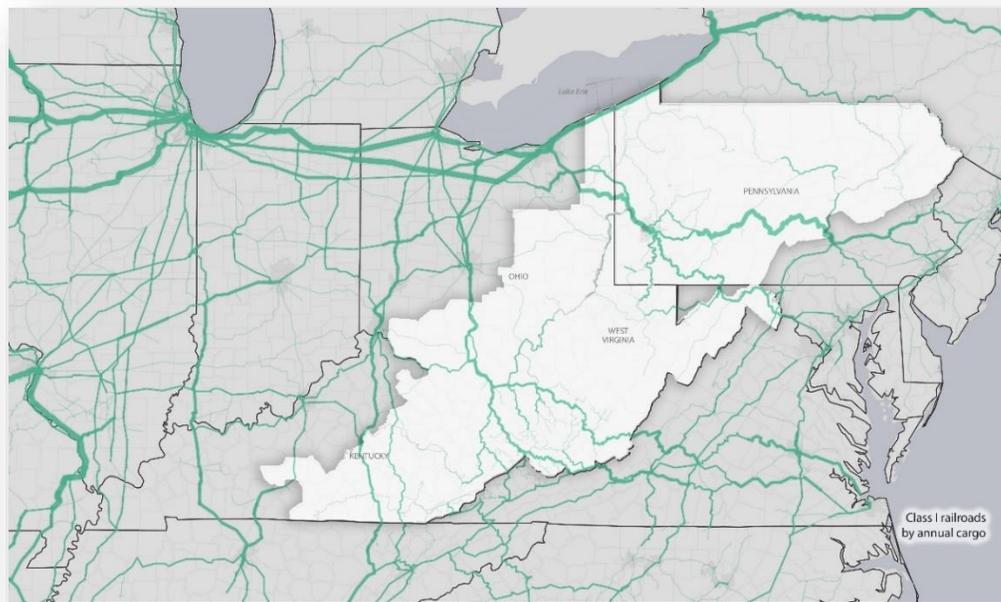


Figure 17. North-central Appalachian Railroads

Looking ahead, rail is central to construction of energy infrastructure, movement of propane+ NGLs, transport of petrochemical derivatives and movement of manufactured products. Growing opportunities in the region, such as shipping products from the petrochemical or manufacturing industries, could provide new revenue sources for rail carriers, potentially leading to more interest in preserving or enhancing rail access in the region.

Box 6. Department of Transportation

In June 2018, \$16.25 million was awarded by the Department of Transportation to the Ohio Rail Development Commission to improve rail transportation in eastern Ohio. The Infrastructure for Rebuilding America (INFRA) grant is being used to improve safety and capacity of 30 miles of rail line along the banks of the Ohio River. These rail upgrades will benefit the proposed PTT petrochemical complex, among other projects.

In December 2018, the Department of Transportation awarded Monroe County, Ohio, a \$20 million rail grant. The “Better Utilizing Investments to Leverage Developments” (BUILD) grant is being used to fund Monroe County’s Appalachia NGL-Rail Transloading project.

The Federal Government, utilizing grant programs at the Department of Transportation could support upgrades to strategic rail infrastructure that would support Appalachian economic development. Examples of two recent grants that serve this purpose are highlighted in Box 6.

6.2 WATERWAYS

Waterways, specifically lock and dam infrastructure and barge facilities, have long been the lowest cost method for transporting coal and other commodities. The Ohio River Valley has historically provided a reliable and affordable means of transporting these products out of

Appalachia to market. The Tennessee-Tombigbee Waterway and the Mississippi River, along with their infrastructure, provide the critical gateway from the Ohio River to the Gulf Coast. See Figure 18. The lock and dam infrastructure is owned by the Federal Government and managed by the Army Corps of Engineers. Ownership (i.e., public vs. private) of ports and barge loading facilities varies widely from location-to-location. In spite of its importance to commerce, Appalachian waterway infrastructure is in varying states of repair.

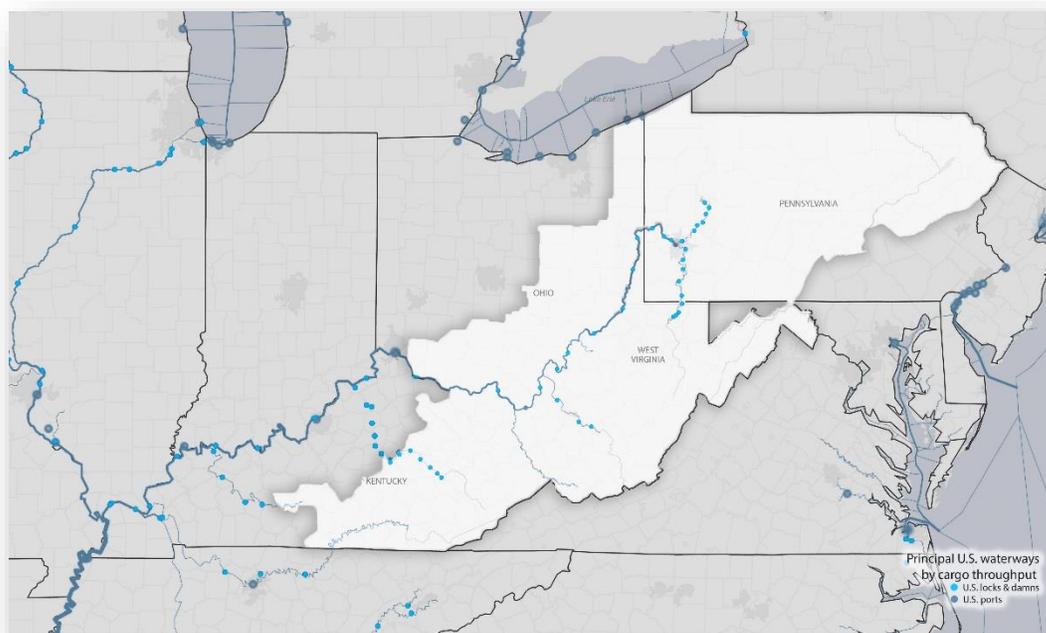


Figure 18. North-central Appalachian Waterways

Six new lock projects have been proposed that would serve Northern to Central Appalachian waterways: three on the upper Ohio River and three on the lower Monongahela. The decline in coal production and transport has reduced the demand for barge transport of coal along the Ohio River by nearly half.⁸⁸

