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Prospects to Enhance Pennsylvania's Opportunities in Petrochemical Manufacturing

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TEAM PENNSYLVANIA

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PA

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DEPARTMENT OF COMMUNITY & ECONOMIC DEVELOPMENT

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For more information, contact:
Ron Whitfield
Vice President, Economics & Country Risk Consulting, IHS Markit
ron.whitfield@ihsmarkit.com

For press information, contact:

Melissa Manning
Global Public Relations Director, IHS Markit
melissa.manning@ihsmarkit.com

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Executive in charge

- Ron Whitfield, Vice President, Economics & Country Risk Consulting

Project manager

- Phil Hopkins, Director, Economics & Country Risk Consulting

Project team

- Tabitha M. Bailey, Director, Economics & Country Risk Consulting
- Joe Campana, Consultant, Chemical Consulting
- Debnil Chowdhury, Director, Midstream & NGL Research and Consulting
- Pam Giordano, Managing Director, Chemical Consulting
- Julie Gressley, Consultant, Economics & Country Risk Consulting
- Mike Kratochwill, Managing Director, Chemical Consulting
- Veeral Mehta, Senior Consultant, Midstream & NGL Research and Consulting
- Ben Nevarez, Consultant, Midstream & NGL Research and Consulting
- Anthony Palmer, Senior Director, Chemical Consulting
- Adam Perdue, Consultant, Midstream & NGL Research and Consulting
- Darryl Rogers, Managing Director, Midstream & NGL Research and Consulting

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Contents

Frequently used concepts and abbreviaions

Concept	Definition
Aromatics	The general term referring to benzene, toluene, and xylene-based chemicals
bbl	Barrels, a measure of liquid hydrocarbon products; 1 bbl = 42 gallons
Bcf	Billion cubic feet – the typical measurement unit for natrual gas
Btu	British thermal unit - the typical measurement unit for the heat content of fuel
Butanes	A hydrocarbon family consisting of normal-butane (n-butane) and iso-butane (i-butane)
EIA	Energy Information Administration (a division of the US Department of Energy)
FCC	Fluid catalytic cracking is one of the main conversion processes in a refinery
GSP	Gross State Product is a measure of the economic output of a state
HDPE	High-density polyethylene resin
kMT	Thousand metric tons
LDPE	Low-density polyethylene resin
LLDPE	Linear low-density polyethylene resin
LPG	Liquified Petroleum Gas (either propane or butane)
LQ	Location Quotient (LQ) is a measure of a region's industrial specialization relative to a larger geographical unit (usually the nation as a whole)
MT	Metric tons
NAICS	North American Industry Classification System is the standard method of classifying businesses by their industrial output
NGL	Natural Gas Liquids, a mixture of ethane, propane, butanes, natural gasoline, and higher order hydocarbons
Olefins	The general term referrring to ethylene, propylene, and C4 hydrocarbons (which include butanes, butylene, and butadiene)
PADD	Petroleum Administration for Defense District; the United States is divided into 5 districts for this purpose
PADD I	East Coast PADD includes Pennsylvania and West Virginia
PADD II	Midwest PADD includes Ohio
PADD III	Gulf Coast PADD includes Texas and Louisiana
PADD IV	Rocky Mountain PADD includes Colorado
PADD V	West Coast PADD includes California
PDH	Propane dehyrogenation; describes a technology that converts propane into propylene
PE	Polyethylene resins, includes LDPE, LLDPE, and HDPE
PP	Polypropylene resin
USGC	US Gulf Coast

Source: IHS Markit

Executive summary

Natural gas: Powering petrochemical and plastics manufacturing in Pennsylvania

"Prospects to Enhance Pennsylvania's Opportunities in Petrochemical Manufacturing" is an independent report by IHS Markit. Team Pennsylvania Foundation (Team PA) commissioned the report to identify and evaluate the opportunities for petrochemical and plastics manufacturing in Pennsylvania based on natural gas resources available in the Marcellus and Utica Shale plays. The Marcellus Shale resource alone represents the second largest natural gas field in the world and underlays two-thirds of Pennsylvania, extending into the neighboring states of New York, Ohio, and West Virginia. In 2015, the natural gas from the Marcellus and Utica Shale plays accounted for a quarter of all natural gas produced in the United States and is expected to account for more than 40% of the nation's natural gas production by 2030. A critical component of the natural gas produced in the region includes the abundant availability of ethane and propane—two important and high-value natural gas liquids (NGL) used in basic petrochemical production and plastics manufacturing.

The analysis conducted by IHS Markit highlights the economic opportunities for Pennsylvania based on predicted growth of both natural gas and NGL production in the Marcellus and Utica Shale plays. The findings of this report conclude that there will be significant potential for driving economic development and job creation across the state thanks to a variety of existing and future competitive advantages. Pennsylvania's advantages for petrochemical processing and plastics manufacturing include cost and freight advantages driven by the availability and abundance of natural gas and NGL, proximity to high-demand North American end use markets, existing and planned infrastructure investments, a skilled workforce and specialized talent pipeline, and a well-established plastics manufacturing industry.

Pennsylvania's NGL resource base

The abundance of natural gas from the Marcellus and Utica Shale plays has resulted in significant economic benefits for Pennsylvania over the past decade, even during periods when natural gas prices are low. A significant factor that continues to drive natural gas development in Pennsylvania is the fact that up to 40% of natural gas produced in the Marcellus and Utica Shale plays is rich in NGL, more than 70% of which is ethane and propane. This has important economic consequences for existing and potential petrochemical manufacturing companies in the region as ethane and propane are important raw materials for petrochemical production.

IHS Markit predicts continued upward production trends for both natural gas and NGL through at least 2030, with the Marcellus and Utica Shale plays acting as a key contributor to ongoing growth. Between 2026 and 2030, NGL production to meet US demand is expected to reach nearly 6.3 million barrels per day (b/d), of which more than 1 million b/d of NGL is expected to be produced in the Marcellus and Utica Shale plays. The high-value of the NGL contained in the natural gas stream—specifically ethane and propane—is responsible for driving ongoing production increases. The substantial increase in NGL production from US tight oil and shale gas plays, including from the Marcellus and Utica Shales, has resulted in a remarkable shift in the US refining and petrochemical industries.

Opportunities for ethane

There is an abundance of ethane available in the Marcellus and Utica Shale plays. Ethane contained in natural gas can either be recovered as a purity product for petrochemical feedstock to produce ethylene (a key petrochemical building block), which is used to manufacture polyethylene (PE)—a plastics resin—or it can simply be left in the natural gas stream. As of the end of 2016, 100% of the ethane produced in Pennsylvania and recovered as a petrochemical feedstock is being shipped out of the state to other end use markets for petrochemical processing. This is largely because of the low cost of ethane produced in the Marcellus and Utica Shale plays compared to ethane produced from the US Gulf Coast (USGC) and other global locations. The IHS Markit forecast shows that between 2026 and 2030, the expected ethane production from the Marcellus and Utica Shale plays will be enough to support up to four additional world-scale ethane steam crackers in the region, even after meeting the demand from the future Shell Pennsylvania Chemicals ethane steam cracker in Southwestern Pennsylvania. This is also in addition to meeting the demand for ethane from pipelines currently shipping it out of the region and future pipeline projects that will do the same.

Opportunities for propane

As with ethane, propane production is expected to increase in the Marcellus and Utica Shale plays through at least 2030 and is expected to be priced lower than propane from the USGC. While IHS Markit predicts ethane will primarily be used as a petrochemical feedstock with opportunities for additional steam crackers locating in the footprint of the Marcellus and Utica Shale plays, propane has multiple competing end uses that may result in NGL being used for other purposes.

Propane can be used as a heating fuel source or as a petrochemical feedstock to produce propylene—through a process known as propane dehydrogenation (PDH)—or by steam cracking a mixture of ethane and propane. Propylene can be converted into polypropylene (PP), a versatile and high-growth plastic resin. IHS Markit predicts propane will continue to be used primarily in residential, commercial, industrial, and utility sectors as a fuel because of strong demand in both domestic and international markets. In addition to determining the fuel market as the most likely and viable economic opportunity for propane, IHS Markit also reviewed the competitiveness of the two types of propane petrochemical processing as second and third-tier opportunities. Based on its evaluation, IHS Markit identifies a stronger potential for demand for propane as a petrochemical feedstock for PDH rather than for steam cracking. The analysis concludes that this is because petrochemical steam crackers have a less expensive feedstock readily available in abundance, namely ethane.

From NGL to plastics

IHS Markit estimates that 73% of United States and Canada's PE demand and 67% of PP demand falls within a 700-mile region of Southwestern Pennsylvania. These percentages are well above relative capacities to meet the demand within the target region, meaning that producers within this region will enjoy a location advantage over suppliers outside the region. New regional petrochemical producers will be well positioned to compete for a respectable share of this domestic demand because of a shorter supply chain. Additionally, petrochemical producers operating in the region will also be in a strong position to take advantage of export opportunities as well.

The first large scale NGL-based petrochemical investment in Pennsylvania will be the Shell Pennsylvania Chemicals ethane cracker in Southwestern Pennsylvania. It is slated to be a world-scale, ethane-fed steam cracker that will produce 1.5 million metric tons per year of ethylene, which will be converted to more than 1 million metric tons per year of high-density polyethylene (HDPE) and 550,000 metric tons per year of linear low-density polyethylene (LLDPE). HDPE and LLDPE are two of the fastest growing and largest volume plastic resins globally. IHS Markit expects construction to be completed by 2021–22, including the significant feedstock and transportation infrastructure required. The infrastructure needed to meet the demands of the project is expected to exceed what is typically required for a similar facility built in the USGC.

Despite higher capital and developmental costs than the USGC, which has an established and mature petrochemical industry, Southwestern Pennsylvania's PE and PP production is forecast to be highly competitive on a cash cost basis relative to existing production centers. This includes not only the USGC, but also Alberta, Canada; Sarnia, Canada; and the Middle East. The cost advantages over these global existing industry hubs are driven by low-priced ethane and propane (the main feedstocks for production), proximity to major North American demand centers (resulting in reduced freight and transportation costs), and a significant base of plastics manufacturers in Pennsylvania and the Northeastern United States.

With the growth of a regional supply of PE and PP, Pennsylvania's plastics companies may see significant cost savings and advantages over competitors located outside of the region. IHS Markit identified an industry cluster of plastics manufacturers in Pennsylvania that use PE and PP to produce products such as plastic films, containers, housewares, food-grade packaging, and bottles for industrial and consumer markets. The development of PE and PP production in-state will benefit Pennsylvania's plastic manufacturers that use these resins as the foundational building blocks for their respective plastics products.

Economic development opportunities for the future

Pennsylvania currently has a sufficient supply of NGL to support a world-class petrochemical industry. Its major competitive advantage is access to an expanding supply of low-cost natural gas and NGL (particularly ethane and propane) capable of supplying up to four additional world-scale, integrated ethane crackers similar in size to Shell Pennsylvania Chemicals.

In addition, Pennsylvania has a significant locational advantage. Over two-thirds of US and Canadian PE and PP demand is located within 700 miles of Southwestern Pennsylvania, and the state already has a large installed base of plastics manufacturers available to purchase some of the output of Shell Pennsylvania Chemicals. The cost of doing business for manufacturing operations in Southwestern Pennsylvania is comparable to costs across the Marcellus and Utica basins, and these costs are also competitive compared to those in the petrochemical hub along the USGC.

IHS Markit notes that Pennsylvania is currently only using a limited portion of the available Marcellus and Utica Shale natural gas and NGL in-state. As such, it must begin taking immediate steps to support a long-term strategy that will maximize in-state economic development—as other US states and regions are also competing for the resources.

To maximize the potential economic development benefits of increasing NGL production volumes and related investment, including both attracting additional petrochemical companies and expanding the plastics manufacturing sector, IHS Markit recommends that Pennsylvania take aggressive action to address potential developmental and infrastructure constraints proactively. This includes investing in suitable sites to accelerate pad-ready development and supporting NGL pipeline infrastructure and storage capacity. These actions are critical to ensuring that Pennsylvania is positioned to develop long-term, job-creating manufacturing opportunities.

Introduction

The last decade has seen a remarkable shift in the US refining and petrochemical industries because of the substantial increase in oil, natural gas, and natural gas liquids (NGL) extracted from the US shale gas and tight oil reserves. IHS Markit expects this prolific production trend to continue at least to the next decade. The Marcellus and Utica Shale plays' contribution to the total US natural gas supply is expected to increase from approximately 25% in 2015 to more than 40% by 2030, reaching approximately 40 Bcf/d in 2030.

An important economic driver for this growth in natural gas production is the value of the NGL contained in the natural gas stream, particularly ethane and propane. In June 2016, the industry confirmed the importance of NGL production for petrochemical processing when Shell Pennsylvania Chemicals announced it would begin construction of a large, integrated ethane cracker in Southwestern Pennsylvania—the first of its kind in the Northeastern United States. The plant will make ethylene and two types of plastics resins—high-density polyethylene (HDPE) and linear low-density polyethylene (LLDPE)—materials that are used to make a wide range of plastics products.

With these trends in mind, Team Pennsylvania Foundation (Team PA) commissioned IHS Markit to conduct an in-depth analysis to investigate a number of important questions regarding the expected growth in the volume of NGL in the region and the economic development opportunities for further petrochemical production and plastics manufacturing across the state. The major issues addressed in this report include:

- What are the size, composition, and competitive cost positions of the natural gas and NGL resource base in the region?
- What is the potential to extract a reliable supply of NGL feedstocks (ethane and propane) to support the already-announced Shell Pennsylvania Chemicals ethane cracker and additional crackers in the region?
- How adequate is the capacity of the regional midstream natural gas industry (the natural gas processing plants, NGL fractionation facilities, NGL pipelines, and storage facilities) to support the already-announced ethane cracker and additional crackers in the region?
- How large is the current installed base of plastics manufacturers in Pennsylvania that could immediately benefit from these upstream and basic chemical investments?
- Looking beyond the already-announced Shell Pennsylvania Chemicals facility, what are the economic development opportunities for plastics manufacturing and related industries across Pennsylvania?
- What are the major bottlenecks and obstacles that may limit or delay these potential economic development gains in Pennsylvania?

"Prospects to Enhance Pennsylvania's Opportunities in Petrochemical Manufacturing" presents an independent assessment of the opportunities to grow petrochemical processing and plastics manufacturing in Pennsylvania. The analysis and metrics developed during the course of this research represent the independent views of IHS Markit. They are intended to inform industry, government, and economic development groups how Pennsylvania will benefit from the chemical transformation of ethane and propane into useful petrochemicals and resins for downstream plastics production.

Chapter 1: Unconventional natural gas production in the Marcellus and Utica Shale formations

Key takeaways

- Natural gas and natural gas liquids (NGL) are available in abundance in the Marcellus and Utica Shale plays, which lay under over two-thirds of Pennsylvania and stretch into surrounding states (West Virginia, Ohio, and New York).
- Unconventional extraction methods, namely horizontal drilling and hydraulic fracturing, have led to an increase in natural gas and by-product NGL volumes for consumption.
- Drilling activity in the Marcellus and Utica Shale plays to produce natural gas has been economical even in a lower natural gas price environment, and is linked to continued growth in NGL production from Pennsylvania, Ohio, and West Virginia.
- Approximately 30–40% of the natural gas produced is estimated to be rich in NGL content.
- Ethane and propane are the most abundant NGL contained in the natural gas stream, accounting for more than 70% of the total NGL.

Shell's recent decision to construct a world-class ethane cracker in Beaver County, Pennsylvania (Figure 1.1) has proven that Southwestern Pennsylvania has an abundant amount of NGL.

As a result, Team PA is interested in understanding how the abundance of NGL, coupled with Shell's multi-billion dollar investment, will play a role in Pennsylvania's economy and how this world-class ethane cracker will enhance opportunities for additional petrochemical manufacturing, economic growth, and job creation.

History and background

The Marcellus Shale is a sedimentary rock thousands of feet beneath the earth's surface. This prolific natural gas resource stretches from upstate New York south through Pennsylvania to West Virginia and west to parts of Ohio (Figure 1.1). Named after a town in upstate New York, the source rock is millions of years old, formed from mud and organic material deposited during the Devonian period. The Marcellus Shale is just one of the many shale formations across the world. When the industry speaks of tapping shale gas, it often refers to it as a "shale play."

The depth of the Marcellus Shale ranges from almost zero feet in central Pennsylvania to over 9,000 feet in parts of southwestern and northeastern Pennsylvania. The gross thickness of the Marcellus Shale ranges from less than 20 feet along the Lake Erie shoreline in northwestern Pennsylvania to several hundred feet in central and northeastern Pennsylvania.[1] The net thickness of organic-rich Marcellus Shale varies from less than 10 feet in western Pennsylvania along the Ohio border to over 250 feet in northeastern Pennsylvania.[2]

The Utica Shale, like the Marcellus Shale, is also sedimentary source rock and this natural gas resource is in parts of Quebec, Canada and in New York, Pennsylvania, Ohio, and West Virginia in the United States. The Utica Shale is approximately 170,000 square miles and is nearly twice the size of the Marcellus Shale. Even though the Utica Shale is larger than the Marcellus Shale, it is deeper. As a result, it has not seen as much development as compared to the Marcellus Shale. Depth is proportional to drilling costs and the

1 The gross thickness of a shale gas formation is established from log data and cross-sections of the geologic formation.

2 The net thickness of the shale formation is measured as the gross thickness less the thickness of barren areas of the formation that contain no hydrocarbons.

relative productivity of a Utica well has to overcome the depth in order to be economically justified. The Utica Shale was deposited before the Marcellus Shale; it is located about 3,000 to 7,000 feet below the formation. The zone of interest for exploration and production includes the Utica black carbonate-rich shale and the Point Pleasant limestone of the Middle Ordovician Period, placing its age between 490 and 440 million years. The depth of the Utica Shale increases from an oil window in the west to a gas window in the east, ranging from 6,000 feet to 9,000 feet. The thickness of the Utica Shale varies from less than 100 feet to over 500 feet. The thickest areas are on the eastern side of the play, and it generally thins to the northwest.

Natural gas production activity in the Pennsylvania portion of the Marcellus Shale is primarily focused in the northeast and southwest corners of the Commonwealth of Pennsylvania. The majority of the natural gas produced in the northeast is "dry gas"; however, the natural gas production that occurs primarily within Southwestern Pennsylvania and Northwestern West Virginia is deemed as "wet gas." Dry gas is defined as the raw natural gas stream from the wellhead that is not rich in NGL content, and hence does not require natural gas processing to remove and recover NGL from the raw natural gas stream. Wet gas is defined as the raw natural gas stream from the wellhead that is rich in NGL content and does require processing to remove and recover NGL. Approximately 30–40% of the natural gas produced is estimated to be rich in NGL content. Figure 1.1 indicates the relative location of the wet gas region of the Marcellus and Utica Shales. Ethane and propane are the most abundant NGL contained in the natural gas stream, accounting for more than 70% of the total NGL.

