



Forge the Future:

Pennsylvania's Path to an Advanced,
Energy-Enabled Economy



THE PURPOSE OF THIS DOCUMENT

Pennsylvania sits atop one of the largest gas and natural gas liquids (NGLs) basins in the world. This energy resource has significant potential to propel the Commonwealth's economic growth, but this potential is still mostly untapped.

Over the past several years, the upstream oil & gas industry has worked to develop the resource, and has created measurably strong job growth for Pennsylvanians. But there is limited demand within Pennsylvania for the energy it produces, which in turn limits the extent to which Pennsylvanians can benefit from their resource.

Meanwhile, other jurisdictions are seeing their own energy booms in parallel. The Permian basin in the southwest, for example, is growing rapidly and produces low-cost gas that will compete with Pennsylvania's. This is our window of opportunity to lock in the benefits to Pennsylvania for years to come.

"Forge the Future" is a private sector-led effort, launched by Chevron and Peoples Gas, to unlock the economic potential of Pennsylvania's energy resource – in terms of GDP growth, jobs growth, and government revenues to support the needs of the state. Achieving this potential will require close collaboration between the private and public sectors, coordination within the private sector, and – above all else – a drive to practical action.

The "Forge the Future" effort envisions a rapid sequence of steps. The first step is to lay out the facts, as objectively and rigorously as possible, to ensure a clear view of the opportunity and priorities on which to focus. This document summarizes the findings of the diagnostic work. Fact-based analysis was provided by McKinsey & Company.

This paper, however, represents only the first step. Moving forward, the task is for Pennsylvania companies and leaders – private and public sectors both – to refine the perspectives described here and develop an action plan to forge the future together, for the benefit of all Pennsylvanians.

July 2017

EXECUTIVE SUMMARY

- Pennsylvania has a world-class energy resource that could propel the Commonwealth's economy. However, only a fraction of its potential has been captured due to limited in-state demand. The time is now to translate our energy potential into sustained, broad-based prosperity for the state and the region.
- Within the next decade, Pennsylvania can take strategic steps to improve its economic performance above its current trajectory by:
 - \$60 billion, ~6-9% growth in annual state GDP over about 10 years, from ~\$720 billion (under a business-as-usual scenario) to ~\$780 billion by pursuing targeted growth actions (increase from 1.6% to 2.3% in average annual growth rate);
 - >100,000 more jobs, a ~1-2% increase over about 10 years, from ~6.2 million jobs in 2025 (under a business-as-usual scenario) to ~6.3 million jobs in 2025 by pursuing targeted growth actions (increase from 0.65% to 0.85% in average annual growth rate);
 - >4.5 trillion cubic feet (Tcf) increase in gas demand, a ~90% increase over 10 years, from ~5 Tcf in 2025 (under a business-as-usual scenario) to ~9.5 Tcf by pursuing targeted growth actions;
 - Significant increase in state revenues – estimated to be at least \$2-3 billion, supported by large expansion in state GDP and corporate activity.
- Pennsylvania can achieve these concrete economic benefits through three development strategies:
 - Increased gas-fired power and heating – ensuring all Pennsylvanians benefit from low-cost gas for residential and commercial/industrial users;
 - Clusters in Petrochemicals, Advanced Materials, and Data-Driven Automated Manufacturing – driving GDP and jobs growth and positioning Pennsylvania as an Industry 4.0 manufacturing leader;
 - Exports – crucial to make gas production viable, without hurting competitive gas prices in state.
- Pennsylvania has unique strengths, but must overcome deep-rooted challenges, including:
 - Legacy in manufacturing and chemicals, but must attract higher-growth segments;
 - Available labor pool, but cost disadvantages and potential skill gaps (e.g., high-end manufacturing);
 - Significant production of science and engineering talent, but brain drain to other regions;

- Academic leadership in IT and engineering, with relatively limited translation of innovation into commerce;
 - Large network of brownfield sites, but issues of topography, size and connectedness to gas supply or end markets; in many cases, existing sites need investments to be useable;
 - Low-cost natural gas, but not fully reflected in retail power prices.
- Going forward, the Pennsylvania private and public sectors should work on targeted statewide initiatives, reflecting the most important actions to attract the right companies, prioritize the right infrastructure, and ensure Pennsylvania's low-cost gas and human capital translate into competitive opportunities to realize the full potential of its world-class natural gas reserves.

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Forge the Future – Phase 1: Establishing the facts

INTRODUCTION

Pennsylvania faces a historic opportunity. Within it lies most of the vast Marcellus shale and a significant portion of the Utica and Devonian shales, which together represent one of the largest gas basins in the world. This energy resource has already begun to transform not only the US energy landscape, but also flows of energy around the world.

Pennsylvania's opportunity – obligation even, on behalf of every Pennsylvanian – is to capture the full value of this world-class resource. By doing so, Pennsylvania will tap into a much-needed wellspring of growth – in GDP, jobs, and significant expansion of public revenues – for decades to come. With this abundant, economically and environmentally efficient energy source, Pennsylvania can drive a modern and reinvigorated economy that converges its historic strengths with the technology- and automation-driven enterprises now emerging in the Commonwealth and around the world. With natural gas and related products as the energy pulse running through Pennsylvania, we can pursue evidence-backed plans, strategies, and actions to forge a future of unparalleled economic vitality, and realize benefits that will extend to the social and cultural fabric of every community.

In the decade or so since hydraulic fracturing and horizontal drilling technologies made shale gas accessible at scale, most of the focus in Pennsylvania has been “upstream” – the process of finding, developing, and producing the gas resource. Pennsylvania's upstream oil & gas industry has played an important role in our region's ability to weather the Great Recession, bringing both jobs and government revenues into Pennsylvania while other regions faced more significant struggles. For example, it added on the order of \$15 billion to Pennsylvania's annual real GDP between 2008 and 2016; it added more than 15,000 jobs between 2007 and 2012 even while total annual average employment declined in Pennsylvania by more than 74,000 jobs and declined across America by almost 3%; and the jobs it created were well paying, with average annual pay of ~\$83,000 in 2012, compared to a state average of ~\$48,000.

But the full benefit of Pennsylvania's energy resource will emerge when the state's gas supply is met by robust and sustained demand locally – the “downstream” sectors that will multiply GDP, jobs, and government revenues through a greater mix of in-state and export consumers.

The successful attraction of the Shell cracker to Western Pennsylvania has stirred more attention statewide and beyond to downstream demand and development, with several studies in play, and growing discussion and speculation. The time is now to feed momentum in this direction, and do so in the context of a range of issues and opportunities such as workforce, infrastructure, access to capital, competition from other domestic and international regions, partnerships and collaborations, and more. Enabling new sources of economic activity that can make competitive use of Pennsylvania's energy reserves will require creativity and a commitment to be bold. The opportunity is to go beyond individual company attraction alone, and to lever what is uniquely Pennsylvania – to forge a future that truly optimizes our differentiated assets and market position.

Pennsylvania's business, government, economic development, labor, and academic communities can come together behind a strategic plan of action to guide decisions that will capture the full economic opportunity at hand. This report covers Phase 1 of a project whose goal is development and activation of such a plan – ultimately, one that will reflect far more inputs, insights, and refinements from Pennsylvania leaders on the path ahead.

The following discussion provides an analytical fact base to inform such a plan of action. It aims to:

- Define a practical vision for energy-driven economic development in Pennsylvania
- Quantify the potential benefit to Pennsylvania in GDP, jobs, and government revenues, at a high level
- Prioritize which sectors to build, expand, and attract in Pennsylvania
- Understand Pennsylvania's strengths to harness and challenges to address
- Suggest major themes/directions for development of specific actions

The goal is to lay out the facts, as objectively and clearly as we can know them, and clarify a path to an energy-enabled economy that will serve all Pennsylvanians.

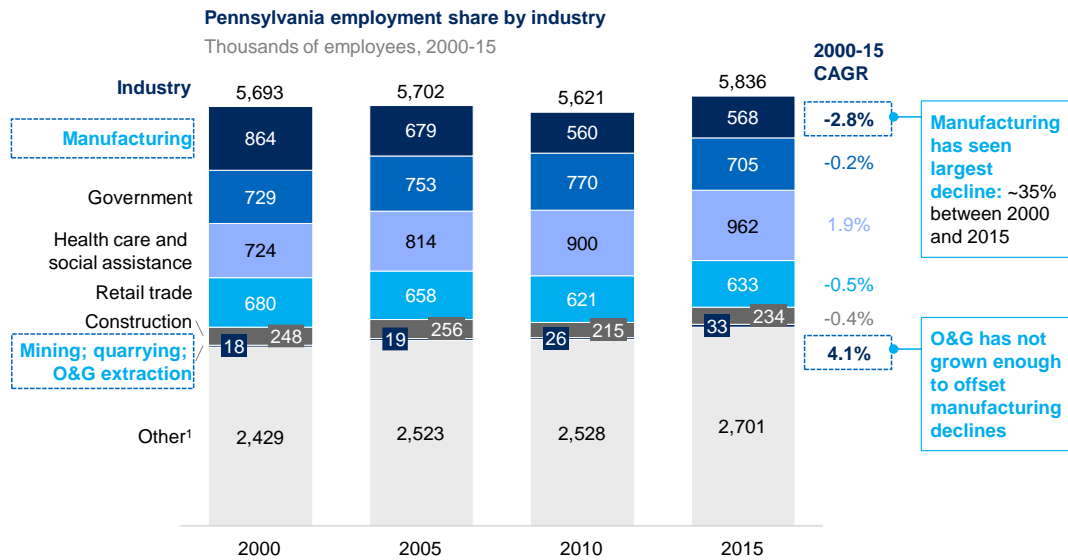
THE GROWTH IMPERATIVE

Pennsylvania needs to grow. Its economy and population have faced stagnation for a decade, buffeted by the Great Recession and global business dynamics. The state's GDP growth averaged 1.1% per year from 2005 to 2015, compared to a US average of 1.4% per year. In the same period, the state labor force grew 0.2% per year, compared to a US average of 0.7% per year. In particular, manufacturing jobs – which made up ~15% of Pennsylvania employment in 2000 – have declined ~35% (~2.8% per year) and now reflect only ~9% of employment (**Exhibit 1**). Although some of those losses have been offset by gains in other sectors like healthcare or financial services, these have not been enough to propel Pennsylvania to a new trajectory of growth and employment.

Pennsylvania’s low-cost energy can launch and sustain new manufacturing sectors – supplying products to high-growth domestic and global markets – that would be anchored to our state.

EXHIBIT 1

Over the past 15 years, energy has seen the fastest growth, but it will need to catalyze broader growth to offset ~35% decline in manufacturing jobs



¹ Other sectors include accommodation and food services, professional and technical services, admin services and waste management, finance and insurance, transportation and warehousing, educational services, wholesale trade, mgmt. of companies, arts/entertainment, information, real estate and rental/leasing, utilities

SOURCE: Moody's Analytics

Pennsylvania’s population has been stable (~12.5 – 13 million every year for the past decade). In the current economic environment, without significant and urgent action, stability means the state will fall behind others that have built momentum and growth. Pennsylvania needs an economic environment that attracts people who want to take advantage of desirable job opportunities, and a business buzz that results in more highly skilled workers and college grads seeking and finding their career start here.

Pennsylvania’s vast energy resources offer the opportunity to choose strategic collaboration and collective action over the status quo – to power, through energy, an engine of business and population growth. By unlocking the full potential of Pennsylvania’s Marcellus and Utica resources, the state will unleash a powerful competitive weapon in the fight for more and better jobs, income growth, community investments, health and safety – an increasingly improved quality of life that, because of this energy resource, is within the grasp of all Pennsylvanians and our leaders.

That competitive opportunity – and the gas itself -- are currently “stranded.” Low prices and a lack of infrastructure to move the gas is inhibiting investment decisions and direction that otherwise would be much more robust. Creating new demand will make production of these resources economical. Moreover, given how extensive and low cost the resources are, demand growth is unlikely to increase prices to levels that would erode the competitive edge that Pennsylvania’s low-cost gas offers.

THE URGENCY IMPERATIVE

Pennsylvania is competing with other domestic and international jurisdictions that want to lever their energy resources to advance the economies and quality of life in their regions. We want and need to win that race.

The window of time is limited. Sectors that would make the most use of Pennsylvania’s resources – for example, petrochemicals, ammonia, plastics, glass, and various forms of advanced manufacturing – are in the middle of deciding how to reposition their manufacturing footprint nationally and globally. Within the next 2-5 years, billions of dollars in capital investment decisions will be finalized – after which, they may be locked in for decades.

Over that time, other regions will become increasingly well-positioned to compete with Pennsylvania for investments and contracts. In particular, the Permian basin in the US southwest will produce an enormous amount of “associated gas” as it produces oil, which – since it is a byproduct – is effectively free. The earlier Pennsylvania can lock in opportunities, the better.

APPROACH TO ENERGY-DRIVEN ECONOMIC DEVELOPMENT

The objective is energy-driven economic development for Pennsylvania. By “energy driven,” we mean that, although there are many actions Pennsylvanians can and should consider to support the economy, we will focus only on the subset related to Pennsylvania’s energy resource. By “economic development,” we mean growth across multiple metrics of economic health: state GDP, jobs, and government revenues.

Naturally, an “energy driven” strategy must start by taking stock of what the energy resource contains. Pennsylvania sits atop the bulk of the Marcellus shale and a portion of the Utica shale. These areas produce gas (methane) and natural gas liquids (NGLs: ethane, propane, butane, and heavier C5 fractions). Gas can be burned for heat or to produce electricity. NGLs are used as feedstocks for refining and the complex chains of chemicals production (ethane into ethylene, propane into propylene, C5 fractions into refined products, and so forth).

These basic petrochemicals are the building blocks for materials and products that define how we live – our computers and cell phones, medical equipment, automobiles, sporting goods, clothing, cosmetics, packaging, appliances, and just about everything else we consume.

How much natural gas and NGLs are produced varies region by region, acre by acre. On average, Pennsylvania's acreage tends to be "dry" (gas rich) rather than "wet" (liquids rich): about 93% of production is methane, about 6% is ethane, and the small remainder is split among the rest. However, Pennsylvania's strategy for energy-driven economic growth can leverage production profiles across the region, including portions of basins predominantly in Ohio and West Virginia – for example, ~30% of ethane production in 2025 is projected to come from the Utica basin. By 2025, Pennsylvania will access enough ethane annually from across the tristate area to support 3-5 world-scale crackers alongside Shell's Franklin facility, depending on pipeline exports and production trends (see **Exhibit 8** later in the discussion).

In turn, "economic development" rests on a few pillars for success, based on both research and the real experiences of other US states and other countries:

- It should **benefit a broad base of Pennsylvanians**, whether in terms of more jobs, better jobs and job stability, or more money in people's pockets;
- It should prioritize the creation of **competitive tradeable clusters**. Clusters concentrate an industry value chain in tight geographic proximity, which enables easier and more frequent interactions among suppliers and customers and their customers, accelerates knowledge sharing and innovation, and thereby establishes a synergistic competitive advantage that is hard for other regions to break. Ideally, clusters should be built around tradeable sectors – meaning, those with goods or services that can be sold outside of the region (e.g., a technology) rather than those that are purely internal (e.g., a restaurant). Tradeable sectors have a greater impact on growth because they grow the state pie, pulling revenues in from national and global markets;¹
- It should be **sustainable**. In Pennsylvania's case, this means ensuring there is enough gas demand growth to **make gas production economical** – otherwise, it will be impossible to make use of the resource. It also means that any new sectors built as part of the strategy should be **attractive in the long term** (not accordions that expand in the near term but quickly retract), in areas where Pennsylvania can **become a leading competitor**.

¹ For more information on clusters, see for example, Michael E. Porter, "Clusters and the New Economics of Competition," *Harvard Business Review*, Nov-Dec 1998; and <http://www.isc.hbs.edu/competitiveness-economic-development/frameworks-and-key-concepts/pages/clusters.aspx> (as of April 2017)

OVERVIEW OF THE OPPORTUNITY AND POTENTIAL IMPACT

With these principles in mind, a detailed, sector-by-sector microeconomic analysis was conducted to understand Pennsylvania's full range of opportunities and determine which to prioritize.

The analysis gave shape to an integrated approach to energy-driven economic development in Pennsylvania. The approach entails three "development strategies" working together:






1. **Increased gas-fired power and heating:** Ensure all Pennsylvania consumers feel the benefits of low-cost gas for heating and efficient power generation, enabled by intrastate pipelines and (in part) distributed power generation;
2. **New clusters in sectors of the future:** Actively build clusters in three areas – Petrochemicals, Advanced Materials, and Data-Driven Automated Manufacturing – all of which harness Pennsylvania's competitive energy, build on other intellectual and industrial advantages of the state, and have the potential for large long-term growth;
3. **Gas exports:** Ensure Pennsylvania always has enough outlets for its gas to keep production viable. Importantly, exports will send a powerful signal that Pennsylvania competes on a global stage and is a lucrative destination for investment capital.

These development strategies must work together for energy-driven growth to spark and endure. First, gas-fired power and heating makes sure that improved quality of life is widespread rather than concentrated, which is good in itself, but is also important to ensure state-wide benefits. Second, new clusters serve as the engine of growth. Third, gas exports make sure that the "fuel" for that growth engine is affordable and available for use. If any one of these strategies is left out, the edifice crumbles in the long term.

Other regions will become increasingly well-positioned to compete with Pennsylvania for investments and contracts. The earlier Pennsylvania can lock in opportunities, the better.

Exhibit 2 summarizes the vision of what Pennsylvania should create with its world-class energy resource by 2025.