The Budget prioritizes investments in heavily trafficked waterways. Businesses that depend on very large shipments of construction material will consider waterway infrastructure, among other factors, when making investment decisions. Manufacturers who want to utilize multi-modal ways to ship goods require efficient waterway infrastructure. The Army Corps of Engineers is making significant investments in improving inland waterways infrastructure. See Box 7.

6.3 PIPELINES

The shale gas boom in Appalachia has led to development of an expanded pipeline system that continues to grow. Figure 19 shows the extensive pipeline infrastructure already existing in the region. In 2019 alone, 9 pipelines originating in the region came online, representing new pipelines, pipeline reversals, expansions, and lateral expansions to the Appalachia pipeline network. An additional 9 pipelines that originate in Pennsylvania, Kentucky, Ohio, or West Virginia have been approved by FERC, are currently under construction, or have completed construction and are scheduled to come online in 2020.⁸⁹ Much of this growth has been focused on increasing the region's natural gas takeaway capacity. As production growth outpaces takeaway capacity, pipeline bottlenecks have increasingly suppressed the price of natural gas near the wellhead. Pipelines that came online in 2019 are expected to increase the takeaway capacity of the region by four bcf/d.⁹⁰

While the Appalachian natural gas industry needs more pipelines to reach other natural gas markets, projects currently underway have run into regulatory and legal challenges, driving up the cost. Costs for the Atlantic Coast Pipeline (ACP), which is scheduled to come online in 2021 and will connect

shale gas in western Pennsylvania with the Eastern Seaboard, are \$7.5 billion more than the original FERC estimate. That pipeline is expected to cost \$13.1 million per mile. Like the ACP, the Mountain Valley Pipeline (MVP) has faced many delays due to regulatory and legal challenges and is now expected to cost \$15.1 million per mile.⁹¹

While expanding the natural gas takeaway capacity of the region is essential to maintaining high production levels, efforts to expand the petrochemical industry will require developing intra-region infrastructure rather than a solitary focus on increasing NGL takeaway capacity.

Box 7. Ohio River System Upgrades

The Army Corps of Engineers is investing in maintaining an effective river transportation system along the Upper Ohio River System. Two recent example projects are:

- \$89 million effort for the Lower Monongahela River project to continue construction of a new river chamber at Charleroi Lock and Dam; dredge a new navigation channel; and award contracts for smaller project features.
- \$2.5 million in pre-construction design work for a proposed project at Emsworth, Dashields, and Montgomery locks and dams on the Ohio River. The cost to implement the improvements is estimated at \$2.6 billion.



