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Sustaining growth

Appalachia's natural gas opportunity

Executive summary

"We are now witnessing a period of expansion in US oil and gas production that matches or exceeds any historical records ever achieved by the oil and gas industry."

—Tim Gould, head of the Energy Supply Outlook division

The expansion of domestic natural gas production can be largely attributed to the shale gas revolution, and to Appalachia, which finds itself at the epicenter. In 2007, Appalachia was the world's 32nd-largest natural gas producing region, with levels comparable to Bolivia and Kazakhstan. Today it is the third largest, trailing only the full United States and Russia.

The speed and magnitude of Appalachia's emergence onto the global natural gas scene is unprecedented and due mainly to the Marcellus and Utica shale plays, which reside mostly within Pennsylvania, West Virginia, and Ohio. Recognizing the growing significance of Appalachia, Deloitte is taking a closer look at this remarkable region as part of our natural gas series. Working with colleagues from Deloitte's Center for the Long View,¹ we explore the possible future evolution of natural gas supply and demand in Appalachia and the factors that will influence the region's future state.

In recent years, Appalachia's natural gas production has surpassed that of entire continents (i.e., Africa and South America), and while impressive, it is only the beginning. US shale gas production is expected to double by 2040, with much of the growth coming from Appalachia, which is estimated to have 50 years of natural gas that is recoverable for less than \$3 per Mcfe. In 2017, US domestic natural gas production is expected to exceed consumption, marking the year of inflection.

As a result, the United States as a whole faces a new world in which exports will be a key element to gas utilization. The market for Appalachian shale gas and its constituent elements extends beyond the United States as natural gas liquids (NGLs)² are used by international petrochemical manufacturers and

liquefied natural gas (LNG) can help meet global energy demand. The question addressed herein, however, is the extent to which Appalachia may seek to realize the full value of its shale gas through regional upgrading (i.e., conversion into higher-value products).

Through the use of scenarios, we will explore the factors that will influence the manner in which Appalachia's natural gas opportunity evolves. While many of those factors are regional in nature (e.g., infrastructure and workforce), others are global (e.g., innovation and market). Appalachia has a generational opportunity that requires a coordinated response to maximize the economic potential locked within its shale gas.

The opportunity is so great that the region will undoubtedly benefit to some degree, whether it makes an effort to do so or not. If, however, Appalachia collectively decides to realize more of the value inherent in its shale gas and develops a cohesive and coordinated plan to do so, the economic implications are staggering. For example, in November 2017 China Energy Investment Corp announced plans to invest in WV shale gas industries—the proposed investment of \$83.7B exceeds the state's GDP.

It is imperative that regional leaders look to the horizon and not trade the future for the present. A long-view perspective that anticipates the shape shifting of the global economy and strategically positions Appalachia to capitalize on opportunities will yield benefits for both the public and private sectors for decades to come.

Introduction

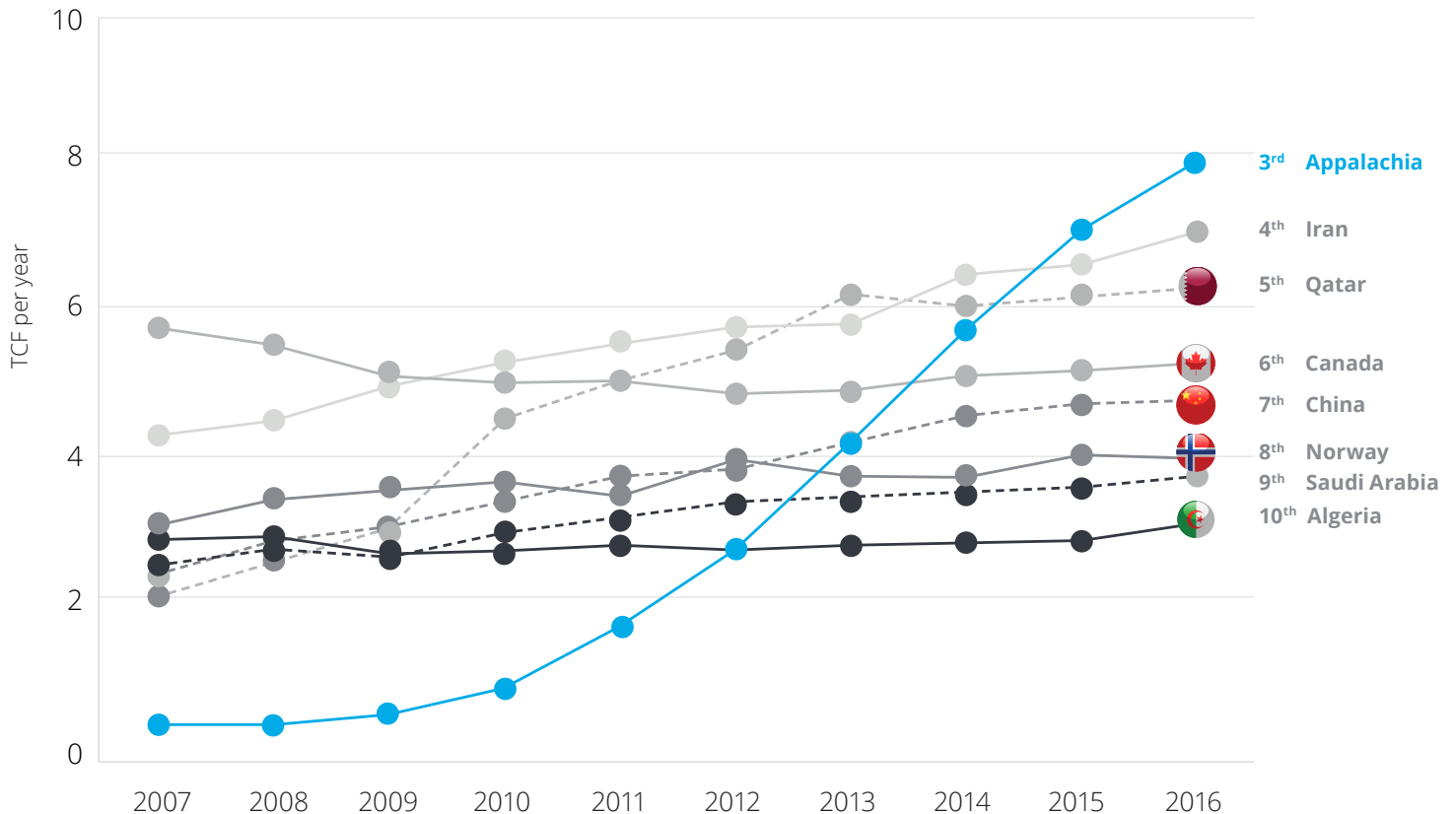
Appalachia's natural gas production primarily consists of gas extracted from shale rock formations composed of mineral-rich layers of clay that split along mineral lines. For years, extracting natural gas from these nearly impenetrable rocks seemed futile, but hydraulic fracturing and horizontal drilling, made possible through federally funded research, have led to a shale gas revolution in the United States.