Figure 1.1

Marcellus and Utica NGL shale plays

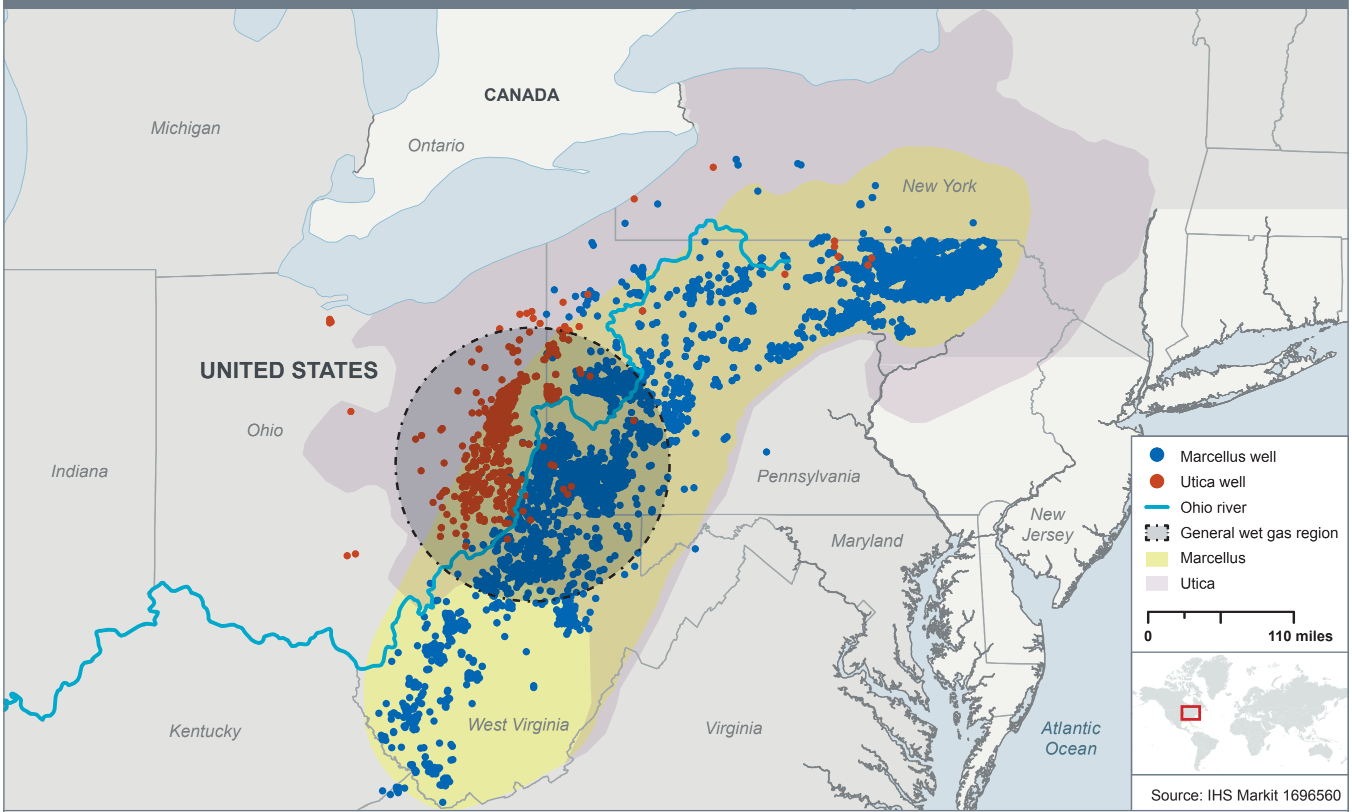
Comparing Marcellus and Utica to other key US shale gas plays

Early in this century, a "Shale Revolution" occurred and upstream producers and operators began to extract oil and natural gas (and removed and recovered the by-product NGL from the natural gas) from shale gas and tight oil formations. Prior to the beginning of the early twenty-first century, upstream producers and operators could not economically extract oil and natural gas from these ultra-low permeable source rocks. As time passed, the technology improved, and a step-change occurred in the ability to withdraw oil and natural gas from the source rock by applying unconventional techniques. These unconventional techniques to withdraw oil and natural gas included the application of horizontal drilling and hydraulic fracturing to bring oil and gas to the surface more economically and the "Shale Revolution" was born. These once uneconomical formations and plays included, but were not limited to, the Woodford Shale in Oklahoma, the Barnett Shale and the Eagle Ford Shale in Texas, and the Haynesville Shale in Louisiana. These techniques spread across to other plays and formations, including the Marcellus Shale and the Utica Shale, and the results have been game changing.

Figure 1.2 depicts Marcellus and Utica wells drilled and producing natural gas as of November 2016. Approximately 10,295 wells have been drilled; the wells are producing natural gas from the Marcellus Shale. Likewise, approximately 1,600 wells have been drilled, producing natural gas from the Utica Shale.

Figure 1.2

Marcellus and Utica wells - as of March 2016



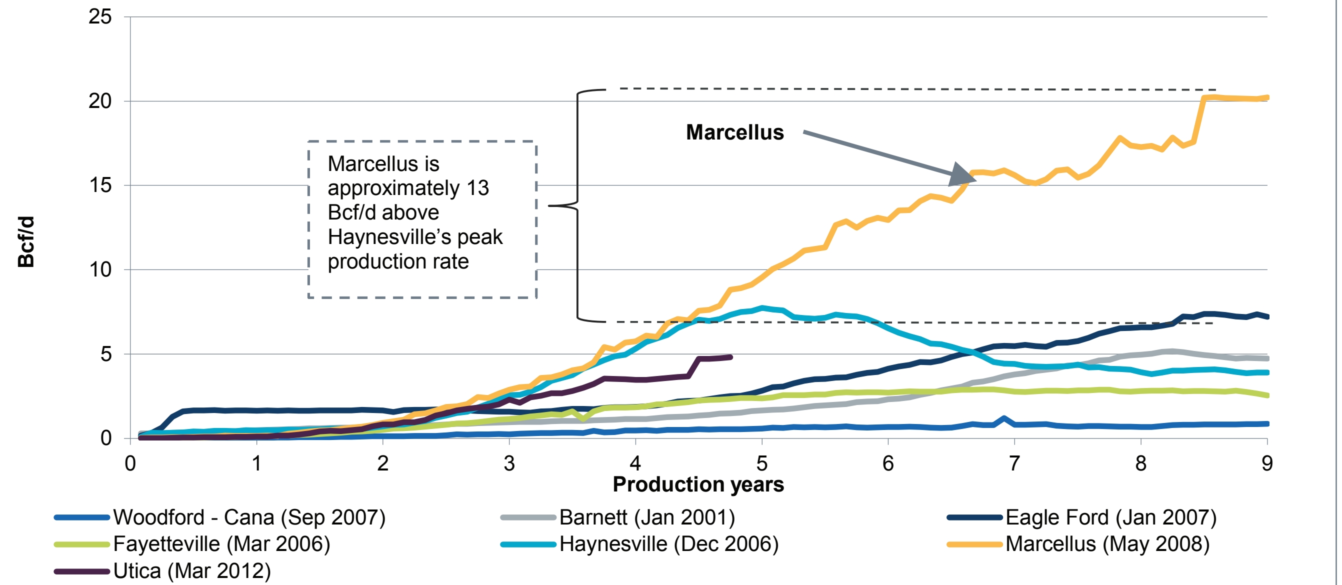
Source: IHS Markit 1696560

Comparing and contrasting several US shale gas plays to the Marcellus and Utica Shales provides an insightful view of the productive performance of these key US shale gas plays. Figure 1.3 compares and contrasts monthly production from the Marcellus and Utica Shale gas plays relative to other key shale gas plays in the United States.

The other key shale gas plays consist of the Woodford Shale, the Barnett Shale, the Fayetteville Shale, and the Haynesville Shale. A new entrant to the list of key shale gas plays is the Eagle Ford Shale. The first month of production for each shale gas play is noted in the graph below.

Figure 1.3

US shale gas plays comparison since first production



Source: IHS Markit

The earliest producing key shale gas play, the Barnett, started producing natural gas on a measureable basis in January 2001. Production rates grew slowly as technological advancements in oil and gas extraction, such as horizontal drilling and hydraulic fracturing techniques became more refined. Natural gas production from the Barnett grew from a very small production base, around 0.3 billion cubic feet per day (Bcf/d), to slightly higher than 5 Bcf/d in 2009, nearly eight years later. Other key shale gas plays, including Fayetteville, Woodford, and Eagle Ford, had similar trajectories that reached peak production rates within six to nine years after the first production.

The production trajectory for each shale gas play was influenced by market forces—natural gas and oil fundamentals of supply, demand and pricing, and adoption and application of horizontal drilling and hydraulic fracturing. Along with access to capital to find and develop related hydrocarbons, the activity and production rates for each play are influenced and bounded by the number of economically attractive drilling locations and the market forces noted above.

The Haynesville Shale gas play is an example of the right factors influencing a high-growth trajectory in a short amount of time. The Haynesville shale gas play's production rate increased significantly over a short amount of time—four years—before giving way to market factors that negatively affected the play's economics, causing activity to fall along with production. It is important to note that both the technology to find and develop the resource and the market forces and factors change; thus, shale plays that are uneconomical today may become economical at some point in the future and vice versa. An upstream producer continuously monitors the market against its upstream activity and production economics; and correspondingly, a shale gas play's life cycle will adjust to market factors and forces.

The Haynesville Shale gas play rose from a zero base in December 2006 to around 8.5 Bcf/d five years later in 2011, a significant increase in a short amount of time. After this five-year period, fundamental shifts occurred in the global oil and US natural gas markets. The shifts were characterized by a significant oversupply of US natural gas and weak prices, while global crude oil markets stabilized along with prices. Global and US oil prices disconnected from North American and US natural gas prices and did not decline, and upstream producers' supply portfolios refocused on liquids production, oil, and NGL, to improve their profitability. The annual US average crude oil price (West Texas Intermediate or WTI) in 2011 was around $95 per barrel and stayed at the same level in 2012, while the US natural gas price (Henry Hub or HH) fell from around $4 per million British Thermal Units (MMBtu) in 2011 to around $2.80 per MMBtu in 2012. Lower natural gas prices could no longer support increasing upstream activity and increasing production rates from Haynesville and other US shale gas plays.

Well productivity from the Marcellus and Utica Shale plays along with access to valuable by-product NGL provided an economic uplift to upstream producers as compared to drilling and completing wells in other key plays like the Haynesville Shale. Correspondingly, upstream producers shifted their focus to the Marcellus and Utica producing areas—Pennsylvania, Ohio, and West Virginia. Upstream producers also rushed into unconventional shale oil plays like the Bakken Shale in North Dakota and tight oil plays like those found in the Permian Basin in Texas.

Upstream producers operating in the productive and NGL-rich Marcellus and Utica Shale gas plays benefit from superior economics. The natural gas and oil price levels experienced since early 2012 and expected going forward—global and US crude oil in the $80 to $90 per barrel range and US natural gas in the $2.50 to $4 per MMBtu range—supports increasing activity in the Marcellus and Utica Shale gas plays, while slowing and/or maintaining activity in the other US key shale gas plays (like Haynesville and Barnett).

The production trajectory of the Marcellus Shale is significant as compared to all other major US shale plays in the United States (Figure 1.3). Marcellus production grew from a zero base in May 2008 to 7 Bcf/d in September 2012. This rate of increase is very comparable to the Haynesville Shale's production trajectory over the same four-year period, both increasing from zero to around 7 Bcf/d. Marcellus upstream operators have continued to benefit from the natural gas and NGL production streams from this prolific shale gas play after September 2012.[3]

US natural gas and NGL prices supported further development activity in the Marcellus Shale while Haynesville activity and production rates slowed. US natural gas prices averaged around $3.70 in 2013, $4.33 in 2014, $2.60 in 2015, and $2.44 per MMBtu in 2016, average crude oil prices were $98 in 2013, $93 in 2014, $48 in 2015, and $43 per barrel in 2016. Fundamental supply and demand balances for global oil are out of balance and the global crude oil market is currently oversupplied and is not expected to come into balance until 2017. Global and US oil prices are expected to rebound in the coming years rising from around $56 in 2017 to $96 per barrel in 2025. Demand for liquids will increase, enabling additional natural gas and NGL production growth from prolific shale gas plays like the Marcellus and Utica.

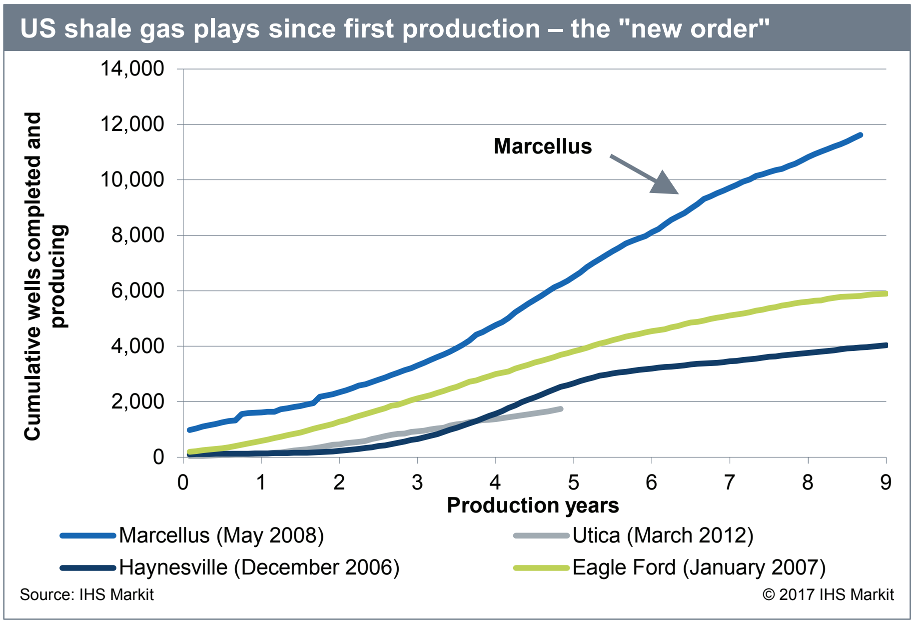
The "new order" of US natural gas supply is Marcellus and Utica, followed by the other shale gas plays.

Natural gas and NGL activity in the Marcellus and Utica—Trends and expectations

Natural gas production levels have been remarkable in both the Marcellus and Utica Shale gas plays (Figure 1.4), compared to the other two most prolific US shale plays, Haynesville and Eagle Ford. In the Marcellus Shale, activity level, as measured by the numbers of wells on-line and producing on a monthly basis, has been increasing.

3 NGL are defined as being ethane, propane, normal butane, isobutane, and natural gasoline, where natural gasoline is a pentane and heavier hydrocarbon mixture.

Figure 1.4



Cumulative wells producing at the nine-year mark for the Marcellus is almost 11,500, while the Utica is expected to reach almost 6,000 wells—both exceeding activity levels and wells in production in both the Haynesville and Eagle Ford over a similar period. It is important to note that Marcellus' exploration and development period started in early 2005 with negligible production and only after early 2008 did upstream drilling activity gain momentum and higher natural gas production rates followed.

Observing historical Marcellus Shale natural gas and NGL production rates is insightful to formulating a view of future production rates. This view also helps to form an opinion of the necessary midstream and downstream infrastructure buildout to enable production rate increases and continuous growth over the long term. Both the Marcellus and Utica Shale gas plays and their related liquids production streams will be extremely important to supplies on a go-forward, long-term basis.

Historical monthly natural gas production activity in the Marcellus and Utica Shale gas plays is shown in Figures 1.5 and 1.6. Upstream operators in the Marcellus Shale have slowed activity in the short run as each adjusted to the current lower natural gas price environment. In spite of lower upstream-related activity reflected by less wells brought online and producing on a monthly basis, after late 2014, natural gas production has continued to grow. The average monthly natural gas production in the Marcellus Shale has grown from around 15.7 Bcf/d in December 2014 to around 20 Bcf/d in November 2016.

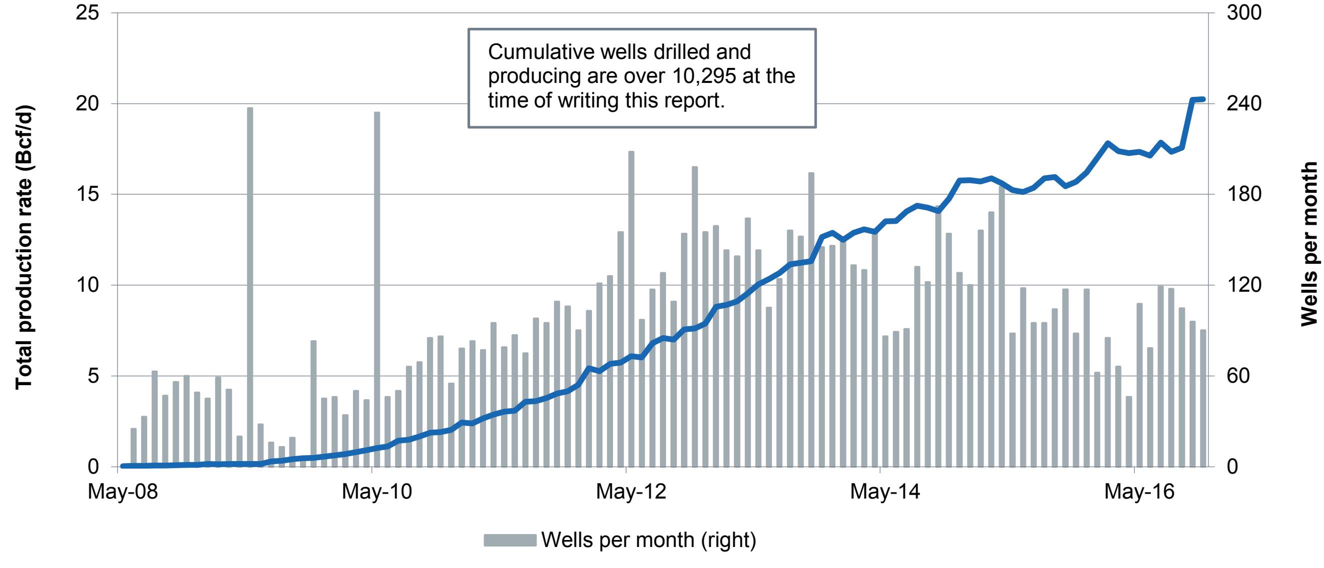
A similar trend is reflected in the Utica Shale's historical activity from the IHS Markit production data. Upstream operators began tapping into this prolific resource in early 2012, growing the average monthly natural gas production to almost 5 Bcf/d by November 2016. Cumulative numbers of wells drilled and producing has steadily increased to over 1,600, averaging around 36 new wells per month during the last two years.

Pennsylvania was the largest contributor to the total natural gas production from these shale gas plays, making up approximately 79% of total production in 2016 at 14.1 Bcf/d.

West Virginia's (Marcellus Shale) total natural gas production rate was approximately 3.8 Bcf/d and Ohio's (Utica Shale) total natural gas production rate was approximately 4 Bcf/d for 2016.

Figure 1.5

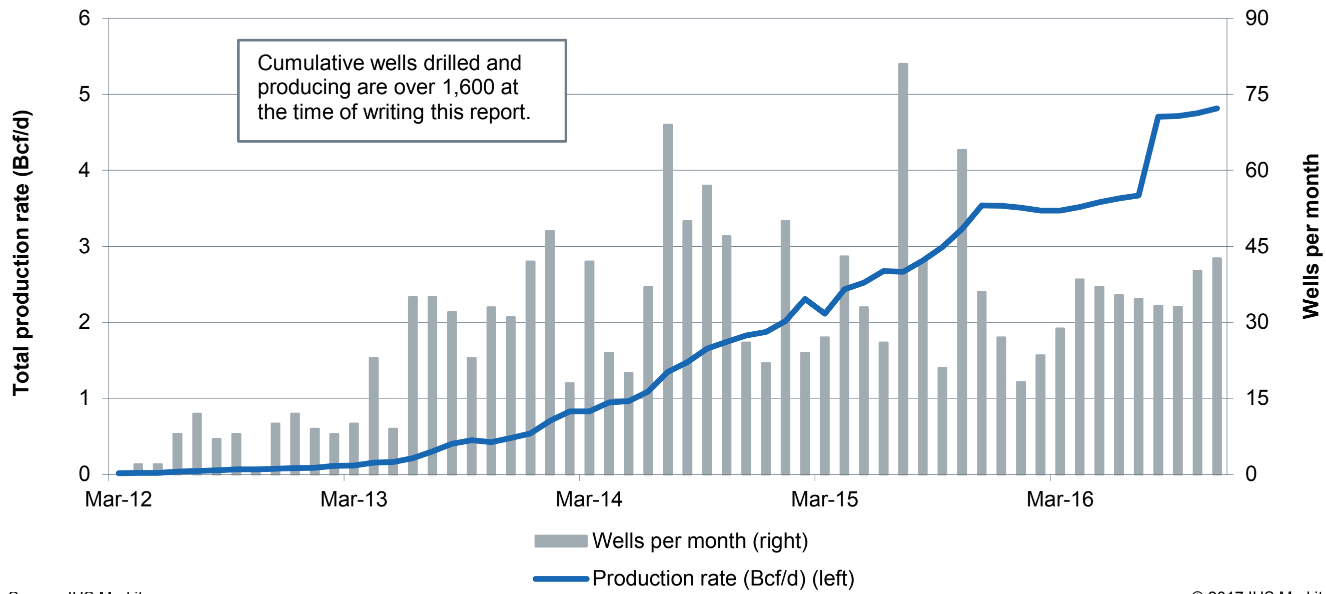
Marcellus Shale Basin natural gas production and wells producing



Source: IHS Markit

Figure 1.6

Utica Shale Basin natural gas production and wells producing



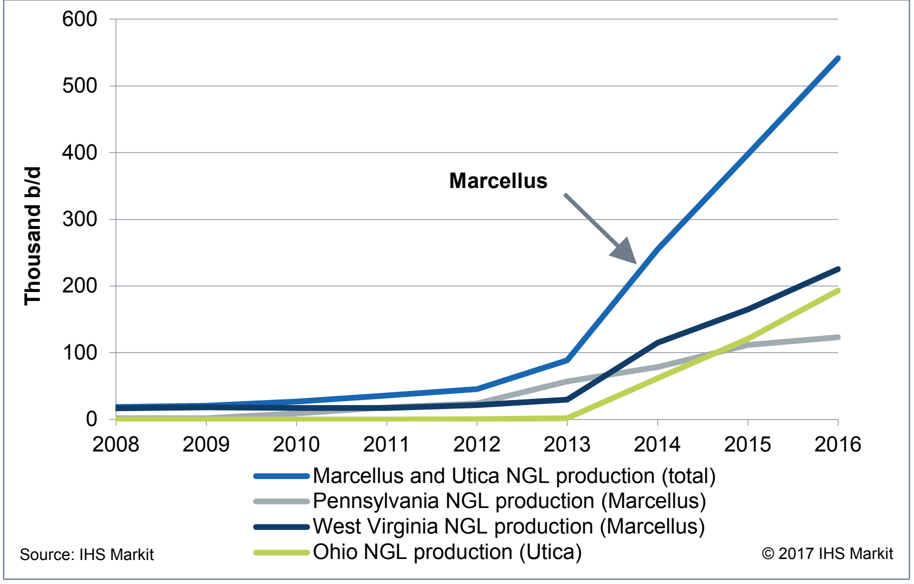
Source: IHS Markit

The activity levels in both the Marcellus and Utica Shale gas plays have added significant volumes of natural gas to the interstate natural gas pipeline system, while at the same time providing major contributions to the US and global NGL supply and demand balances. The increasing supplies of NGL from these two plays have supported growing NGL demand domestically and internationally. The Marcellus and Utica Shale gas plays are a major source of low-cost NGL for consumption in all end use markets, specifically ethane as a petrochemical feedstock. NGL supplies from these plays are currently a major source of NGL to meet US demand and demand outside the United States, namely Canadian demand being met by pipeline exports and a portion of international demand via waterborne trade.