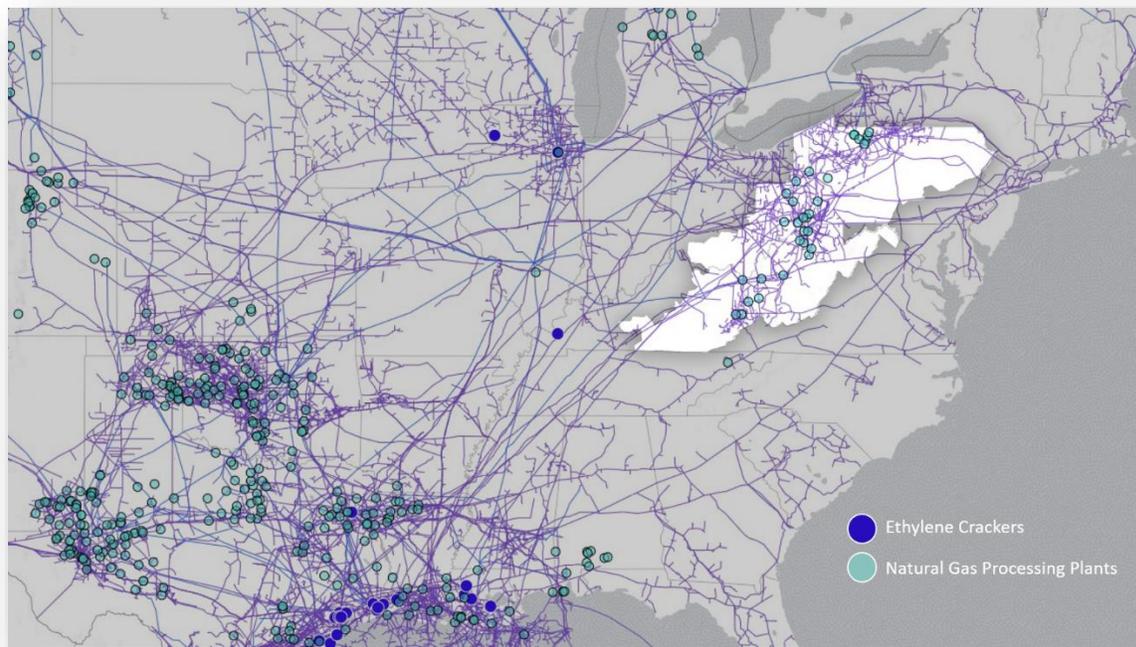


Figure 19. Pipeline Infrastructure

There are currently six major NGL pipelines taking product out of the region, detailed in the petrochemical section of this report. NGL takeaway capacity of the region is growing, especially with partial completion of Energy Transfer Partner’s Mariner East II pipeline. Appalachian NGL production, however, has historically exceeded pipeline capacity, forcing producers to ship NGL products down to market by truck or rail, or to simply reject ethane into the methane stream. While establishing reliable pipeline capacity to take NGLs out of the region will surely encourage additional natural gas and NGLs production, developing an intra-region pipeline network to support a growing petrochemical industry will best support economic activity within the region. Establishing a petrochemical cluster will require a shift in the current infrastructure paradigm, moving away from increasing NGLs takeaway capacity and moving toward increased capacity for processing in the region. As pipeline capacity installation is driven principally by free market forces, the region’s best strategy to ensure that this capacity develops is to entice more NGL consumers (e.g., crackers and basic petrochemical plants) to the region. These consumers will create the in-region NGLs market demand that spurs in-region pipeline and storage development. The Federal role is largely one of streamlining Federal regulations and permitting, as well as communicating the economic development opportunity.

6.4 ROAD

Highway connections are critical to the economy of the Appalachian region. The Federal government has provided sustained investment in Appalachian roadway infrastructure, and recognized its importance with the creation of the Appalachian Development Highway System

(ADHS) in 1965. The ADHS was created by Congress because the new interstate system had largely avoided the mountainous terrain of the Appalachian region, putting Appalachia at an economic disadvantage. The ADHS has helped address this disadvantage. As of September 2018, 90.5 percent of the authorized highways were either complete, open to traffic, or under construction.⁹² Completion of the ADHS remains a priority for Appalachian states. See Figure 20.

While the emergence of the shale gas industry has created extraordinary opportunities, it has also placed significant unanticipated stress on the highway infrastructure and on many secondary roads. Further expansion of the petrochemical and manufacturing sectors would benefit from a greater level of transportation infrastructure.

Through ADHS and supplemental projects, regional and state transportation planners should examine what additional highway infrastructure would maximize economic development in Appalachia. Figure 20 illustrates four additional corridors, important to States in the region, that would support economic growth and diversification, including:

- The I-68 corridor project from Columbus, Ohio to Pittsburgh, Pennsylvania which connects eastern Ohio's energy production and processing center with the two nearest major economic centers.
- The Marcellus highway project that parallels the Ohio River, which would be a main corridor connecting the current and likely future locations of most petrochemical cracking facilities, as well as many anticipated downstream manufacturers.
- A Morgantown-Moundsville connector project, which would provide more direct access between I-79 (an existing north-south interstate connection between Charleston, West Virginia and Pittsburgh, Pennsylvania) and one of the principal centers of energy production and processing in Ohio.
- The King Coal Highway project, which would connect parts of rural Appalachia to economic centers substantially cutting travel times and opening up new areas for manufacturing and economic diversification.

States and transportation planners may identify additional projects.



Figure 20. Appalachian Development Highway System

6.5 BROADBAND AND OTHER INFRASTRUCTURE

Broadband and community infrastructure in Appalachia also present challenges to growing the energy, petrochemical, and manufacturing industries in the region. The ARC reports that broadband internet is essential to community and economic development in Appalachia.⁹³

A recent ARC analysis of telecommunications and technology concluded that areas with higher levels of broadband internet availability perform better on economic development indicators such as income, unemployment, and job creation. Additionally, broadband internet benefits education and health services; it also lowers costs for business transactions and government services. In many parts of Appalachia, due to low population density and topography, even basic cell coverage is limited.

Programs to help develop rural Appalachia and to improve telecommunications and broadband capabilities are currently in place. To support continued economic growth, continued investment will be needed.

Water, sewer, and energy distribution are also critical supporting infrastructure elements that must be in place to support industry growth. Areas that lack the capacity to expand these services quickly may be at a disadvantage when it comes to economic development. The ARC has found that investing in public infrastructure projects creates a multiplier effect, returning a much greater economic benefit than the original investment would imply.

7. CONCLUDING REMARKS

Building on the foundation of the shale gas revolution, Appalachia has an opportunity to realize unprecedented long-term economic growth. Abundant, low-cost natural gas and co-produced NGLs, along with private investment capital, can be an engine for unprecedented growth in the energy, petrochemical, and manufacturing sectors. For its part, the public sector (Federal, State and local governments) has an opportunity to help catalyze private capital investment in Appalachia through its own investment in:

- (1) A **business environment** that is supported by pro-growth tax policy, increased regulatory certainty, efficient permitting processes, and timely government actions;
- (2) **Public infrastructure**, such as roads, rail, locks, ports, and broadband, which enables commerce;
- (3) **Workforce development**, which enables businesses, families, and communities to grow and thrive; and
- (4) **Innovation** particularly with respect to early stage R&D and public-private partnerships that advance technology to the point where the private sector can carry it forward to the marketplace.

In addition, government has a role in bringing attention to the opportunity for economic growth through active communication and **stakeholder engagement**.