Overview of the opportunity – Harnessing Pennsylvania’s low-cost energy to promote economic growth and competitiveness

		End-state objective by 2025	
1	Pennsylvania power and heating		<ul style="list-style-type: none"> Build ~6,000 MW of new natural gas power in Pennsylvania Convert ~500,000 homes heating from fuel oil to natural gas Install ~2,200 MW of distributed combined heat and power
2	Petrochemicals		<ul style="list-style-type: none"> Build a world-class petrochemical hub with 3-5 ethane crackers, 3-5 PDH plants, 2-3 ammonia plants and inorganic chemical plants Expand into high-value specialty plastics manufacturing
	Advanced materials		<ul style="list-style-type: none"> Be the leading materials supplier for US northeast infrastructure growth (2-3% annual growth), harnessing historical strength in steel, aluminum, cement, and glass Establish the commercial hub of advanced materials technology (e.g., fiberglass, advanced cement) drawing on R&D leadership
	Data-driven automated manufacturing		<ul style="list-style-type: none"> Achieve national Top 3 position in data-hungry advanced manufacturing focusing on Pennsylvania leadership in robotics, artificial intelligence, and additive manufacturing Develop data center network (6-8 major centers) harnessing low-cost power, preparing for worldwide rollout of data-hungry Internet of Things
3	Gas exports		<ul style="list-style-type: none"> Expedite key pipelines (including Transco, Texas Eastern, Columbia Gulf, PennEast/UGI) to increase gas exports by 3.6 Tcf by 2025, ensuring stable gas production needed for Pennsylvania long-term competitiveness and investor confidence

Each of these development strategies anchors on Pennsylvania’s world-class energy resource, whether for low-cost gas and NGL feedstock (Pennsylvania power and heating; Petrochemicals), low-cost gas-fired electricity (Pennsylvania power and heating; Advanced Materials and Data-Driven Automated Manufacturing), or access to broader gas demand in order to make gas economical to produce (Gas exports). These strategies are explained in detail later in the analysis.

Pursuing this approach would create substantial, enduring benefits for all Pennsylvanians. By 2025, Pennsylvania could uplift its economic performance above the ‘take no action’ level by:

- \$60 billion, ~6-9% growth in annual state GDP over about 10 years, from ~\$720 billion in 2025 (under a business-as-usual scenario) to ~\$780 billion by pursuing targeted growth actions (increase from 1.6% to 2.3% in average annual growth rate);
- >100,000 more jobs, a ~1-2% increase over about 10 years, from ~6.2 million jobs in 2025 (under a business-as-usual scenario) to ~6.3 million jobs by pursuing targeted growth actions (increase from 0.65% to 0.85% in average annual growth rate);

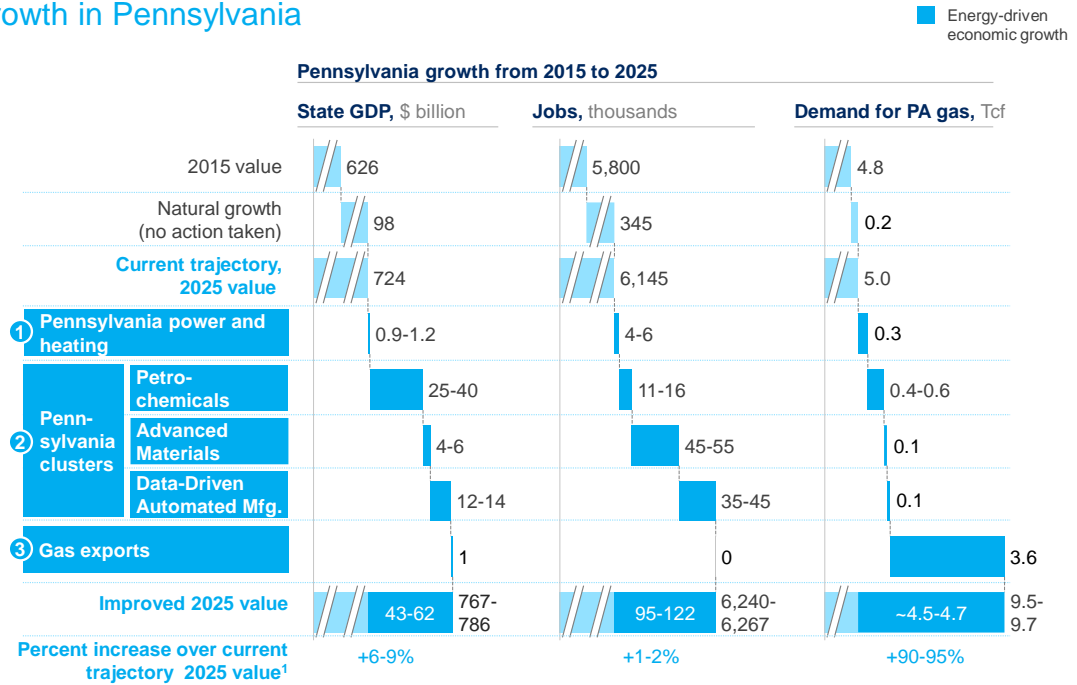
- >4.5 trillion cubic feet (Tcf) increase in gas demand, a ~90% increase over about 10 years, from ~5 Tcf in 2025 (under a business-as-usual scenario) to ~9.5 Tcf by pursuing targeted growth actions;
- Significant increase in state revenues – possibly \$2-3 billion, supported by large expansion in state GDP and corporate activity.

Moreover, it would position Pennsylvania to be an innovation and talent leader in cutting-edge sectors of the future.

Exhibit 3 summarizes the potential economic benefits. These estimates account for not only the direct impacts (e.g., revenues and jobs created by new sectors) but also the secondary and tertiary impacts (e.g., knock-on effects from businesses and services that emerge to support the new sectors).

EXHIBIT 3

Potential impact of energy-driven economic growth in Pennsylvania



¹ 2015-2025 CAGR increase due to economic development: GDP = -0.9%, jobs = -0.2%, gas demand = -6.7%
 SOURCE: EIA; BEA (Moody's Analytics); team analysis

Each development strategy provides a different type of economic benefit:

- **Increased gas-fired power and heating ensures all Pennsylvanians benefit from low-cost energy.** It has moderate effects on GDP and jobs – more importantly, it improves household income for a wide range of residents (e.g., households in rural NW and NE Pennsylvania areas that switch from fuel oil to gas will experience \$1,500-1,800/season savings on their bills);
- **The clusters drive GDP and jobs growth.** Petrochemicals is the single largest contributor to GDP growth (~\$25-40 billion), with significant job growth (~11,000 – 16,000). The Advanced Materials and Data-Driven Automated Manufacturing clusters are large job engines (~80,000 – 100,000 together), and position Pennsylvania as an Industry 4.0 manufacturing leader – providing the robotics equipment and software that will define the next wave of manufacturing facilities in the US and globally, as well as the artificial intelligence, advanced analytics, and “big data” computing that will be required as the “Internet of Things” spreads throughout manufacturing (which is moving toward widespread sensor deployment to allow real-time monitoring and control of equipment);
- **Gas exports are crucial to increase gas demand enough to make gas production viable.** This, in turn, enables the clusters to exist and provide GDP and jobs growth within Pennsylvania.

Clearly, all three of these development strategies must work together to forge the future. Based on studies (Allegheny Conference on Community Development) that show GDP growth increases tax receipts at just over five percent of that growth, revenues to Pennsylvania’s treasury stand to increase by \$2-3 billion based on this analysis.

ANALYSIS OF THE OPPORTUNITY

To identify the right development strategies, we looked at every possible way that Pennsylvania’s energy could be monetized. We then assessed whether it made sense to pursue them based on the economic development pillars outlined above. In addition, we considered global and regional economic landscapes and business cycles that determine timing for new investments.

Increased gas-fired power and heating

Across the United States, major changes in the energy mix for electric power generation and usage are well underway – including fuel-switching in central generating plants and growth in “behind the meter” technologies like wind, solar, distributed generation including fuel cells and combined heat and power (CHP), and battery storage for residential and commercial & industrial users.

By capitalizing on these trends, Pennsylvania’s gas resource can create economic benefits for Pennsylvanians in the near term, without any change to the underlying economy or growth in new industrial sectors, through a combination of fuel switching for distributed power generation and heating.

Fuel switching refers to shifting how power and heating are produced. Historically, baseload, dispatch-able, central generation has been dominated by three fuel sources: nuclear, coal and gas-fired power plants. In PJM (the regional wholesale electric transmission operator), the dispatch curve for these technologies has seen nuclear dispatched first (despite high fixed costs, the marginal fuel cost is near zero), followed by coal and then gas – only as the need arises. For the first time, gas prices have driven gas-fired power ahead of coal on the dispatch curve and have often lowered overall wholesale power prices – meaning that gas-fired power will be “in the money” far more often than its coal-fired counterparts.

As a result, shifting from coal-fired to gas-fired power plants allows potentially lower-cost electricity from highly efficient combined cycle gas turbines (CCGT), and the construction and retrofitting of coal-fired plants provides a significant economic opportunity. Already, since 2010, the share of gas-fired plants in Pennsylvania’s generation mix has almost doubled from 15% to 28%.

At the same time, on the retail side, the opportunity for systematically lower electric prices provides further incentives for residential customers to switch from fuel oil to electric power for heating.

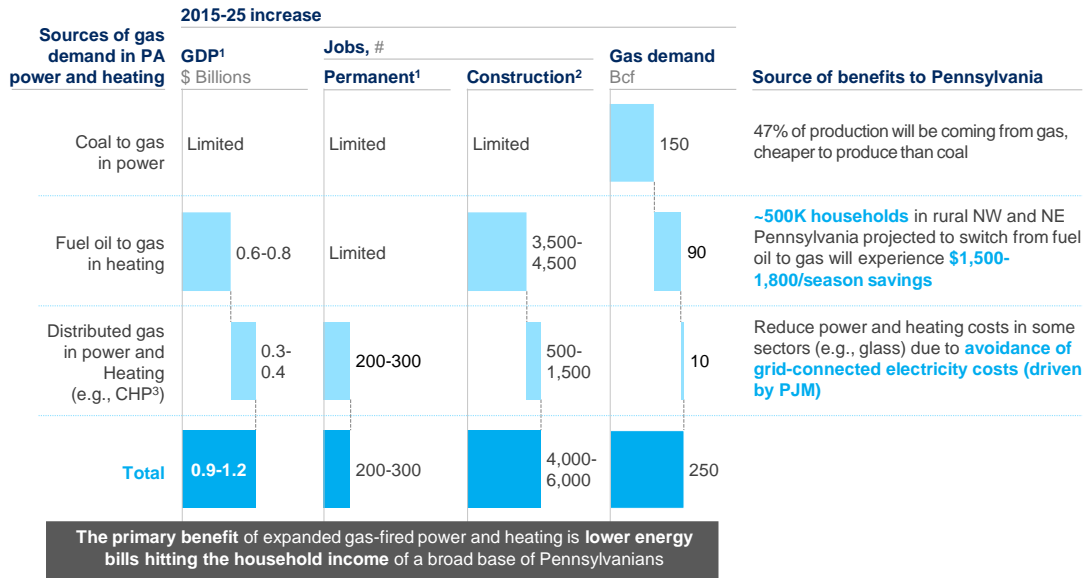
Finally, economics is driving adoption of new, distributed “behind the meter” technologies that enable residential and commercial & industrial customers to generate on-premise power. While a subset of the population is adopting these technologies for non-economic reasons (e.g., additional resiliency in the case of microgrids; “green” considerations), a convergence in the levelized cost of electricity between central grid-supplied power and these new technologies will occur throughout the US in the coming years – with “grid parity” between these technologies and central power, in pure economic terms, slated to occur in the early part of the next decade.

As this occurs, utilities will face increased affordability pressure from customers and regulators, thereby potentially driving down retail power prices. In addition, some “behind the meter” technologies will directly leverage gas to generate on-premise power, including combined heat and power and natural gas-fired fuel cells.

Exhibit 4 provides a closer look at the potential economic impact on GDP and jobs.

EXHIBIT 4

1 Pennsylvania power and heating – important because it distributes the benefit of low-cost gas across all Pennsylvanians



1 Assumes that coal to gas and fuel oil to gas GDP is offset by loss from existing fuel sources
 2 Values are based on temporary construction
 3 Other distributed gas include micro-grids, fuel cells
 SOURCE: Expert interviews; team analysis

The main benefits of increased gas-fired power and heating are twofold. First, it improves household income for a wide swathe of Pennsylvanians. Almost 60% of the opportunity to switch to low-cost gas is focused on residential consumers. Second, its benefits can be felt near term, rather than waiting for new sectors to be attracted or new interstate pipelines to be built. In addition, it provides a significant amount of construction jobs, as in many cases existing pipeline infrastructure must be extended to new geographic areas and central generating facilities will need to be constructed or retrofitted. The caveat is these jobs are limited to the time it takes to construct the new infrastructure.

New clusters in sectors of the future

Pennsylvania’s low-cost energy resource can be the engine of new growth sectors for the state. The most powerful way to build that engine is to create competitive tradeable clusters, with two characteristics.

First, the clusters should be anchored to energy-intensive sectors in which low-cost energy – whether as electricity, heat, or feedstock – generates a measurable and meaningful competitive advantage for companies in the sector. Second, the clusters should use energy-intensive sectors as springboards to high-value sectors, which harness other unique strengths of Pennsylvania and will position Pennsylvania for sustained growth and competitiveness in the global economy of the future.

We followed exactly this twofold logic to identify promising sectors and piece them together into coherent clusters, as described in **Exhibit 5**.

EXHIBIT 5

2 Pennsylvania clusters – Catalyze sustained growth through clusters anchored to energy-intensive sectors that are springboards to high-value growth



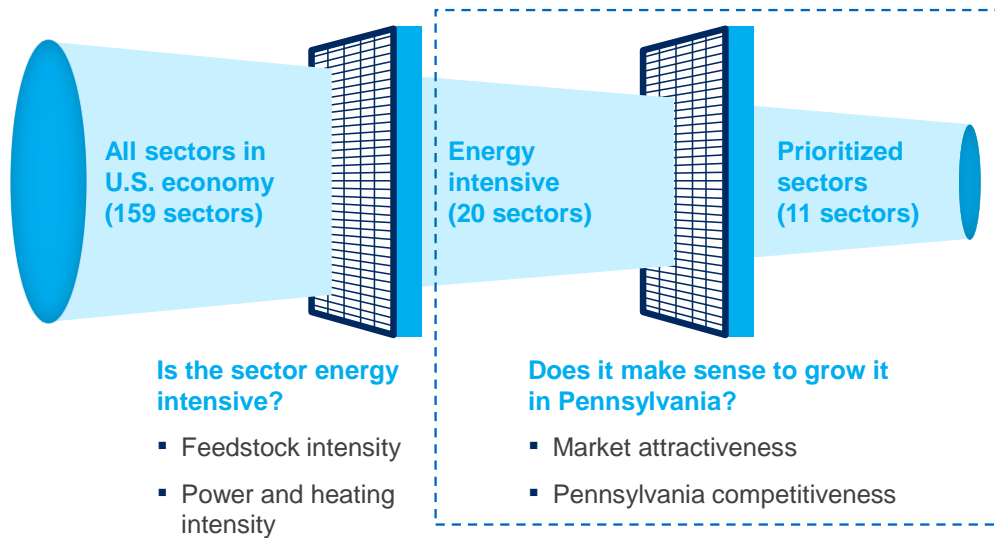
To prioritize energy-intensive anchor sectors, we used a filtering process (**Exhibit 6**). We started by looking at all 159 sectors of the US economy, as defined by the US Department of Labor (see **Appendix B** for data on the subset surveyed by the US EIA). From that list, we focused on the 20 most energy-intensive sectors, based on data on feedstock intensity, power intensity, and heating intensity. We then conducted a close microeconomic analysis of those 20 sectors to determine which of them had the most promise for Pennsylvania, based on the answer to two questions:

- In general, will the sector have attractive economics for the next 10-20 years?
- Could Pennsylvania offer unique competitive advantages to win in the sector (either domestically or globally)?

EXHIBIT 6

- 2 Out of 159 sectors that comprise the U.S. economy, we
A identified the 20 most energy-intensive sectors for
closer evaluation

Discussion follows



Close sector-by-sector analysis suggests that 11 out of 20 energy-intensive sectors merit significant consideration for Pennsylvania (**Exhibit 7**). There are clear patterns for what distinguishes these sectors from the rest. They reflect some combination of a large and growing market (either domestically or globally), high margin potential, or some other advantage that would allow Pennsylvania to lead the market despite generally difficult competition or tight margins – typically, a regionalized structure where Pennsylvania is located near key regional markets and has existing commercial ties to those markets.

EXHIBIT 7

2 Promising sectors – out of 20 energy-intensive sectors, 11 stood
A out for market attractiveness and Pennsylvania competitiveness

High
 Moderate
 Limited/none

Anchor sector	Global growth ¹ CAGR 2015-25	Post-2025 trends	Attractive market	Can Pennsylvania be competitive?	
Feedstock intensive	Ethane cracker/ PE units	4.4	↑	Large global market (\$360B)	70% of PE mfg. w/in 300 mi; large low cost ethane
	PDH plants/ PP units	6.0	↑	Large global market (\$160B); growth in Asia	Large, low-cost propane supply
	Ammonia plants	2.1	↑	Large mkt. (\$200B); low margins; global oversupply	Gas cost advantage critical post-2025 in \$65/bbl oil
Power / heating intensive	Data centers	5.4	↑	Large future demand for data access and manipulation	20-30% electricity cost; sites close to major urban centers
	Glass	3.0	→	Diversified mkt; commodity and tech products	30% electricity cost; close to MW auto and NE const. mkts.
	Plastics (commodity and specialty)	1.9	→	Specialty products offer high margins (~50%)	Access to abundant Pennsylvania feedstock supply
	Fabricated materials (e.g., machine shops)	1.5	→	Large U.S. mkt (\$140B); high margin for specialty products	Prox. to NW auto and NE const. demand centers
	Cement ²	2.6	→	Regional markets insulated due to transportation costs	30% electricity cost; existing industry with 45% NE supply
	Inorganic chemicals	2.1	→	Highly diversified with some high margin products	Inorganic chemicals are input for other Pennsylvania sectors
	Aluminum	2.1	→	Potential demand growth from emerging countries	30-40% electricity costs; prox. to MW auto demand
	Steel	0.4	→	Potential demand growth from emerging countries	Pennsylvania 2nd supplier in US with large existing support hub

¹ Product highly exportable, therefore, using global demand growth most applicable to evaluate market attractiveness; each CAGR refers to the end product from the plant (e.g., 4.4% CAGR for polyethylene, 6.0% CAGR for polypropylene; 2.9% global CAGR for butadiene) ² Includes gypsum and lime
 SOURCE: Expert interviews; Team analysis

Sector 1: Ethane cracker / polyethylene units. Through a chemical “cracking” process, ethane can be used as a feedstock to produce ethylene, which can then be turned into polyethylene pellets for use in a variety of derivative chemical applications. These form the basis for products that are important to our everyday lives – for example, packaging, hospital equipment, autos, pharmaceuticals, clothing, appliances, and so on. The global polyethylene market is large (~\$300 billion today), will grow ~4-5% per year for the next 10 years, and is expected to continue growing after that.