- Horizontal drilling directs wells horizontally through a rock formation, touching more of the resource-bearing rock and allowing multistage fracturing.
- Hydraulic fracturing involves pumping large volumes of water mixed with chemicals and proppants such as sand under high pressure into a wellbore through hydrocarbon-bearing rock, resulting in the creation of fractures along which hydrocarbons can flow back to the surface.

Since the advent of horizontal drilling and hydraulic fracturing, the rise in Appalachia's natural gas production has been meteoric. The region went from producing very little natural gas in 2006 to more than 20 billion cubic feet (BCF) per day in 2016.³ During the last 10 years, operators have collectively extracted roughly 32.6 trillion cubic feet (TCF)⁴ of natural gas from Appalachia's shale plays, while driving down production costs. Current estimates project roughly 50 years of natural gas at less than \$3 per Mcfe.

To put this into perspective, if Appalachia were a country, it would rank third in terms of production, surpassing leading natural gas producing countries such as Iran and Qatar. Appalachia's rapid ascension among global natural gas producers is shown in Figure 1.

Figure 1: Appalachia's natural gas production compared to global leaders⁵

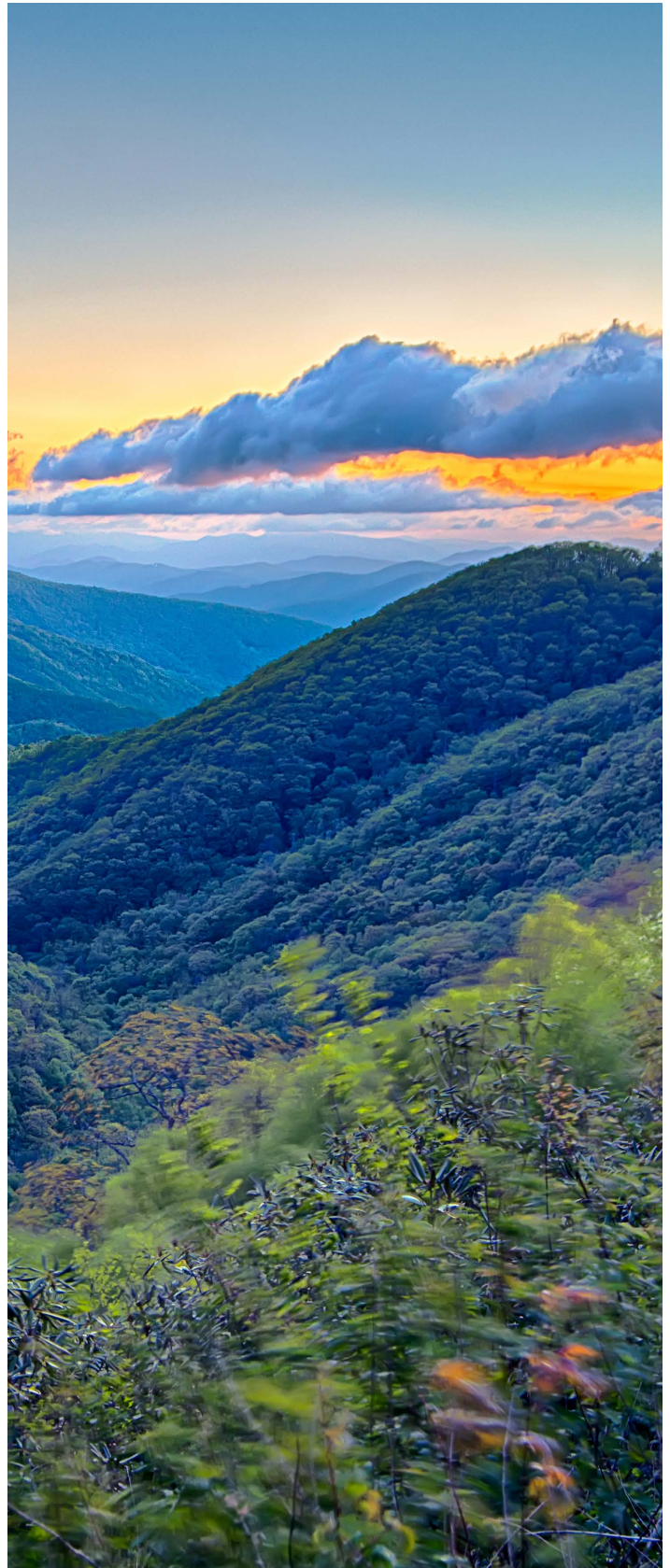


While Appalachia's growth continues to surprise the global community, the historical production curve has not yet encountered an asymptote. In fact, US shale gas production is expected to double by 2040,⁶ with most of the increase coming from Appalachia. The economic impact of natural gas is particularly important to Appalachia, which was hard hit by the recent collapse of the coal industry and ongoing challenges within the manufacturing sector. In addition to the economic stimulus associated with natural gas production and the peripheral upstream industries, significant value creation opportunities exist for converting natural gas into power, heat, and chemical products.

Given the multitude of value creation opportunities for shale gas,⁷ it is important to understand the market obstacles and drivers at various points along the value chain. Although Appalachia presents a vast market opportunity for shale gas utilization, the infrastructure and ecosystem needed is largely lacking. For example, much of the ethane currently produced in the region is never separated from raw natural gas; instead, it is transported and combusted with methane for power and heating purposes. This phenomenon is known as "ethane rejection."

But even if ethane was more fully separated from shale gas, there are not enough pipelines or ethane crackers in the region to take advantage of its market potential. Given the abundance of ethane and the region's geographical proximity to downstream petrochemical markets, companies are exploring the feasibility of building more Appalachian ethane crackers. While only one ethane cracker has moved from conception to construction, recent studies suggest the region could sustain five to nine world-class ethane crackers.⁸

Clearly, Appalachia will be a leading natural gas producer for the foreseeable future. In fact, anticipated growth through 2040 is expected to be so great that much of it will be internationally exported.⁹ Still, the domestic resource base is large enough to also support the development of gas-based industries in the United States. Attracting and growing these industries will help Appalachia retain more value from its shale gas. Identifying conversion pathways that align to Appalachia's capabilities will enable regional leadership to build out portions of the ecosystem to capture more of the resource's inherent value before shale gas derivatives are exported elsewhere.¹⁰