Specific actions in each of these areas that the public sector could take, in collaboration with the private sector and other stakeholders, include the following:

Continue to develop a pro-growth business environment

- Continue implementation of the Tax Reform Act of 2018, including the promotion of opportunity zones.
- Streamline Federal approval processes, which delay or unnecessarily constrain, energy infrastructure projects with a goal of ensuring the environment is protected, public safety is ensured, all interested parties receive timely decisions, and project costs are controlled. Examples include EPA's recently completed regulations governing Clean Water Act 401 section certifications; the Department of Interior's recent improvements to implementing regulations of the Endangered Species Act; and the Department of Transportation's ongoing efforts to update LNG safety regulations for facilities and rail transport.
- Support efforts to enforce the United States Constitution's Interstate Commerce Clause and Federal statutes governing foreign trade and interstate commerce, as it applies to pipeline, LNG infrastructure, and other energy infrastructure siting and transportation decisions and activities to help ensure access to United States energy resources.
- Support efforts to ensure that access is provided to Federal lands for energy infrastructure projects, such as pipelines, while simultaneously protecting human health and the environment and avoiding unnecessary conflicts with other land use purposes.

- Promote fuel-neutral access to capital markets for energy-related projects.
- Promote export opportunities for coal, oil, and gas consistent with free-market principles. This includes support for continued build-out of United States LNG infrastructure.
- Continue the pursuit of equitable trade agreements that protect United States interests in energy (e.g., coal) and energy-related commodities (e.g., steel).
- Support efforts to provide research and technical assistance that aids with increasing capital access for small and medium businesses through programs such as those administered by the SBA and USDA's Office of Rural Development.

Invest in public infrastructure

- Support efforts to ensure waterway infrastructure projects in Appalachia are a priority, including the Ohio River system's locks and dams as well as the Mississippi River system and associated port infrastructure that provides access to the Ohio River.
- Support State and local efforts to identify and complete highway corridor projects that are essential to facilitate economic development, including the remaining segments of the Appalachian Development Highway System, where local community support exists.
- Support rail infrastructure upgrades that facilitate Appalachian growth (e.g., improved access to petrochemical facility development sites, and loading/unloading centers).
- Support efforts to prioritize the development of Appalachian broadband.
- Through existing or augmented programs, similar to Department of Interior's Abandoned Mine Land Reclamation Program and State-led redevelopment programs, develop build-ready sites for major energy infrastructure facilities.
- Support community-level infrastructure projects that enable growth in the energy, petrochemical, and manufacturing sectors. This should include reviewing grant program eligibility and other requirements to ensure Appalachian communities in need can effectively participate.

Support workforce development

- Seek opportunities to expand workforce development efforts in Appalachia, both in terms of numbers of individuals engaged and geographic reach. Where possible, expand existing successful efforts and ensure that these efforts enable clear pathways to new or higher-level positions in the workforce.
- Encourage employers to become signatories of the Pledge to America's Worker. To date, more than 300 companies and organizations have signed the Pledge, contributing to over 12 million new education and training opportunities for American students and workers over the next 5 years.

Spur innovation

- Through existing DOE programs, increase the emphasis on coal-to-products R&D and R&D pertaining to critical mineral and REE extraction from coal. These have the potential to create new, non-thermal markets for coal and to help stabilize the economy of coal communities.
- Advance a next generation of coal-fueled power plants that are near-zero emissions and meet the future needs of the electricity grid through DOE's Coal FIRST program.
- Invest in R&D that increases the productivity of shale gas reservoirs.

Engage stakeholders

- Communicate the opportunity for Appalachian economic development in the energy, petrochemical, and manufacturing sectors.
- Develop data-based information that informs private-sector investors, including improved energy resource estimates, workforce profiles, supply chain information, characterization of downstream markets, characteristics of available development sites, and profiles of supporting transportation infrastructure.

A number of regions in the United States would welcome increased public sector investment, but there are three factors that elevate Appalachia toward the top of the list:

1. Northern to Central Appalachia has an abundance of strategically located energy resources that should be accessed for the maximum benefit of the region and the Nation.
2. There is short window in which targeted public sector action can fundamentally accelerate the pace of economic development in Northern to Central Appalachia. Absent that action, newly abundant natural gas and natural gas resources will disproportionately leave the region and, in significant measure, be exported to international markets. Much of the associated economic benefit will be exported with them. Some level of exports is healthy for the economy and provide geopolitical benefits, but an appropriate balance must be maintained.
3. The Appalachian economy has significantly improved over the past 2 years; however, for decades, many Appalachian economic growth indicators have lagged national averages. The region deserves an opportunity to accelerate its growth, utilizing the natural resources produced within it.

As Appalachia's energy, petrochemical, and manufacturing industries expand, manufacturers and consumers of the industrial Midwest, New England, and the East Coast have an opportunity to benefit from low-cost energy and energy-related products, such as petrochemicals and finished products. This will enable Appalachia and the surrounding regions to create jobs and sustain a higher quality of life, and to compete more successfully in the global marketplace.