Marcellus and Utica NGL production rates have grown along with increasing upstream activity with the major production streams originating from Pennsylvania (Figure 1.7). Initially, the Utica Shale was believed to have a large oil production component. However, so far, this has not been the case and significant productivity and economic results related to natural gas directed drilling have yielded increasing natural gas and by-product NGL production rates as opposed to oil.

Figure 1.7

Marcellus and Utica NGL production



Source: IHS Markit

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Marcellus and Utica NGL production is expected to increase to 541,000 barrels per day (b/d) in 2016. Pennsylvania's annual NGL production for 2016 is expected to average around 123,000 b/d. NGL recovered on an annual basis for West Virginia is expected to reach 225,000 b/d, while the Utica Shale—all in Ohio—is expected to reach around 193,000 b/d.

In summary, natural gas and NGL production from the Marcellus and Utica Shale gas plays is expected to continue to grow for many years to come, penetrating more deeply into the existing end use and new markets. Current and future upstream producer's activity in these plays are underpinned by superior upstream economics and IHS Markit expects upstream producers to continue to explore, develop, and produce the significant natural gas and NGL resource base in the basins with the best economics—the Marcellus and Utica Shales.

Chapter 2: Overview of natural gas liquids (NGL) production in the United States with a focus on Marcellus and Utica Shale formations

Key takeaways

- The last decade has seen a remarkable shift in the US refining and petrochemical industries because of a substantial increase in the NGL supply from the US shale gas and tight oil plays. IHS Markit expects this prolific production trend to continue over the next decade, and the Marcellus and Utica Shale formations will play a key role.
- Marcellus and Utica's contribution to total US natural gas supply is expected to increase from around 25% in 2015 to more than 40% by 2030, reaching approximately 40 Bcf/d.
- By 2026–30, NGL production to meet demand in the United States is expected to reach about 6.3 million b/d, of which more than 1 million b/d of NGL is expected to originate from natural gas production in the Marcellus and Utica regions. This includes Shell Pennsylvania Chemicals' (Shell's ethane cracker) expected ethane demand.
- NGL have many diverse applications: they are used as a fuel in residential and commercial sectors; they are used as feedstock for petrochemical plants; they are used as utility gas and engine fuel; and they are used in refineries.
- Ethane contained in natural gas can either be recovered as a purity product for petrochemical feedstock purposes or left in the natural gas stream to be used as fuel. Ethane price in the Marcellus and Utica Shale region is discounted compared to prices on the US Gulf Coast (USGC).
- There is an abundance of ethane available in the Marcellus and Utica region. Additional ethane can be recovered from natural gas to support up to four additional world-scale steam crackers (above the demand from the Shell Pennsylvania Chemicals) by 2026–30.
- While propane production is expected to increase from PADD I (Marcellus Shale) through the forecast period, its use as a petrochemical feedstock over ethane yields less favorable economics. Hence, IHS Markit does not expect a strong demand for propane as a petrochemical feedstock. However, propane will continue to be used in the residential/ commercial, industrial, and utility sectors as a fuel.
- Over the long term, IHS Markit expects PADD I (i.e., Marcellus-derived) ethane and propane prices to be discounted to the Mont Belvieu ethane and propane prices.

The US refining and petrochemical markets have undergone rapid and significant changes since 2008. Robust growth in shale gas and tight oil production has dramatically increased supplies of natural gas, NGL, naphtha-rich light crude oils, and condensates. The "Shale Revolution" that began earlier in this century and its resulting increase in North American NGL production has led to advantages for the US NGL and petrochemical feedstock suppliers, refiners, petrochemical companies, and traders. These market participants are evaluating opportunities to use ethane and liquefied petroleum gas (LPG) and other associated hydrocarbons to serve both domestic and foreign markets.[4] The primary markets for these products include residential, commercial, industrial, chemical (petrochemical feedstock), utility gas, engine fuel, and refinery customers. These market changes will continue to affect the traditional interfaces between the refining and petrochemical industries. The prevalence of "homegrown" fuel and feedstock is shifting the supply-demand balance and creating new market opportunities.

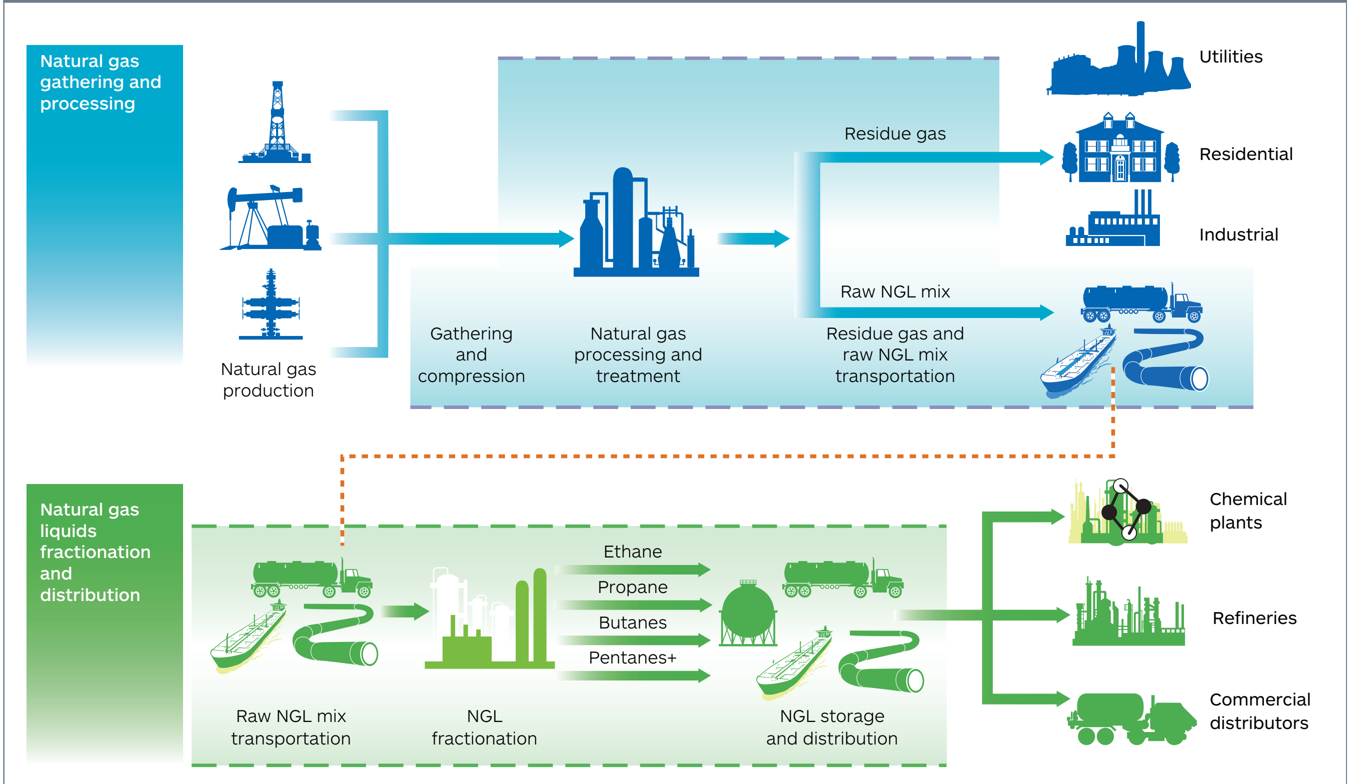
4 Liquefied petroleum gas, or LPG, consists of propane and butane. These are a subset of NGL.

US NGL supply and demand

As shown in Figure 2.1, NGL production is a by-product of crude oil and natural gas production and has end use opportunities in chemical plant, refineries, and commercial distributors. Since 2008, production of natural gas from tight oil and shale gas plays has increased significantly, resulting in rapid growth in the overall NGL production in the United States. NGL are by-products of natural gas production and refinery runs and most of the NGL production in the United States is sourced from natural gas.

Figure 2.1

Natural gas liquids (NGL) production chain



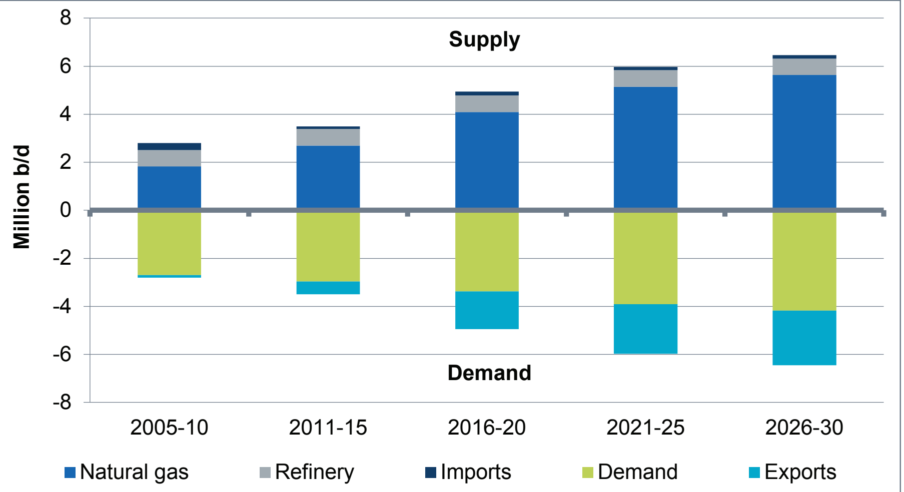
Source: IHS Markit

Figure 2.2 shows the current and significant forecast changes in the NGL supply and demand balances through 2030. NGL production from natural gas processing and refinery operations averaged about 3.4 million b/d between 2010 and 2015. With growing natural gas production, the total NGL production is estimated to nearly double—to average about 6.3 million b/d from 2026 to 2030 solely because of natural gas processing. In contrast, NGL production from refinery operations is not expected to grow through the rest of the forecast period. Imports of NGL have been declining since 2005 and will continue to decrease to minimum levels (some level of imports are required to balance the markets).

The US demand for NGL is expected to grow, driven primarily by the feedstock needs of the petrochemical industry. Demand for NGL in other sectors is expected to be flat to declining over the long term. The total demand for NGL from the various sectors in the United States will still not be enough to consume all of the NGL production, resulting in increased exports of NGL to international markets. Total exports from the United States averaged 0.5 million b/d between 2011 and 2015 and it is expected to average around 2.3 million b/d between 2026 and 2030.

Figure 2.2

US NGL supply and demand balance (average for the period)



Source: IHS Markit

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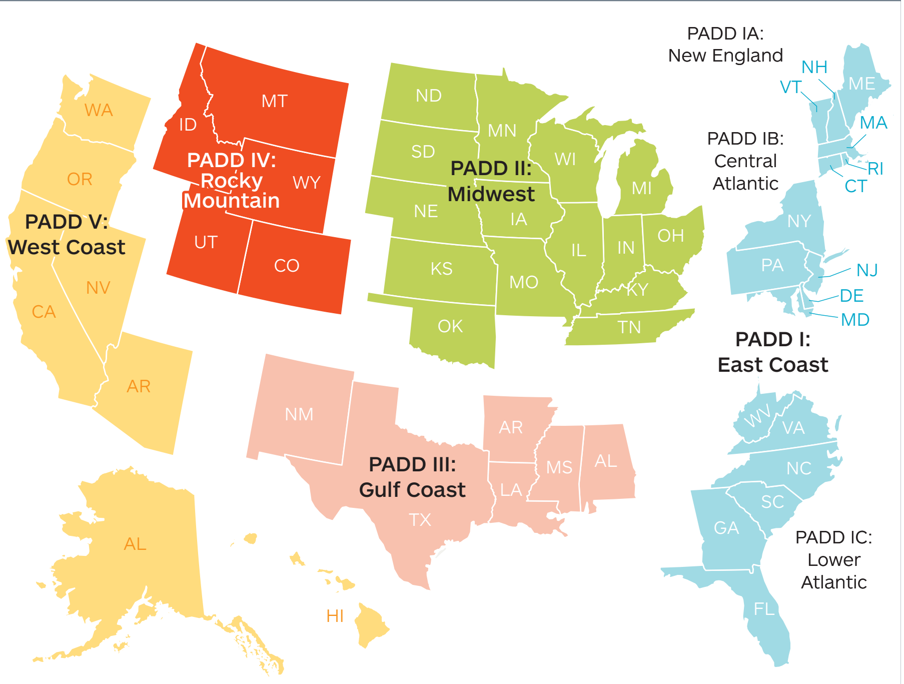
PADD I and PADD II NGL supply

The Petroleum Administration for Defense Districts (PADDs) are geographic aggregations of the 50 states and the District of Columbia. Each of the 50 states is placed into one of the five districts: PADD 1 is the East Coast, PADD 2 the Midwest, PADD 3 the Gulf Coast, PADD 4 the Rocky Mountain Region, and PADD 5 the West Coast (Figure 2.3). Production for crude oil, refined products and NGL is reported to the US Energy Information Administration (EIA) on a PADD level basis.

Figure 2.3

Petroleum Administration for Defense Districts



Source: IHS Markit

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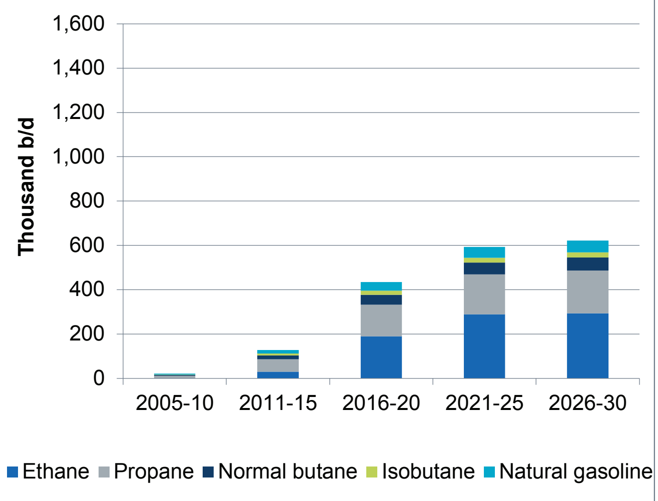
NGL production from both PADD I and PADD II has grown over the last few years, driven mostly by the development of the Marcellus, Utica, Bakken, Woodford, South Central Oklahoma Oil Province (SCOOP), and Granite Wash Shale plays. The Marcellus play is the major producing shale gas play in PADD I.

Figure 1.7 in Chapter 1 indicates historical NGL production from Pennsylvania (Marcellus), West Virginia (Marcellus) and Ohio (Utica). NGL production from natural gas production in Marcellus is projected to grow in the near term. It averaged 127,000 b/d between 2011 and 2015, and will grow to 600,000 b/d between 2021 and 2025, before almost flattening out through the rest of the forecast period (Figure 2.4).Almost all of NGL production occurring in PADD I is sourced from natural gas production in Marcellus Shale.

In comparison, total NGL production from PADD II is expected to increase significantly throughout the rest of the forecast period. For the most part, this growth will be driven by an increase in upstream activity in the Bakken, SCOOP, Woodford, and Utica Shale plays. By 2030, total NGL production from PADD II is expected to more than double its current production level (Figure 2.5).

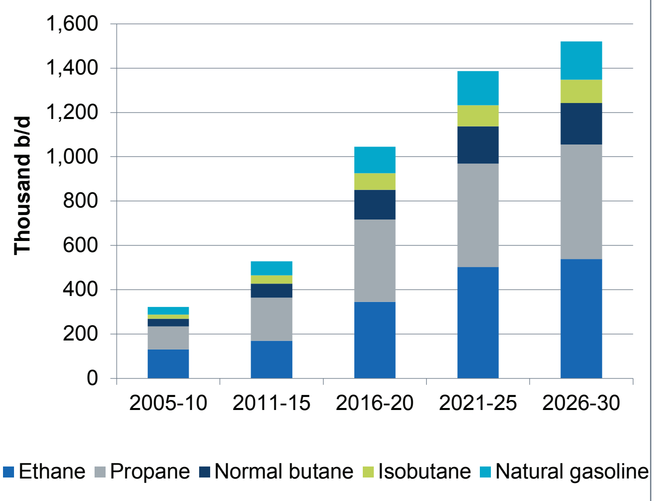
Figures 2.4 and 2.5

PADD I NGL production (average for the period)



Source: IHS Markit © 2017 IHS Markit

PADD II NGL production (average for the period)



Source: IHS Markit © 2017 IHS Markit

The growth in ethane production from PADD I and PADD II throughout the forecast region will be due to two primary factors: 1) a significant increase in natural gas production from the prolific plays within the region and 2) higher ethane recovery (less rejection) as demand for ethane increases.

The growth in propane, butanes, and natural gasoline production from PADD I and PADD II through the forecast period, for the most part, will be due to the overall growth in gas production.

Marcellus and Utica natural gas and NGL production outlook

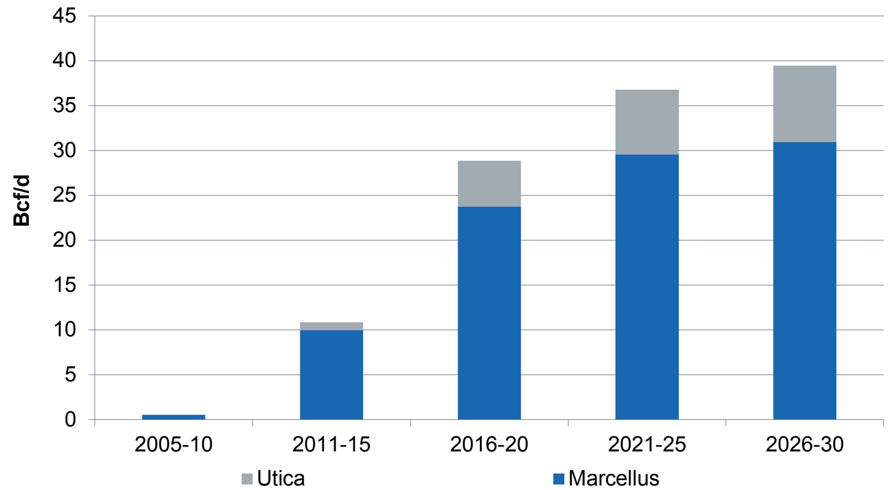
Natural gas production outlook

As discussed in Chapter 1, natural gas production from Marcellus and Utica Shale gas plays has grown substantially since 2008. Between 2005 and 2010, natural gas production averaged about 0.5 Bcf/d and then grew to an average of about 11 Bcf/d between 2011 and 2015. IHS Markit expects this growth trend to continue over the long term. Total Marcellus and Utica natural gas production is expected to approach 40 Bcf/d between 2026 and 2030, indicating a significant increase from current levels (Figure 2.6).