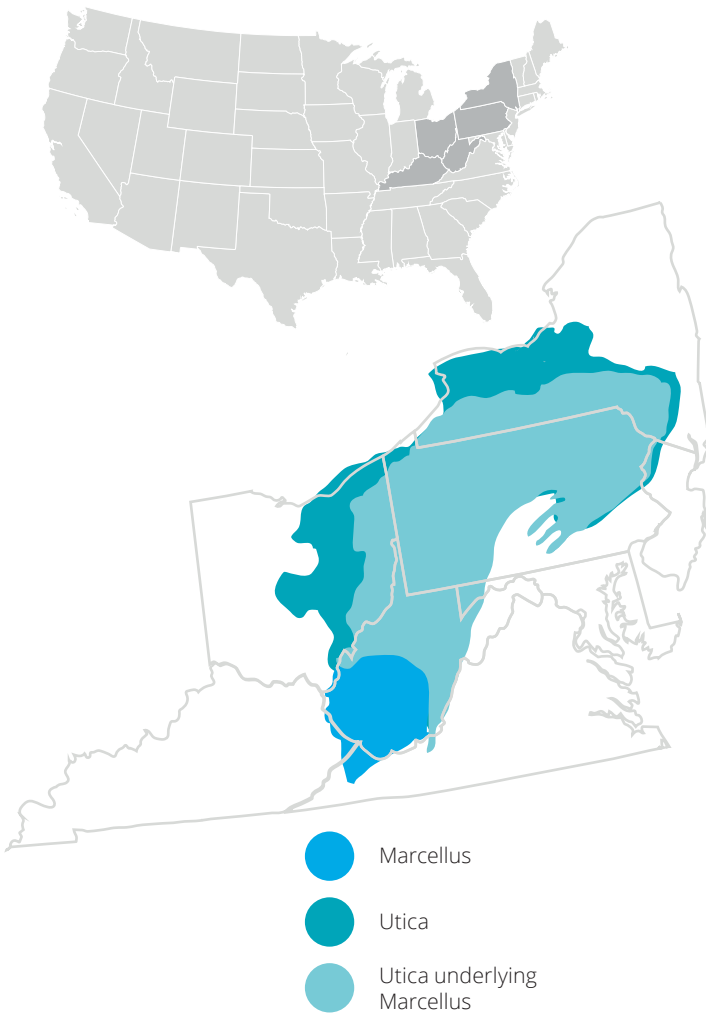
Supply

In the United States, shale gas production accounted for more than half of US natural gas production in 2015. It is projected to more than double from 37 BCF per day in 2015 to 79 BCF per day by 2040, amounting to about 70 percent of total US natural gas production.¹¹

The Marcellus shale, which is the primary play driving the domestic shale gas revolution, has proven reserves of 77.2 TCF.¹² As impressive as the Marcellus shale is, Appalachia has tapped a second shale play, the Utica shale, which has proven reserves of 6.4 TCF. The gas extracted from the Marcellus and Utica shales generates 21 BCF per day.

Since January 2012, natural gas production from both formations has accounted for 85 percent of the increase in US natural gas production.^{13,14} Both the Marcellus and Utica shales are expected to generate more than 40 BCF per day by 2040, which is projected to be 50 percent of domestic shale gas production.¹⁵