8. ABBREVIATIONS AND UNITS

ACP	Atlantic Coast Pipeline
ACC	American Chemistry Council
ADHS	Appalachian Development Highway System
AEO	Annual Energy Outlook
AML	abandoned mine land
API	American Petroleum Institute
ARC	Appalachian Regional Commission
ARM	Advanced Robotics for Manufacturing
ATEX	Appalachia-to-Texas Express
BPD	barrels per day
bcf/d	billion cubic feet per day
BTU	British Thermal Unit
BUILD	Better Utilizing Investments to Leverage Developments
CH ₄	methane
C ₂ H ₆	ethane
C ₃ H ₈	propane
C ₄ H ₁₀	butane
C ₅ H ₁₀₊	natural gasoline
CO ₂	carbon dioxide
DOD	Department of Defense
DOE	Department of Energy
EDA	Economic Development Administration (U.S. Department of Commerce)
EDC	ethylene dichloride
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FID	Final Investment Decision
FY	fiscal year
HGL	hydrocarbon gas liquids

INFRA	Infrastructure for Rebuilding America
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LTO	light tight oil
MEP	Manufacturing Extension Partnership
MATS	Mercury and Air Toxics Standards
MMtpy	million metric tons per year
MMst	million short tons
MATACC	Mid-Atlantic Trade Adjustment Assistance Center
MVP	Mountain Valley Pipeline
MW	megawatt
NCC	National Coal Council
NGLs	natural gas liquids
NIST	National Institute of Standards
PDH	propane dehydrogenation
PVC	polyvinyl chloride
R&D	research and development
RWFI	Regional Workforce Initiative
SBA	Small Business Administration
SOAR	Shaping Our Appalachian Region
STEM	Science, Technology, Engineering, and Mathematics
TAAF	Trade Adjustment Assistance for Firms
TAAC	Trade Adjustment Assistance Center
TEAM	Tri-State Energy and Advanced Manufacturing
U.S.	United States
USDA	Department of Agriculture
VCM	vinyl chloride monomer

9. REFERENCES

- ¹ <https://www.arc.gov/noindex/research/IndustrialMakeUp2002-2017/Ohio-IndustrialSnapshot.pdf>
- ² <https://www.eia.gov/coal/production/weekly/>
- ³ <https://www.eia.gov/naturalgas/weekly/#tabs-supply-2//PROD75-FS6.admin.netl.doe.gov/home/HARKERA/MyFiles/BalancedScoreCard>
- ⁴ <https://www.afpm.org/newsroom/blog/personal-protective-equipment-life-saving-gear-grounded-petrochemicals>
- ⁵ <https://www.epa.gov/newsreleases/epa-issues-final-rule-helps-ensure-us-energy-security-and-limits-misuse-clean-water-0> (press release dated June 1, 2020).
- ⁶ <https://www.eia.gov/coal/production/weekly/>
- ⁷ *Pennsylvania State Energy Profile*, U.S. Energy Information Administration. <https://www.eia.gov/state/?sid=PA> accessed October 20, 2019).
- ⁸ *2018 Fact Sheet: Shell in Pennsylvania*, https://www.shell.us/about-us/projects-and-locations/appalachia-pennsylvania/_jcr_content/par/textimage.stream/1572286299954/e7bffc9dfe801b47d0524f4d2effad39b6ab2c75/2019-shell-in-pennsylvania-factsheet.pdf
- ⁹ *2019 Guide to the Business of Chemistry*, American Chemistry Council, 2019. <https://www.americanchemistry.com/GBC2019.pdf>
- ¹⁰ *Economic Assessment of Appalachia: An Appalachian Regional Development Initiative Report*, Appalachian Regional Commission, June 2010. <https://www.arc.gov/images/programs/ardi/EconomicAssessmentofAppalachiaJune2010.pdf>
- ¹¹ *County Economic Status in Appalachia, FY 2019*, Appalachian Regional Commission, last modified August 18, 2018. https://www.arc.gov/research/MapsofAppalachia.asp?MAP_ID=148
- ¹² *Source & Methodology: Distressed Designation and County Economic Status Classification System, FY 2007 – FY 2019*, Appalachian Regional Commission, accessed July 29, 2019. <https://www.arc.gov/research/sourceandmethodologycountyeconomicstatusfy2007fy2019.asp>
- ¹³ Ibid
- ¹⁴ *Appalachian Region Industry Report-2014, Historical Data 2000-2010, 2020 Forecast*, Woods and Poole Economics, Inc., 2014, Prepared for the Appalachian Regional Commission. <http://www.arc.gov/images/appregion/AppalachianRegionIndustryReport2014.pdf>
- ¹⁵ *U.S. North East Petrochemical Industry Market Outlook 2018*, Petrochemical Update. <http://analysis.petchem-update.com/content/us-north-east-petrochemical-industry-market-outlook-2018>
- ¹⁶ *Annual Energy Outlook 2019*, U.S. Energy Information Administration, January 24, 2019.
- ¹⁷ Ibid
- ¹⁸ *The Potential Economic Benefits of an Appalachian Petrochemical Industry*, American Chemistry Council Economics & Statistics Department, May 2017. <https://www.americanchemistry.com/Appalachian-Petrochem-Study/>