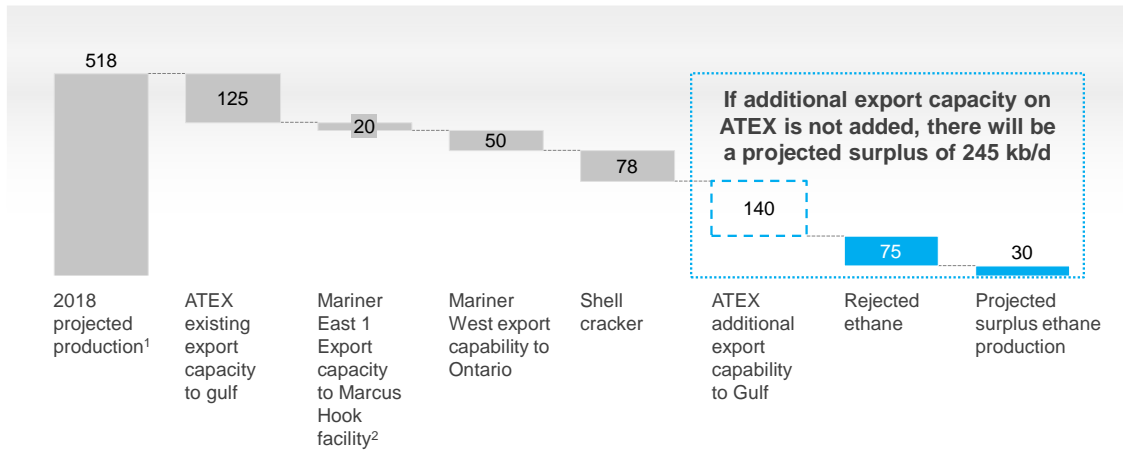
Pennsylvania is well positioned to compete. First, it is proximate to key demand markets: 70% of US downstream polyethylene manufacturing is within 300 miles of Pittsburgh. Second, Pennsylvania will have a surplus of ethane even after accounting for expected expansion of the Appalachia-to-Texas (ATEX) pipeline, which can be absorbed by additional crackers in Pennsylvania (**Exhibit 8**).

EXHIBIT 8

- 2 Marcellus and Utica shale are projected to produce surplus ethane,
- A which could be absorbed by additional cracking capacity

Depending on pipeline capacity expansions, there may be an excess of 105-245 kb/d of excess ethane production in 2018

kb/d



1 Assume no increase in ethane production post 2018

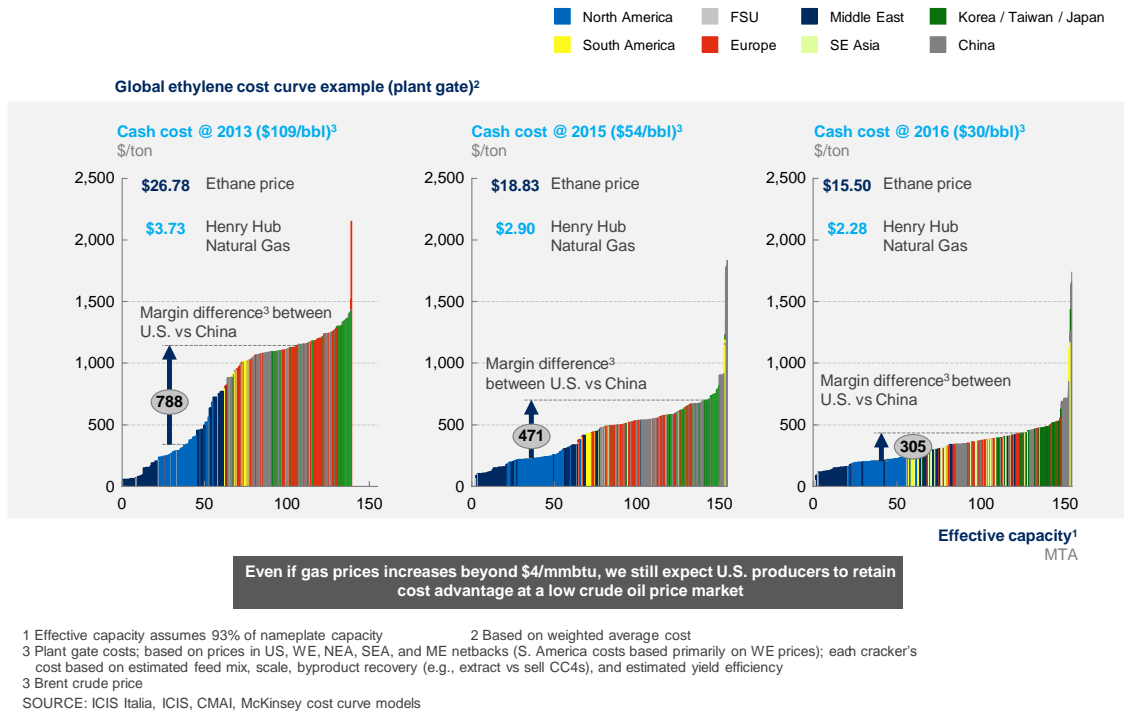
2 Total export capacity on Mariner East 1 is expected to be 70 kb/d, of which only 20 kb/d is projected to be ethane, the remaining includes other NGLs including propane

SOURCE: Platts

Third, though ethylene / polyethylene can be produced using naphtha, a crude oil product whose prices move with oil prices, the cost advantage of the ethane route over the naphtha route to ethylene production is large and resilient, even if oil prices stay low (Exhibit 9).

EXHIBIT 9

2 U.S. ethane-based ethylene retained its cost advantage over naphtha-based ethylene despite decreases in oil price between 2013 and 2016



Sector 2: PDH plants / polypropylene units. Propane dehydrogenation (PDH) uses propane as a feedstock for on-purpose production of propylene, which is usually procured as a byproduct of naphtha or propane cracking. The global propylene market is large (\$160 billion today), largely centered on Asia. Pennsylvania’s high-volume, low-cost propane (~\$3/mmbtu), making up ~25% of projected 2025 NGL production in the region, would allow PDH plants to compete in the global propylene market despite higher capex than in the US Gulf Coast (driven by greenfield investments and ~25% higher construction labor costs) and higher transportation costs versus producers in Asia. But there is a wrinkle: propylene margins have shrunk due to over-supply. In turn, PDH margins have compressed. There is an option, however: polypropylene – a derivative of propylene – has healthy margins and will likely remain robust. Integrated PDH/polypropylene plants could give Pennsylvania an attractive route to monetize its propane. Pennsylvania’s propane feedstock cost may be low enough to keep the region competitive in polypropylene despite over-supply of propylene elsewhere. Polypropylene production, in turn, can be the basis for a wide variety of plastics and other products.

Sector 3: Ammonia plants. Natural gas (methane) can be used as a feedstock to produce ammonia. The global ammonia market is large (~\$200 billion), as is the US market. For the next several years, the ammonia market will be over-supplied. Moreover, European oil-linked ammonia producers are no longer the marginal suppliers – supply growth is largely coming from low-cost sources (e.g., Trinidad & Tobago, Middle East), significantly squeezing the margins available to US producers to ~5%. That said, the market is worth considering for Pennsylvania. After 2025, growth in global ammonia demand could make Pennsylvania ammonia plants more comfortably “in the money” – an effect which would be reinforced if oil prices rise and sustain above ~\$65 per barrel. Because natural gas feedstock used to make ammonia is linked to oil prices outside the US, rising oil prices push the foreign marginal producers of ammonia higher on the global cost curve, giving Pennsylvania a low-cost natural gas feedstock advantage. Pennsylvania’s proximity to large Midwestern agriculture markets that use fertilizer created from ammonia offers a location advantage as well.

Sector 4: Data centers. Data centers will become increasingly important as the “Internet of Things” creates an exponentiation in data measurement, storage, and access, much of it in real time. The market will grow rapidly (~5.4% per year through 2025), with certain segments like service providers / hyperscalers (which can scale up flexibly with data demand) seeing outsized growth (~9% per year through 2020 globally). Pennsylvania’s potential to provide low-cost retail and off-grid electricity can be a competitive differentiator, given that electricity constitutes 20-30% of total data center costs. This energy resource advantage could combine with Pennsylvania’s research strength in the software services data centers need (e.g., advanced analytics, data processing, artificial intelligence) to become a magnet for data center attraction. Key technology companies have already established a presence in the state (e.g., SAP, Google, Uber), which provides a starting point.

Sector 5: Glass. The glass market is growing nationally and globally, propelled by the construction, automotive, and electronics industries. This growth links to deep-seated economic trends, whether the rise of consuming classes in emerging markets or the need for new infrastructure buildout in the OECD. Further, the glass market has a variety of segments, ranging from commodity flat glass to more advanced fiber and specialty glass, with double or even triple the profitability; one can be a springboard to the other. Pennsylvania’s potential to provide low-cost retail electricity can offer an advantage, as electricity accounts for ~30% of total glass production costs. Alternatively, Pennsylvania glass manufacturing plants could make use of CHP given their heat requirements. In addition, Pennsylvania has a regional advantage. The glass market is highly localized due to product fragility and the difficulties of transportation. Pennsylvania is proximate to key glass markets: automotive in the US Midwest, construction in the US northeast.

Sector 6: Plastics (commodity and specialty). The US market for specialty plastics and resins is fairly large (\$5-10 billion), and it boasts large margins (~20-40%).

Moreover, growth in specialty plastics is projected to outpace GDP growth as demand for these products grows in Asian markets. Asia must import many specialty plastics due to lagging technology that constrains their ability to manufacture closer to home. Pennsylvania has multiple advantages to help it compete. First, Pennsylvania has ample feedstock supply of polyethylene and polypropylene locally, particularly after the Shell ethylene / polyethylene capacity comes online. This means low feedstock transport costs. Second, Pennsylvania already has a plastics industry: it is the 5th largest state producer of plastics in the US, reflecting 5% of the total US plastics market and 40% of the northeast plastics market. Third, if low-cost electricity can be provided, it would advantage energy-intensive plastics manufacturing processes.

Sector 7: Fabricated materials (e.g., machine shops). Fabricated materials comprise a \$140 billion market in the US, with high margins for specialty segments. Both general and precision fabrication of metals and plastics are expected to grow through 2025 (2.5% and 8% per year, respectively). A Pennsylvania fabricated materials sector would benefit moderately from low-cost electricity, but that advantage combines with other Pennsylvania strengths. For one, the sector fits well with Pennsylvania's heritage as a place for steel, metalwork, and 'building the things to build things.' Pennsylvania is already the 6th largest state supplier of fabricated materials, with 5% of US output and 30% of northeast output. It will be hard for Pennsylvania to compete on the global market, but the state enjoys a location advantage in the domestic US market, situated near two demand zones: manufacturing in the Midwest (including automotive) and construction in the northeast.

Sector 8: Cement. The cement market is highly regionalized due to transportation costs – therefore, the US market is what matters to Pennsylvania. In the near term, there is sufficient cement supply to meet US demand. By 2025, however, demand growth will require new plants to come online. Pennsylvania is advantaged by the potential for low-cost power (electricity is ~30% of total operating cost) and by its existing base of cement manufacturing (Pennsylvania is the 4th largest state supplier of cement, with 5% of US output and 45% of northeast output). Further, the regionalized market insulates northeast producers from low-cost country competition.

Sector 9: Inorganic chemicals. The inorganic chemicals market is moderately attractive for Pennsylvania, but small (~\$3B US market). Caustic soda and chlorine comprise ~70% of the inorganic market, while the rest is spread between highly diversified acids and other products. US inorganic chemicals growth is projected to be ~2% through 2025. Inorganic chemicals used in consumer and industrial products (e.g., cleaning products, solvents, etc.) could supply manufacturing in the northeast.

Sector 10: Aluminum. The aluminum market is moderately attractive for Pennsylvania. Chinese demand growth has declined precipitously (from 17% to 5% per year over the last 6 years), though the decline could be offset by demand growth in India, Southeast Asia, and Africa in the coming years.

Moreover, the long-term cost curve is flattening due to accelerated use of recycled aluminum, putting pressure on margins. That said, Pennsylvania is well-situated to be a competitor, at least in the US market: electricity comprises 30-40%% of total operating cost; Pennsylvania is already the 5th largest aluminum producing state, with an existing metal craft industry; and it is close to the Midwest auto manufacturing hub, which is the largest driver of US aluminum demand, as well as to Northeast urban areas which may see considerable growth in construction (the next largest driver of aluminum demand).

Sector 11: Steel. The steel market story is a mixed bag. Like aluminum, Chinese demand growth has declined (from 18% to 6% per year over the last 8 years), though new demand could come from India, Southeast Asia, and Africa. Like aluminum, the supply cost curve will flatten due to the rise of low-cost direct reduced iron / electric arc furnace (DRI/EAF) mini-mill capacity. As it flattens, marginal producers – for example, US mills with high labor costs versus competing parts of the world – will face tighter and tighter margins. That said, Pennsylvania has obvious advantages to help its steel manufacturing survive the competition – not only its potentially low-cost energy, but also its long experience in steel. Pennsylvania remains the #2 producing state in America and boasts a highly capable talent pool.

The remaining 9 energy-intensive sectors were de-prioritized due to either difficult markets, limited sources of Pennsylvania advantage, or both (**Exhibit 10**).

EXHIBIT 10

2 Challenging sectors – 9 of 20 sectors were de-prioritized due to
A challenging markets or Pennsylvania competitive disadvantages

High
 Moderate
 Limited/none

	Sector	Global growth ¹ CAGR 2015-25	Post 2025 trends	Attractive market	Can Pennsylvania be competitive?
Feed- stock inten- sive	Methanol plants	7.0	➔	High growth mostly in China; proj. US oversupply	Low cost gas but high transport cost to China
	BDH plants	2.9	➔	Low demand growth; plentiful naphtha-based supply	Hard to compete with “free” naphtha-based butadiene
Power / heating inten- sive	Brick and structural clay	2.6	➔	Small U.S. mkt (~\$4B) with commoditized products	Pennsylvania 4th largest supplier, but mkt small (~\$270M)
	Nonferros metals	2.1	➔	Potential demand growth from emerging countries	Pennsylvania 2nd largest supplier; but end markets dispersed
	Wood products	0.8	⬇	Long-term demand decline due to synthetic materials	Production may shift over time to raw resource centers
	Paper	0.7	⬇	Digital displacing paper publications (~31% to-date)	Production may shift over time to raw resource centers
	Petroleum and coal products	-0.7	⬇	Long-term demand drop from fuel emissions and efficiency std.	Close to major NE markets for refined products
	Food processing and production	-0.5	➔	Tight margins as developing countries produce more	Pennsylvania less comp. due to labor cost and dispersed pop.
	Textile mills	-1.7	➔	Small U.S. mkt (~\$8B); production shift to LCC	Small mkt (~\$250M); Pennsylvania not comp. on global mkt

¹ Product highly exportable, therefore, using global demand growth most applicable to evaluate market attractiveness; each CAGR refers to the end product from the plant (e.g., 4.4% CAGR for polyethylene, 6.0% CAGR for polypropylene; 2.9% global CAGR for butadiene)
 SOURCE: Expert interviews; Team analysis

This micro-economic analysis provides a clear view of energy-intensive anchor sectors to prioritize.

The next step in the logic of cluster development is to identify the other Pennsylvania strengths that, tied to energy-intensive anchor sectors, provide a springboard to high-value growth. “High-value growth” means growth in sectors that are not commoditized, that hinge on technological sophistication that is hard to replicate, and that ride major economic trends in the 21st century economy around computing and physical materials innovation.

Pennsylvania’s innovation leadership connects some of the most exciting growth areas in the US and global economy of the 21st century

The first place to look for strengths is where Pennsylvania has intellectual and innovation leadership in technologies or practices that connect with major trends in the economy. **Exhibit 11** indicates several areas of leadership in universities across the state. Pennsylvania has some of the top academic research programs in the country in robotics, artificial intelligence, and materials science and nanotechnology, which align to high-value growth sectors. Moreover, as shown in **Exhibit 12**, Pennsylvania is ranked among the top producers of academic and corporate patents in the US for practical applications of this research, across computing and electronics products, chemicals, machinery, fabricated metals, and plastics, which align to the energy-intensive anchor sectors.

EXHIBIT 11

2 To build clusters around energy-intensive anchors, Pennsylvania can
B draw on its research leadership in high-value sectors of the future (1/2)

Leading academic programs in key disciplines –artificial intelligence, robotics, electronics, materials, nanotechnology, additive manufacturing



- CMU **School of Computer Science ranked #1 in U.S.** – research in computing, AI, machine translation, human computer interaction, and robotics
- **#2 U.S. programs in AI**
- **Scott Institute for Energy Innovation** develops smart grids, new materials for energy and shale gas, etc.



- Dept. of **Material Science and Engineering** ranked **top 5 in U.S.**



- **Center for Advanced Materials & Nanotechnology** research in metals processing, glass synthesis/processing for biomedical and optical computing applications, materials for additive mfg.