Figure 2: Marcellus and Utica formations¹⁶



Marcellus



First well: **2004**
Total number of wells: **22,429**



Rigs: **21**



Well operators: **274**
Rig operators: **14**



Footprint: **95,000 square miles**
Rig operators: **14**



Prospective area: **72,000 square miles**



Proven reserves: **77.2 TCF**

States: **NY, PA, OH, WV, KY**

Utica



First well: **2011**
Total number of wells: **374**



Rigs: **18**



Well operators: **55**
Rig operators: **8**



Footprint: **115,000 square miles**
Rig operators: **8**



Prospective area: **85,000 square miles**



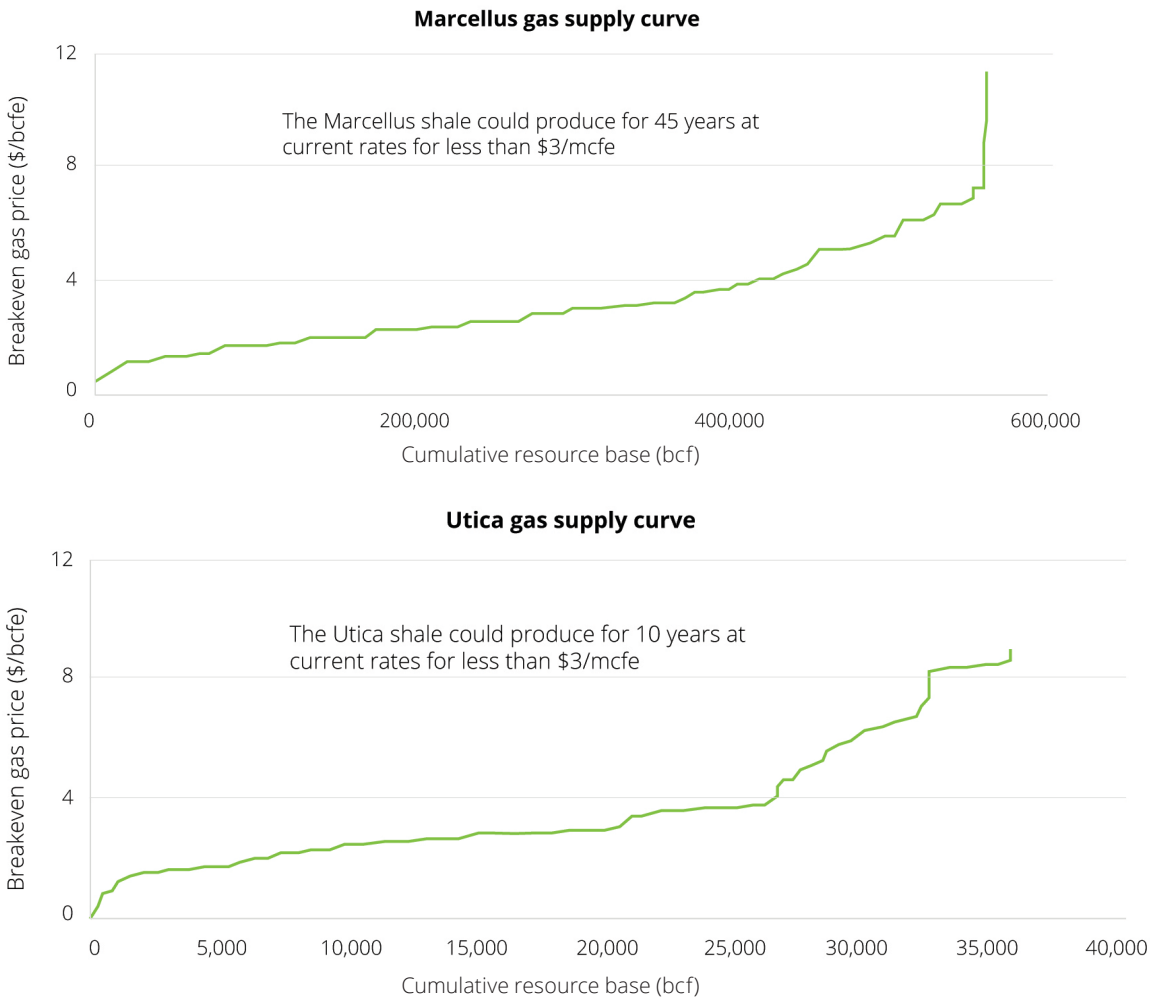
Proven reserves: **6.4 TCF**

States: **NY, PA, OH, WV**

The competitiveness of Appalachia, particularly the Marcellus shale, is driven by a plethora of companies vying to generate value for their shareholders. Large gas concentrations and shallow well depths attract producers that test and tailor their drilling and completion strategies based on the area's geology to optimize well performance.

A voracious appetite for performance improvements leads producers to continuously evaluate the length, placement, and spacing of horizontal wells, as well as experiment with the proppants used in hydraulic fracturing to better stimulate the flow of natural gas.

Figure 3: Marcellus and Utica gas supply curves



Source: Deloitte analysis, Rystad Energy

While advances have been made on all the aforementioned fronts (placement, spacing, proppants, etc.), opportunities for improvement still exist. Innovation should continue to drive down costs. Producers are turning to big data to explore operational enhancements to extract more gas from fewer wells.¹⁷ The value proposition of big data aligns squarely with many of the challenges facing producers, including:

- Understanding the subsurface and its response to various stimulation strategies
- Improving the precision of the drilling process through informed, real-time adjustments
- Optimizing the cost/benefit of operational parameters for enhanced economics

The takeaway is that the region has an ample supply of natural gas that can accommodate new demand. Appalachian shale gas will undoubtedly have a lasting impact on the US economy for decades to come. The only question is, what part of the country or world will create and capture value through conversion and utilization?

Demand

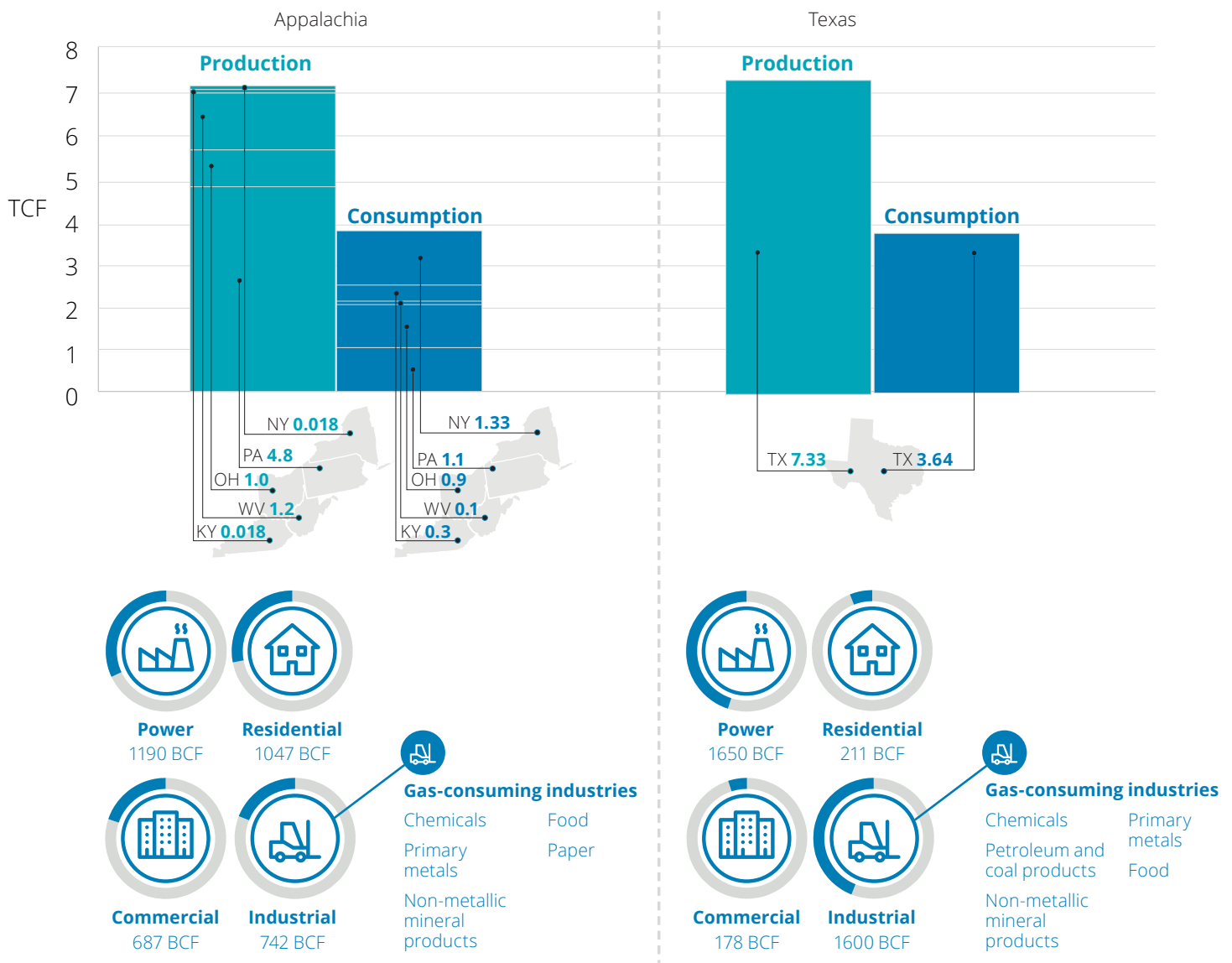
The power, industrial, transportation, commercial, and residential sectors all use natural gas. The US Energy Information Administration's (EIA) current projections see little to no growth in the demand for natural gas from the transportation, commercial, and residential sectors, and modest growth in demand from the electric power and industrial sectors. Thus, as production continues to rise, exports will become increasingly important to balance the market.

Appalachia in many ways represents a microcosm of the US market, with regional demand projections that are proportionally similar to national projections. The manner in which downstream markets evolve will be dependent on a number of factors. As outlined in the recent Deloitte paper, "Seeking Growth,"¹⁸ market demand will largely be driven by gross domestic product (GDP) growth and the composition of the US economy. As explained in the paper, in a flat growth environment, the nation would continue to use natural gas in a manner similar to today. In a moderate growth environment, the

nation would see an uptick in power generation and exports, with industrial entities and petrochemical manufacturers key to achieving sustained growth.