-
- ¹⁹ Leslie F. Ruppert and Robert T. Ryder, *Coal and Petroleum Resources in the Appalachian Basin: Distribution, Geologic Framework, and Geochemical Character*, U.S. Geological Survey Professional Paper, March 15, 2015. <https://pubs.er.usgs.gov/publication/pp1708A.1>
- ²⁰ DrillingInfo, accessed August 8, 2019
https://info.drillinginfo.com/?utm_source=google&utm_medium=cpc&utm_term=drillinginfo&utm_campaign=DrillingInfo_Brand&utm_adgroup=DI_Generic_Brand_Match;&bt=341635638626&bm=e&bn=g&bk=drillinginfo&gclid=CjwKCAjw0tHoBRBhEiwAvP1GFdTH9V5L5dNyBBU1mpYSoNBVQChNAqMRpYLM-4jRmcYGcL5TmaRmeBoCWawQAvD_BwE
- ²¹ *Drilling Productivity Report*, U.S. Energy Information Administration, June 17, 2019.
<https://www.eia.gov/petroleum/drilling/>
- ²² Dyl, Katie, *Increases in Natural Gas Production from Appalachia Affect Natural Gas Flows*, Today in Energy, U.S. Energy Information Administration, March 12, 2019.
<https://www.eia.gov/todayinenergy/detail.php?id=38652>
- ²³ Clemente, Jude, *Pennsylvania's Natural Gas to the Rescue*, Forbes. April 23, 2017.
<https://www.forbes.com/sites/judeclemente/2017/04/23/pennsylvanias-natural-gas-to-the-rescue/#97b91674ec3d>
- ²⁴ Wilczewski, Warren, *The Trajectory of Shale Gas Development, Natural Gas Liquids, and the Plastics Industry in the Northeastern U.S.*, Shale Network Workshop 2019, May 17, 2019, State College, Pennsylvania. <https://psu.app.box.com/v/2019-Shale-Network/file/468885505168>
- ²⁵ *Kentucky State Profiles*, U.S. Energy Information Administration, last modified May 16, 2019.
<https://www.eia.gov/state/print.php?sid=KY>
- ²⁶ *Historic Coal Production Data*, U.S. Energy Information Administration and the U.S. Mine Safety and Health Administration, updated <https://www.eia.gov/coal/data.php>
- ²⁷ *Short Term Energy Outlook*, U.S. Energy Information Administration, accessed August 4, 2019.
https://www.eia.gov/outlooks/steo/pdf/steo_full.pdf
- ²⁸ Ibid
- ²⁹ Josh Bivens, *Updated Employment Multipliers for the U.S. Economy*, Economic Policy Institute, January 23, 2019.
<https://www.epi.org/publication/updated-employment-multipliers-for-the-u-s-economy/>
- ³⁰ Eric Bowen et al., *An Overview of the Coal Economy in Appalachia*, West Virginia University, January 2018, prepared for the Appalachian Regional Commission.
https://www.arc.gov/assets/research_reports/CIE1-OverviewofCoalEconomyinAppalachia.pdf
- ³¹ Randall Jackson and Péter Járosi, *An Economic Analysis of the Appalachian Coal Industry Ecosystem County-level CIE Supply Chain Analysis*, Regional Research Institute, West Virginia University, January 2018, prepared for the Appalachian Regional Commission.
https://www.arc.gov/assets/research_reports/CIE2-CountyLevelCIESupplyChainAnalysis.pdf
- ³² Matthew Murray and Peter Schaeffer, *An Economic Analysis of the Appalachian Coal Industry Ecosystem: Human Capital and the CIE*, West Virginia University and the University of Tennessee, January 2018, prepared for the Appalachian Regional Commission.
https://www.arc.gov/assets/research_reports/CIE5-HumanCapitalandtheCIE.pdf
- ³³ *Increases in natural gas production from Appalachia affect natural gas flows*, Energy Information Administration, March 12, 2019. <https://www.eia.gov/todayinenergy/detail.php?id=38652>

-
- ³⁴ J.B. Montgomery and F.M. Sullivan, *Spatial Variability of Tight Oil Well Productivity and The Impact of Technology*, Applied Energy, 195, January 2017. <https://erlweb.mit.edu/spatial-variability-tight-oil-well-productivity-and-impact-technology>
- ³⁵ Svetlana Ikonnikova, *What Changed in the U.S. Shale in Five Years? Geology, Technology, and Economics*, U.S. Energy Information Administration, Energy Forecasting Forum, April 2018.
- ³⁶ Bradford, Andrew, *Peak Appalachia Gas Production or Not?*, BTU Analytics, February 19, 2019. <https://btuanalytics.com/peak-appalachia-gas-production-or-not/>
- ³⁷ *Natural Gas Savings to End Users: 2008-2018, A Technical Briefing Paper*, Kleinhenz and Associates, prepared for the Ohio Oil and Gas Energy Education Program, February, 2019.
https://shalecrescentusa.com/wp-content/uploads/2019/12/Kleinhenz-Associates_Natural_Gas_Savings_to_End_Users_2008-2018.pdf
- ³⁸ David Fritsch, *In 2018, U.S. Coal Exports were the Highest in Five Years*, Today in Energy, U.S. Energy Information Administration, March 27, 2019. <https://www.eia.gov/todayinenergy/detail.php?id=38774>
- ³⁹ Annual Energy Outlook 2020, U.S. Energy Information Administration, January 29, 2020. <https://www.eia.gov/outlooks/aeo/data/browser/#/?id=95-AEO2020®ion=0-0&cases=ref2020&start=2018&end=2050&f=A&linechart=ref2020-d112119a.2-95-AEO2020~ref2020-d112119a.7-95-AEO2020~ref2020-d112119a.12-95-AEO2020&ctype=linechart&sourcekey=0>
- ⁴⁰ Eric Bowen et al., *An Overview of the Coal Economy in Appalachia*, West Virginia University, January 2018. Prepared for Appalachian Regional Commission https://www.arc.gov/assets/research_reports/CIE1-OverviewofCoalEconomyinAppalachia.pdf
- ⁴¹ *Advancing U.S. Coal Exports*, National Coal Council, October 2018. <https://www.nationalcoalcoalcouncil.org/studies/2018/NCC-US-Coal-Exports-2018.pdf>
- ⁴² *Coal First – Coal Plant of the Future*, National Energy Technology Laboratory (NETL), accessed August 8, 2019. <https://www.netl.doe.gov/node/6928>
- ⁴³ Presidential Executive Order on a Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, The White House, December 20th, 2017. <https://www.whitehouse.gov/presidential-actions/presidential-executive-order-federal-strategy-ensure-secure-reliable-supplies-critical-minerals/>
- ⁴⁴ Report on Rare Earth Elements from Coal and Coal By-Products, Report to Congress, United States Department of Energy, January 2017. <https://www.energy.gov/sites/prod/files/2018/01/f47/EXEC-2014-000442%20-%20for%20Conrad%20Regis%202.2.17.pdf>
- ⁴⁵ Randall Atkins, et al., *Coal in a New Carbon Age*, National Coal Council, May 2019. <https://www.nationalcoalcoalcouncil.org/studies/2019/NCC-COAL-IN-A-NEW-CARBON-AGE.pdf>
- ⁴⁶ Ibid
- ⁴⁷ Ibid
- ⁴⁸ Smith, Happ, *Gas Pipeline Costs Run Higher, Again*, BTU Analytics, February 1, 2019. <https://btuanalytics.com/costs-run-higher-ii/>
- ⁴⁹ Cunningham, Stephen, *Dominion Says Permit Delays to Blame for Canceled Gas Project*, Bloomberg, June 28, 2019. <https://www.bloomberg.com/news/articles/2019-06-28/dominion-says-permit-delays-to-blame-for-canceled-gas-project>