Not all of the natural gas produced from Marcellus and Utica Shale gas plays are rich in NGL content. NGL content reflects the quality and quantity of the ethane, propane, normal butane, isobutane, pentanes, and other heavier hydrocarbons in the raw natural gas produced. Only a portion of the natural gas that is rich in NGL needs to be processed to remove and recover the NGL. NGL contained in the natural gas stream is removed and recovered for two primary reasons: 1) NGL removed from natural gas enables the natural gas to meet transmission pipeline quality and safety specifications, and 2) NGL recovered from natural gas has a greater petrochemical feedstock value than fuel value.

Figure 2.6

Marcellus and Utica natural gas production (average for the period)



Source: IHS Markit

NGL production outlook

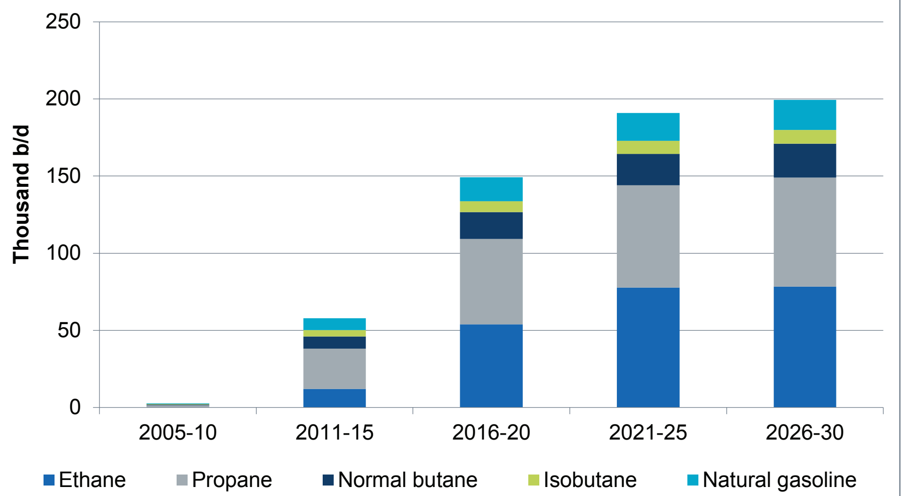
Natural gas that is rich in NGL content is processed at a gas processing facility to remove and recover NGL (ethane, propane, normal butane, isobutene, and natural gasoline). The amount of NGL recovered from the natural gas stream depends on several factors such as the quality of the natural gas, gas processing technology, producers and processor agreements, and the overall upstream production economics. Unlike the other NGL components, the decision to remove and recover ethane from the natural gas stream depends critically on its opportunity cost. If ethane prices are too low to justify its profitable recovery, producers can forego removal and recovery while continuing to economically remove and recover propane and heavier liquids. The residue gas stream, by definition, is the natural gas leaving the natural gas processing plant and entering the natural gas transmission and distribution system. On the other hand, if ethane prices are relatively high, gas processors are incentivized to remove and recover ethane for sale to ethane consumers. A substantial amount of the ethane contained in natural gas produced in the US Northeast is currently being rejected (or left in the residue gas stream) because of the lack of demand and poor ethane removal and recovery economics.

The increasing supply of ethane and its relatively low cost is attracting demand as a feedstock for new ethylene manufacturing plants (crackers) on the USGC and in the US Northeast, as well as for exports. As a result, the total ethane production sourced from natural gas produced in Pennsylvania is expected to reach about 80,000 b/d by 2030.

Production of the other NGL—propane, butanes, and natural gasoline—is also expected to increase through 2030. Practically all of the propane, butanes, and natural gasoline that are contained in the natural gas stream processed at a natural gas processing facility are being removed and recovered. The increase in production of propane, butanes, and natural gasoline within Pennsylvania will be a direct function of the increase in gas production and gas processed from the Marcellus region.

Figure 2.7

Pennsylvania NGL production from natural gas (average for the period)



Source: IHS Markit

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IHS Markit estimates that the total NGL production from Pennsylvania will average about 200,000 b/d between 2026 and 2030, of which 40% will be ethane (Figure 2.7).

A focus on ethane and propane supply and demand within PADD I and PADD II

Both ethane and propane are petrochemical feedstocks for the manufacturing of ethylene and propylene. With the growth in natural gas supply from Marcellus and Utica Shale plays, IHS Markit expects production of ethane and propane to grow throughout the basin for the rest of the forecast period.

Even with growing natural gas production in the Marcellus and Utica Shales, ethane production from these plays has remained subdued (i.e. being rejected and kept in the natural gas stream, the residue gas stream) because of the lack of demand and improper infrastructure to move the commodity to the market. However, this trend is changing and ethane production is expected to increase rapidly as the new crackers are added in the USGC and Pennsylvania. Over the next few years, new pipeline capacity and expansions to ethane cracking capacity will help bring ethane consumption and exports into closer alignment with supply.

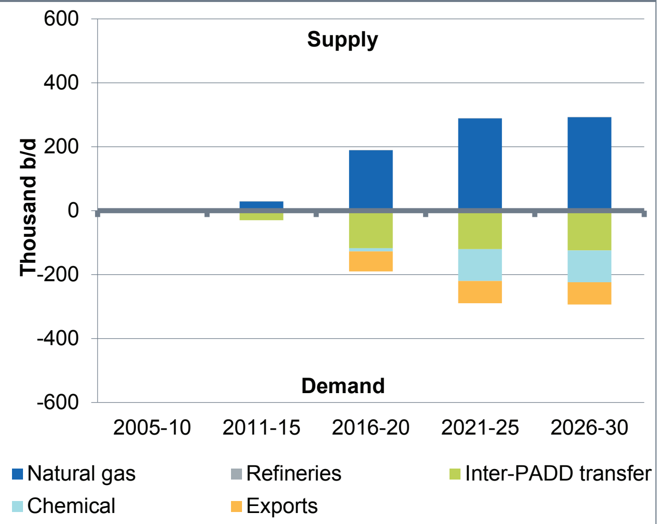
In early 2016, the first waterborne ethane exports commenced from Marcus Hook, exporting Marcellus-sourced ethane to markets in Europe. Currently, ethane from PADD I and II (Pennsylvania, West Virginia, and Ohio) is being transported to PADD III (Texas) via the Enterprise Products Partners L.P.'s Appalachia-to-Texas Express (ATEX) ethane pipeline. Volumes transported via the ATEX pipeline are expected to rise as new ethylene plants on the USGC start operations.

Approximately 100,000 b/d of the future ethane production within PADD I will be consumed by Shell Pennsylvania Chemicals, which IHS Markit expects to start operations in 2021–22 (Figure 2.8).

A significant portion of the ethane production from PADD II, averaging 320,000 b/d between 2026 and 2030, will be transported to PADD I (Marcus Hook for exports) and PADD III via various pipelines, either as a pure product or within the Y-grade (raw mix of NGL) (Figure 2.9). The average demand from the petrochemical sector for ethane in PADD II will grow from 57,000 b/d currently to 84,000 b/d between 2026 and 2030. Pipeline exports are underway to move production from the PADD II states of North Dakota and Ohio into western and eastern Canadian markets.

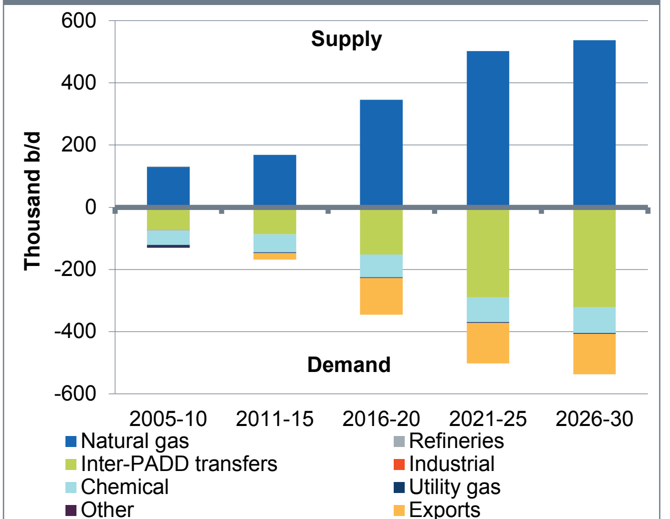
Figures 2.8 and 2.9

PADD I (East Coast) ethane supply and demand (average for the period)



Source: IHS Markit © 2017 IHS Markit

PADD II (Midwest) ethane supply and demand (average for the period)



Source: IHS Markit © 2017 IHS Markit

Propane supplies in the United States are derived from natural gas processing plants, refineries, and imports. Overland imports are brought into the United States via pipeline, rail, and truck from Canada and waterborne imports can be sourced from a variety of origins, primarily Algeria, West Africa, Venezuela, the North Sea, and the Middle East. Propane is a very flexible NGL that is used as a heating fuel and as a source of clean direct process heat in several end use sectors. It is also widely used in the United States as a petrochemical feedstock.

Historically, domestic production of propane has generally been evenly divided between natural gas processing and refinery production. However, this relationship has started to shift as gas plant production is rising quickly and refinery propane production is generally on the decline. The supply of propane from gas plants (PADD I and PADD II) currently represents around 60% of total production from both PADD's, but this percentage is expected to increase in the future as propane production from natural gas processing continues to rise (Figure 2.10 and 2.11).

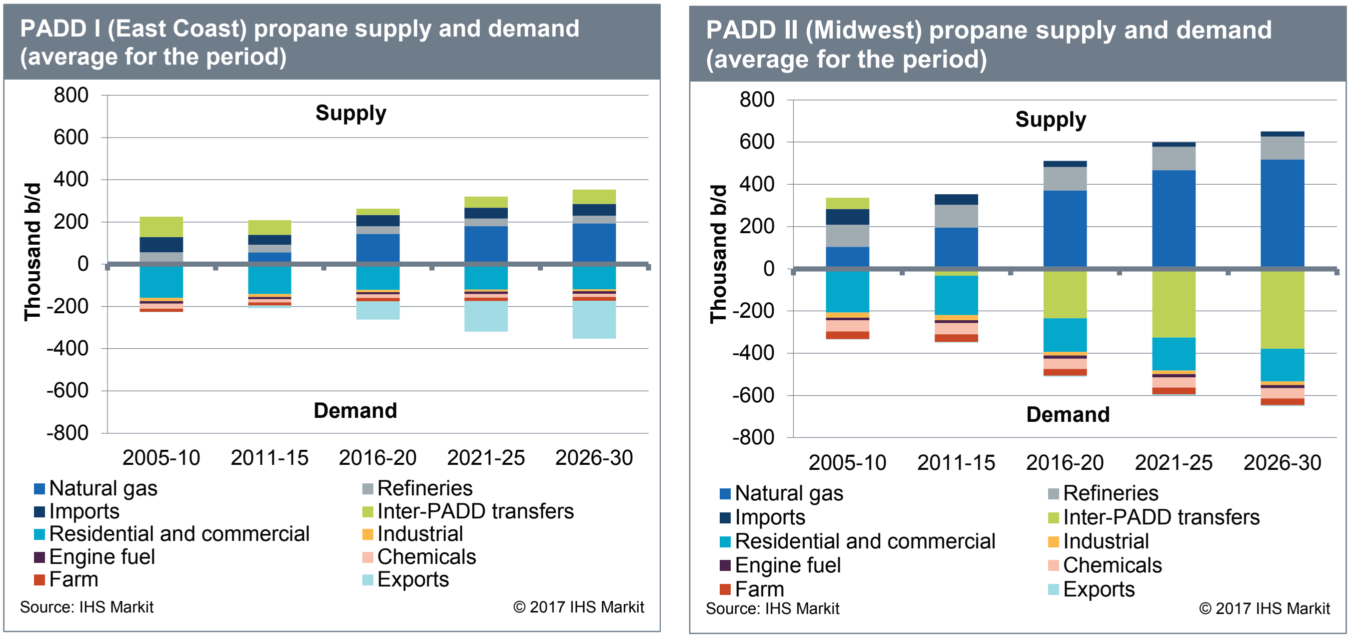
With the significant increase in domestic propane production from natural gas processing, imports have declined in recent years. They are expected to continue to decline over the next few years before leveling off at around 80,000 to 90,000 b/d combined for PADD I and PADD II.

Propane is used as both a fuel and as a feedstock for petrochemical plants. As a fuel, propane is used in several end use markets including residential/commercial, industrial, utility, and farming. Demand for propane as a fuel is expected to rise relatively slowly over the forecast period. Demand for propane as a feedstock for petrochemical plants is the second largest end use for propane in the United States. This issue will be discussed in more detail in the next chapter.

Historically, PADD I received large quantities of propane from PADD III, but this is expected to cease in the future, as production from the Marcellus Shale play will be sufficient to meet the demand for the region. PADD I will continue to receive some volumes, but it will all be from PADD II. The supply and demand imbalance will result in surplus propane being exported to international markets from PADD I. IHS Markit expects propane exports to average about 180,000 b/d between 2026 and 2030. A substantial amount of propane production from PADD II will be transported to PADD III for exports and for the new PDH (propane dehydrogenation) capacity that is being added in the USGC.[5] PDH technology will be discussed in greater detail in Chapter 3.

While IHS Markit anticipates significant amounts of propane will be produced from natural gas produced in PADD I (Marcellus Shale), its use as a petrochemical feedstock over ethane for ethylene production yields less favorable economics. Hence, IHS Markit does not expect a strong demand for propane from an ethylene cracker. Propane's market potential as a feedstock for propylene from a PDH plant could be viable, but IHS Markit currently does not forecast a new PDH plant being built in PADD I. Nevertheless, propane will continue to be used in residential/commercial, industrial, and utility sectors as a fuel. Overall demand for propane in the region is not expected to exceed its supply; therefore, exports of propane out of the region will increase throughout the remainder of the forecast period.

Figure 2.10 and 2.11



Ethane availability from Marcellus and Utica

As IHS Markit has indicated, natural gas production from both Marcellus and Utica Shale plays is growing and only a portion of this gas produced is rich in NGL content (i.e., wet gas). Increasing gas production will require additional investments to build new natural gas processing facilities or to increase the capacity of existing ones to remove and recover NGL. As mentioned earlier, a significant amount of ethane is currently left in the natural gas stream, a process known as *rejection*. As new petrochemical plants that use ethane as a feedstock come online, the demand for ethane will increase and more ethane will be recovered at gas plants rather than be rejected into the existing natural gas stream.

IHS Markit estimates that approximately 30–40% of the total natural gas production from the Marcellus and Utica Shales is wet gas and could contain between 8% and 12% ethane. As natural gas production grows in Marcellus and Utica, the total ethane supply, or the ethane contained in the natural gas stream, is also expected to grow. More ethane could be recovered, but it depends on the ethane demand. Figures 2.14 and 2.15 show Marcellus and Utica forecast ethane demand growth and incremental hypothetical demand against the potential ethane supply.

5 Propane dehydrogenation plants convert propane into propylene, the second most important petrochemical building block after ethylene.

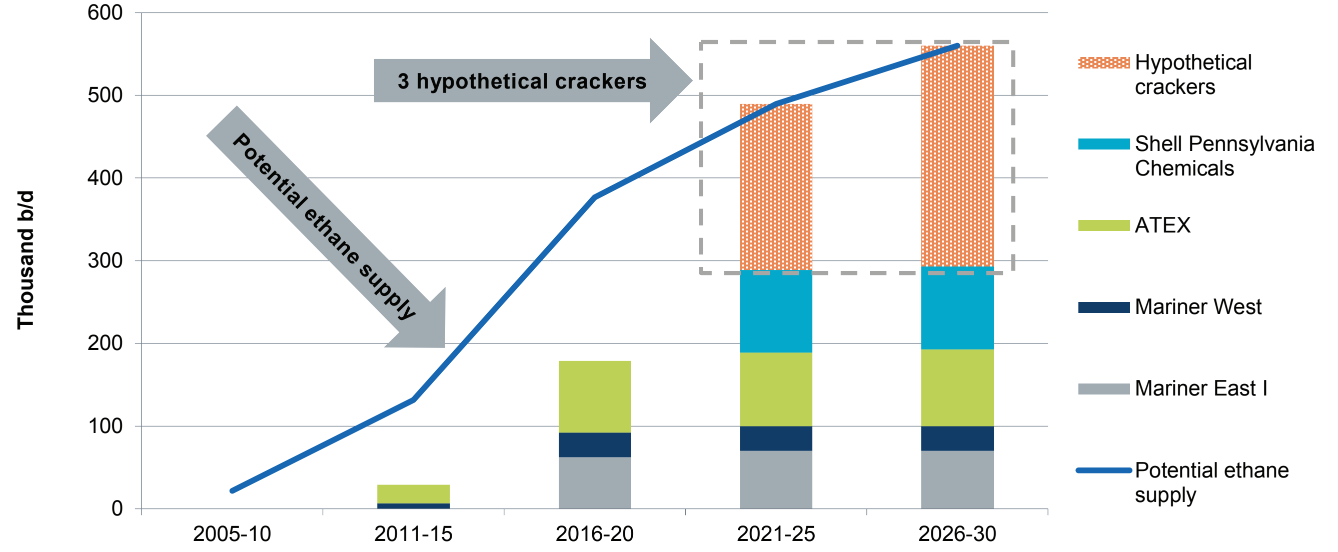
Based on estimates from IHS Markit, the amount of ethane that could potentially be recovered from natural gas production from Marcellus and Utica are around 560,000 b/d and 235,000 b/d, respectively, by 2026–30 (Figures 2.12 and 2.13).

During that period, the average forecast ethane demand from Marcellus and from Utica is estimated to be around 293,000 b/d and 128,000 b/d, respectively. This indicates additional ethane can be recovered to support hypothetical crackers.

Correspondingly, by 2026–30, an additional 267,000 b/d of ethane could be available for use as a petrochemical feedstock from Marcellus (Figure 2.12). IHS Markit estimates that approximately 90,000 b/d of ethane is required as a feedstock to produce 1.5 million metric ton per year of ethylene, therefore, the additional 267,000 b/d of ethane is equivalent amount of feedstock to support up to three additional world-scale ethane crackers.

Figure 2.12

Marcellus ethane – forecasted demand versus availability



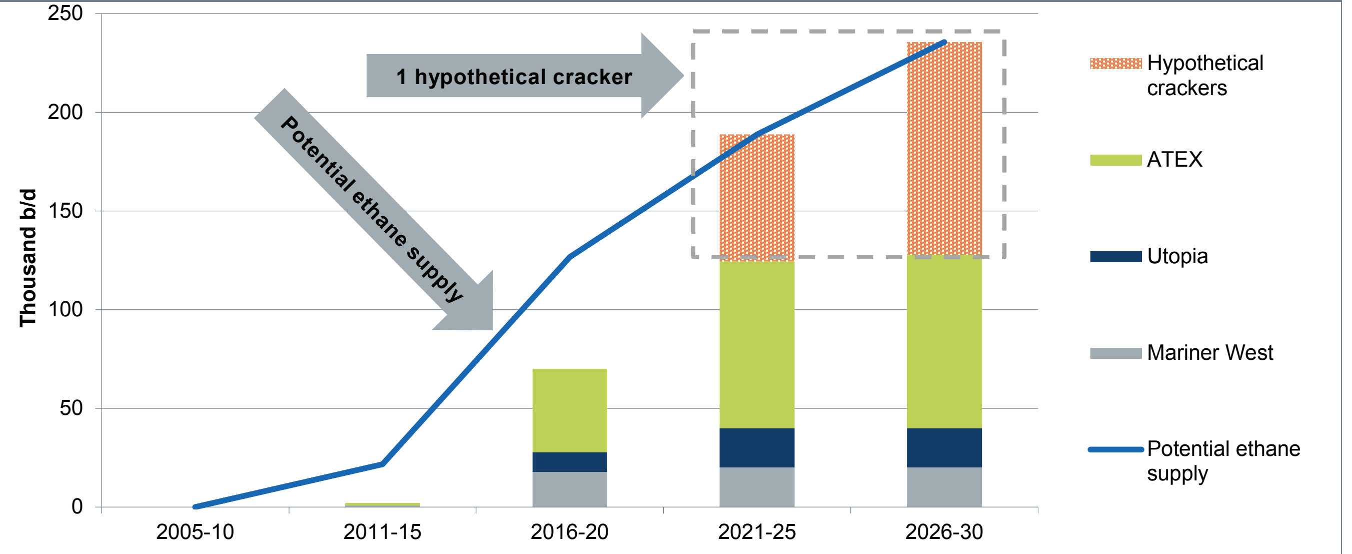
Note: Hypothetical crackers indicate the number of world-scale ethane crackers that could be supported by the additional available supply.
Source: IHS Markit

Similarly, between 2026 and 2030, an additional 107,000 b/d of ethane could be available for use as a petrochemical feedstock from Utica (Figure 2.13). The additional 107,000 b/d of ethane is equivalent amount of feedstock to support one world-scale ethane cracker.