As it relates to Appalachia, growth will similarly depend on the levels of industrial consumption and petrochemical conversion, which are currently limited within the region. Compared to Texas, Appalachia exhibits similar production and consumption levels, yet the segments that comprise the demand profiles are vastly different, as shown below. While consumption in Appalachia is largely driven by residential and commercial heating, Texas has a large industrial contingent vying to use natural gas as a fuel and/or feedstock. If Appalachia seeks to produce more high-value products through the combustion and/or conversion of natural gas, it will require a viable ecosystem with sufficient infrastructure to support the additional industrial activity.

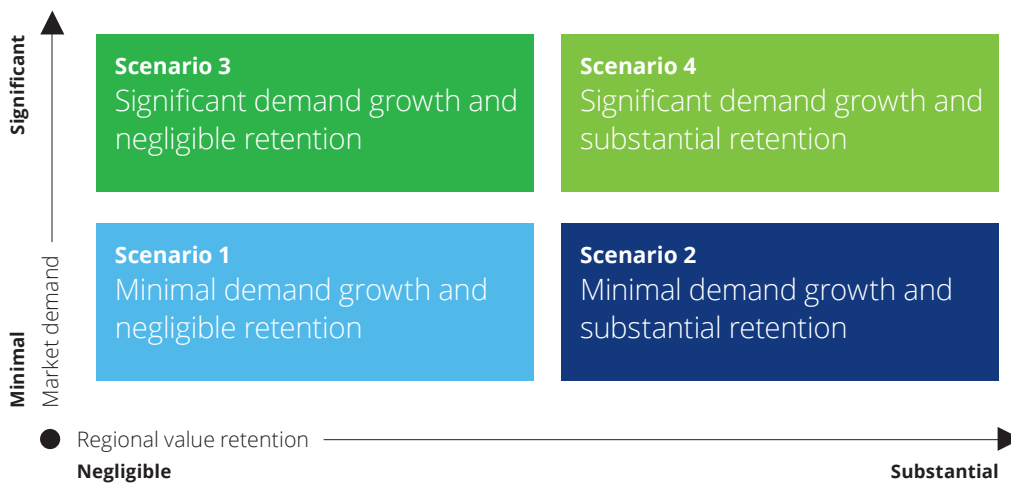
Figure 4: Annual production and consumption profiles of Appalachia and Texas¹⁹



Ultimately, the future state of Appalachia and the industries that drive natural gas consumption in and out of the region will be contingent on numerous factors that can potentially generate different and possibly divergent realities, depending on the manner in which they evolve. In an effort to develop a long-view perspective for the region until 2040, a high-level scenario analysis was performed to explore this complex environment and contemplate potential future states.

Scenario analyses help decision makers evaluate drivers, achieve transparency concerning underlying assumptions, and develop strategies in a complex and dynamic context.²⁰ With respect to shale gas and its potential impact on the Appalachian region, there are two critical uncertainties we have chosen to explore: market demand and regional value retention.

Figure 5: Appalachia's long-view scenarios



Influencing **market demand** (i.e., moving up in the quadrant chart) depends on consumption patterns within the aforementioned natural gas demand sectors (i.e., residential, commercial, industrial, power, and transportation). The EIA projects most consumption growth to come from the industrial and electric power sectors, as well as exports. Since natural gas production recently outpaced domestic demand, an increase in exports is necessary to balance the market.

Increasing **regional value retention** (i.e., moving over in the quadrant chart) depends on the degree to which Appalachia chooses to use, convert, or upgrade its natural gas resources prior to those resources leaving the region. While opportunities exist to convert shale gas into fuel and petrochemicals within the region itself, the majority of demand is forecasted to grow outside the region, either within the larger United States or as US exports. The natural gas retained within the region is primarily expected to be used for power production.

Market demand for shale gas and its constituent elements will largely drive the economics of production as supply is projected to be fairly elastic. **Regional value retention** depends on the measures taken by Appalachian stakeholders to create an environment that enables and incentivizes vertical integration of shale gas industries. In essence, **market demand** is the size of the pie, while **regional value retention** represents the portion of the pie that remains within Appalachia.

Simply put, most of the natural gas will be sent elsewhere, and the gas that remains in the region will likely be combusted for power and heating purposes, which together will produce less value for the region than on-site chemical and fuel conversion. Moving right in the quadrant chart flips the current paradigm to enable value creation and retention through the vertical integration of shale-based industries (i.e., on-site chemical and fuel conversion). For example, it is estimated that converting natural gas into petrochemicals generates eight times more value than using natural gas for power and heat purposes.²¹

In an effort to explore the universe of possibilities, the figure below contains descriptions of the four quadrants, each of which profiles a future state. The ultimate end state will depend on a variety of factors discussed later in this paper.



Scenario 3: Significant demand growth and negligible retention

Situation: There is an uptick in demand, yet the majority of that demand resides beyond the region. The region refrains (whether a conscious decision or inability to capitalize) from engaging in downstream opportunities. Instead, priority is placed on the midstream, which is viewed as being of paramount importance to get shale gas and its products to market regardless of where that market might be.

Risks: Risks abound since major infrastructure additions are subject to regulatory approval and the current political environment poses numerous challenges. Also, the prices that spurred the LNG export market are falling and could hinder the build-out of LNG export terminals.

Opportunities: Both the EIA and IEA project that significant portions of US natural gas production will be exported. Appalachia will be in a position to send its shale gas products to destinations around the globe via pipeline and LNG tankers.

Scenario 4: Significant demand growth and substantial retention

Situation: Demand is high across all sectors and producers respond accordingly. Regional interests receive priority weighting when making strategic decisions. That is, stakeholders have considered the plethora of potential end points and have devised a strategy to optimize value creation along the value chain based on alignment to regional interests and capabilities.

Risks: The largest risk associated with this quadrant is the obvious lack of existing infrastructure and the potential lack of talent, both of which are abundant in the Gulf. The inevitable question is why build duplicative assets in an area that lacks the infrastructure, legacy, activity, and ecosystem. Overcoming that hurdle is a regional issue with national implications.

Opportunities: A balanced portfolio of demand growth with innovative usage options. A greater percentage of regional usage comes from industrial entities and petrochemical manufacturers in particular.

Scenario 1: Minimal demand growth and negligible retention

Situation: Products continue to trade at a discount to Henry Hub due to the lack of infrastructure. Market conditions do not incite investment, and products follow the path of least resistance with methane being used primarily for power generation and ethane largely being rejected. Appalachia is viewed as an important supply point for a low-cost domestic resource that could be more economically "upgraded" by leveraging existing assets in the Gulf.