-
- ⁵⁰ *BLS Annual Employment and Wages*, U.S. Department of Labor, Bureau of Labor Statistics, last modified March 7, 2017. https://data.bls.gov/cew/apps/data_views/data_views.htm#tab=Tables
- ⁵¹ *Impacts of the Oil and Natural Gas Industry on the US Economy in 2015*, American Petroleum Institute. <https://www.api.org/~media/Files/Policy/Jobs/Oil-and-Gas-2015-Economic-Impacts-Final-Cover-07-17-2017.pdf>
- ⁵² Chuck Zelek, *Appalachian Petrochemicals A Generational Opportunity for the Ohio Valley*, Appalachian Storage Hub Conference, June 6, 2019. <https://www.appastorage.com/presentations/> [Add this link too? https://www.appastorage.com/app/download/14961320/Storage_Hub_June_6_Zelek.pptx]
- ⁵³ *Ethane Storage and Distribution Hub in the United States*, U.S. Department of Energy, Report to Congress, 2018. https://www.energy.gov/sites/prod/files/2018/12/f58/Nov_percent202018_percent20DOE_percent20Ethane_percent20Hub_percent20Report.pdf
- ⁵⁴ Ibid
- ⁵⁵ Ibid
- ⁵⁶ *Shell will suspend construction on cracker plant in Beaver County*, Pittsburgh's Action News 4, March 18th, 2020. <https://www.wtae.com/article/shell-cracker-plant-to-stay-open-amid-coronavirus-concerns/31690929>
- ⁵⁷ Annual Energy Outlook 2019, U.S. Energy Information Administration, January 24, 2019.
- ⁵⁸ Wilczewski, Warren, *The Trajectory of Shale Gas Development, Natural Gas Liquids, and the Plastics Industry in the Northeastern U.S.*, Shale Network Workshop 2019, May 17, 2019, State College, Pennsylvania. <https://psu.app.box.com/v/2019-Shale-Network/file/468885505168>
- ⁵⁹ Maarten Neelis, Ernst Worrell, and Eric Masanet, *Energy Efficiency Improvement and Cost Saving Opportunities for the Petrochemical Industry, An ENERGY STAR® Guide for Energy and Plant Managers*, Lawrence Berkeley national Laboratory, June 2008. <https://ies.lbl.gov/publications/energy-efficiency-improvement-and-8>
- ⁶⁰ *Ethylene Product Stewardship Guidance Manual*, American Chemistry Council, December 2004.
- ⁶¹ *Short-Term Outlook for Hydrocarbon Gas Liquid*, U.S. Energy Information Administration, March 2016. https://www.eia.gov/outlooks/steo/special/supplements/2016/hgl/pdf/2016_sp_01.pdf
- ⁶² *Quarterly Horizontal Shale Production*, Ohio Division of Oil and Natural Gas Resources, last modified May 31, 2019. <http://oilandgas.ohiodnr.gov/production>
- ⁶³ Andrew R. Thomas and Iryna V. Lendel, *Investment into Shale Development in Ohio*, Cleveland State University, Tri-State Shale Summit, November 29, 2017. <https://www.tristateshalesummit.com/2017-presentations>
- ⁶⁴ *Analysis of Global Competitiveness of Selected Industries and Clusters in the Appalachian Region*, Jack Faucett Associates and Economic Development Research Group, November 2004, prepared for the Appalachian Regional Commission. https://www.arc.gov/assets/research_reports/AnalysisofGlobalCompetitivenessofSelectedIndustriesClusters.pdf
- ⁶⁵ *What Cobots Can Do for your Business*, National Institute of Standards and Technology, last updated May 10, 2019. https://www.nist.gov/sites/default/files/documents/2019/05/10/nist_cobotinfographic-digital_8.5x22_-_web.pdf
- ⁶⁶ Andrew B Bernard et al., *Assessing the Impact of Trade Liberalization on Import-Competing Industries in the Appalachian Region*, July 2005, prepared for the Appalachian Regional Commission.

https://www.arc.gov/assets/research_reports/Assessing_percent20the_percent20ImpactTradeLiberalizationonImportCompetingIndustriesinAppalachia1.pdf

⁶⁷ *The Potential Economic Benefits of an Appalachian Petrochemical Industry*, American Chemistry Council, Economics and Statistics Department, May 2017.