In summary, total additional available supply of ethane from Marcellus and Utica could support up to four world-scale ethane crackers between 2026 and 2030.

Figure 2.13

Utica ethane – forecasted demand versus availability



Note: Hypothetical crackers indicate the number of world-scale ethane crackers that could be supported by the additional available supply.
Source: IHS Markit

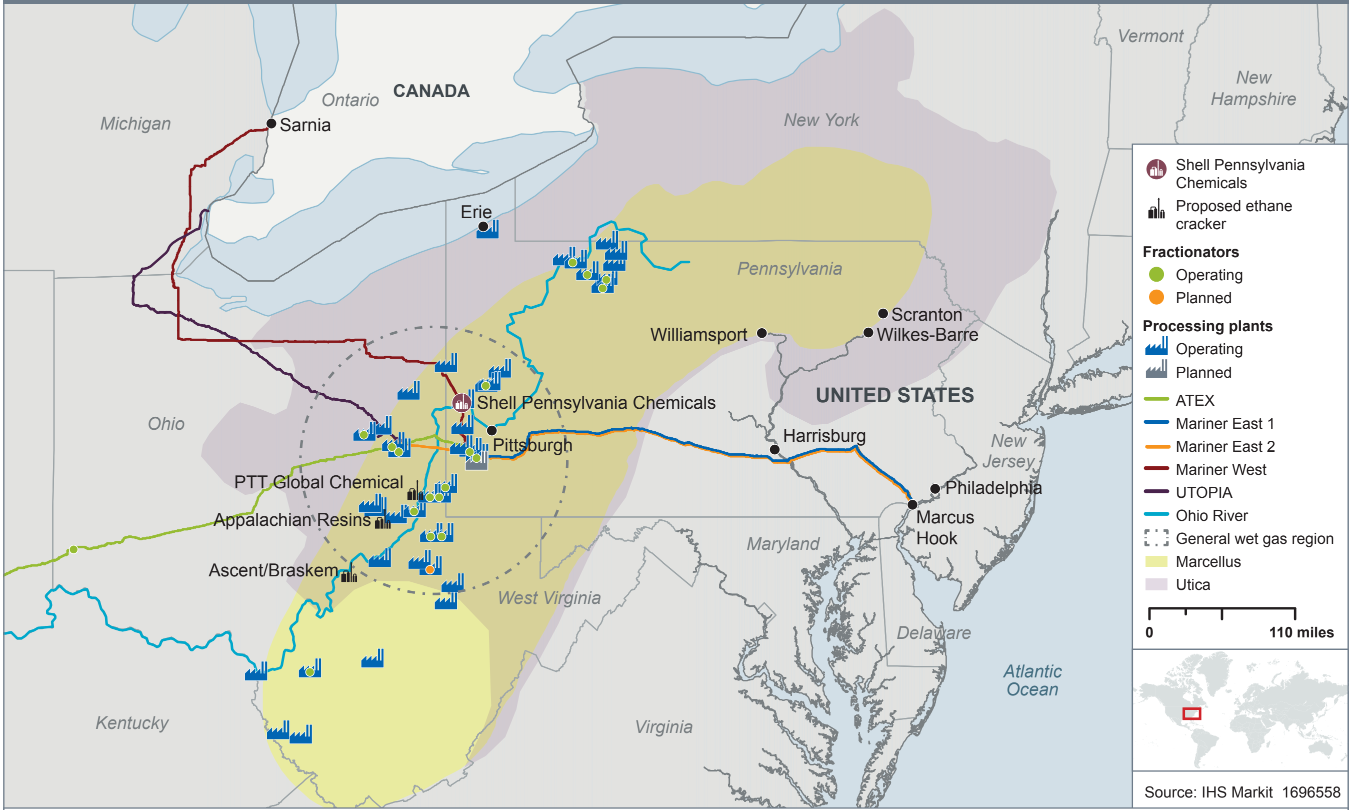
Marcellus and Utica NGL infrastructure

As natural gas production from Marcellus and Utica grows, new infrastructure will be required to move the hydrocarbons from producing regions to consuming regions. This section focuses on the need for additional natural gas processing capacity, NGL fractionation capacity, NGL pipeline capacity, and storage capacity (ethane and propane).

Based on views of upstream activity and NGL production from IHS Markit, additional midstream NGL infrastructure will be needed to support the forecasted demand. IHS Markit estimates incremental natural gas processing will be required, NGL pipelines, NGL fractionation (specifically de-ethanizer capacity), and ethane and propane storage will be required by 2020 to meet forecasted demand. Forecasted demand includes the startup and commissioning of Shell Pennsylvania Chemicals and does not include any of the hypothetical crackers. Figures 2.14 and 2.15 show NGL-related infrastructure in the Marcellus and Utica regions.

Figure 2.14

Marcellus and Utica NGL existing and planned infrastructure



Source: IHS Markit 1696558

Figure 2.15

Southwest Pennsylvania NGL existing and planned infrastructure

Source: IHS Markit 1696557

PADD I and Mont Belvieu NGL pricing

In the United States, NGL prices are generally tied, either directly or indirectly, to Mont Belvieu, Texas (near Houston and on the USGC)—the primary storage and fractionation center of the US NGL industry. The Mont Belvieu area has a highly-developed infrastructure for storage and movement of pipeline and waterborne NGL to and from a wide variety of locations. As a result, Mont Belvieu is an important market in which refining and petrochemical feedstock economics directly influence market-clearing prices for NGL. NGL prices in other markets such as Houston, Pennsylvania (Marcellus market center), Conway, Kansas (the Midwest market center), and the Louisiana Gulf Coast ("The River") are related directly to Mont Belvieu. Among the regional US NGL markets, NGL prices in the Los Angeles area are least strongly related to Mont Belvieu prices because of the lack of pipeline capacity to connect the markets.

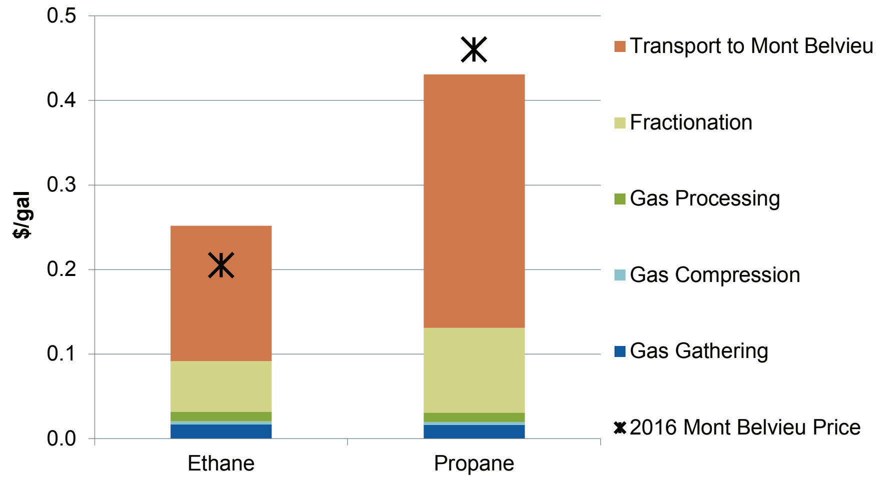
With the robust increase in natural gas production and related NGL production in the US East Coast, much attention has been focused on whether it can become a significant NGL hub. IHS Markit assumes that while the potential for new demand from additional ethane crackers and export terminals (such as Marcus Hook) exists in the Northeast, Mont Belvieu will continue to be the primary NGL hub over the long term as it will remain much larger on a volume basis in terms of supply, demand, pipeline, storage, and export infrastructure.

Marcellus ethane and propane cost

In order to assess the cost of producing ethane and propane from natural gas at the wellhead, an analysis of the midstream supply chain is required. In this assessment, ethane and propane costs from the Marcellus Shale gas producing area are compared to the realized price at Mont Belvieu, Texas for each of the products.

Figure 2.16

Cost of Marcellus sourced ethane and propane compared to 2016 Mont Belvieu price



Source: IHS Markit

The total midstream supply chain cost for ethane and propane in the Marcellus Shale assumes natural gas is produced and gathered, compressed, processed, and fractionated locally before being transported. Ethane production from Pennsylvania is transported via pipeline (the ATEX ethane pipeline) to Mont Belvieu, while propane is transported via rail to Mont Belvieu. The total 2016 midstream costs for ethane and propane in the Marcellus Shale are approximately $0.25 and $0.43 per gallon, respectively (Figure 2.16). The largest cost component for each product is transportation, which is approximately 65% and 70% of the cost for ethane and propane, respectively. The average 2016 Mont Belvieu price is was $0.21 per gallon for ethane and $0.47 per gallon for propane.

This analysis indicates that the overall cost of producing and transporting ethane from the Marcellus region to Mont Belvieu ($0.25 per gallon) is higher than the average 2016 realized price of ethane at Mont Belvieu ($0.21 per gallon). Consequently, this means that the Mont Belvieu ethane price will need to trade above $0.25 per gallon for upstream producers to realize a positive margin. Currently, US ethane supply is in excess of demand, and this is reflected in the cost comparison for ethane. In addition, there are no other major markets for ethane as a petrochemical feedstock other than the USGC, the Mont Belvieu market.

The situation is different for propane. The propane market price is higher than the supply chain costs, which implies a positive margin on recovering propane for sale. Propane costs to produce and deliver to Mont Belvieu are lower than the average 2016 realized price. Since there is no pipeline transporting propane and other higher hydrocarbons from Pennsylvania to Mont Belvieu, most of the production is being railed to the USGC (with a very small portion being trucked or barged locally and therefore excluded in the assessment), which has a substantial cost associated with it. As demand for ethane and propane in the USGC is expected to increase, Mont Belvieu prices are expected to rise as well, which would result in a higher netback for producers incentivizing higher recovery of ethane and propane from natural gas sourced from the Marcellus region.

Pricing outlook for ethane and propane

The IHS Markit price forecasts are based on careful evaluations of possible changes in market conditions. Key assumptions are described below, including possible consequences if markets do not develop as IHS Markit expects.

Crude oil price forecast

Crude oil prices are a key factor affecting NGL prices. The recent trough in crude oil prices emerged during the second half of 2014, reflecting a fundamental oversupply of crude oil. Brent and West Texas Intermediate (WTI) average annual crude oil prices troughed in 2016 at around $45 and $44/bbl, respectively. Brent is a blended crude stream produced in the North Sea region, which serves as a reference or "marker" for pricing a number of other crude streams. WTI is a crude stream produced in Texas and southern Oklahoma. It serves as a reference or "marker" for pricing a number of other crude streams and trades in the domestic spot market at Cushing, Oklahoma. IHS Markit forecasts a recovery in crude oil prices in 2017 and continuing for several years to follow.

A recovery period (2017–25) is expected where prices sustain an average level of approximately $75/bbl for Brent crude measured in constant 2015 US dollars (around $86/bbl nominal US dollars). The decline rate of existing traditional production and the development of new well production are the largest factors behind the expected price recovery. A large percentage of available resources cannot be sustainably developed below a median $75/bbl price threshold, even with an expected near term 15–20% cost reduction. An equilibrium level of $90/bbl on a 2015 constant dollar basis is expected to follow the muted mini-cycle reflecting the establishment of a long-term average price level necessary to incentivize upstream development.

Natural gas price forecast

Natural gas prices in the United States are very low because of the rapid development of tight oil and shale gas resources. The IHS Markit analyses show that these resources are very plentiful. If regulatory changes raise the cost of developing the resources, natural gas prices would increase along with ethane prices and gas-processing margins would be depressed. Northeast Hub prices (Appalachia, Dominion South Point, and TGP Z4 Marcellus) are expected to remain at a significant discount to Gulf Coast Henry Hub prices.[6]

Natural gas prices for the Northeast Hub prices are expected to trade below the US benchmark natural gas price, the Henry Hub price. IHS Markit estimates the 2016 annual average Henry Hub natural gas price was around $2.15/MMBtu while the Northeast Hub prices were approximately $0.60/MMBtu below this average price. The Henry Hub annual average natural gas price is expected to continue to rise, albeit slightly, over the next few years reaching around $4.70/MMBtu (nominal US dollars). The Northeast Hub annual average price will reflect the increasing supplies from Marcellus and Utica and will therefore stay below the Henry Hub price by around $0.60/MMBtu.

NGL price forecast

Over the next 15 years, all Mont Belvieu NGL prices are expected to rise as expansions of export terminal capacities and new petrochemical crackers help shrink the ethane and LPG (liquefied petroleum gases—typically propane and butanes) surplus. Annual average ethane prices are expected to rise from around 21 cents per gallon (cpg, nominal US dollars) in 2016 to approximately 85 cpg in 2030 while annual average propane prices are expected to rise from around 48 cpg to approximately 156 cpg by 2020. Moreover, domestic crude prices (WTI) are expected to strengthen over the long term approaching $117/bbl (nominal US dollars) in 2030.

PADD I and Mont Belvieu ethane pricing

Historically, the United States has been the largest consumer of ethane in the world. The ethylene industry on the USGC was structured to consume large quantities of light feedstocks including ethane and propane. These light feedstocks have been readily available because of the large refining base and the proximity to oil and gas production. Further, the USGC has access to large amounts of relatively

6 Natural gas hubs are physical trading points typically at the intersection of several transportation options linking production to consumers. Prices at these hubs represent benchmark prices at particular points in time at that location.

inexpensive underground storage in the form of salt dome wells, which make it convenient to store large quantities of ethane and other NGL to accommodate the seasonality of NGL demand compared to relatively consistent production. The USGC's proximity to NGL infrastructure makes it a desired location for ethane export terminals. For example, Enterprise Products Partners recently commissioned a 200,000 barrel per day terminal along the Houston ship channel.

After the USGC, IHS Markit expects the US Northeast to see a significant increase in activity in the ethane market. With strong future supply growth expected in the region over the next decade, much focus has been placed on new demand infrastructure including new ethylene crackers, such as the Shell Pennsylvania Chemicals, and export terminals, such as the Marcus Hook, Pennsylvania export terminal.

The future price and supply of US ethane is intrinsically linked to the natural gas market. In developing the ethane price forecast, IHS Markit considered the following factors: natural gas prices, the volume and composition of natural gas production, natural gas fractionation costs, and NGL transportation costs.

Ethane prices fell sharply in late 2014 because of downward pressure from propane prices and increases in ethane supply, and remained depressed through 2015 to near parity with the heating value of natural gas. The Mont Belvieu annual average ethane price for 2016 was around 21 cpg. However, rising demand because of new ethane-based ethylene capacity in 2016–20, as well as new ethane export capacity, will result in a recovery of ethane prices. Average annual ethane prices are expected to rise over the next few years as demand for ethane increases as a petrochemical feedstock thereby increasing from around 21 cpg in 2016 to more than 42 cpg in 2020.

Post 2020, incremental ethane demand is expected to take advantage of available ethane supply, which will lead to ethane prices remaining favorable for ethane consumers. Ethane prices are expected to reach near propane parity on a petrochemical feedstock cash cost basis. IHS Markit expects PADD I ethane prices to remain below Mont Belvieu prices during the forecast period.

Currently, ethane price in PADD I is depressed, at or above the heating value of natural gas. As prices increase in Mont Belvieu, IHS Markit anticipates ethane prices in PADD I to follow and rise above their heating value. The US Northeast and PADD I ethane price is related to the pipeline transportation cost from the region to the USGC. Thus, over the long term, IHS foresees PADD I ethane price to be discounted to the Mont Belvieu ethane price by as much as 16 cpg and perhaps even higher based on our view of supply, demand, availability, and the cost of transportation.

PADD I and Mont Belvieu propane pricing

Propane is an extremely versatile NGL that is used extensively in the United States as an ethylene plant feedstock. Propane competes with ethane, butane, and naphtha (including natural gasoline and condensate) in flexible olefin plants. Historically, the relationship between propane and naphtha feedstock economics was a key variable in analyzing and projecting future profitability and price levels. However, with the rise in importance of ethane cracking and the decline in naphtha cracking on the USGC, this situation has significantly changed.

Ethane cracking economics are expected to be an important driver in future propane price relationships. On an average annual basis, spot propane prices were generally at or below ethane breakeven values during the early twenty-first century. During this period, ethane was generally a high-cost ethylene plant feedstock and propane was in closer competition with naphtha. However, propane prices have generally been above ethane breakeven values since 2007 and this situation is expected to continue. The differential between the propane/ethane price ratio and breakeven ratio is expected to stay somewhat high over the next few years and then narrow as more ethane-based ethylene plant capacity is brought online after 2016.

Over the long term, IHS Markit expects PADD I propane prices to be discounted to the Mont Belvieu propane price by as much as 30 cpg and remain at this level. The IHS Markit estimate of the 2016 annual average Mont Belvieu propane price is around 47 cpg and is expected to rise to 156 cpg by 2030 (nominal US dollars). Numerous major infrastructure players are currently evaluating projects to reverse existing product pipelines to allow NGL to move from PADD I to other PADD regions. If this were to occur, then the discount to Mont Belvieu reflected in the price forecast would narrow, as transportation costs for pipelines are lower than rail in the range of 10 to 12 cpg.

Given the robust outlook for natural gas and NGL production in the Marcellus and Utica Shale plays and the discounted prices for ethane and propane in the region, the question arises whether there are opportunities to use these resources to manufacture value-added products in Pennsylvania. In the next chapter, IHS Markit describes how the petrochemical industry can use ethane and propane to produce valuable basic chemicals that can subsequently convert into a wide range of plastic products.

Chapter 3: Viability of natural gas liquids (NGL)-based petrochemical investments in Pennsylvania

Key takeaways

- The first large-scale, NGL-based petrochemical investment in Pennsylvania will be the Shell Pennsylvania Chemicals ethane cracker in Southwestern Pennsylvania. It is slated to be a world-scale, ethane-fed cracker that will produce 1.5 million metric tons (MT) per year of ethylene, which will be converted to over 1.0 million MT per year of high-density polyethylene (HDPE) and 550,000 MT per year of linear low-density polyethylene (LLDPE). HDPE and LLDPE are two of the fastest growing and largest volume plastic resins globally.

  - IHS Markit forecasts this project to be completed by 2021–22 despite the significant feedstock and transportation infrastructure required to meet the project's needs, beyond that which is normally incurred in a comparable USGC facility.

- IHS Markit estimates 73% of US and Canadian polyethylene (PE) demand and 67% of polypropylene (PP) demand to fall within a 700-mile radius of Southwestern Pennsylvania (the target region). These percentages are well above relative capacities to meet the demand within the target region, meaning that producers within this region will enjoy a location advantage over suppliers outside the region.

  - Regional polyolefin producers like Shell will be well positioned to capture a respectable share of this domestic demand because of its shorter lead times. Established resin producers that may have several plants in North America and can service broader customer needs will likely challenge Shell and any new entrants to the resin market.