- **#1 in US in materials research**
- **#8 in US computer science research**

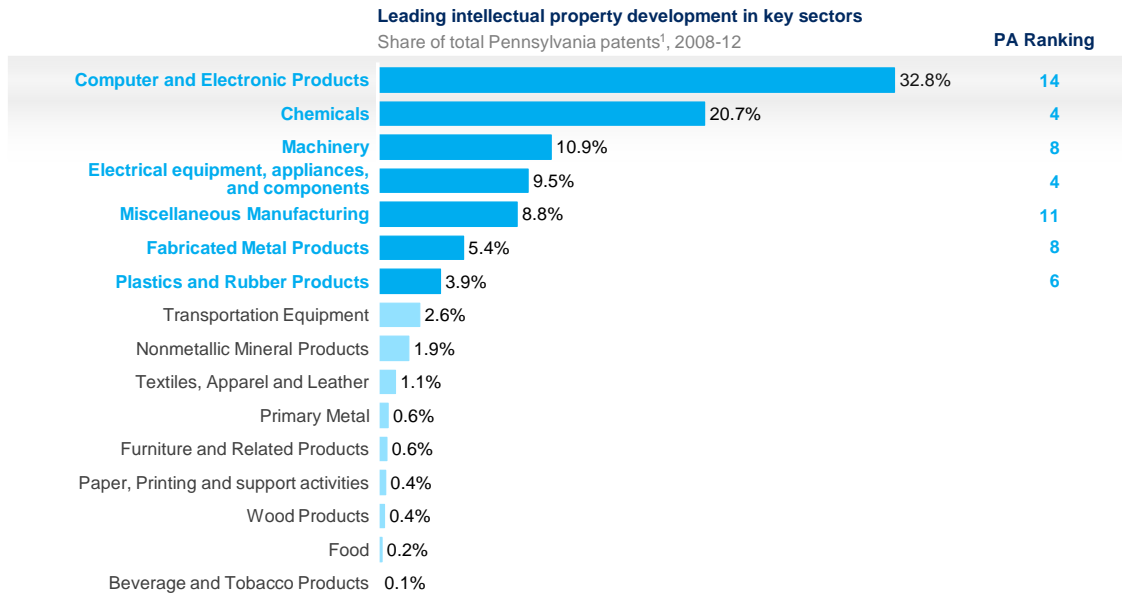


- **Top US research program in chemistry, nanoscience and technology –** developing anti-icing coating, semiconductors, etc.

1 Including corporate and academic R&D patent activity
 SOURCE: US Patent and Trademark Office; press search

EXHIBIT 12

2 To build clusters around energy-intensive anchors, Pennsylvania can
B draw on its research leadership in high-value sectors of the future (2/2)



¹ Including corporate and academic R&D patent activity
 SOURCE: US Patent and Trademark Office; press search

All of these areas of intellectual leadership can be a springboard to build on Pennsylvania’s industrial base. For example, Pennsylvania has established sectors in metals, cement, and plastics product manufacturing. Its ability to innovate in materials could be the basis for growing into the next-generation version of these materials. Its experience in manufacturing metals products could feed into burgeoning robotic machining sectors.

Moreover, Pennsylvania’s innovation leadership connects with some of the most exciting growth areas in the US and global economy of the 21st century. For example, the robotics market is expected to grow 13% per year (**Exhibit 13**), and robots are starting to be integrated into every part of the economy, from automotive to food production and processing.

EXHIBIT 13

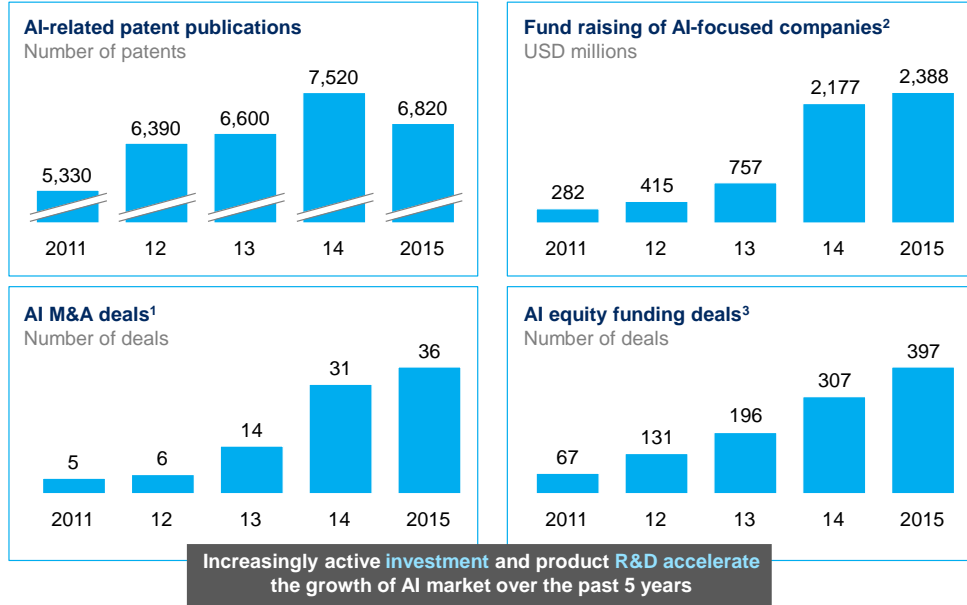
2 Historical and expected growth in the robotics market
B



SOURCE: IFR World Robotics 2016, McKinsey analysis

Similarly, artificial intelligence is attracting huge investment growth (**Exhibit 14**), as it is being applied across a wide range of sectors to improve data-based decision making (e.g., predictive maintenance supported by machine learning algorithms) and productivity (e.g., robotic process automation). In turn, it will be one of the main drivers of data and server growth over the next 5 years.

2 Artificial intelligence R&D and funding continue to grow
B

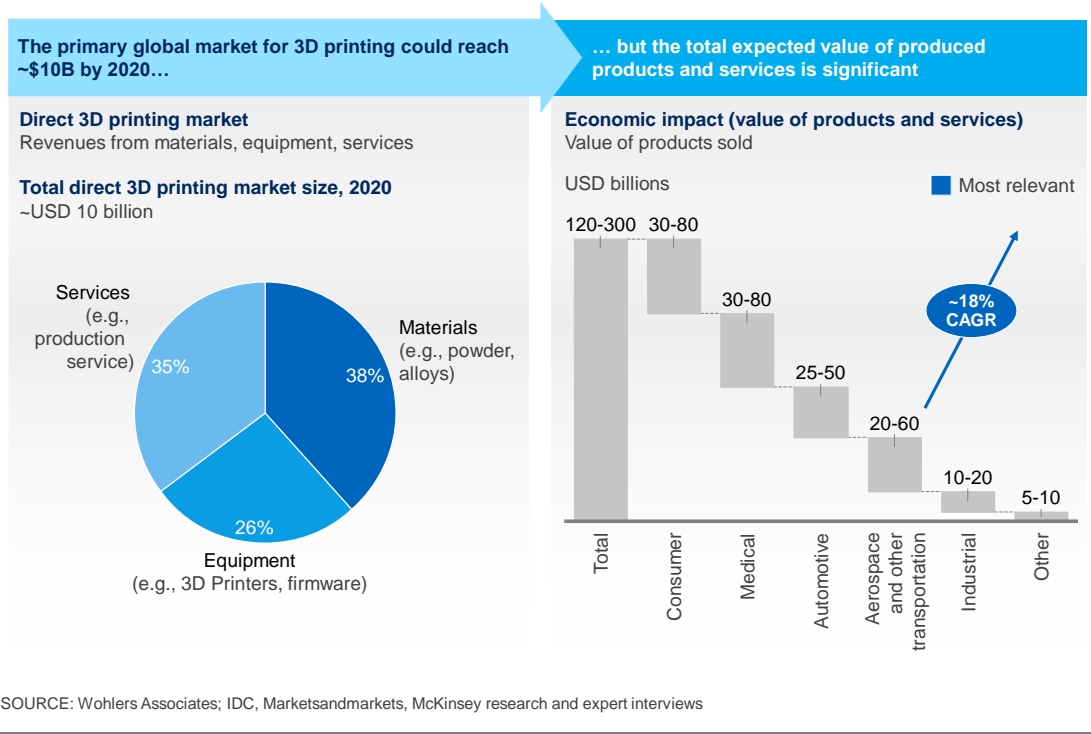


1 M&A deals involving companies developing core AI algorithms as well as those applying AI solutions to specific industries like healthcare and cybersecurity
 2 Equity funding dollars of AI-focused companies, including all equity funding rounds and convertible notes
 3 Equity funding deals of AI-focused companies, including all equity funding rounds and convertible notes
 SOURCE: CB Insights, Google patent

Additive manufacturing or 3D printing (which eliminates materials waste by “printing” 3D objects precisely to design) will be a small market of ~\$10 billion globally by 2025, but 3D-printed components will be a ubiquitous feature of the manufacturing economy – supporting \$120 to 300 billion in products sold by 2025 (**Exhibit 15**).

EXHIBIT 15

- 2 The global additive manufacturing market could reach ~\$10 billion by 2020, leading to ~\$120-300 billion in economic impact
- B



These promising growth areas can be advantaged by low-cost energy, both directly and indirectly. For example, Pennsylvania’s potential for cheap electricity, if realized, could give the state a direct competitive advantage in materials production, which – combined with Pennsylvania materials innovation – allows for unpredictable and potentially transformative business opportunities. Economical and reliable electricity also supports data-hungry pursuits like robotics and artificial intelligence, which will produce increasingly voluminous amounts of data that must be managed in real time and stored in energy-demanding data centers. Processing power requires electric power – and reliable, low-cost electric power can be enabled by Pennsylvania’s abundance of natural gas.

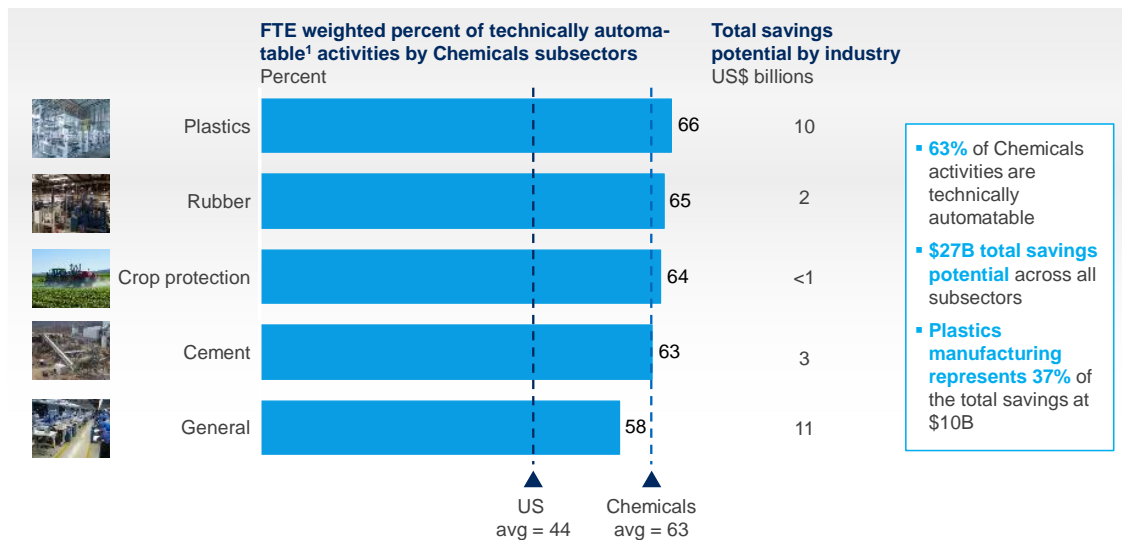
Pennsylvania has an opportunity to build three unique clusters that would position the state to be a leader in the 21st century manufacturing economy.

Perhaps more important are the indirect – but real – benefits of low-cost energy. These indirect benefits create interdependencies between energy-intensive anchor sectors and high-value growth sectors. For example, for Pennsylvania’s robotics and artificial intelligence sectors to blossom, they will need sales markets that allow them to test new products, experiment, and grow to efficient scale. A growing Pennsylvania chemicals sector would be such a market, given the significant automation potential in chemicals manufacturing (**Exhibit 16**) – and a growing Pennsylvania chemicals sector depends on low-cost energy to make it a competitor.

EXHIBIT 16

- 2 Two-thirds of activities in the U.S. chemicals sector are open to
- B automation, representing almost ~\$30B potential (~37% in plastics)

Automation potential of Chemicals subsectors in the U.S.

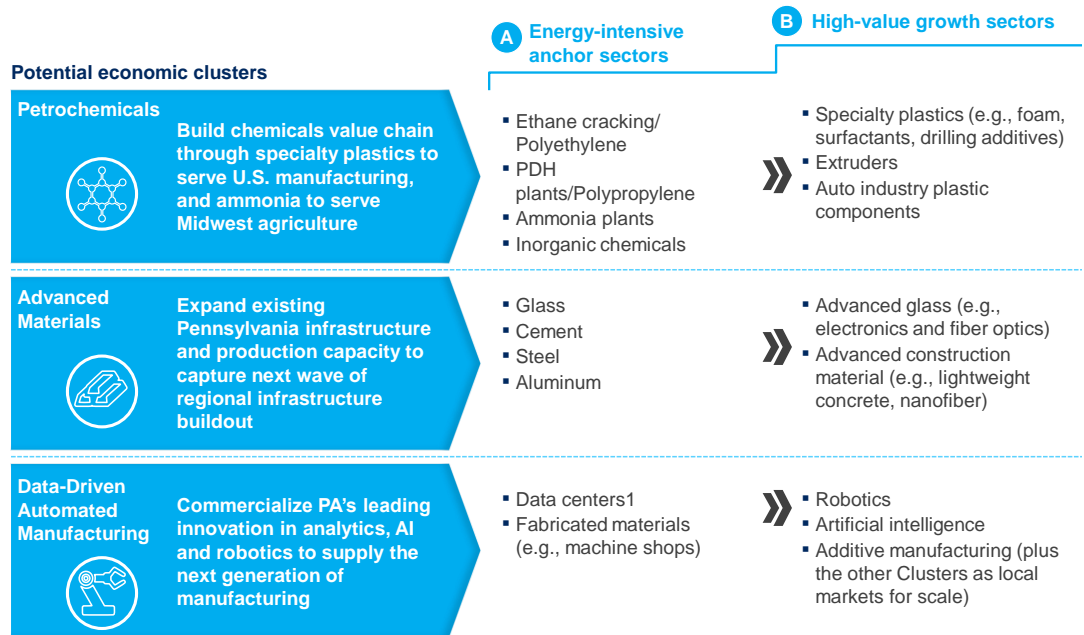


¹ We define automation potential by the work activities that can be automated by adapting currently demonstrated technology
 SOURCE: BLS 2014, O*NET, McKinsey GEM automation database; McKinsey analysis

After following this logic, we can piece together coherent, energy-driven economic clusters for Pennsylvania. Pennsylvania has an opportunity to build three unique clusters: Petrochemicals, Advanced Materials, and Data-Driven Automated Manufacturing (**Exhibit 17**).

EXHIBIT 17

2 Based on the analysis, Pennsylvania should focus on developing three energy-based clusters that enable leadership in future high-value sectors



¹ Enabler for advanced mfg. tech growth (e.g., IOT, AI, additive manufacturing); proximity may matter as data becomes more closely linked with mfg. operations

Each of these clusters anchors to attractive, viable energy-intensive sectors, combines them with areas where Pennsylvania is an innovator, and results in positioning Pennsylvania to be a leader in the 21st century manufacturing economy.

The **Petrochemicals cluster** hinges on the idea that Pennsylvania can harness low-cost feedstock to compete in several chemicals markets. It starts by establishing the foundational elements of large chemicals production chains (e.g., polyethylene, polypropylene, ammonia). These primary petrochemicals provide a springboard to manufacturing a wide variety of plastics and chemicals products that feed into large consumer sectors: for example, foams that go into mattresses and cushion covers, or surfactants that go into cleaning liquids and are used for car repair. Pennsylvania's competitiveness in these markets would be founded on its upfront feedstock advantage.

A Pennsylvania petrochemicals cluster would not aim for equivalency with the US Gulf Coast complex, which is huge, diverse, well-established, and endowed with low-cost feedstock as well. But Pennsylvania is well-positioned for regional market leadership, taking advantage of its proximity to the northeast and Midwest to supply manufacturing markets (specialty plastics), automotive (automotive plastics), and agricultural markets (ammonia).

The **Advanced Materials cluster** would position Pennsylvania to be a leading supplier to the next wave of infrastructure growth in the US. As has been widely noted, America's roads, bridges, buildings, and other physical stock need substantial reinvestment – an investment gap of \$2 trillion over 10 years, according to the American Society of Civil Engineers (ASCE). Much of the new infrastructure will rely on basic materials like glass, cement, and steel, but much will also begin to use advanced versions of materials that are cheaper, lighter, more adaptive, and more environmentally friendly (e.g., carbon fiber, fiber glass and specialty glass, lightweight concrete, clinker substitutes, nanotubes / nanofiber, graphene). Pennsylvania can lead both segments.

The cluster would start by supplying traditional, basic materials for the initial wave of construction, which enjoy a competitive advantage from low-cost power during the production process. In this first phase, Pennsylvania materials companies would expand their customer relationships across the infrastructure space, and deepen trust in their capabilities. The relationships and reputation developed in this period will create natural pathways for Pennsylvania to supply higher value-added materials products like advanced glass, fiber optics, and advanced construction materials. These advanced products would grow out of Pennsylvania's research leadership in materials science, which would need to be commercialized.

Like the Petrochemicals cluster, the Advanced Materials cluster will benefit initially from a regional focus, supplying construction growth in the densely populated urban northeast.

The **Data-Driven Automated Manufacturing cluster** would make Pennsylvania a commercial leader in "making the things that make things." This cluster aims to commercialize Pennsylvania's academic leadership in computer science and robotics – which are central to the trend toward automation and "Internet of Things" data expected to sweep manufacturing – and scale it up to supply the US and global manufacturing market.

Pennsylvania's low-cost energy is important to create this cluster and make it competitive, in two ways. First, some basic enablers of the cluster require a significant amount of electricity – for example, materials fabrication (to create the products that will go into manufacturing plants) and data centers and processing (to handle the exponentiation of data involved in artificial intelligence, remote sensing, and automated response).

Granted, data centers do not need to be physically proximate to where the data is produced – but in the early days of standing up the industry, it will be helpful to anchor these facilities to Pennsylvania and have them specialize in serving the needs of Pennsylvania’s emerging robotics/AI sector (e.g., data processing algorithms tailored for the type and pace of data access required).

More importantly, the other clusters – particularly the Petrochemicals cluster – provide an initial market for a nascent robotics/AI sector. As noted above, chemicals manufacturing has many operations that will move toward automation. The Data-Driven Automated Manufacturing cluster can supply the emerging Petrochemicals cluster, which would be a reliable pool of demand to build a robotics / AI supply chain around – allowing the cluster to scale up faster, reduce costs, and accelerate commercial innovation. In doing so, the cluster would be positioned to lead nationally, if not globally.

Creating this cluster will require careful implementation. Timing and the interplay with other clusters obviously matter significantly. Moreover, if automation technologies are deployed in-state, the priority should be on plants that would already be slated to use such technologies wherever they are built, which helps ensure Pennsylvania does not forgo jobs it could have created in-state.