Risks: Demand in the power sector may not materialize as renewables account for more capacity additions. A Gulf-centric petrochemical industry is of national concern with Hurricane Harvey shutting down roughly 50 percent of Texas refining capacity.

Opportunities: In such an environment where prices are low and gas is used for power, the resulting effect will be low electricity prices, which may stimulate manufacturing within the region and benefit commercial/residential customers writ large.

Scenario 2: Minimal demand growth and substantial retention

Situation: Natural gas demand does not materialize as expected, yet regional stakeholders creatively exploit underserved portions of the product stream. CHP and micro-turbines are considered for methane use, and sporadic investments are made in petrochemicals, but only in select cases where unique circumstances enable companies to clear the requisite hurdles.

Risks: There is a potential disconnect within the value chain as a disproportional amount of value is captured by downstream stakeholders. Due to the lack of clear signals downstream, production occurs in fits and starts, which induces volatility that reverberates throughout the value chain.

Opportunities: Manufacturing facilities might go as far as to locate in areas with direct access to shale gas for operational needs. Arbitrage opportunities among product streams will enable fast-acting companies to capitalize on conversion economics.

Near-term actions

The opportunity at hand is a function of the current state of the region in terms of capabilities, assets, and companies as they represent the foundation for growth. In the event that regional stakeholders choose to realize a future that resembles scenario four, there are certain actions they can take now to help make this future state a reality.

Perform system studies to inform decision making

Increasing conversion and consumption in Appalachia is a complex and double-edged sword since a major competitive advantage of the region is its low-cost feedstock. The current price advantage of regional resources is a function of many factors, including limited demand and offtake opportunities. As demand grows and infrastructure is added, the region's price differential—a cost advantage for downstream industries—may diminish. In fact, 2017 data shows a convergence of Henry Hub and Appalachian prices.²²

Maintaining Appalachia's competitive advantage requires a methodical build-out such that growth along the value chain is sustainable over the long term. The plethora of products derived from shale gas results in multiple economic pathways that depend on the cost of the feedstock and conversion process, as well as the market price of the products in question. Ultimately, the pathway chosen must yield an Appalachian-derived product that is competitive with both domestic and global markets.

Regional policies will influence the opportunity and, as such, they would benefit from comprehensive market models capable of testing options and exploring their implications. Whether installing an LNG export terminal, an ethane storage hub, or an additional cracker (or three), regional policy makers must optimize the multivariable opportunity to best achieve Appalachia's goals and objectives. Producing high-value products requires an understanding of market forces, as well as global and regional price dynamics. Appalachia's low-cost natural gas has global implications, the intricacies of which must be understood so that policies and plans do not render the region uncompetitive.

Attract specific industries through targeted campaigns

Beyond the region's infrastructure challenges, state and local governments must give thought to the logical clusters²³ that can be successful within the region. The productivity, innovation, and prosperity of a region are often driven by clusters that represent unique concentrations of knowledge, skills, and technology within a given field.

As state and local governments strategically select the clusters that have the potential to be globally competitive, they need to assess the supporting and peripheral industries required when building out an ecosystem. For example, a cracker that converts ethane to ethylene creates a molecule that can be used for a variety of downstream products. Given regional interests in tires, adhesives, and coatings, attention should be given to bolstering those industries in particular.


Since only a company or individual can be recruited and not an entire industry, thought must be given to those entities that can help Appalachia achieve its vision and the value proposition that will resonate with its decision makers. That said, competitive clusters will likely span cities and states, thereby requiring a big-picture approach in which economic development agencies and investors work in concert to weigh local and regional interests.







Plan for critical infrastructure additions to support growth

Policy makers in Appalachia need to assess the extent to which existing upstream, midstream, and downstream regional assets (i.e., infrastructure and entities) position Appalachia to be globally competitive. Infrastructure needs to exist throughout the value chain for shovel-ready sites and large strategic installations that can support the broader ecosystem.

Gathering lines, processing plants, pipelines, storage facilities, and fueling stations are all components of a robust natural gas ecosystem. A comparison of Appalachia and Texas reveals a disparity in terms of the infrastructure on hand to support the industry and its growth. Even when normalized based on production, Texas leads in the majority of categories associated with natural gas infrastructure—which is to be expected given its oil and gas (O&G) legacy.

Enabling the continued expansion of natural gas usage within Appalachia will require not only a substantial investment in standard T&D assets, but also strategic installations that affect the broader competitive landscape. An Appalachian ethane storage hub, for example, is the subject of a bill that was recently introduced to Congress. Such a facility would enable suppliers to manage the ebbs and flows of demand and reduce the amount of ethane being rejected. Implementing this storage infrastructure will help alleviate market volatility and create a more stable environment capable of attracting investors.



	Gathering lines	Miles per TCF produced	18,163	12,580
		Plants per TCF produced	24.8	5.1
	Gas processing	MMcf/d capacity per TCF produced	3,197	1,022
		NG miles per TCF produced	6,007	4,895
	Pipelines	NG miles per MMbbl produced	52.97	21.3
		# of sites	36	153
	NG storage	Bcf capacity	546	1,151
		# of methane stations	146	246
	Fueling stations	# of propane stations	470	312
		Approved Bcf/d capacity per TCF produced	.87	.12
	Export terminals			

Sources: "Benefits and Opportunities of Natural Gas Use, Transportation, and Production," Prepared for American Petroleum Institute, ICF, June 2017. US Department of Energy, Energy Efficiency & Renewable Energy – Alternative Fuels Data Center, November 16, 2017. Federal Energy Regulatory Commission, Approved LNG Export Terminals as of May 1, 2017.

Long-term considerations

Ultimately, the path the region takes and its eventual end state will depend on a number of social, technical, economic, environmental, and political factors.

Social

The evolution of Appalachia's natural gas opportunity will partly depend on social acceptance of the industries that comprise the overall ecosystem. The upstream segment faced its share of resistance as a region unaccustomed to O&G activity rapidly became the third-largest gas producer in the world. Going forward, as Appalachia explores opportunities to expand the value chain, it must communicate better. Industry must proactively present a compelling case that clearly articulates a value proposition to the public. The public must weigh all factors and engage its respective representatives to ensure public opinion is accounted for in economic development decisions.

The potential increase in industrial activity is appealing to a region whose citizens are in need of employment opportunities, yet this increase also poses significant challenges. The manpower needed to support a robust Appalachian economy based on products derived from shale gas is unlike anything the region has experienced for a century. Accommodating this growth will require a workforce with unique skill sets that may not align to capabilities within the existing talent pool. A range of educational institutions will need to establish programs that train individuals across the career continuum.