- Despite higher capital and developmental costs than a comparable USGC plant, Southwestern Pennsylvania's PE and PP production is forecast to be highly competitive on a cash cost basis relative to existing production centers such as the USGC; Alberta, Canada; Sarnia, Canada; and the Middle East.

  - This cost advantage is driven mainly by: 1) significantly lower ethane and propane prices (the main chemical feedstocks), and 2) the proximity to major North American demand centers, which will yield freight cost advantages relative to supplies from other competitive regions.

  - Pennsylvania and the US Northeast already have a significant installed base of plastics manufacturing and converter capacity. A new regional source of PE and PP in this target region may spur additional growth because of the new, low-cost local supply. As with any new entrant to a market, Shell and other potential crackers will likely take price concessions and/or temporary allowances to gain regional market share up to the point at which exports are equally viable.

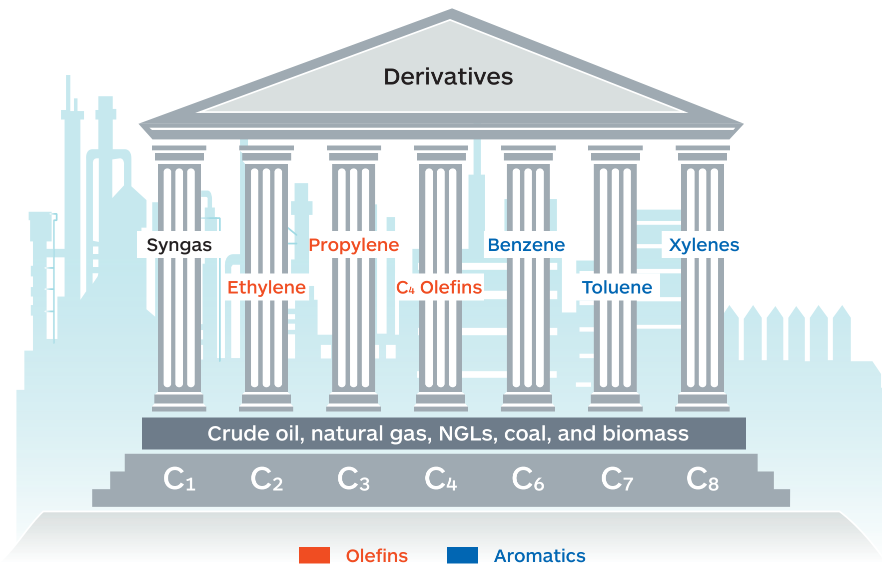
- Because of the rapid increase in capacity for PE and PP in North America, highly-competitive PE or PP production in Southwestern Pennsylvania may directly and indirectly lead to an increase in exports by less competitive producers. Exports will remain an essential component to all resin producers' offtake strategies such that netback margins from all potential sales are maximized.

- As a competing olefin plant feedstock, propane prices are forecast to remain above ethane breakeven prices as outlined in Chapter 2. Therefore, steam cracker projects have focused more on ethane as their primary feedstock. In addition, propane's potential as a large-volume chemical feedstock is further reduced thanks to: 1) growing propane export volumes, 2) demand in the heating fuel market, and 3) higher capital expenditure (Capex) requirements for propane dehydrogenation—another commercially viable, propane-consuming chemical process.

Petrochemical industry structure

Figure 3.1

Seven petrochemical building blocks



Source: IHS Markit

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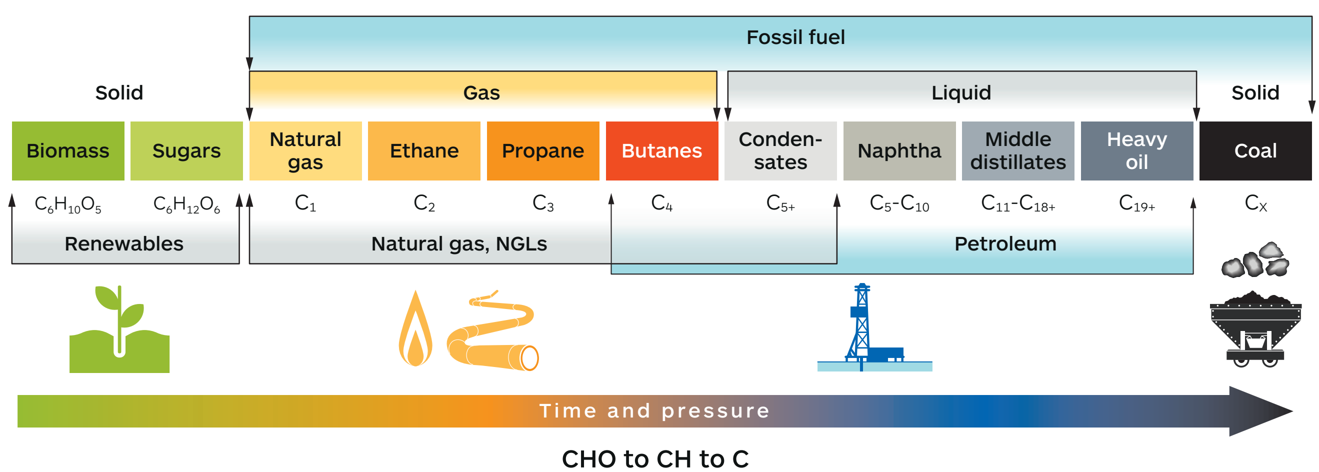
The chemical industry uses science and technology to transform raw materials into the myriad of products that we use every day. The structure of the industry can be depicted by defining the basic chemical "value chains" and the products, companies, and business lines that are involved in each value chain. A simple way to conceptualize these chemical value chains is to examine the feedstock that underpins the chemical products produced, as shown in Figure 3.1. The feedstock "foundation" depicted in the figure comprises natural gas, NGL, and crude oil components. The pillars represent the key intermediates in each major value chain, often also referred to as chemical "building blocks." These key intermediates are then converted to a large number of derivatives, including PE and PP, through numerous chemical transformations and combinations.

In this depiction, there are seven basic chemical value chains and an increasing number of carbon atoms in the feedstock characterizes each chain. The ultimate sources of the individual feedstocks are crude oil, natural gas, NGL, coal, and biomass. For the purposes of this discussion, IHS Markit focuses on the C_2 and C_3 value chains.

- The C_2 value chain is based on ethylene as the key intermediate olefin. Large-volume derivative products along this value chain are high-density PE and ethylene glycol.
- The C_3 value chain is based on propylene as the key intermediate olefin. Large-volume derivative products along this value chain are PP and propylene oxide.
- The feedstock choices available to the chemicals industry can be thought of in terms of increasing carbon numbers and arranged in the form of a palette (Figure 3.2, corresponding with the "foundation" of Figure 3.1).

Figure 3.2

Petrochemical feedstock palette



Source: IHS Markit

The major locally-sourced NGL that will provide value-added petrochemical manufacturing opportunities for Pennsylvania are ethane (C_2) and propane (C_3). The major intermediate chemical of the C_2 (ethane) value chain is ethylene, a large volume commodity chemical that is used to produce numerous derivative products. The single largest family of derivatives is PE. This group of plastic resins includes low-density polyethylene (LDPE), linear LLDPE, and HDPE. For example, the Shell Pennsylvania Chemicals ethane cracker in Southwestern Pennsylvania is an example of a project that is designed to create value-added products along the ethane value chain, consuming ethane via steam cracking to produce ethylene and subsequently produce PE.

The C_3 (propane) value chain is based on propylene as the key intermediate. Propylene has numerous derivative products and the single largest derivative is PP, a versatile plastic. PP currently is in short supply in North America and producers are scrambling to debottleneck existing capacity and are exploring options to expand capacity.

Background on the Shell Pennsylvania Chemicals ethane cracker in Southwestern Pennsylvania

The first large-scale, NGL-based petrochemical investment in Pennsylvania will be the Shell Pennsylvania Chemicals ethane cracker in Southwestern Pennsylvania. It is slated to be a world-scale, ethane-fed cracker that will produce 1.5 million MT per year of ethylene, which will be converted to over 1.0 million MT per year of HDPE and 550,000 MT per year of LLDPE. HDPE and LLDPE are two of the fastest growing and largest volume plastic resins globally. IHS Markit forecasts this project to be completed by 2021–22 despite the significant feedstock and transportation infrastructure required to meet the project's needs, beyond that which is normally incurred in a comparable USGC facility.

Regional ethylene and propylene market

There have been a significant number of ethylene expansions and new capacity announcements over the past few years. Some announcements have come from existing producers and others have come from producers new to North America seeking to take advantage of the low-cost, shale-based ethane feedstock that will give North America the second-lowest ethylene cash production cost behind only the Middle East.

To date, companies are planning to build over 13 million MT of additional ethylene capacity by 2022, and over 2.6 million MT of propylene capacity. Even with the large amount of already announced capacity additions, it is expected that there still may be an additional one or two projects announced during the upcoming years.

Regional propylene market

The major petrochemical intermediate in the C_3 value chain is propylene. Propylene has numerous derivative products and the single largest derivative is PP, a versatile large volume plastic. Although the propylene produced from olefins plants and fluid catalytic cracking (FCC) units is typically considered a coproduct in the process to make the more important primary products of ethylene and motor gasoline, propylene is also commercially produced "on purpose" by the catalytic dehydrogenation of propane (also known as "propane dehydrogenation" or PDH) or by the catalytic disproportionation of ethylene and butene (also known as metathesis).[7]

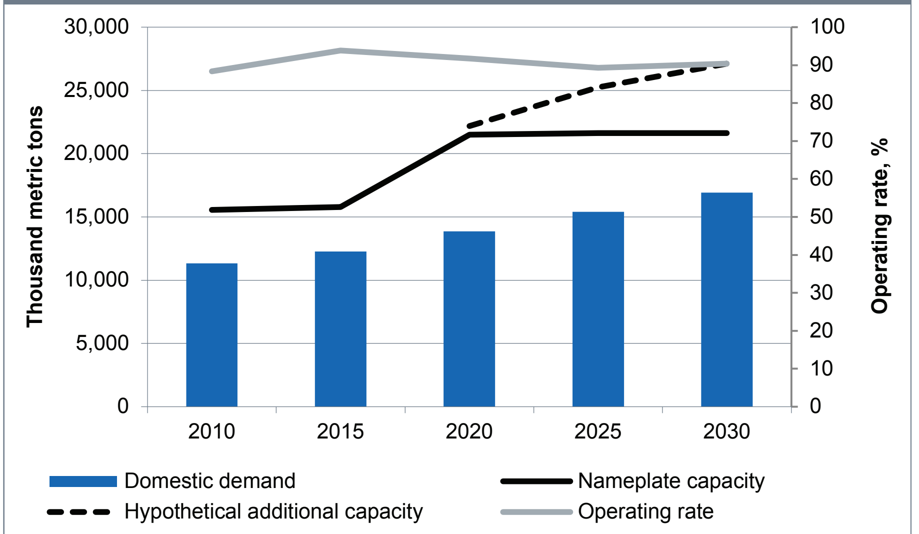
Shale-based propane from the Marcellus Shale could be used on-site in a PDH plant to make propylene for the merchant market. However, PDH plants are generally expensive to build and operate, often requiring extremely inexpensive propane among other extraordinarily favorable project characteristics.

Supply and demand forecast for key downstream PE and PP applications

PE and PP (collectively referred to as polyolefins), the large volume derivatives in the C_2 and C_3 value chains, are experiencing robust supply growth in North America. The following two graphs (Figures 3.3 and 3.4) illustrate the domestic demand, operating rate, and nameplate capacity for PE and PP in the United States.

Figure 3.3

Polyethylene supply and demand: United States



Source: IHS Markit © 2017 IHS Markit

For PE, IHS Markit anticipates that new capacity additions will outstrip US demand growth over the forecast horizon as depicted in the supply/demand balance shown in Figure 3.3. This will lead to major increases in PE exports, and if non-confirmed new projects (shown as hypothetical) are also built, the overcapacity will be even more dramatic.

IHS Markit estimates 73% of US and Canadian PE demand and 67% of PP demand to fall within a 700-mile radius of Southwestern Pennsylvania (the target region). These percentages are well above relative capacities to meet the demand within the target region, meaning that producers within this region will enjoy a location advantage over suppliers outside the region.

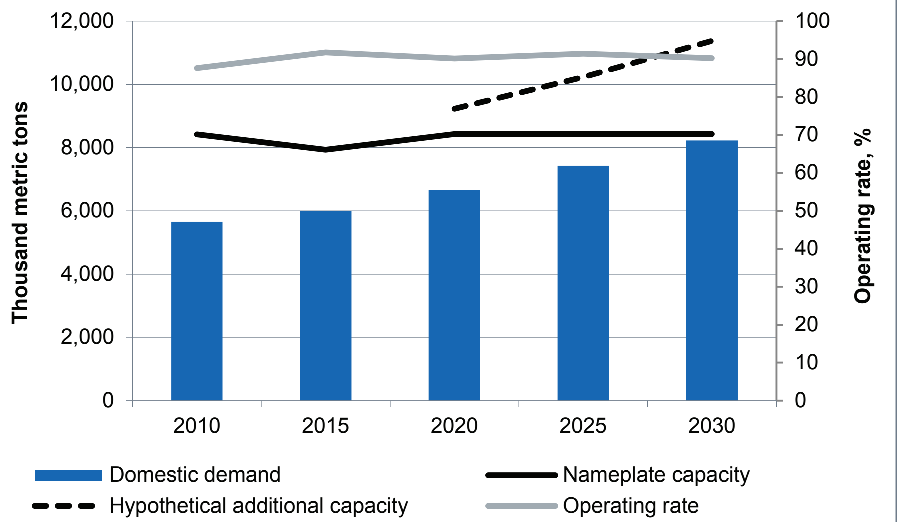
7 Fluid catalytic cracking, or FCC units, are important conversion processes in a refinery.

Regional polyolefin producers like Shell will be well positioned to capture a respectable share of this domestic demand because of its shorter lead times. However, established resin producers that may have several plants in North America and can service broader customer needs will likely challenge Shell and any new entrants to the resin market.

US PE exports are expected to rise from 34% of production to 41% by 2020, with most of this exported from the USGC production hub. Because of the low-cost position of US PE producers, exports to higher-cost regions such as Northeast Asia and Western Europe will be very competitive, leading some producers to build new plants primarily to serve export markets.

Figure 3.4

Polypropylene supply and demand: United States



Source: IHS Markit © 2017 IHS Markit

For PP, the story is currently very different. US PP supply is very constrained, as is overall North American supply, resulting in rising imports from countries like Brazil and Saudi Arabia. Most US producers are currently scrambling to alleviate the existing PP bottleneck (which the following graph illustrates as demand approaches firm nameplate capacity) by restarting idled units (Figure 3.4).

The only new PP capacity additions forecast by IHS Markit are Braskem and Formosa Plastics on the USGC; these plants are expected to come online in 2019 at the earliest. With new capacity centered on the USGC, new potential PP capacity in the Midwestern or Northeastern United States would be at a strong advantage logistically to serve the large demand centers in its vicinity. However, capital and developmental costs, and thus project economics, remain as riskier opportunities over ethane and propane steam crackers.

PE and PP demand segment outlooks

Each of the three types of PE resins (HD, LLD, and LD) and PP resin have different physical properties, and therefore different end uses. These end uses can be characterized by the way the resin is processed:

- Film and sheet applications, such as shrink wrap and stretch film
- Injection molding applications, such as food containers and plastic lids
- Extrusion coating applications, such as lamination film, aseptic cartons, and stand-up pouches
- Blow molding applications, such as plastic milk jugs and containers for household and industrial chemicals
- Wire and cable applications, such as the jacketing material for wire used in data transmission, electronic circuits, and Ethernet connections
- Rotomolding (or rotational molding) applications, such as rotomolded fuel tanks and impact resistant containers.

These products are sold directly to customers and to third parties, such as resin compounders and distributor/reseller partners. Within those key direct sales markets, there are multiple sub-segment applications, which is why major PE and PP producers often have hundreds of different resin grades to satisfy all their respective end use market requirements.

Because of the rapid increase in polyolefin capacity in North America, highly competitive PE or PP production in Southwestern Pennsylvania may directly and indirectly lead to an increase in exports by less competitive producers. Exports will remain an essential component to all resin producers' offtake strategies such that netback margins from all potential sales are maximized.

Cost competitiveness of Marcellus-based ethylene/propylene and PE/PP plants

Despite higher capital and developmental costs than a comparable USGC plant, Southwestern Pennsylvania polyolefin production is forecast to be highly competitive on a cash cost basis relative to existing production centers such as the USGC; Alberta, Canada; Sarnia, Canada; and the Middle East.

This cost advantage is driven mainly by: 1) significantly lower ethane and propane prices (the main chemical feedstocks), and 2) the proximity to major North American demand centers, which will yield freight cost advantages relative to supplies from other competitive regions.

Pennsylvania and the Northeast already have a significant installed base of plastics manufacturing and converter capacity. A new regional source of PE and PP in this target region may spur additional growth because of the new, low-cost local supply. As with any new entrant to a market, Shell and other potential crackers will likely take price concessions and/or temporary allowances to gain regional market share up to the point at which exports are equally viable.

IHS Markit estimated the cost of producing ethylene and PE for an ethane cracker with 1.5 million MT of ethylene capacity, along with integrated PE units located in Southwestern Pennsylvania. IHS Markit performed a similar analysis for propylene and PP where it assumed integrated PDH and PP units that are typical in scale of new plants regionally and worldwide.

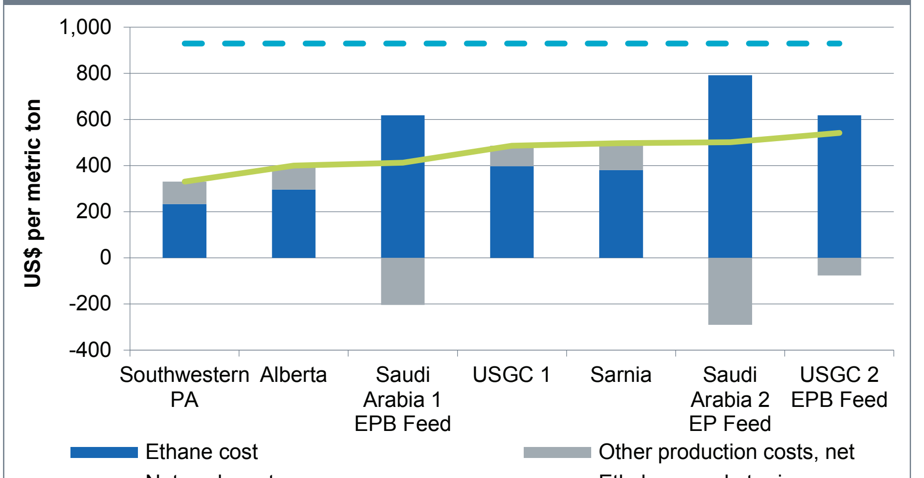
HDPE cost competitiveness

Figure 3.5 displays ethylene cash costs for a typical, integrated ethylene and HDPE producer. With low-cost NGL for both North America and the Middle East expected to remain over the forecast period, both regions are expected to remain competitive in all PE demand centers globally. In particular, Southwestern Pennsylvania having NGL costs well below national prices puts it at an advantage in serving nearby demand centers.

A Southwestern Pennsylvania facility similar in nature to the Shell Pennsylvania Chemicals plant is expected to be highly competitive on a cash cost

Figure 3.5

Estimated ethylene cash cost competitiveness in 2020



Notes: Selected producers all have integrated PE capacity on-site.
Price shown is North American ethylene net transaction pipeline delivered.
Source: IHS Markit

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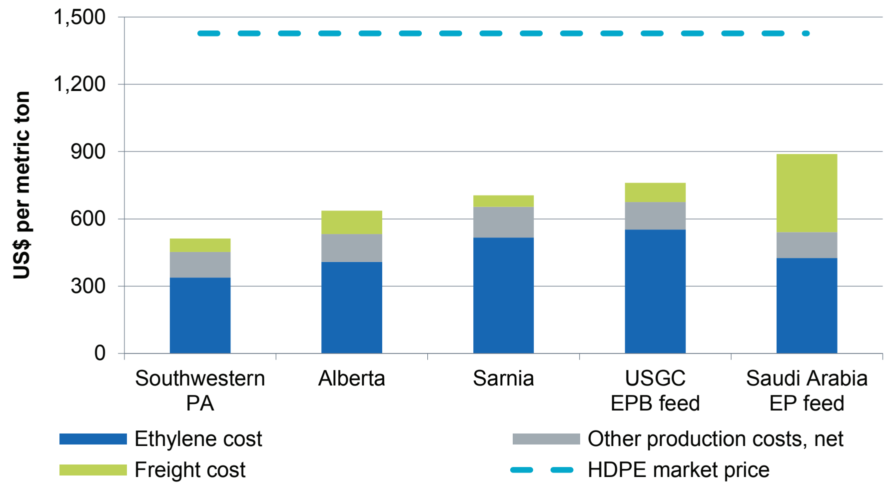
basis relative to producers in other regions competing for customers in the US Northeast and Midwest markets. Southwestern Pennsylvania's inexpensive ethylene production, based upon access to low-cost ethane in the region, is the primary driver behind its competitiveness. Considering the maturity of the PE market and technologies, small cost savings are unlikely to be realized other than feedstock costs at the plant gate (i.e., variable and fixed costs are similar in magnitude).