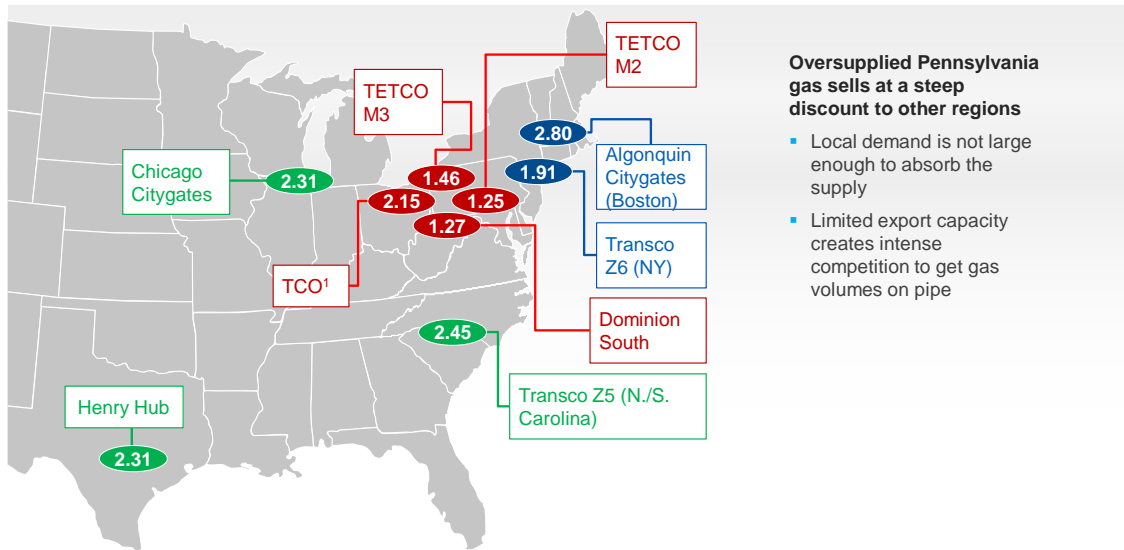
Gas exports

Pennsylvania has a vast amount of gas and NGLs looking for an outlet; however, today there is little gas demand growth within the state and limited pipeline capacity to move the gas out of the state. As a result, Pennsylvania’s voluminous gas supply capability must compete for a very finite pool of demand, which means that gas is sold at a steep discount (**Exhibit 18**).

3 Pennsylvania’s gas is sold at significant discount to other markets (averaging \$1.25-2.15/mmbtu) given export pipeline constraints

- Local markets (incl. PA, OH)
- Regional export markets
- National export markets

WTD average index price at pricing hubs
\$/mmbtu, average Nov. 2015- Oct. 2016



Oversupplied Pennsylvania gas sells at a steep discount to other regions

- Local demand is not large enough to absorb the supply
- Limited export capacity creates intense competition to get gas volumes on pipe

1 TCO, a local pricing hub trades that higher than other local hubs because it is a bottleneck point largely supplying the Gulf and South
SOURCE: Energy Velocity, from InterContinental Exchange (ICE); Pipeline tariffs and maps

These discounts have forced Pennsylvania gas producers, in many cases, to either produce at cash cost (i.e., little to no return on large capital investments) or leave resources shut into the ground. To make the gas economical to produce on a sustainable and growing basis, oil & gas companies need access to out-of-state markets – which widens the pool of demand that can absorb Pennsylvania gas supply. Such access would alleviate significant investment risk for oil & gas companies to increase gas production.

Put differently, Pennsylvanians will see the benefits of low-cost gas at home only if the state can supply more gas to other regions. As **Exhibit 3** shows, the cluster development strategies by themselves add ~1 tcf in gas demand, which will not raise gas prices enough to sustain production growth – export to out-of-state markets is crucial. Exports are unlikely to raise prices to a level that would impair Pennsylvania’s manufacturing cost competitiveness or hurt consumers, since the state has at least 30 years’ worth of low-cost gas reserves.

In principle, Pennsylvania could gain access to out-of-state gas markets in two ways: pipelines over land to other US regions or liquefied natural gas (LNG) over water to Asia or Europe. In practice, only pipelines make economic sense – Pennsylvania would face difficulty competing in LNG exports to foreign markets.

Eleven export pipeline expansions have been announced. By 2025, these expansions will allow for 75% growth in gas export capability, as summarized in **Exhibit 19**. The most critical pipelines are Transco, Texas Eastern, Columbia Gulf, and PennEast (UGI) – these supply the North and South regions, which will comprise ~60% of the gas export volume in 2025 – as well as Rover, which supplies the East North Central area including Michigan (**Exhibit 20**).

EXHIBIT 19

3 List of major gas pipeline expansions out of Pennsylvania

Planned pipeline export capacity additions^{1,2,3} out of Appalachian basin

Pipeline	Planned capacity addition Bcf	New capacity or expansion on existing capacity	Expected completion year
Columbia Gulf	548	New	2017
Rex	292	New	2017
Empire	183	New	2017
Texas Gas	146	New	2017
Transco	621	New	2018
Texas Eastern (Gulf)	256	New	2018
Texas Eastern (South)	219	New	2018
Rover	730	Expansion	2019
Nexus	329	Expansion	2019
Mountain Valley	584	Expansion	2020
Atlantic Coast	438	Expansion	2020
Total planned expansions	4,344		
<i>2016 existing capacity</i>	<i>3,030</i>		
Total capacity after 2020	7,373		

1 Capacity projections assume 100% pipeline utilization; actual export likely to range 70-90% depending on the pipeline; new pipeline capacity discounted to 60-80% of reported capacity given uncertainty in new pipeline builds that are still 2-3 years out

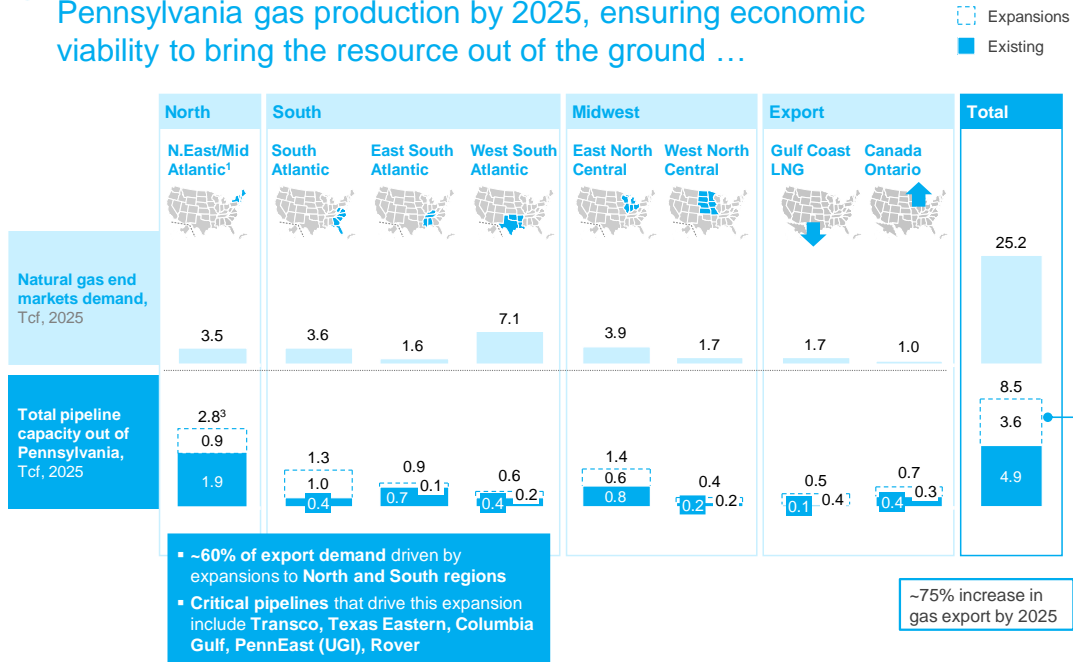
2 Export capacity does not include supply to the northeast and midatlantic markets, these are considered regional markets

3 New pipeline capacity is risked for delays in pipeline completion timeline and capacity (assumed 60-80% of currently reported pipeline capacity on new pipelines)

SOURCE: EIA, FERC, Platts, Bentek, SNL, company websites, investor presentations, trade press

EXHIBIT 20

3 Expected export pipelines will enable 75% growth in Pennsylvania gas production by 2025, ensuring economic viability to bring the resource out of the ground ...



¹ Also includes Ohio, but excludes Pennsylvania
² Netback pricing analysis done for one representative market within the South and Midwest and extrapolated to other markets in that region
³ Algonquin AIM Expansion & Constitution Pipeline included in existing capacity; 0.9 Tcf of expansions out of Pennsylvania on Columbia Gas Transmission, Dominion Transmission, TETCO, UGI Energy Services, Transcontinental Gas Pipeline ; only announced/approved projected included in expansions (likely additional expansions to fully supply NE/Mid-Atlantic demand from Appalachian)
 SOURCE: EIA, FERC, Platts, Bentek, SNL, company websites, investor presentations, trade press

Although capacity expansions have been announced, their implementation is not inevitable. Interstate pipeline projects are commonly beset by delays and sometimes rollbacks, whether driven by financing gaps, construction challenges, or stakeholder concerns.

In theory, Pennsylvania LNG is an option. It would have the advantage of low-cost natural gas feed for liquefaction. In practice, however, Pennsylvania would need to build greenfield (new) liquefaction facilities and pipeline feed-lines from scratch. To win Asian LNG markets, Pennsylvania LNG would have to compete with lower cost competitors: US Gulf Coast LNG (which are brownfield facilities) and Western Canadian and Australian facilities (which are much closer to market). To win European LNG markets, Pennsylvania LNG would have to compete with Middle East and African LNG, which are much lower cost. Although nearby Maryland is advancing Cove Point LNG, that facility has the advantage of brownfield economics.

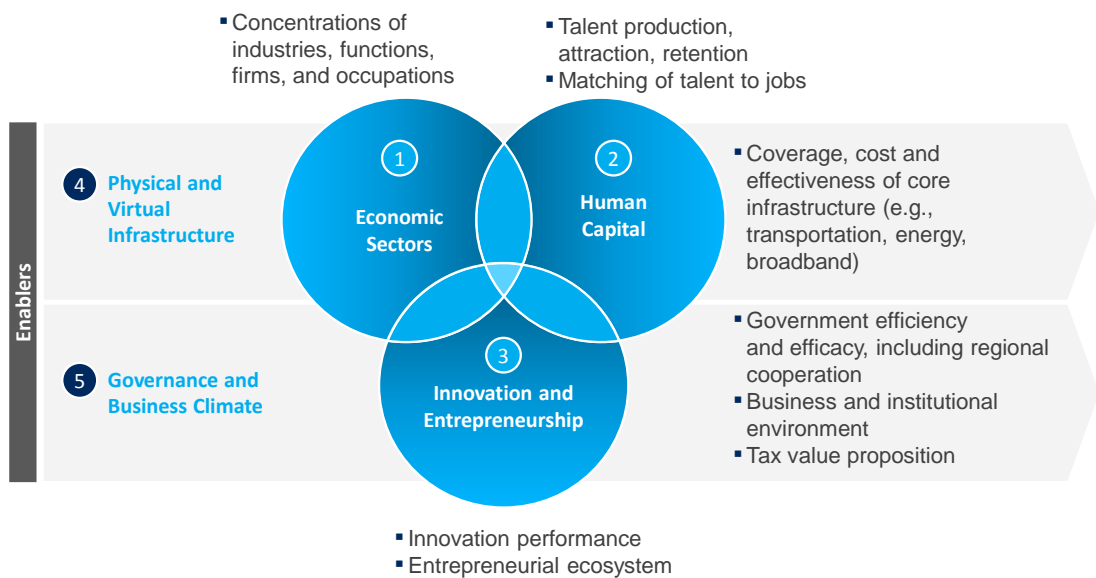
PENNSYLVANIA’S STRENGTHS AND CHALLENGES

Defining economic development strategies requires careful analysis and rigor, but it is only the first step. Strategies must be put into action. Successful action requires taking advantage of Pennsylvania’s existing strengths, while addressing critical challenges that act as barriers or delays to achieving the full potential of Pennsylvania’s energy resource.

It is useful to use five “lenses” of economic development to take stock of Pennsylvania’s starting point today (**Exhibit 21**). These five lenses have proved important across a wide range of economic development efforts in the US and globally. Development strategies succeed when they are underpinned by initiatives to ensure health across all five lenses.

EXHIBIT 21






Five lenses to assess economic competitiveness



SOURCE: McKinsey Economic Development Service Line

Exhibit 22 summarizes Pennsylvania’s most salient opportunities and challenges, considered through these lenses.

Pennsylvania's competitive strengths and potential challenges

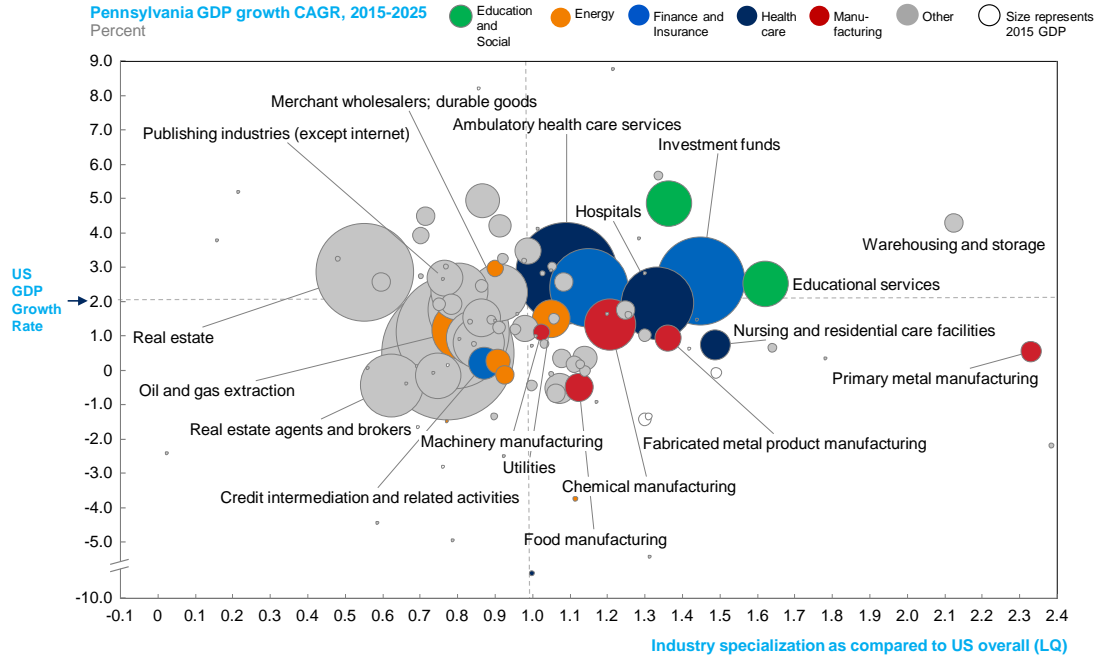
	Competitive strengths	Potential challenges
Economic sectors 	<ul style="list-style-type: none"> World-class energy resource Pennsylvania highly specialized vs. rest of the country in several key sectors: metal fabrication, chemical and metal manufacturing 	<ul style="list-style-type: none"> Sectors that are both specialized and tradeable are expected to grow less than national average GDP growth through 2025
Human capital 	<ul style="list-style-type: none"> Large under-utilized manufacturing and construction workforce pools (i.e., 45-50k unemployed each) Large engine of STEM talent pool (~19% of PA graduates are STEM) 	<ul style="list-style-type: none"> Engineering talent migrating outside the state (e.g., 50-75% CMU and UPenn engineering graduates leave the state) Labor costs higher than other states (e.g., construction labor +25% vs. TX)
Innovation and entrepreneurship 	<ul style="list-style-type: none"> Academic R&D leadership (e.g., CMU #1 in computer science, UPenn top 5 in material science) Proven ability to grow businesses (e.g., PA #7 for business survival after 10 years) 	<ul style="list-style-type: none"> Lacking incubators and early stage capital (e.g., PA ranks 20th in the nation in VC investments) Relatively low collaboration between universities and companies
Physical and virtual infrastructure 	<ul style="list-style-type: none"> Strong legacy infrastructure, including rail, ports and highways ~240 existing brownfield sites, of which ~20 able to host larger ethane crackers or other petrochemical facilities 	<ul style="list-style-type: none"> Insufficient gas LDC infrastructure coverage to reach small businesses and residential demand (e.g., PA North-East region lacking coverage to industrial brownfield sites)
Governance and business climate 	<ul style="list-style-type: none"> Existing state support for the development of the petrochemical industry (e.g., existing feedstock incentive for ethane cracking) 	<ul style="list-style-type: none"> PA power costs higher than some competing states despite low-cost gas Longer regulatory approval process vs. competing states Incentive programs not well-utilized

Economic sectors

Pennsylvania hosts a diversity of economic sectors, many of which boast higher specialization than in other US states – which is a proxy for the degree of Pennsylvania’s incumbency and hard-to-replicate experience in those sectors. Though some of Pennsylvania’s traditional sectors like heavy manufacturing are seeing lower growth than the US average or even declining, service sectors – healthcare, financial services, and education – are large, growing, and starting to fill the gap (**Exhibit 23**).