Public and private sectors must work together to design training programs that accommodate prior experiences and leverage existing skill sets to incrementally advance individuals toward O&G industry openings at a pace that is mutually agreeable. While many training programs are being put in place, recent reports indicate the region will continue to struggle to fill job openings, particularly in highly technical fields.²⁴

If Appalachia seeks to retain more of the value in its shale gas, the public must be on board and the workforce must be prepared to take on the activities associated with value creation and capture.

Technical

Opportunities exist for technological progress across the O&G value chain. Researchers are studying matters related to natural gas and its conversion into high-value products, which may ultimately affect the way Appalachian shale gas is utilized. In 2017 a new research center, RAPID,²⁵ was established to focus on modular chemical process intensification, which offers the potential to increase efficiencies and reduce the costs of natural gas conversion. Identifying alternative conversion pathways and developing enabling technologies will help the region realize more value from its shale plays, which are often remote or removed from end users.

One need only look at the Bakken play where value was squandered as natural gas flared due to the lack of infrastructure to get it to market. Novel technologies that enable the economic conversion of distributed and diverse product streams could tilt the competitive landscape such that industry favors resource proximity over conversion scale. The federal government recognizes the opportunity to realize more value from its domestic shale gas resources, as evidenced by the National Science Foundation's (NSF) recent \$20 million investment in the Center for Innovative and Strategic Transformation of Alkane Resources (CISTAR), an engineering research center led by Purdue University focused on converting light hydrocarbons into chemicals and fuels.

The research performed by RAPID and CISTAR is contributing to a critical mass of activity that could lead to technological breakthroughs that revolutionize how the region uses its shale gas resources. For example, direct conversion of shale gas products could be a game changer if selectivity and reaction extents can be improved. Also, hydrogen and carbon material production from methane could have significant implications for transportation in terms of alternative fuels and lightweighting if economic pathways are realized.

Given the magnitude of the opportunity, a coordinated program led by the federal government that prioritizes early stage research according to national interests and de-risks technology scale-up to incentivize industry involvement would create an environment conducive to spawning next-generation technologies that enable greater value realization.

Economic

As investment decisions are made, the region will move toward its eventual future state; thus, the sequencing of investments is critical. Near-term investments will influence future investments. Specifically, investments related to pipelines, export terminals, and other facilities that take natural gas out of the region will influence the investments aimed at utilizing the gas within the region.

The governors of Pennsylvania, West Virginia, and Ohio have signed an agreement to collaboratively grow the regional natural gas industry. The agreement, which expires at the end of 2018, seeks to spur investment in the systems that will expand sustainable gas usage.²⁶ The alliance is a step in the right direction, since sequencing investments to optimize value retention will require informed conversations among stakeholders and coordination among decision makers that span the public and private sectors. Upstream, midstream, and downstream representatives should have a seat at the table to ensure a regional strategy incorporates interests across the value chain.

Because many of the investments on the table have multiyear construction schedules with multi-decade payback periods, stimulating investment requires public policy institutions to:

- Understand the economic and market drivers of potential investments across the value chain
- Provide an accommodative policy and regulatory framework
- Ensure the rules of the game are fairly stable over an investment life cycle

Environmental

As the region and nation rely more on shale gas to grow the economy and enhance national security, the potential environmental impact of shale gas extraction, conversion, and use must be understood. The environmental impacts of production receive a lot of attention, specifically the effects of production on air quality, water quality, and induced seismicity. If natural gas is to play a more prominent role in the national energy portfolio, the industry must employ more sustainable technologies and techniques.

Upstream issues are largely water-related (i.e., impact on ground and surface water), with relatively new concerns surrounding induced seismicity. Midstream environmental challenges are mainly related to the risk of methane emissions, which, if left unabated, could tarnish the image of natural gas as the clean alternative to coal. Finally, as Appalachia seeks to expand its presence downstream, it must also recognize environmental challenges related to utilization.

Much in the same way that Appalachia sat at the precipice of the shale gas revolution 10 years ago, it finds itself on the cusp of a petrochemical boom today. While the region has a manufacturing legacy, it is a generation removed from many energy and environmentally intensive industries. As the region expands its interests, upstream, midstream, and downstream stakeholders must work with the public to protect Appalachia's air, water, and land to enable the region to maximize the value of its entire resource endowment.

Political

Policy is a fundamental lever by which the region can influence and incentivize stakeholders to achieve its desired future state. Opportunities exist across the value chain to take political action to create an environment conducive for industry and protective of public interests. Numerous policy mechanisms exist, some of which help establish a market, while others serve to elicit action within that market.

For instance, consider the efforts underway to assist with market creation by building an Appalachian ethane storage hub, including a number of laws that would expedite permitting, provide loan guarantees, and study the general feasibility of such a hub (e.g., H.R. 2568, S. 1075, S. 1337, S. 1340). Such actions are necessary if the government wants to remove and/or lower the impediments to investment.

Shell's recent decision to build a cracker in the region is also an example of the power of incentivizing activities. Shell offered three specific reasons for its decision to proceed with the cracker: cost-advantaged feedstock, market proximity, and strong local support. Undoubtedly, an element of the local support included the various tax credits offered by Pennsylvania, which could potentially reduce Shell's tax bill by 20 percent.²⁷

Companies have different motivations for transforming their businesses—they relocate, make investments, and grow for a set of interrelated economic, geographic, and cultural reasons. Understanding these motives and decision points is critical if Appalachia seeks to establish policy and offer incentives that will attract companies that will foster productivity across the ecosystem.

Conclusion

Appalachia's shale gas reserves have a material impact on the region's economic growth, even if the full value of these reserves has yet to be realized. Over the coming decades, the Marcellus and Utica shales will continue to be tapped. If the region seeks to retain more of the value from these reserves, it will require a concerted effort between the public and private sectors. If successful, the resulting economic growth and job creation opportunities will be unlike anything the region has ever experienced.

The path forward will likely be a circuitous one and not uniformly aligned to any one of the aforementioned scenarios. That is, given the size of the investments, each pipeline, cracker, or LNG terminal will cause the region to gravitate toward one of the four scenarios until a subsequent investment is made. While each investment will likely be rational, given market fundamentals, those investments may or may not be in the best interests of the region.

If left to its own devices, industry will predictably and appropriately act according to its own interests. Absent a comprehensive and cohesive regional strategy that provides the vision and direction for value creation and capture, the private sector will act independently along sector, industry, and company lines, and the region as a whole may trade the future for short-term gain.

A recent report by the Brookings Institute²⁸ looked at whether Pittsburgh, a major metropolitan hub within Appalachia, could achieve the status of a global innovation city. The report found that the region excels at producing innovation (i.e., papers, patents, research funding), but those activities are not translating to downstream economic impact.