Figure 3.6 and Figure 3.7 illustrate the delivered cash cost from five major HDPE-producing regions to major US HDPE markets: the US East Coast and the US Midwest. Among these five competing regions, Southwestern Pennsylvania is the most competitive HDPE-producing region, considering it has the lowest feedstock costs and freight costs because of its locational advantage, both of which a regional producer may exploit to gain a foothold within the nearby markets.

Figure 3.6

Estimated HDPE delivered cash cost in 2020: US Midwest



Notes: Feedstock cost is the integrated ethylene cash cost.
PE price shown is North American HDPE domestic market contract delivered.
Source: IHS Markit

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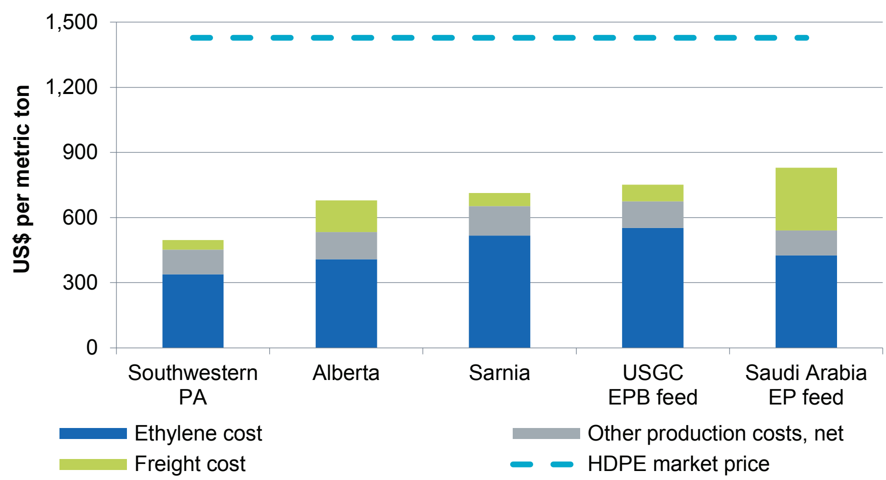
Figure 3.7

Estimated HDPE delivered cash cost in 2020: US East Coast



Notes: Feedstock cost is the integrated ethylene cash cost.
PE price shown is North American HDPE domestic market contract delivered.
Source: IHS Markit

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Southwestern Pennsylvania is expected to have a large cash cost advantage in the US Midwest as well as the US Northeast, adding to its benefit of its low cash cost of production. Alberta is the region with the next lowest delivered cash cost, which is estimated to be $132/MT and $192/MT above the delivered cash cost of Southwestern Pennsylvania to the Midwest and Northeast, respectively. These cost differences translate to sizable delivered cash cost advantages for Southwestern Pennsylvania over Alberta, which were 37% and 24% in the US Northeast and Midwest HDPE markets, respectively.

Because of its favorable feedstock cost position, HDPE producers in Southwestern Pennsylvania will also be a more cost competitive HDPE-producing region than both the USGC and Canada in serving global customers in high-cost regions such as Northeast Asia and Western Europe. Even before the first ethylene cracker in Southwestern Pennsylvania becomes operational, IHS Markit forecasts US HDPE export growth of nearly 10% between 2015 and 2020. Considering Southwestern Pennsylvania's strong cash cost position post-2020, IHS Markit believes that a regional, integrated HDPE facility can compete well in both domestic and overseas markets during 2020–30. As such, HDPE producers will seek customers that will yield the highest netback returns.

PP cost competitiveness

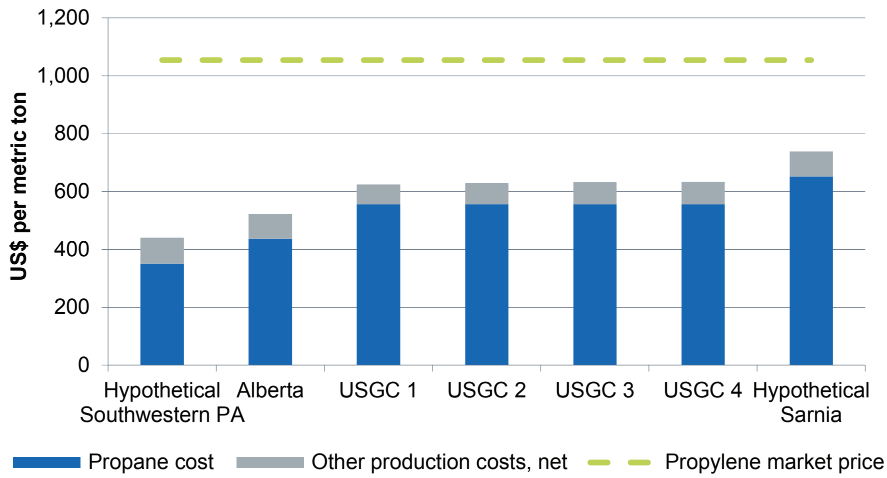
As a competing olefin plant feedstock, propane prices are forecast to remain above ethane breakeven prices. Therefore, steam cracker projects have focused more on ethane as their primary feedstock. In addition, propane's potential as a large-volume chemical feedstock is further reduced thanks to: 1) growing propane export volumes, 2) demand in the heating fuel market, and 3) higher Capex requirements for propane dehydrogenation—another commercially viable, propane-consuming chemical process.

A PDH unit producing propylene can be integrated with PP to convert ultimately propane (NGL) to PP resin. A PDH facility in Southwestern Pennsylvania would have a distinct cash cost advantage over other producing regions, given the forecast of inexpensive propane feedstock (Figure 3.8). Alberta would be the next most competitive region, with cash costs at $85/MT above that of Southwestern Pennsylvania. The cash cost of the four USGC producers are higher than Alberta and all fall within a narrow range of less than $10/MT, which illustrates how consistent costs can be in an area of high petrochemical development. Sarnia is expected to be the least competitive producing region in North America, with its disadvantage lying mainly in the area's high propane feedstock prices.

Similar to HDPE, about 67% of the North American PP market demand lies within 700 miles of Pittsburgh, Pennsylvania. As such, both the US Midwest and Northeast were again assumed as potential PP customer offtake locations (Figure 3.9 illustrates US Midwest competitiveness and Figure 3.10 illustrates US East Coast competitiveness). Since both resins are shipped in pellet form, the freight costs for both resins will be similar (i.e., the locational advantage remains for Southwestern

Figure 3.8

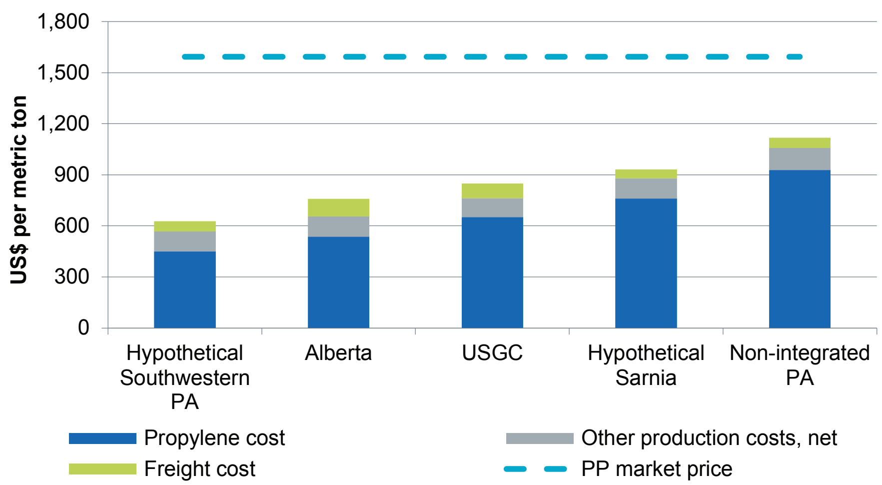
Estimated PDH cash cost competitiveness in 2020



Notes: The two hypothetical plants assumed 500 kMT propylene capacity.
Propylene price shown is North American contract benchmark delivered.
Source: IHS Markit

Figure 3.9

Estimated polypropylene delivered cash cost in 2020: US Midwest

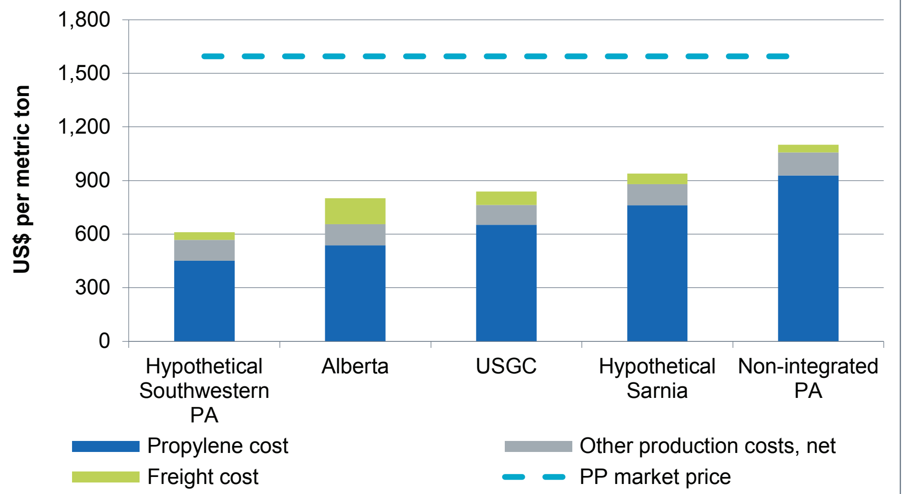


Notes: The two hypothetical plants assumed 400 kMT PP capacity.
PP price shown is North American domestic market contract delivered.
Source: IHS Markit

Pennsylvania in this scenario). Therefore, the locational advantage for a Southwestern Pennsylvania hypothetical PP plant integrated with a PDH unit should expect the lowest delivered cash costs in North America given its strong NGL feedstock price advantage.

Figure 3.10

Estimated polypropylene delivered cash cost in 2020: US East Coast



Notes: The two hypothetical plants assumed 400 kMT PP capacity.
PP price shown is North American domestic market contract delivered.
Source: IHS Markit

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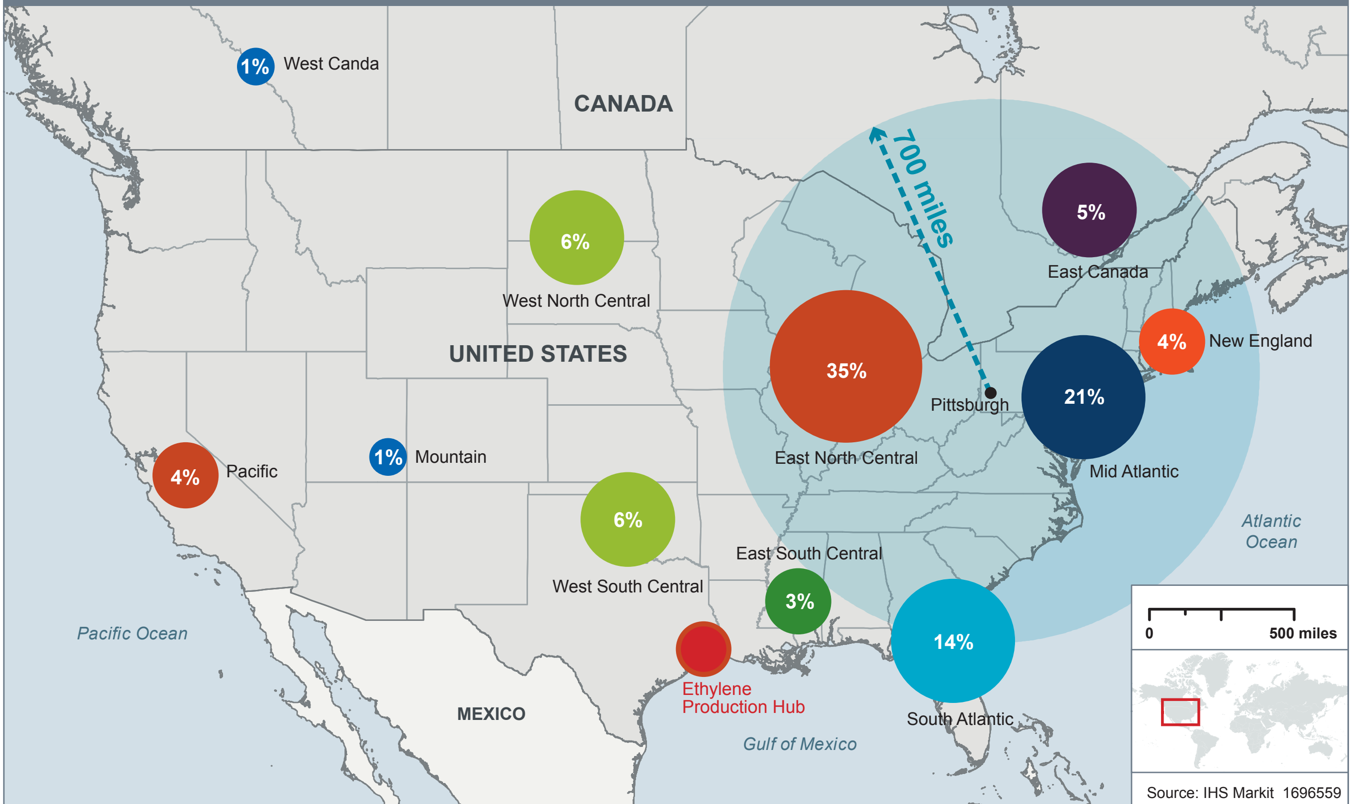
Advantages for PE or PP resin buyers sourcing from a Pennsylvania producer

For PE and PP, the production hub in the United States is the USGC, where the rail systems can serve the domestic North American markets and the local ports can handle the large volume of exported resin. A PE or PP producer in Southwestern Pennsylvania starts with two main advantages: it can purchase relatively low-cost ethane and it is in close proximity to the highly-concentrated customer base. As shown in the example for PE (Figure 3.11), an estimated 73% and 67% of PE and PP demand, respectively, in the United States is inside that radius.

Figure 3.11

Regional polyethylene consumption in the United States and Canada (by volume)



Source: IHS Markit 1696559

IHS Markit expects these advantages to remain unchanged over the forecast horizon. This proximity to a concentrated customer base means that a local resin producer would have two additional key offtake advantages:

- **Lower bulk rail freight costs to the concentrated customer base:** Over 90% of PE and PP resin in the United States and Canada is moved in 200,000-pound bulk rail cars. The average freight rate per pound for PE and PP resin in the United States is approximately 3–5 cents per pound. This cost is included in the delivered market price to customers. Therefore, a producer whose shipping costs exceed the 3 ¾ cent per pound range will be absorbing the overage.

Shorter delivery time to these target customers: Average delivery time to a nearby resin customer can be a week or less for a regional resin producer, and could take three weeks or more for a bulk rail car to arrive from the USGC.

- Shorter delivery times have two key advantages:
  - For resin producers, more rail car turns per year. Quicker car returns provide the producer with greater use of its rail fleet, which can provide a significant financial advantage.
  - For resin customers, shorter order lead time can result in lower inventory holding costs when a car can be delivered within a week of order placement.

Summary of downstream plastic manufacturing opportunities

Pennsylvania is uniquely well positioned to tap into an ample and growing supply of low-cost hydrocarbon feedstocks coming from the Marcellus and Utica Shale gas developments. The feedstocks do not need to be transferred to other regional centers—they can be converted nearby into value-added petrochemical building blocks (e.g. ethylene and propylene) and then further transformed into polyolefin resins (e.g. HDPE and LLDPE) as evidenced by the proposed Shell ethane cracker. Further value can be created by plastic manufacturers converting the resins into a wide variety of plastics products and shapes such as film, containers, housewares, and bottles. In summary, Southwestern Pennsylvania PE and PP producers are expected to have significant competitive advantages serving plastics manufacturing customers within the target radius.

- The production costs of PE and PP resin at the plant gate compares favorably to competitors in other regions because of their access to low-cost feedstocks.
- Demand for PE and PP resin within the target region greatly exceeds the available supply from producers within the region, even after the Shell plant begins operations. Thus, customers within the region will need to purchase resin from suppliers on the USGC, Western Canada, or even more distant suppliers.
- There is a large and concentrated installed base of plastics consumers within the target region.
- PE and PP producers in Southwestern Pennsylvania will incur lower bulk rail freight costs by supplying resin to customers in close proximity to the plant.

For a PE or PP resin producer, shorter delivery time to these target customers will provide additional financial and non-financial benefits through a more efficient use of the transportation fleet and lower inventory holding costs. For a PE or PP resin purchaser, quicker delivery times translate into lower inventory costs.

Chapter 4: Economic development opportunities beyond Shell Pennsylvania Chemicals

Key takeaways

- Pennsylvania currently has a sufficient supply of NGL to support a world-class petrochemical industry. Its major competitive advantage is access to an expanding supply of low-cost natural gas and NGL (particularly ethane and propane) capable of supplying up to four additional world-scale, integrated ethane crackers similar in size to Shell Pennsylvania Chemicals.

- Pennsylvania has a significant locational advantage. For instance, 73% of US and Canadian PE demand and 67% of PP demand is located within 700 miles of Southwestern Pennsylvania.

- The cost of doing business for manufacturing operations in Southwestern Pennsylvania is comparable to those across the Marcellus and Utica Shale basins, also to those in the petrochemical complex along the US Gulf Coast.

- IHS Markit notes that while Pennsylvania consumers are currently using a portion of the available Marcellus Shale natural gas, 100% of ethane produced and recovered as a petrochemical feedstock is currently (Winter 2017) being shipped out of the Commonwealth to other end use markets.

- Pennsylvania already has a large installed base of plastics manufacturing plants available to purchase some of the output of Shell Pennsylvania Chemicals.

- While Pennsylvania has current and emerging competitive advantages for the petrochemicals production, it must begin taking immediate steps to maximize the long-term economic development benefits as other states and US regions are also competing for NGL.

Developing a roadmap for the petrochemical and plastics value chains in Pennsylvania

The economic development opportunity around natural gas and NGL in Pennsylvania has arisen quickly over the last 10 years. Drilling and production activity began to accelerate quickly in 2008, so that by 2014, Pennsylvania ranked second among the 50 states based on the amount of natural gas produced. The abundance of "wet" natural gas in the western part of the Marcellus region meant that the production of NGL also began to grow rapidly. Because of the high demand for the natural gas and NGL and their competitive prices, the market responded and firms began building infrastructure to process and deliver the natural gas and NGL to markets elsewhere in the United States, Canada, and even international markets (i.e., ethane is now being shipped regularly out of Marcus Hook to Northern Europe).

IHS Markit notes that while Pennsylvania consumers are currently using a portion of the available Marcellus Shale natural gas, 100% of ethane produced and recovered as a petrochemical feedstock is being shipped out of the Commonwealth to other end use markets.