EXHIBIT 23

Pennsylvania economic sectors – by type



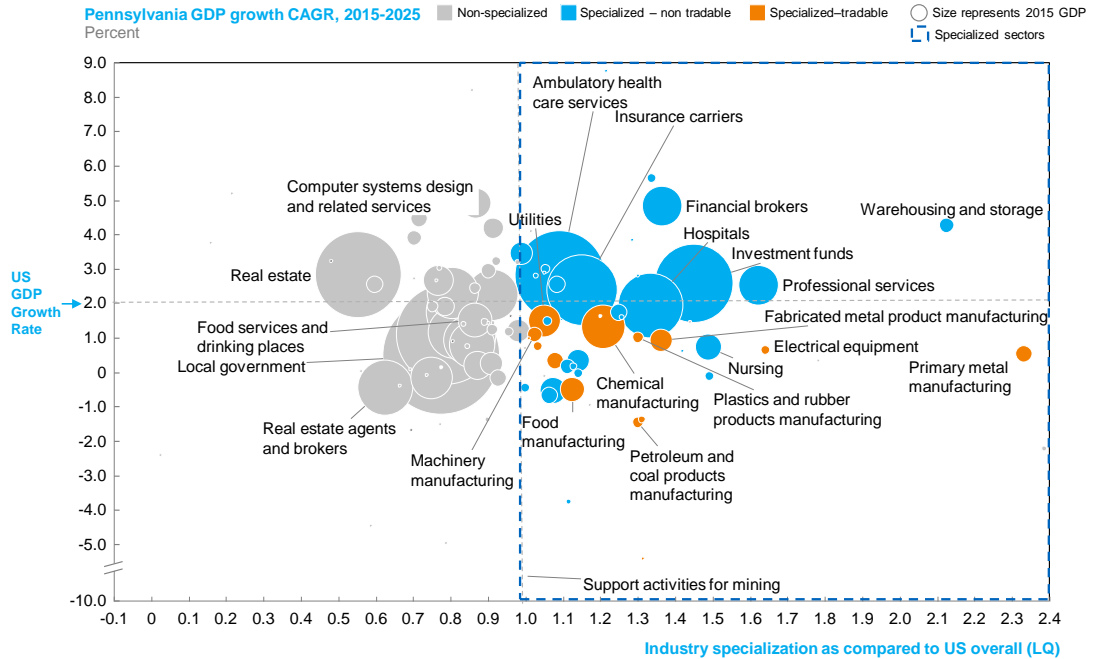
Note: Location Quotient (LQ) is measured as the ratio of an employment's share of output in a given area to that employment's share of output in the U.S. as a whole.

SOURCE: Moody's Analytics, US Bureau of Labor Statistics

That said, in today's world, many of Pennsylvania's higher growth, higher specialization sectors are non-tradeable – for example, local healthcare, local professional services, and storage (Exhibit 24). Their potential for value creation is largely limited to what can be generated and consumed within the state.

EXHIBIT 24

Pennsylvania economic sectors – by specialization and tradability




Note: Location Quotient (LQ) is measured as the ratio of an employment's share of output in a given area to that employment's share of output in the U.S. as a whole.

SOURCE: Moody's Analytics, US Bureau of Labor Statistics

Without action, Pennsylvania's tradeable sectors – which can pull in value from the whole world – and therefore Pennsylvania's overall economy will struggle to move at pace with the nation. Pennsylvania's tradeable sectors encompass the industrial bases crucial to energy-driven clusters – for example, metals, machinery, chemicals, and plastics. The cluster development strategy would help Pennsylvania propel these sectors to be at least on par with US average growth, if not surpass it.

Human capital

Pennsylvania has an impressive base of talent. It has a large pool of workers trained and experienced in industrial construction and operation, who are available for work in new sectors that can be developed in the state (Exhibit 25).

 **Pennsylvania has a significant underutilized manufacturing and construction labor pool, based on its legacy sectors**

Pennsylvania labor pool characteristics

Population, thousands

Sector	Total labor pool	Unemployment pool	Part-time pool
Health services	1,018	40	223
Retail	908	42	213
Professional & Business Services	844	56	149
Government	713	4	52
Manufacturing	611	44	32
Leisure & Hospitality	590	32	143
Financial Activities	330	13	44
Construction	285	50	25
Transportation	268	23	23
Other Services	266	8	90
Education services	247	9	59
Information	90	4	13
Farm	79	1	17
Mining and Logging	34	9	1
Utilities	25	1	1

SOURCE: BLS, US Census

Generating new manufacturing jobs would deepen the stability of employment for Pennsylvanians in comparison to other sectors, like health services, professional services, or retail, which entail a higher proportion of part-time versus full-time work.

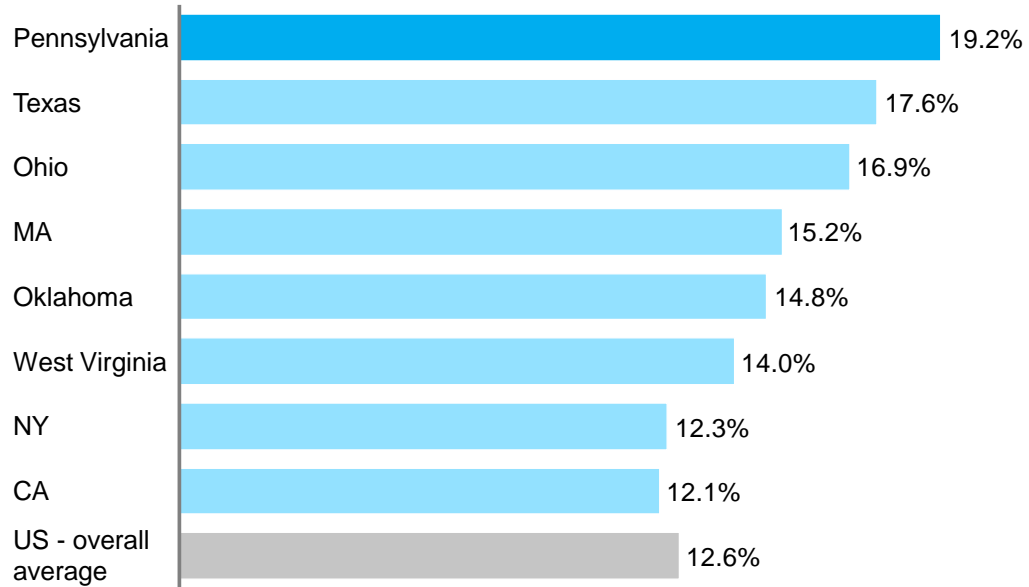
Pennsylvania is also an engine of science, technology, engineering, and mathematics (STEM) talent – whether compared to the tristate area, other energy states, or the nation as a whole (**Exhibit 26**).



Pennsylvania is an engine of engineering talent

STEM graduates by state, 2014


% of total degrees



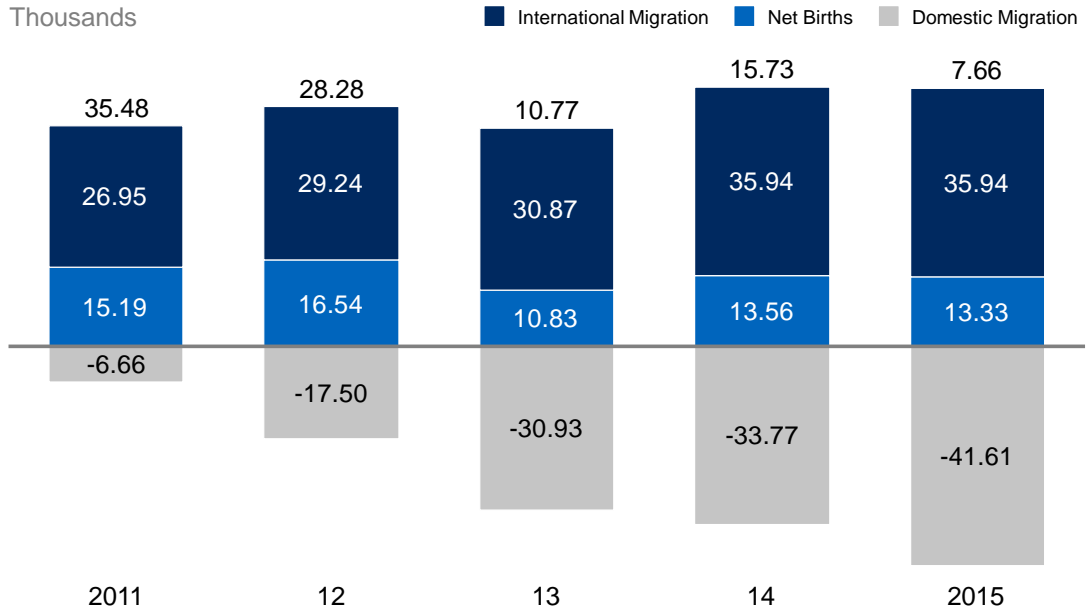
SOURCE: IPEDS, NCES

Pennsylvania's human capital challenge when it comes to energy-driven development is threefold. First, Pennsylvania must combat the population outflows that have accelerated over the past five years (**Exhibit 27**). Some of the solution will come through economic growth spurred by the development strategies – but those strategies will take time to bear fruit. In the interim, Pennsylvania needs to find ways to keep its best talent at home.

EXHIBIT 27

 Overall, Pennsylvania has experienced significant growth in domestic migration out of the state over the past 5 years

Pennsylvania total population change (working and non-working)



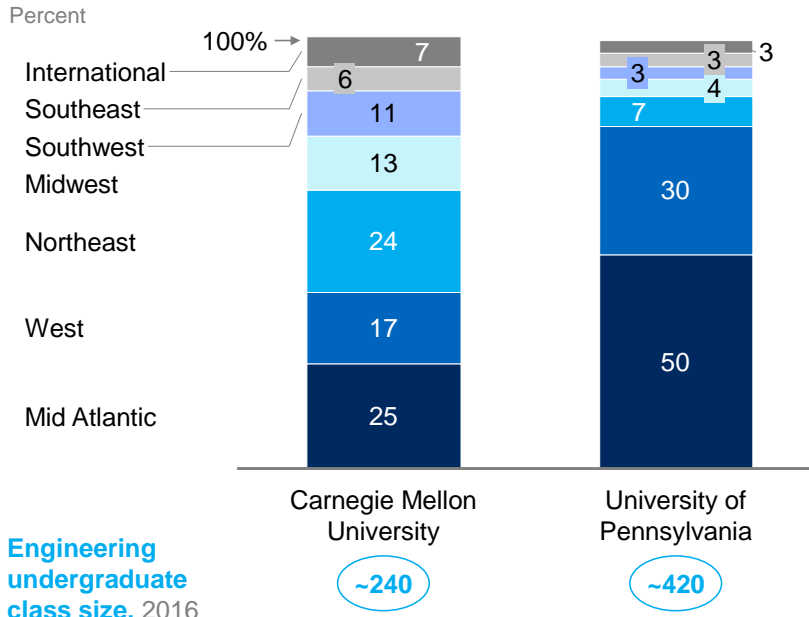
SOURCE: Moody's Analytics

Second, Pennsylvania's population outflows are especially pronounced among STEM graduates. Pennsylvania produces some of the best science and engineering talent in the world, with practical relevance to important growth sectors – but more of them are leaving the state once they obtain their undergraduate or graduate degrees than are staying (**Exhibit 28**).

A majority of Pennsylvania engineering graduates appear to leave the region, finding jobs outside the Mid-Atlantic

Example: Engineering graduates¹ geographic distribution post-graduation

EXAMPLES - NOT EXHAUSTIVE



¹ Including undergraduate and graduate students

SOURCE: Carnegie Mellon University website, University of Pennsylvania website; press search

Third, Pennsylvania’s labor force may need to go through “upskill” training to channel its traditional industrial experience into the next-generation industrial sectors envisioned in the cluster development strategy – for example, working a metal shop may require a different set of hard and soft skills than working a robotics manufacturing plant.

Innovation & entrepreneurship

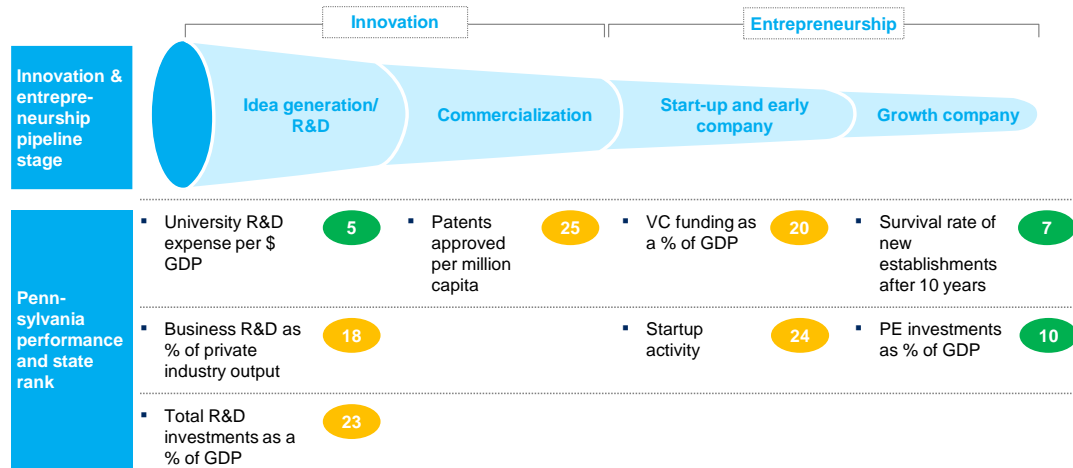
Pennsylvania has at least three clear strengths to support its innovation and entrepreneurship environment. First, Pennsylvania ranks highly among US states on the very front end and very back end of the “innovation funnel” – that is, the end-to-end process of moving from an idea to a patentable technology or process, to a viable commercial venture, to a growing business at scale. In particular, Pennsylvania is distinctive in generating innovative research (front end) and ensuring new companies can grow and survive (back end), as shown in **Exhibit 29**. When it comes to front-end research, Pennsylvania’s universities lead the nation in robotics, artificial intelligence, and materials science, among other fields (as shown in **Exhibit 11** earlier).

EXHIBIT 29



Pennsylvania's innovation funnel faces a disconnect in translating academic R&D leadership into new businesses and economic growth

PA State rank
 # Top 15
 # Middle 15
 # Bottom 20



SOURCE: US Bureau of Labor Statistics, Kauffman Foundation, National Science Foundation, Private Equity Growth Capital Council, PwC Moneytree, SBA, SBIR, US Patent and Trademark Office

Second, Pennsylvania has an existing start-up funding sector, albeit small relative to hubs like Silicon Valley or New York. Third, Pennsylvania has a robust financial services sector that, although it focuses more on commercial banking, could be a springboard to growth in private equity and venture capital.

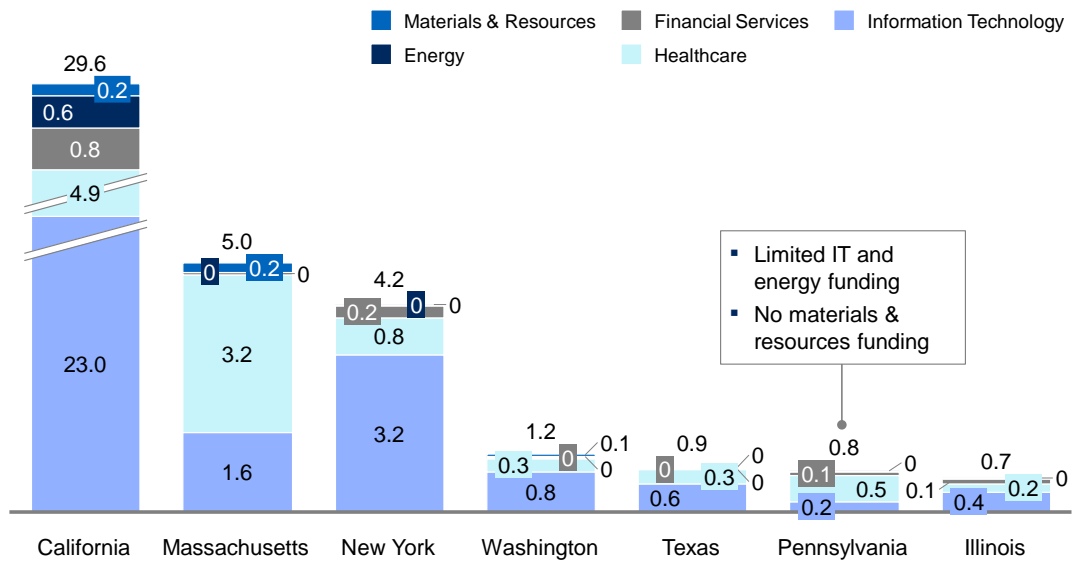
Each of these areas of strength is mirrored by a challenge. As Exhibit 29 also demonstrates, Pennsylvania's innovation funnel faces a disconnect between the front-end research and back-end survival of growth companies: it lags other states in commercialization, start-up activity, and start-up funding. Even the front-end research faces a gap, in that most of the strength is in academic institutions rather than corporate R&D, which is one step closer to commercialization. Moreover, ~70% of funding from Pennsylvania's venture capital and angel investors goes to healthcare and financial services, and virtually none to energy or materials start-ups (Exhibit 30). If Pennsylvania wants to build Automated Data-Driven Manufacturing or Advanced Materials clusters – which entails investing in new businesses in energy-intensive sectors as well as high-value sectors that depend on computing and materials innovations – more private capital must be directed into these sectors.

EXHIBIT 30

Over 70% of Pennsylvania VC and angel investment is in healthcare and financial services, while IT and energy sectors have limited funding

Venture capital and angel investment in top sectors

\$B, 2015



SOURCE: Pitchbook

Pennsylvania has a set of start-up incubators, university programs, and other support efforts in place to help get the start-up sector off the ground. For impact at scale, however, and to ensure linkage to energy-driven economic development, new and creative approaches should be attempted building on this excellent foundation. Some examples of new and creative approaches tried in other regions include competitions or “challenges” to solve a particular problem; innovative financing mechanisms that pay for performance; and highly effective public-private partnerships embodied in new entities subject to financial and performance pressures.

Physical & Virtual Infrastructure

One of Pennsylvania’s advantages and challenges, as it aims to attract new companies and plants as part of cluster development, is its constellation of unused industrial brownfield sites. They range from <35 acres to some that are >450 acres, which could handle a range of commercial/industrial needs, but are in many cases too small for world-scale petrochemical facilities. In fact, about 20 sites would be able to host larger ethane crackers or other petrochemical facilities. These sites are distributed around the


state, which means – in principle – that the benefits of industrial growth could be more directly shared across the state.