Put plainly, Appalachia exports much of its innovation in the same way it exports its shale gas. While exports are a valid option given current market dynamics, increasing the retention of value (in both cases) could have a positive impact on the regional economy for decades to come. Altering the dynamics is no small task and will require strong leadership, coordination among the public and private sectors, and a shared vision of mutual gain.

A recently announced initiative, "Forge the future," aims to incite the creation of a regional action plan and points to the following economic development opportunities as critical to a regional strategy:

- Increased gas-fired power and heating
- New clusters in sectors of the future (i.e., petrochemicals, advanced materials, and data-driven automated manufacturing)
- Gas exports

These opportunities reinforce the idea that an optimal future for Appalachia is one with a diverse and robust downstream ecosystem with multiple pathways for realizing the value of its shale gas reserves. While regional interests are apparent and should serve to mobilize local stakeholders, a question remains as to whether the economic elevation of Appalachia and the geographic diversification of petrochemicals are of national interest. If so, many federal agencies (e.g., Department of Energy (DOE), Department of Commerce (DOC), Environmental Protection Agency (EPA)) should be engaged in conversations related to regional strategies as the outcome will have national implications.

The potential of the opportunity at hand may be its peril. The sheer size of the Appalachian region spans states and sectors, which complicates matters and leads to participating entities with competing interests. Moving the region in a decisive direction will require leadership across the public and private sectors to arrive at a unified vision and articulate that vision to the public and workers in a way that creates buy-in. While the conceptual message is clear and compelling (i.e., economic growth, job creation, public dollars), the details are not. As is typically the case with generational opportunities, time is of the essence as other regions and countries are seeking to monetize Appalachian resources.

While we think the region would benefit from adopting a long-view perspective, doing so does not diminish the importance of near-term action. A long view simply serves to anchor those actions to a desired future state in a way that flexibly accounts for critical uncertainties. Addressing these uncertainties requires the region to have open dialogues with stakeholders across multiple spectrums so that definitive action can be taken to move the region in a mutually agreed-upon direction.

While the resource itself has been tapped, its value largely has not. If the region is able to develop the downstream sector at the same pace as upstream, Appalachia may soon find its name on another chair at the proverbial table of global leaders.

Endnotes

1. The Center for the Long View (CLV) is Deloitte's competence center for the development of scenario-based innovative strategies that assist decision makers in developing robust strategies for companies and organizations.
2. Per the US Energy Information Association, natural gas liquids include ethane, propane, butane, isobutene, pentane, and natural gasoline.
3. "Appalachian Storage Hub: What is needed to store and maximize the regional development and use of NGLs?" B. Anderson, Appalachian Storage Hub Conference, Canonsburg, Pennsylvania, June 15, 2017.
4. US Energy Information Administration Drilling Productivity Report.
5. This figure was created with data compiled from "BP Statistical Review of World Energy," June 2017, and "Drilling Productivity Report," US Energy Information Administration.
6. US Energy Information Administration, *Today in Energy*, August 15, 2016.
7. Shale gas includes a number of gas and liquid hydrocarbons, including methane, ethane, propane, butane, and pentane, the exact composition of which varies across shale plays and locations within a single play.
8. "Prospects to Enhance Pennsylvania's Opportunities in Petrochemical Manufacturing," IHS Markit, March 2017, and "The Potential Economic Benefits of an Appalachian Petrochemical Industry," American Chemistry Council, May 2017.
9. "Liquefied natural gas exports expected to drive growth in US natural gas trade," US Energy Information Administration, *Today in Energy*, February 22, 2017.
10. Ultimately, the region's export portfolio will span the value chain from raw resources to refined products across the various conversion pathways such that a competitive pricing environment is maintained within each market.
11. "Shale gas production drives world natural gas production growth," Faouzi Aloulou and Victoria Zaretskaya, US Energy Information Administration, August 15, 2016, <http://www.eia.gov/todayinenergy/detail.php?id=27512>.
12. US Energy Information Administration Marcellus Report.
13. "Utica and Marcellus Natural Gas Production Defying the Skeptics," Jude Clemente, *Forbes*, October 2, 2016, <http://www.forbes.com/sites/judeclemente/2016/10/02/utica-and-marcellus-natural-gas-production-defying-the-skeptics/2/#61c38468696a>.
14. "Marcellus, Utica provide 85% of US shale gas production since start of 2012," John Krohn and Grant Nülle, US Energy Information Administration, July 28, 2015, <http://www.eia.gov/todayinenergy/detail.php?id=22252>.
15. "Future US tight oil and shale production depends on resources, technology, markets," Danya Murali, Faouzi Aloulou, US Energy Information Administration, August 22, 2016, <http://www.eia.gov/todayinenergy/detail.php?id=27612>.
16. Data provided by Drillinginfo: "Marcellus Shale Play – Geology Review," US Energy Information Association, January 2017; "Utica Shale Play – Geology Review," US Energy Information Association, April 2017.
17. Deloitte's recent report, "Digital Transformation in Oil and Gas," takes a focused look at the potential impact of digital technology on upstream operations. See <https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/gx-online-from-bytes-to-barrels.pdf>.
18. "Seeking growth – What will drive US Natural Gas Demand," Deloitte Development LLC, 2017, <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-er-natural-gas-demand.pdf>.
19. "Benefits and Opportunities of Natural Gas Use, Transportation, and Production," Prepared for American Petroleum Institute, ICF, June 2017.
20. While scenarios were used to frame the conversation, the effort stopped short of performing a detailed scenario analysis whereby key stakeholders would have been engaged and artificial intelligence would have been leveraged to identify and prioritize driving forces, develop scenario narratives, determine critical implications, develop strategic options, and monitor developments.
21. Committee on Energy and Natural Resources: United States Senate Hearing on the Future of Natural Gas, the Dow Chemical Company, Statement for the Record, July 19, 2011.
22. SNL Energy, Spot Natural Gas Prices.
23. A cluster is defined as a group of interconnected companies and institutions that are not only physically located in the same place but also linked by common suppliers, technology needs, and other overlaps or synergies.
24. "Inflection Point: Supply, Demand, and the Future of Work in the Pittsburgh Region – A forward look at the coming transformation of work across the Pittsburgh region and its implications for employers, educators, and workforce talent," Burning Glass Technologies, the Council for Adult and Experiential Learning, Allegheny Conference on Community Development, 2016.
25. Rapid Advancement in Process Intensification Deployment (RAPID).
26. "Tri-State Regional Cooperation Agreement," WV, OH, PA, October 13, 2015.
27. "Pennsylvania tax incentive plan played major role in luring Shell cracker plant," Brad Bumsted, *Tribune Review*, June 7, 2016.
28. "Capturing the next economy: Pittsburgh's rise as a global innovation city," Scott Andes, Mitch Horowitz, Ryan T. Helwig, and Bruce Katz, Brookings Institute, September 13, 2017.

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