<https://www.americanchemistry.com/Appalachian-Petrochem-Study/>

⁶⁸ *Analysis of Global Competitiveness of Selected Industries and Clusters in the Appalachian Region*, Jack Faucett Associates and Economic Development Research Group, November 2004, prepared for the Appalachian Regional Commission.

https://www.arc.gov/assets/research_reports/AnalysisofGlobalCompetitivenessofSelectedIndustriesClusters.pdf

⁶⁹ Ibid.

⁷⁰ *Making it in America: Revitalizing U.S. Manufacturing*, McKinsey Global Institute, November 2017.

https://www.mckinsey.com/~media/mckinsey/featured_percent20insights/Americas/Making_percent20it_percent20in_percent20America_percent20Revitalizing_percent20US_percent20manufacturing/Making-it-in-America-Revitalizing-US-manufacturing-Full-report.ashx

⁷¹ Ibid

⁷² *Manufacturing USA: A Third-Party Evaluation of Program Design and Progress*, Deloitte, January 2017.

<https://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-mfg-manufacturing-USA-program-and-process.pdf>

⁷³ *The Go-To experts for advancing U.S. manufacturing*, Manufacturing Extension Partnership.

<http://mepnams.com/about/>

⁷⁴ Ibid

⁷⁵ *America Makes*, last accessed August 2, 2019. <https://www.americamakes.us/>

⁷⁶ *Advanced Robotics for Manufacturing*, last accessed August 2, 2019. <http://arminstitute.org/>

⁷⁷ *Analysis of Global Competitiveness of Selected Industries and Clusters in the Appalachian Region*, Jack Faucett Associates and Economic Development Research Group, November 2004, prepared for the Appalachian Regional Commission.

https://www.arc.gov/assets/research_reports/AnalysisofGlobalCompetitivenessofSelectedIndustriesClusters.pdf

⁷⁸ *Appalachia Then and Now: Examining changes to the Appalachian Region since 1965*, Center for Regional Economic Competitiveness and West Virginia University, February 2015, prepared for Appalachian Regional Commission,

https://www.arc.gov/assets/research_reports/AppalachiaThenAndNowCompiledReports.pdf

⁷⁹ Ibid

⁸⁰ *Program Evaluation of the Appalachian Regional Commission's Infrastructure and Public Works Projects*, HDR Decision Economics with Cambridge Systematics Economic Development Research Group and Mt. Auburn Associates, 2013, prepared for the Appalachian Regional Commission.

https://www.arc.gov/assets/research_reports/ProgramEvaluationofARCInfrastructureandPublicWorksProjects.pdf

⁸¹ *U.S. Census Bureau*, last accessed August 2, 2019.

<https://qwexplorer.ces.census.gov/static/explore.html>

⁸² *Making it in America: Revitalizing U.S. Manufacturing*, McKinsey Global Institute, November 2017.

https://www.mckinsey.com/~media/mckinsey/featured_percent20insights/Americas/Making_percent20it

[percent20in percent20America percent20Revitalizing percent20US percent20manufacturing/Making-it-in-America-Revitalizing-US-manufacturing-Full-report.ashx](#)

⁸³ U.S. Census Bureau, last accessed August 2, 2019.
<https://qwiexplorer.ces.census.gov/static/explore.html>

⁸⁴ *Forge the Future: Pennsylvania's Path to an Advanced, Energy-Enabled Economy*, Chevron and Peoples Gas, July 2017. <https://paforgethefuture.com/pdf-2/Pa-Forge-The-Future-2.pdf>

⁸⁵ *Inflection Point 2016: Supply, Demand and the Future of Work in the Pittsburgh Region*, Burning Glass Technologies and the Council for Adult and Experiential Learning, 2016, prepared for Allegheny Conference on Community Development. <http://www.alleghenyconference.org/>

⁸⁶ *Manufacturing USA: A Third-Party Evaluation of Program Design and Progress*, Deloitte, January 2017. <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-mfg-manufacturing-USA-program-and-process.pdf>

⁸⁷ Mark L. Burton and David B. Clarke, *An Economic Analysis of the Appalachian Coal Industry Ecosystem: Transportation Implications of Coal*, West Virginia University and the University of Tennessee, January 2018, prepared for Appalachian Regional Commission.
https://www.arc.gov/assets/research_reports/CIE3-TransportationImplicationsofCoal.pdf

⁸⁸ Ibid.

⁸⁹ *Natural Gas Pipeline Projects Tracker*, U.S. Energy Information Administration.
<https://www.eia.gov/naturalgas/pipelines/EIA-NaturalGasPipelineProjects.xlsx>

⁹⁰ T.L. Hamilton, *Appalachia Pipeline Expansions to Release Flood of Natural Gas* (blog), Argus Media, August 23, 2018. <https://www.argusmedia.com/en/blog/2018/august/23/appalachia-pipeline-expansions-to-release-flood-of-natural-gas>

⁹¹ Smith, Happ, *Gas Pipeline Costs Run Higher, Again*, BTU Analytics, February 1, 2019.
<https://btuanalytics.com/costs-run-higher-ii/>

⁹² *Status of the Appalachian Development Highway System as of September 30, 2018*, Appalachian Regional Commission, December 2018.
<https://www.arc.gov/images/programs/transp/ADHSStatusReportFY2018.pdf>

⁹³ Sarah Lawrence et al., *Program Evaluation of the Appalachian Regional Commission Telecommunication and Technology Projects, FY 2004 – FY 2010*, RTI International, November 2015, prepared for the Appalachian Regional Commission.
https://www.arc.gov/assets/research_reports/ProgramEvaluationofARCTelecommunicationsandTechnologyProjectsFY2004-2010.pdf