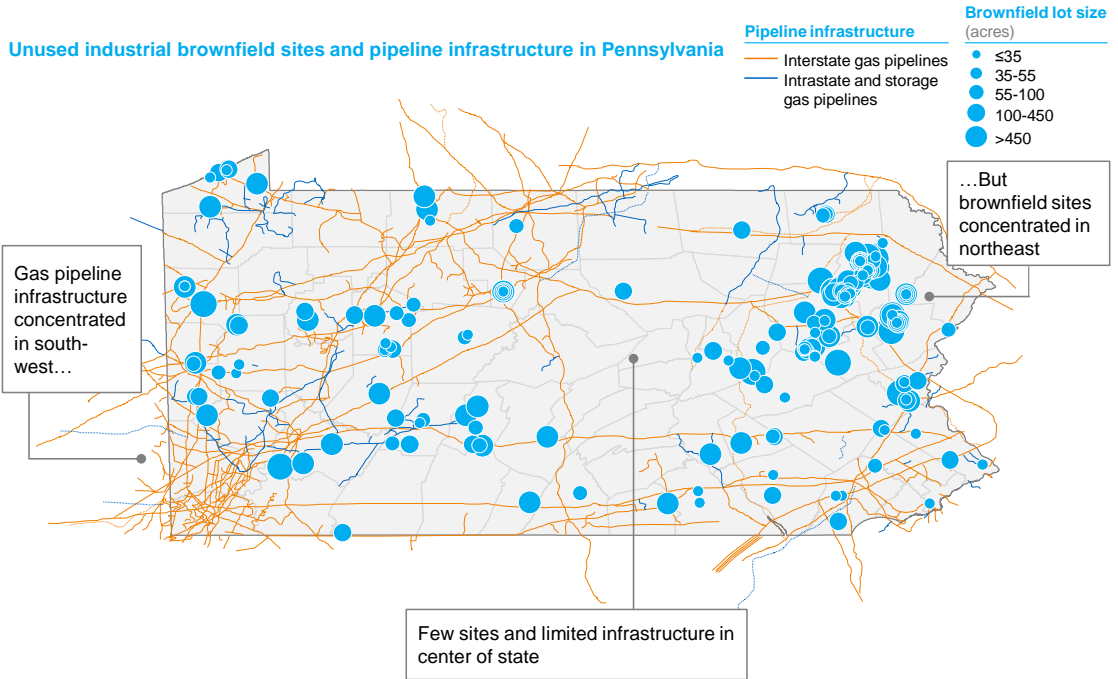
The challenges reflect the practicalities of turning these sites into useable locations for the specific sectors we want to attract for cluster development. First, many of the sites have the right acreage, but not the right topography, which precludes large facilities (for example, an ethane cracker) from being built.

Each cluster should be physically concentrated, integrated to the energy it needs, with pipeline and rail connections to access critical markets

Second, the largest physical “cluster” of sites is in the northeast of the state, but the gas and feedstock comes more from the west of the state – and the two regions are not connected by enough intrastate pipeline capacity to meet future needs (**Exhibit 31**). This pipeline disconnect between producing and consuming areas within Pennsylvania is solvable – even greater distances have been bridged in places like Texas and Louisiana, where the resource is often hundreds of miles away from the petrochemical facilities that use it.

EXHIBIT 31

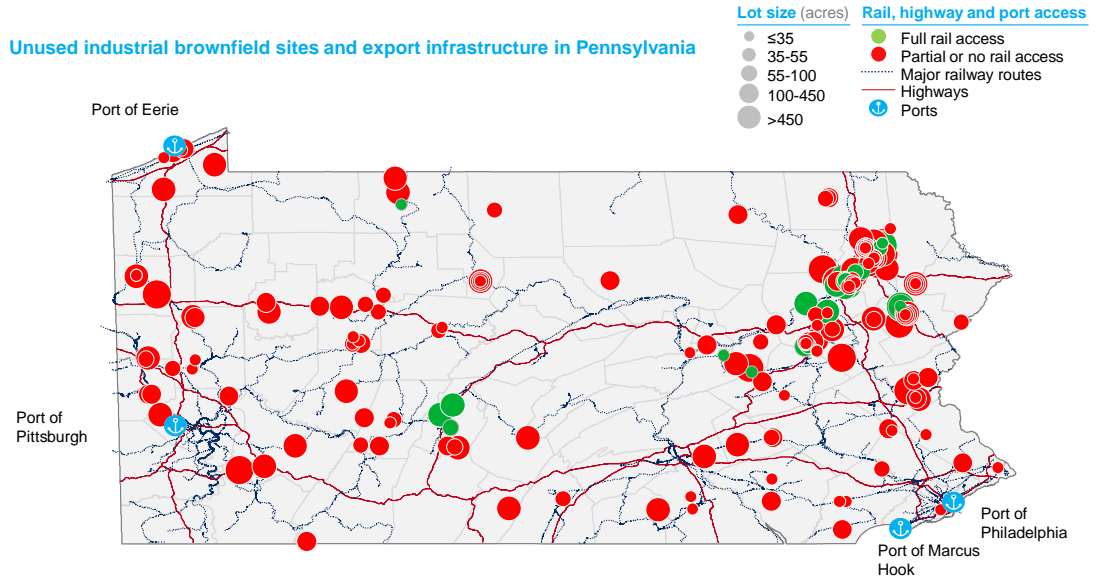
 Significant number of available industrial brownfield sites, but many areas are not well-connected to intra-state pipelines (e.g., northeast)



SOURCE: NETR Online, Pennsylvania Federal Brownfield Site Location Directory, US EPA

Third, although most of the sites have highway access, many of them lack easy rail or port access, which will be particularly important as Pennsylvania’s energy-driven clusters seek to sell Pennsylvania products and technology into national and global markets (Exhibit 32).

Brownfield sites have uneven access to rail and highways and tend to be far from ports, which may constrain getting end products to market



SOURCE: NETR Online, Pennsylvania Federal Brownfield Site Location Directory, US EPA

All of these challenges are addressable – but they must be treated together, as part of a statewide approach to cluster development, rather than topic-by-topic or region-by-region. There must be a clear and integrated perspective on where each cluster should be physically concentrated, what type of energy input each cluster needs and where it will come from, and therefore what site preparation, pipeline and rail buildout, or other actions must be taken.

Governance & Business Climate

Pennsylvania’s government clearly recognizes the opportunity presented by its world-class energy resource, and is committed to realizing that opportunity. Government leaders and agencies appear to share this recognition at the state and city levels. Moreover, they have already undertaken programs that could support energy-driven economic development, depending on how they are used – for example, company attraction programs and legislation to enable special economic zones.

Achieving the vision for energy-driven economic growth will require several steps to advance the governance and business climate, some of them challenging. First, the programs already in place need to be tailored to best serve economic development objectives.

For example, special economic zones and company attraction should focus on cluster development – not any company that would be ‘nice to have,’ but does not fit the development strategy. Furthermore, company attraction should reflect efficient statewide coordination rather than regionally cloistered initiatives as they are today – which cannot easily account for synergies between regions (e.g., redundant efforts to reach the same companies and recreating the wheel regionally on company support programs).

Second, in business friendliness, Pennsylvania is not perceived as well as other states – whether neighboring states, like Ohio, or other energy states, like Texas and Oklahoma (Exhibit 33 provides a small business example). Business friendliness matters if Pennsylvania wishes to attract companies to form energy-driven clusters. In particular, Pennsylvania lags in perceptions of how hard it is to navigate the labor market – for example, ease of hiring and training.

EXHIBIT 33



On some dimensions, Pennsylvania ranks lower than peers on business friendliness



Survey of states friendliness towards small business, 2014

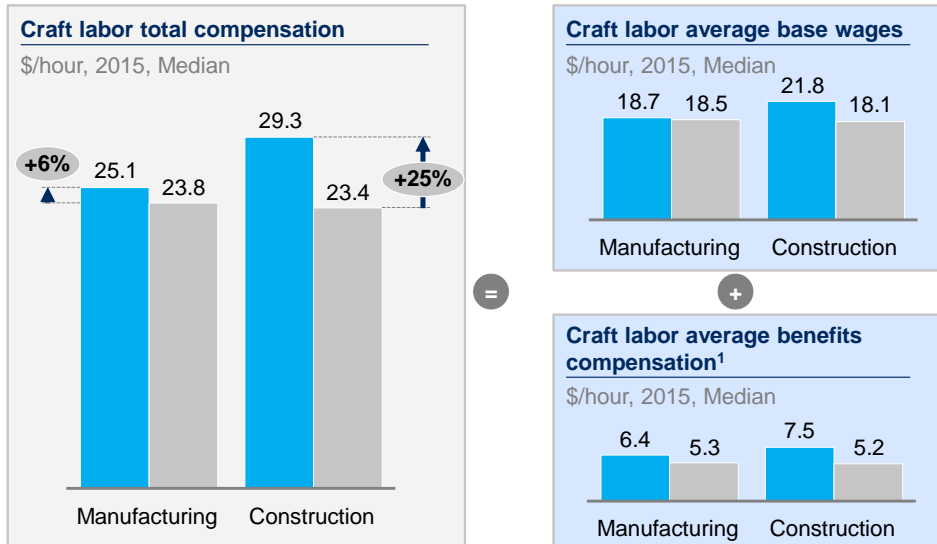
	Factor	Pennsylvania	Ohio	Oklahoma	Texas
Labor	Ease of hiring	36	30	37	5
	Employment and labor	32	14	17	3
	Training and networking	36	21	3	8
Permitting	Environmental	35	23	12	3
	Licensing	31	18	9	5
	Health and safety regulation	31	17	20	1
	Zoning	31	20	4	1
	Ease of starting a business	30	26	4	3

SOURCE: Kauffman-Thumbtack.com Small Business Friendliness Survey

Moreover, Pennsylvania labor costs tend to be higher than labor costs in other states that will compete for the same energy-driven sectors. For example, construction labor costs are 25% higher in Pennsylvania than in Texas (**Exhibit 34**). This difference is driven by disparities both in base wages and in benefits compensation. Fifty percent of the difference in benefits compensation is caused by supplemental (overtime) pay, which in Pennsylvania is ~2.5x that in Texas. The government will be faced with finding ways to offset these costs in order to make Pennsylvania as attractive as possible, while supporting Pennsylvania’s workforce.

EXHIBIT 34

 Labor costs are higher in Pennsylvania, especially for construction labor ■ PA ■ TX

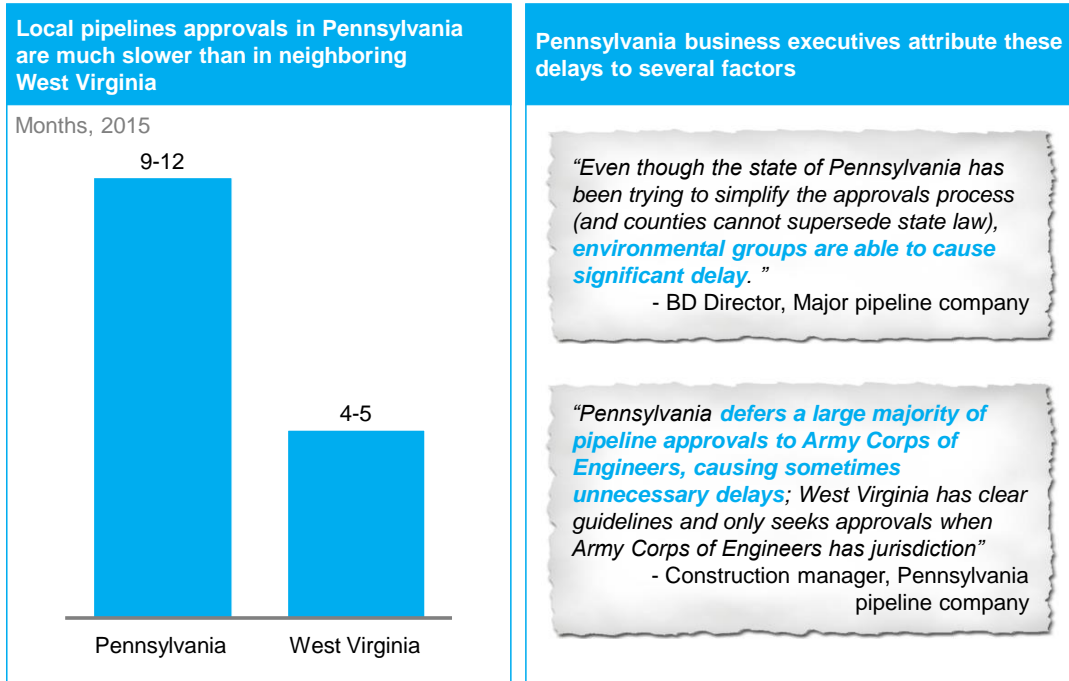


¹ Benefits compensation includes paid vacation, supplemental pay (overtime), insurance, retirement benefits, and other legally required benefits
 SOURCE: US Census Bureau; Bureau of Labor Statistics

Moreover, by some measures, Pennsylvania’s regulatory process creates burdens of time and cost on companies seeking to do business in the state that may put it at a disadvantage relative to competing jurisdictions seeking to attract those companies (**Exhibit 35** provides one example, regarding pipeline approvals).



Regulatory and administrative hurdles in Pennsylvania can slow down approval for pipelines and industrial facilities in the state



SOURCE: Expert interviews

Third, Pennsylvania’s low-cost gas does not automatically translate into low-cost electricity for all end users. Pennsylvania is part of the PJM Interconnection, a regional transmission operator that covers all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Tennessee, Virginia, West Virginia, and the District of Columbia, alongside Pennsylvania.

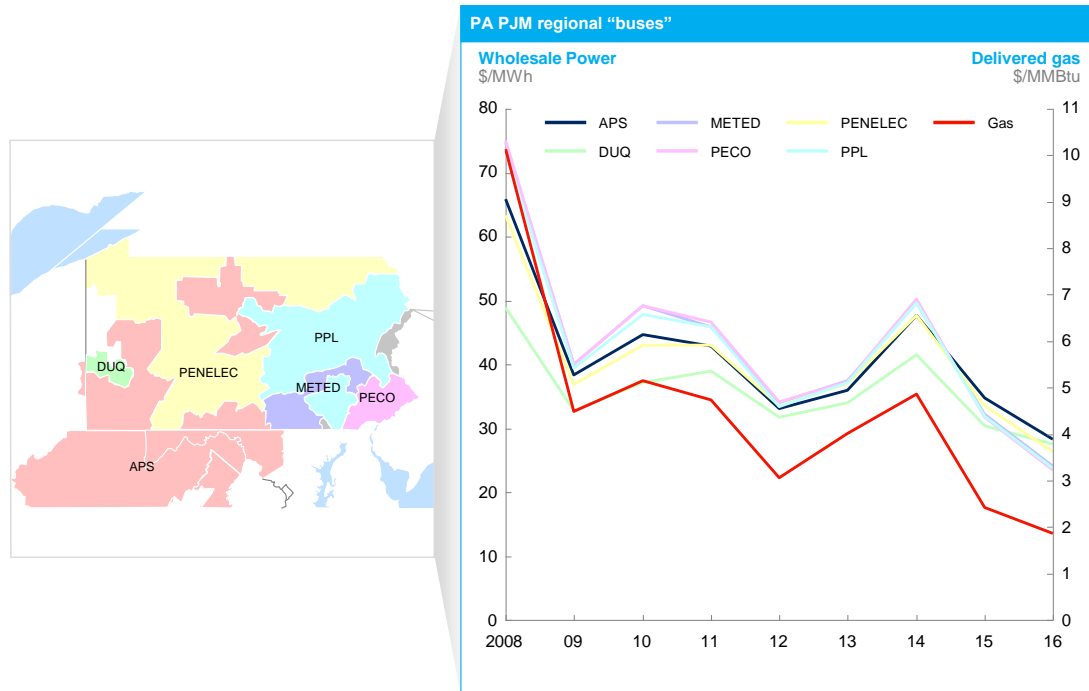
Wholesale locational marginal power prices (which reflect the cost of the next megawatt of load for a certain area using the lowest production cost of generation at that time) are a combination of a system energy price plus local transmission congestion costs plus the cost of marginal losses. The system energy price is set at the PJM level, with local adjustments on the other two dimensions. At the same time, retail prices are set through rate case determination between individual utilities and state regulators.

Exhibit 36 shows how PJM and Pennsylvania’s regional “buses” have seen decreased wholesale power prices alongside lower gas prices – to be further aided by transmission investment along the Pennsylvania and Maryland border.

This has had a direct impact on large industrial customers, who are able to procure power closer to wholesale prices given their volume and frequent ability to take higher voltage power – thereby removing the need for distribution-level supply infrastructure.

EXHIBIT 36

 Since 2008, wholesale power prices across all zones in PA have moved down with the delivered price of gas to generators




SOURCE: ABB Energy Velocity

The spread between retail and wholesale prices can be attributed to a number of factors, including the degree of retail competition; the degree to which a state is a net generation supplier, procurer or in balance; and most substantially, on the degree of investment required in the grid and commensurate regulator pressure on Transmission and Distribution utilities.

While the competitiveness of retail power pricing is often described in “rate” comparison terms (cents per kilowatt hour), the ultimate measure of competitiveness is total “bill impact” – what the end user actually spends per month (cents per kilowatt hour times kilowatts consumed). Utilities will adjust tariffs based on actual demand so that they achieve their “revenue requirement.”

By the first measure, **Exhibit 37** illustrates how Pennsylvania has recently compared to others states on retail rates – just below the national average, but disadvantaged relative to competitors like Texas, West Virginia and Ohio.


EXHIBIT 37

 **In 2016, Pennsylvania retail energy rates were middle of PJM pack – but higher than tri-state neighbors and Texas, driven by residential segment**
Cents per kwh (2016 average)

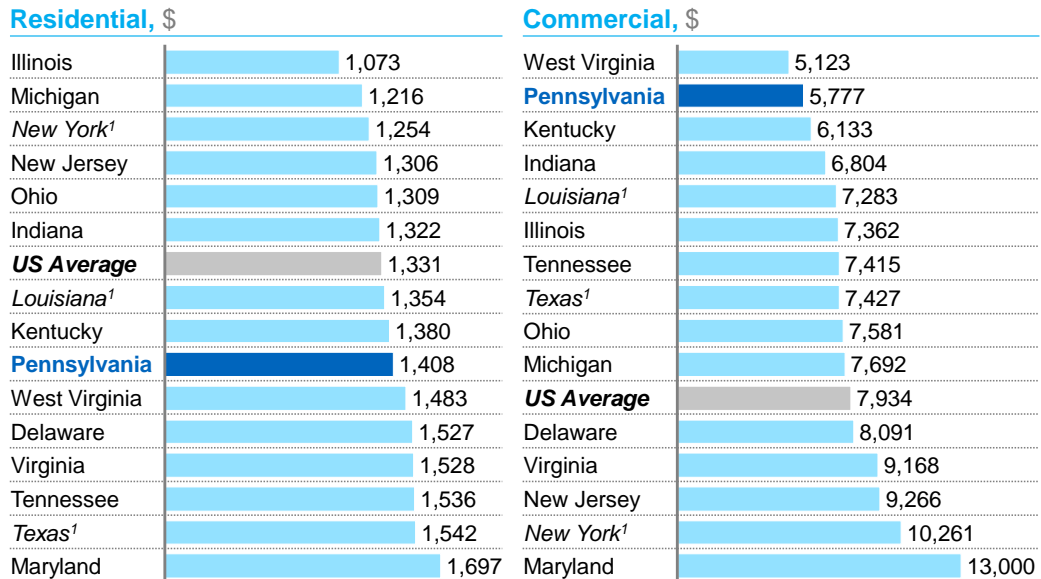
	Overall (all sectors)	Residential	Commercial	Industrial
Kentucky	8.26	10.29	9.37	5.49
Texas (ERCOT) ¹	8.28	11.02	7.71	5.22
West Virginia	8.89	11.22	9.34	6.57
Indiana	9.14	11.39	9.75	7.02
Virginia	9.16	11.42	7.97	6.67
Illinois	9.17	12.23	8.75	6.37
Tennessee	9.26	10.33	10.03	5.82
Ohio	9.74	12.28	9.87	6.78
Pennsylvania	10.26	14.03	9.25	6.92
US Average	10.28	12.55	10.37	6.75
Delaware	11.15	13.47	10.12	7.98
Michigan	11.16	15.30	10.68	7.04
District of Columbia	11.87	12.87	11.73	8.96
Maryland	12.21	14.23	10.98	7.84
New Jersey	13.49	15.75	12.42	10.14

¹ Not part of PJM
SOURCE: EIA

However, a look at the total “bill” for end users adds some nuance to this assessment (**Exhibit 38**). In 2016, Pennsylvania residential users spent more than the US average on retail power per customer and more than some immediate neighbors like Ohio. However, they spent less on average than some key competitors (e.g., Texas and West Virginia). On the Commercial side, the story is more positive – with Pennsylvania Commercial users spending less per customer in 2016 than all neighboring and competitive states, with the exception of West Virginia. Given that the industry mixes across states is so idiosyncratic, a “rate” comparison is still the best proxy for affordability.

 However, a look at total “bill impact” (what customers spend) – shows PA outperforming its neighbors in the Commercial segment and Texas in both Residential and Commercial

Residential and Commercial Spend Per Customer, 2016



¹ Not part of PJM
SOURCE: EIA

In looking at this retail power data, one can see that Pennsylvania end users are benefiting from low-cost gas alongside its PJM neighbors, but there is a further opportunity to build a more distinctive advantage through a variety of avenues, including:

- Debottlenecking any remaining transmission constraints (above and beyond the \$300M program announced earlier in 2017). These constraints alone drove the difference between Ohio and Pennsylvania prices in the 2012 and 2013 PJM auctions – which in large part dictated prices today;
- Incentivizing lower power consumption through energy efficiency and demand side management programs. According to the American Council for an Energy Efficient Economy, Pennsylvania ranks 19th in the US in terms of state and local policies to incentivize energy efficiency, which is higher than many direct neighbors, but lower than its New England neighbors. For example, in its recently passed Future Energy Jobs Act (2016), Illinois increased energy efficiency funding, extended its regulatory decoupling “formula rate” mechanism (to “decouple” the impact of energy efficiency from utility financials), set a more ambitious target for energy efficiency (21% by 2030) and allowed its utilities to treat energy efficiency spend as a regulatory asset, upon which to earn a return;

- Regulators working with Pennsylvania utilities to drive greater affordability efforts – reducing operations & maintenance spend (O&M) and encouraging more efficient deployment of capital – as part of the rate case process.

Finally, power prices will decrease further as a secondary benefit of other interventions previously discussed – population growth, for example, which spreads the fixed cost of transmission and distribution infrastructure over a larger number of users.

CONCLUSION

Themes for action

Pennsylvania has a chance to forge the future, translating its world-class energy resource into world-class competitive leadership in the 21st century global economy. This kind of vision sometimes collapses into mere buzzwords – but for Pennsylvania, it could become a practical reality in the next 10 years, if the full range of Pennsylvania leaders take strategic action today.

Pennsylvania can achieve this vision by undertaking three economic development strategies, working together in unison: increased gas-fired power and heating, new clusters in sectors of the future (Petrochemicals, Advanced Materials, and Data-Driven Automated Manufacturing), and gas exports to ensure the sustainable production of the resource.

To that end, Pennsylvania has great strengths to harness, as well as challenges to tackle head-on, across the five lenses of economic development: economic sectors, human capital, innovation and entrepreneurship, physical and virtual infrastructure, and governance and business climate.

The task ahead is for private sector, government, and community leaders to work together to identify and implement specific initiatives. These initiatives should be focused, performance-manageable and measurable, owned by clear parties who will be accountable for delivery, and directed squarely at magnifying Pennsylvania strengths and addressing challenges in order to execute the 3 development strategies.

Exhibit 39 provides example themes for action, organized by the five lenses that underpin economic competitiveness and aimed at supporting the three development strategies. These ideas need to be refined, sharpened, and expanded – but they provide a template for potentially high-impact initiatives that can support breakthroughs for energy-driven economic development. They set the starting point for Pennsylvania to forge its future from a world-class energy resource, and are the foundation for pursuit of unparalleled economic advancement.

Example ideas for initiatives to help unlock energy-driven economic growth for Pennsylvania

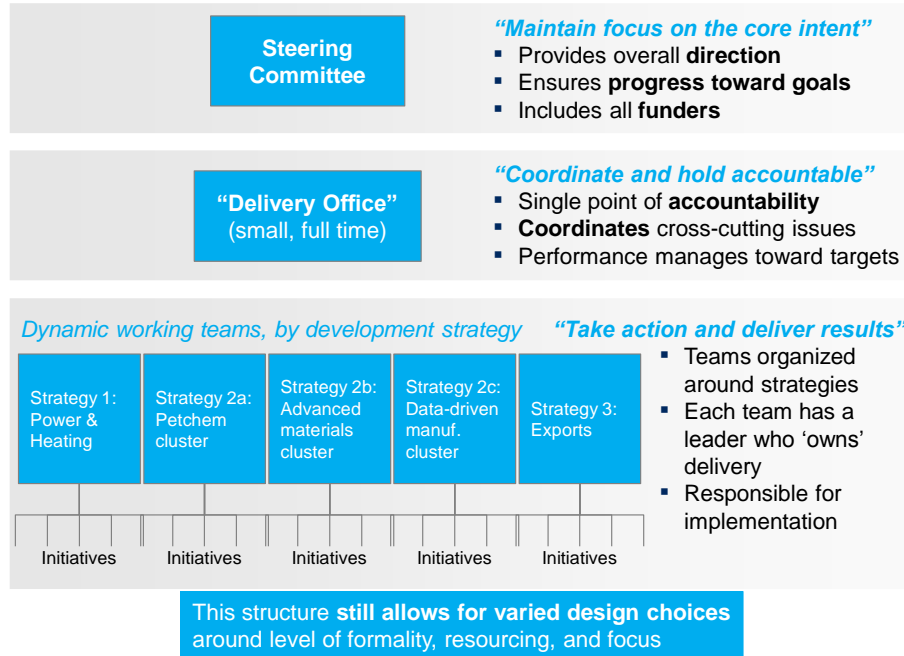
Lenses	Initiatives	Description
Economic sectors	1 Cluster company attraction	Organize a company attraction program that is statewide , is public-private , and focuses squarely on targeted economic clusters
	2 Cluster economic zones	Proactively design "cluster economic zones" that reflect the unique location, infrastructure, and market access needs of targeted clusters
Human capital	3 Labor financial offsets	Establish financial incentives to offset Pennsylvania's relatively high labor cost in manufacturing sectors to better attract investments vs. other states
	4 Sector-led upskilling program	Create sector-led program to rapidly upskill the large under-utilized labor pool (without a bachelor's degree) with the specific skills PA clusters will require
Innovation and entrepreneurship	5 University innovation partnerships	Coordinate university partnerships with companies and other universities at a statewide level and focus on innovation funnels relevant to clusters
	6 Early stage investment firms	Facilitate home-grown early stage firms which have a vested interest in keeping startups nearby , leveraging existing Pennsylvania financial services strength
Physical and virtual infrastructure	7 Interstate pipeline acceleration	Coordinate a cross-industry effort (including gas-consuming sectors dependent on viable production) to accelerate export pipeline approvals
	8 Ports expansion	Invest in Philadelphia and Erie port expansion to provide supply and export infrastructure to midwest, northeast, and global markets relevant to clusters
	9 LDC development	Support development of LDCs to provide gas to all Pennsylvania communities
Governance and business climate	10 PA power price reduction	Support reductions in retail energy prices and growth of distributed power in-state to ensure low-cost gas provides competitive advantage in power
	11 Market entry navigator program	Set up best-practice market entry "navigator" program based on private sector lessons from other jurisdictions to simplify new entrants permitting process (e.g., one-stop permit support for new entrants)

Path forward

Ensuring initiatives gain traction will require an organized effort by private sector institutions, collaborating with the public sector, to implement them in a sustained way. There are many ways to organize such an effort, and different regions have tried different models in the past. **Exhibit 40** illustrates one version. Whatever the setup, a degree of formal structure is critical to ensure focus, accountability, and sustained follow-through.

Lessons from other development efforts suggest a basic formal setup is needed to drive focus, accountability, and results (vs. ideas on a shelf)...

Illustrative example



“Forge the Future: Pennsylvania’s path to an advanced, energy-enabled economy” provides the analytical fact base that is a starting point for the ultimate objective: activation. Pennsylvania has strong leaders across the private and public spectrum who share a deep commitment to advance the prosperity of Pennsylvania and all Pennsylvanians – we seek to develop a plan that will be additive, integrated and complementary to a range of growing initiatives that aim to realize the full potential of our natural gas resources. What it will take is the unwavering commitment of Pennsylvania’s leaders – in business, in government, and in communities across the state – to act with purpose and urgency to forge our future.

Appendix

Appendix A: List of References

1. Bentek
2. EIA
3. Energy Velocity
4. FERC
5. Forbes
6. IBM
7. McKinsey sector practices
8. McKinsey Economic Development practice
9. McKinsey Energy Insights
10. McKinsey Global Institute
11. Moody's Analytics
12. Pennsylvania Center for Workforce Information and Analysis
13. Pennsylvania Department of Community & Economic Development
14. Pennsylvania Department of Labor and Industry
15. Pennsylvania Federal Brownfield Site Location Directory
16. Platts
17. Rextag
18. Robotics.org
19. Rystad
20. US Bureau of Labor Statistics
21. US Census Bureau
22. US Patent and Trademark Office
23. Ventyx

Appendix B: Energy intensive sectors

Sector energy intensity – for sectors surveyed by EIA

Industry	Energy, \$M	GDP, \$M	Energy intensity
Air transportation	34,901	158,695	22.0%
Truck transportation	53,279	296,907	17.9%
Water transportation	8,845	52,845	16.7%
Utilities	59,874	385,177	15.5%
Rail transportation	9,105	67,328	13.5%
Transportation and warehousing	124,878	932,509	13.4%
Transit and ground passenger transportation	5,028	48,833	10.3%
Government enterprises	22,296	247,532	9.0%
Other real estate	85,812	993,318	8.6%
Government enterprises	6,256	80,701	7.8%
Other transportation and support activities	11,051	184,686	6.0%
Paper products	9,128	164,142	5.6%
Mining, except oil and gas	5,615	106,419	5.3%
Nonmetallic mineral products	5,216	101,810	5.1%
Farms	16,120	317,306	5.1%
Agriculture, forestry, fishing, and hunting	16,683	362,369	4.6%
State and local	95,449	2,123,713	4.5%
General government	73,153	1,876,179	3.9%
Government	118,931	3,120,611	3.8%
Primary metals	8,164	214,543	3.8%
Real estate	85,820	2,697,795	3.2%
Real estate and rental and leasing	87,663	3,035,089	2.9%
National defense	15,678	563,691	2.8%
Educational services	6,906	284,010	2.4%
Federal	23,482	995,352	2.4%
Warehousing and storage	2,192	98,689	2.2%
Construction	25,506	1,183,123	2.2%
All Industries	602,873	28,425,107	2.1%
Chemical products	15,141	732,893	2.1%
Amusements, gambling, and recreation industries	2,771	136,539	2.0%
Private industries	483,942	25,305,083	1.9%
Wood products	1,528	80,382	1.9%
General government	17,225	914,702	1.9%
Finance, insurance, real estate, rental, and leasing	90,295	4,924,596	1.8%
Waste management and remediation services	1,511	83,011	1.8%
Plastics and rubber products	3,561	199,161	1.8%
Pipeline transportation	477	26,787	1.8%
Nondurable goods	43,694	2,549,777	1.7%
Textile mills and textile product mills	775	48,751	1.6%
Accommodation	3,299	216,240	1.5%
Food and beverage stores	2,878	196,984	1.5%
Mining	7,314	502,845	1.5%
Food and beverage and tobacco products	11,455	799,279	1.4%
Hospitals	10,031	719,193	1.4%
Support activities for mining	951	70,761	1.3%
Nursing and residential care facilities	2,821	211,251	1.3%
Manufacturing	70,790	5,309,111	1.3%
Accommodation and food services	11,257	852,703	1.3%
Arts, entertainment, recreation, accommodation, and food services	14,838	1,140,668	1.3%
Food services and drinking places	7,958	636,463	1.3%

Sector energy intensity – for sectors surveyed by EIA (continued)

Industry	Energy, \$M	GDP, \$M	Energy intensity
Forestry, fishing, and related activities	564	45,209	1.2%
Arts, entertainment, and recreation	3,581	287,905	1.2%
Fabricated metal products	4,026	352,936	1.1%
Educational services, health care, and social assistance	25,730	2,296,107	1.1%
Other services, except government	6,080	580,111	1.0%
Management of companies and enterprises	5,949	601,724	1.0%
Durable goods	27,097	2,788,088	1.0%
Printing and related support activities	813	85,191	1.0%
Administrative and waste management services	7,931	838,583	0.9%
Health care and social assistance	18,824	2,013,026	0.9%
Administrative and support services	6,420	756,376	0.8%
Social assistance	1,280	155,959	0.8%
General merchandise stores	1,509	197,997	0.8%
Retail trade	11,212	1,508,029	0.7%
Furniture and related products	498	69,046	0.7%
Apparel and leather and allied products	211	29,292	0.7%
Professional and business services	20,712	3,231,117	0.6%
Other retail	5,342	849,016	0.6%
Machinery	1,982	355,169	0.6%
Motor vehicle and parts dealers	1,482	268,681	0.6%
Rental and leasing services and lessors of intangible assets	1,842	337,330	0.5%
Electrical equipment, appliances, and components	618	113,778	0.5%
Performing arts, spectator sports, museums, and related activities	810	151,417	0.5%
Petroleum and coal products	2,610	492,222	0.5%
Ambulatory health care services	4,692	927,269	0.5%
Miscellaneous professional, scientific, and technical services	5,928	1,179,611	0.5%
Miscellaneous manufacturing	736	154,467	0.5%
Data processing, internet publishing, and other information services	996	221,649	0.4%
Nondefense	1,547	350,565	0.4%
Wholesale trade	6,022	1,406,144	0.4%
Other transportation equipment	1,243	311,382	0.4%
Motor vehicles, bodies and trailers, and parts	2,491	632,767	0.4%
Professional, scientific, and technical services	6,832	1,792,804	0.4%
Federal Reserve banks, credit intermediation, and related activities	1,819	583,846	0.3%
Broadcasting and telecommunications	2,474	840,494	0.3%
Information	4,008	1,528,861	0.3%
Oil and gas extraction	748	328,438	0.2%
Computer systems design and related services	643	354,296	0.2%
Computer and electronic products	595	401,701	0.1%
Finance and insurance	2,632	1,897,557	0.1%
Securities, commodity contracts, and investments	484	387,946	0.1%
Publishing industries, except internet (includes software)	379	319,734	0.1%
Motion picture and sound recording industries	160	147,316	0.1%
Legal services	261	262,883	0.1%
Insurance carriers and related activities	317	828,819	0.0%
Funds, trusts, and other financial vehicles	12	106,673	0.0%
Housing	9	1,708,517	0.0%

SOURCE: BEA, EIA, Moody's Analytics, US Census, team analysis

Appendix C: Examples of relevant initiatives – past and existing

Lenses	Name of the Initiative	Sponsoring organization	Year started
Economic sectors	▪ Keystone Opportunity Zones (KOZ)	▪ Commonwealth of Pennsylvania	1999
	▪ Keystone Energy Enhancement Act (KEEA)	▪ Commonwealth of Pennsylvania	Planned 2018
	▪ Develop Erie - Knowledge Park	▪ Private-public partnership of seven organizations	2010
	▪ Pennsylvania's Industry Partnerships	▪ Pennsylvania Government	2005
Human capital	▪ ShaleNET	▪ US Dept. of Labor Employment and Training Administration	2010
	▪ StartupPHL	▪ Government of City of Philadelphia and Philadelphia Industrial Development Corporation	2012
Innovation and entrepreneurship	▪ Jump Start Philly	▪ Government of City of Philadelphia	2013
	▪ Collaboration on research initiatives	▪ Penn State and Volvo Group	2013
	▪ Ben Franklin Technology Partners	▪ Pennsylvania DCED and Ben Franklin Technology Development Authority	1983
	▪ Venture Investment Program	▪ Commonwealth of Pennsylvania	2010
Physical and virtual infrastructure	▪ Enhancing Connectivity in Northern Pennsylvania	▪ Executive office of Commonwealth of Pennsylvania	2012
	▪ Port of Philadelphia development	▪ Philadelphia Regional Port Authority; Governor Tom Wolfe	2010-present
	▪ UGI GET (Growth Extension Tariff) Gas Program	▪ UGI	2012
Governance and business climate	▪ Keystone Energy Enhancement Act (KEEA)	▪ Commonwealth of Pennsylvania	Planned 2018