IHS Markit estimates that between 2010 and 2016 about $6 billion was invested in NGL-related assets (e.g., gas processing facilities, NGL fractionators, NGL pipelines and NGL storage facilities) in the portions of the Marcellus and Utica basins located in Pennsylvania. These investments, along with continued rapid growth in NGL production through 2030, provide Pennsylvania with an unprecedented opportunity to promote new economic development in several ways:

- Increase the production of ethylene and propylene, two building block chemicals, by constructing some or all of the four additional new crackers that the Marcellus and Utica regions can support

- Significantly expand the supply of low-cost plastic resins available here, especially PE, which will come from Shell Pennsylvania Chemicals, and potentially PP

- Increase the production of a wide range of plastic goods that require PE and PP as the primary raw material

There is high demand from *outside Pennsylvania* for the attractively-priced NGL (especially ethane) and the plastics derived from them. If the Commonwealth does not begin to take immediate steps to maximize its production and use of these chemicals, **these attractively-priced NGL will be exported and the economic development opportunity will diminish. Infrastructure projects are being considered that would increase the flow of the NGL out of the Marcellus and Utica formations to other US regional markets. If Pennsylvania does not respond, then other states will**.

The NGL market will continue to evolve rapidly, increasing the urgency for Pennsylvania to implement immediately a set of coordinated strategies to maximize the economic development opportunities of producing large amounts of natural gas, NGL, and the petrochemicals and plastics derived from these resources. Pennsylvania currently lacks a comprehensive strategy across state agencies, and regional and local economic development offices that is directed at natural gas and NGL, and perhaps more importantly, energy in general.

Over the long term, a coordinated strategy has the potential to leverage the investment of billions of dollars in Pennsylvania. IHS Markit forecasts $7.3–10 billion will be invested in NGL assets (e.g., gas processing facilities, NGL fractionators, NGL pipelines, and NGL storage facilities) in three states (Pennsylvania, Ohio, and West Virginia) between 2017 and 2025, with $2.7–3.7 billion of that being invested in Pennsylvania. These investments do not include the $6 billion that Shell Pennsylvania Chemicals will invest in its ethane cracker, which is the largest private investment project in the history of the Commonwealth. Pennsylvania needs to move quickly by articulating a clear vision for its own destiny, and implement an economic strategy to cultivate a manufacturing renaissance.

The foundation for building diverse and robust petrochemicals and plastics value chains that create employment and economic activity in Pennsylvania was described in the previous chapters. This foundation includes two principal elements:

- Pennsylvania has attracted Shell Pennsylvania Chemicals that will build an integrated cracker that converts ethane into a versatile petrochemical building block, ethylene, and then will process it on-site to make different types of plastic resins (e.g., Shell Pennsylvania Chemicals will be producing both HDPE or LLDPE) when it begins operating in the 2021–22 time frame.

- Pennsylvania firms currently have access to an expanding supply of low-cost natural gas and NGL (particularly ethane and propane) in the Marcellus and Utica Shale basins that are capable of supplying up to four additional world-scale integrated ethane crackers similar in size to Shell Pennsylvania Chemicals.

This foundation—if developed within the Marcellus and Utica Shale basins—will enable Pennsylvania to develop the petrochemical manufacturing value chain in both breadth and depth further. This includes a broader range of petrochemical building blocks such as propylene and related downstream derivatives, and a deeper range of plastics manufacturers that physically and/or chemically convert them (often with additives to alter and improve their properties) into a wide range of plastics products.

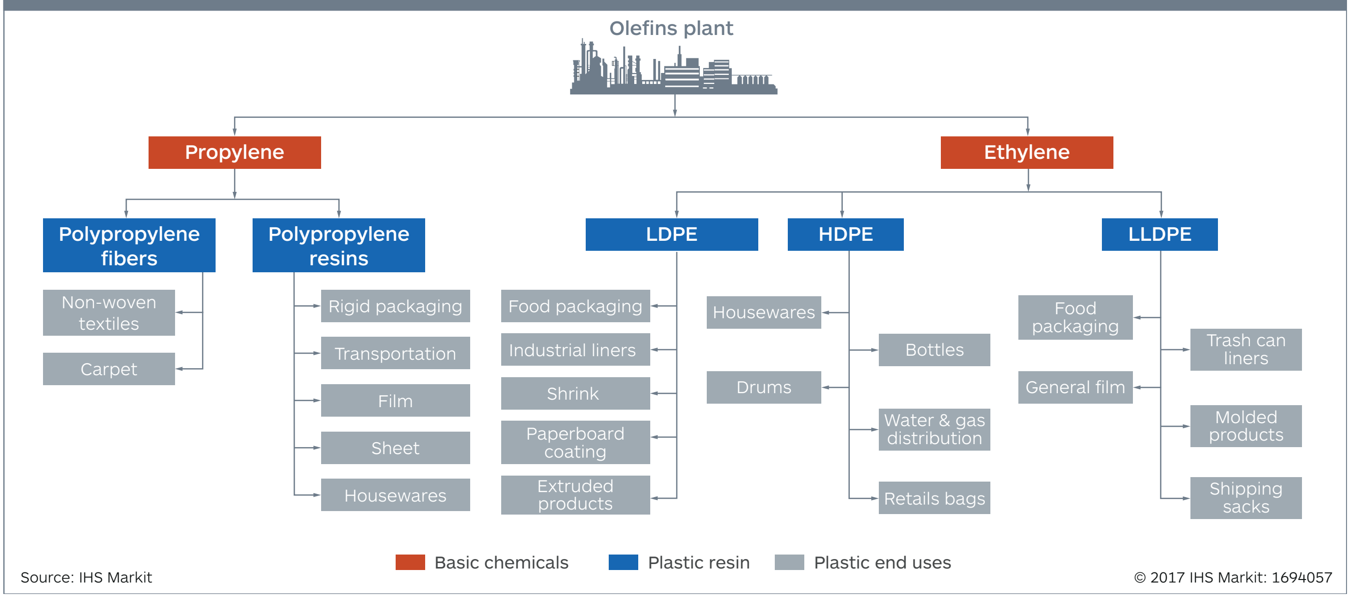
Plastics distributors and resellers also play an important function in the value chain by purchasing resins directly from producers like Shell Pennsylvania Chemicals and then selling them to plastics manufacturers, especially smaller firms and those requiring unique types of resin. In this chapter, IHS Markit refers to the plastics manufacturers, compounders, distributors, and resellers as the **primary use sectors**.

As the foundation for petrochemical manufacturing value chain develops even further, plastics manufacturers will sell their respective products to customers who use them as inputs to make something else—for example, food packaging, milk jugs, containers for pharmaceuticals and cosmetics, straws, pipe and conduit, and containers for household and industrial chemical products. In this chapter, IHS Markit refers to the companies in this part of the value chain that use plastic resins as a primary input as the **secondary use sectors**.

Figure 4.1 depicts Pennsylvania's roadmap for the development of its petrochemical value chain over the next several decades. It builds on the establishment of the first world-scale integrated ethane-to-ethylene cracker ever built in the US Northeast. Shell Pennsylvania Chemicals will use locally-supplied ethane for its ethylene cracker and convert the ethylene on-site to HDPE and LLDPE. These resins will be sold to plastics manufacturers in the primary and secondary use sectors (depicted in gray), many of whom already exist in Pennsylvania and neighboring states. The potential exists to attract further investment along this value chain such as another steam cracker that uses a mixture of ethane and propane to make both ethylene and propylene. The latter can be converted into PP, a versatile plastic used to make an expanded array of products, notably nonwoven fibers, carpet, and high-performance plastics for use in the automobile sector.

Figure 4.1

Roadmap for Pennsylvania's petrochemical value chain



Source: IHS Markit

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Identification of Pennsylvania's principal primary use sectors

Using this roadmap as a guide, IHS Markit used publicly-available databases to identify 13 primary use sectors that will benefit from the development of Pennsylvania's petrochemical value chain to identify what kinds of companies would benefit from having a local supplier of relatively low-cost plastic resin nearby (Table 4.1). Each primary use sector is identified by its six-digit North American Industry Classification System (NAICS) code along with the products they make, the types of plastics resins used, the production processes used, and the secondary use sectors to which they sell.

Table 4.1

Primary use sectors

NAICS	Description	Types of products produced	Resins used as an input	Primary processes applied	Secondary forward linkage sectors and markets
Non-plastics sectors					
325211	Plastics material and resin manufacturing: This industry comprises establishments primarily engaged in (1) manufacturing resins, plastics materials, and nonvulcanizable thermoplastic elastomers and mixing and blending resins on a custom basis and/or (2) manufacturing noncustomized synthetic resins.	Intermediate process for the plastics industry	LP, LLP, HD, PP		
325220	Artificial and synthetic fibers and filaments manufacturing: This industry is comprised of a variety of fibers and will only be marginally affected by change in supply.	Synthetic fibers, such as those used in synthetic carpeting	LP, LLP, HD, PP		
325991	Custom compounding of purchased resins manufacturing: This industry comprises establishments primarily engaged in (1) custom mixing and blending plastics resins made elsewhere or (2) reformulating plastics resins from recycled plastics products.	Intermediate process for the plastics industry	LP, LLP, HD, PP		
Plastics manufacturing sectors					
326111	Plastics bag and pouch manufacturing: This industry comprises establishments primarily engaged in: (1) converting plastics resins into plastics bags or pouches; and/or (2) forming, coating, or laminating plastics film or sheet into single web or multi-web plastics bags or pouches. Establishments in this industry may print on the bags or pouches they manufacture.	Grocery bags, re-closeable bags, food packaging pouches, shipping sacks	LD, LLD, HD	Film & sheet	42, 44 Wholesale & Retail Trade; 561910 Packaging and Labeling Services; 311 Food Mfg.; 31199 Other misc. food mfg.
326112	Plastics packaging film and sheet manufacturing: This industry comprises establishments primarily engaged in converting plastics resins into plastics packaging (flexible) film and packaging sheet.	Agricultural film, paperboard coating, trash bags	LD, LLD, HD, PP	Film & sheet	325998 Agricultural film; 32221 Paperboard container mfg.; 1114 Greenhouse and nursery supplies
326113	Non-packaging plastics film and sheet manufacturing: This industry comprises establishments primarily engaged in converting plastics resins into plastics film and unlaminated sheet (except packaging).	Household appliance wrapping, automotive parts, household products, portions medical devices, construction film	LD, LLD, HD, PP	Thermoforming	3363 Automobile parts mfg.; 325 Chemical mfg.; 3352 Household appliance mfg.; 3254 pharmaceutical and medical mfg.

Primary use sectors (continued)					
326121	Unlaminated plastics profile shape manufacturing: This industry comprises establishments primarily engaged in converting plastics resins into non-rigid plastics profile shapes (except film, sheet, and bags), such as rod, tube, and sausage casings.	Household appliances, automotive parts, pharmaceuticals bottles , wire & cable wrapping, extruded products	LD, LLD, HD	Pipe, injection molding, extrusion	3352 Household appliance mfg.; 3363 Automobile parts mfg.; 3254 Pharmaceutical and medical mfg.; 33592 Communication and energy wire and cable manufacturing
326122	Plastics pipe and pipe fitting manufacturing: This industry comprises establishments primarily engaged in converting plastics resins into rigid plastics pipes and pipe fittings.	Flexible piping, such as those used for lawn & garden care, and municipal water & sewer, natural gas distribution	HD	Pipe	2213 Water & Sewer Utilities; 3331 agricultural, construction, and mining machinery mfg.; 23711 water and sewer line & related structure construction
326130	Laminated plastics plate, sheet, and shapes manufacturing: This industry is comprised of establishments primarily engaged in laminating plastics profile shapes such as plate, sheet (except packaging), and rod. The lamination process generally involves bonding or impregnating profiles with plastics resins and compressing them under heat.	Plastic lawn inserts and tools, rigid automotive parts (such as dashboards), household consumables	HD, PP	Compounder, pipe, thermo	3331 Agricultural, construction, and mining machinery mfg.; 1114 Greenhouse and nursery supplies; 325620 Personal care product mfg.
326160	Plastics bottle manufacturing: This industry comprises establishments primarily engaged in manufacturing plastics bottles.	Bottles for carbonated water, juice, soda, milk, etc., medical/ pharmaceuticals bottles, chemical bottles	LD, LLD, HD, PP	Blow molding	3121 Beverage mfg.; 311511 Fluid Milk mfg.; 325 Chemical mfg.
326191	Plastics plumbing fixture manufacturing: This industry comprises establishments primarily engaged in manufacturing plastics or fiberglass plumbing fixtures. Examples of products made by these establishments are plastics or fiberglass bathtubs, hot tubs, portable toilets, and shower stalls.	Consumer products for home improvement, lawn & garden	HD, PP	Blow molding, injection molding	3331 Agricultural, construction, and mining machinery mfg.; 332913 Plumbing fixtures and trim mfg.
326199	All other plastics product manufacturing: This industry comprises establishments primarily engaged in manufacturing plastics products (except film, sheet, bags, profile shapes, pipes, pipe fittings, laminates, foam products, bottles, and plumbing fixtures).	Drums, consumer goods, industrial liners, packaging, food containers, medical/ pharmaceuticals	LD, LLD, HD, PP	Blow molding, injection molding, roto, pipe, thermo, recyclers	31199 Other misc. food mfg., 561910 Packaging services; 32619 Containers mfg.; 339930 Toy mfg.; 3254 Pharmaceutical and medical mfg.
Wholesale trade					
424690	Other chemical and allied products merchant wholesalers: wholesale distributors of resins. This NAICS is only partly composed of plastics resins and will only be marginally affected by the change in supply.	Intermediate process for the plastics industry	LP, LLP, HD, PP		

Source: IHS Markit

Nine of the primary use sectors are part of the larger Plastics manufacturing sector (NAIC 3261), three are part of the Chemicals sector (NAICS 325) (e.g., resins only producers, makers of fibers, and compounders), and one is part of the Wholesale trade sector (NAICS 42, e.g., resellers and distributors). The nine primary use sectors in the larger Plastics manufacturer sector account for roughly 89% of total output in the Plastics manufacturing sector (NAICS 3261).

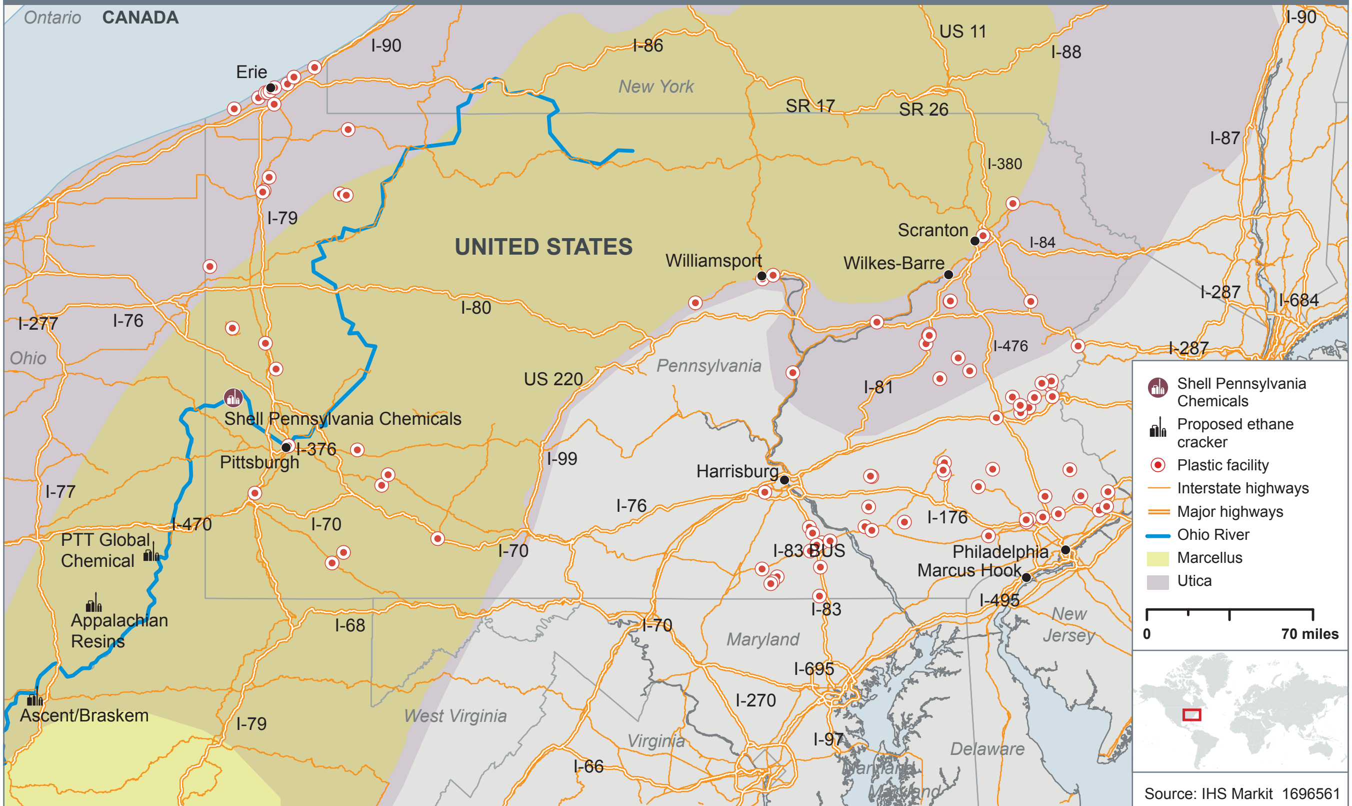
There are some important differences between these primary use sectors that are relevant for Pennsylvania's petrochemical value chain development. Products such as film and sheet have low transportation costs per ton-mile—they can be shipped efficiently over long distances; thus, enabling manufacturers to locate near the resin supply, rather than near their end user market. By contrast, makers of products such as bottles, pipes, tubs, containers, and other blow molded and hollow products, typically locate closer to their respective customers as they have high transportation costs per ton-mile. Pennsylvania is favorably located to attract many types of plastics manufacturers because of its proximity to the US Northeast and Midwest markets and to resin producers operating in Southwestern Pennsylvania, especially when compared to resin producers located in the US Gulf Coast or Western Canada.

How large is Pennsylvania's plastic manufacturing sector?

Even though Pennsylvania will not have a world-scale ethane-to-ethylene cracker within its borders for several years, plastics manufacturers already have a significant presence. Not all of these manufacturers consume the types of resins that will come from Shell Pennsylvania Chemicals. To narrow the analysis and to be conservative, IHS Markit initially identified and mapped the location of approximately 90 manufacturers who currently use PE and PP resins in Pennsylvania (Figure 4.2). The plants were identified from proprietary databases of plastics manufacturing plants and by IHS Markit experts. IHS Markit confirmed details about these plants, their location, employment levels, and building square footage by cross-checking with other databases and company websites. Many of these plants are clustered along major shipment routes in the south and mid-eastern parts of Pennsylvania, such as the I-78, I-80, and I-83 corridor, and the I-90 corridor along Lake Erie.

Figure 4.2

Distribution of resins-using plastic manufacturing plants in Pennsylvania



The plants mapped in Figure 4.2 have an average floor area of 69,100 square feet with a range from less than 20,000 to more than 300,000 square feet; on average have 94 jobs, and are located in 65 different municipalities.

IHS Markit analyzed the firms displayed in Figure 4.2 and identified a sub-set of 34 companies presented in Table 4.2 that are potential customers of Shell Pennsylvania Chemicals because they use either HDPE or LLDPE as raw materials—the same types of resins that Shell Pennsylvania Chemicals will produce.

Table 4.2

Target plastic manufacturing plants in Pennsylvania

Company	City	Primary process	Plant size (square feet)	2012 NAICs code	Employment	Resins used
Multi-Plastics Inc.	Hazelton	Injection molding	15,548	325211	150	HDPE & LLDPE
Ultra-Poly Corp.	Portland	Recyclers	150,000	325211	50	HDPE & LLDPE
J. Meyer & Sons Inc.	West Point	Compounders	11,300	325991	15	PE
Sabic Innovative Plastics	Exton	Compounders	73,555	325991	150	PE
Poly Plastic Products (part of Sigma Plastics)	Delano	Film extrusion	NA	326112	NA	HDPE, LLDPE
Reynolds Consumer Products	Pittsburgh	Film extrusion	86,631	326112	310	LLDPE
Markel Corp.	Plymouth Meeting	Pipe	160,000	326121	150	HDPE
Oil Creek Plastics Inc.	Titusville	Pipe	91,000	326122	50	HDPE
Adept Corp.	York	Pipe	62,000	326130	50	HDPE
McClarin Plastics Inc.	Hanover	Thermo	7,000	326130	120	PE
Washington Penn Plastic Co. Inc.	Washington	Compounders	195,000	326130	200	PE
Suscon Inc.	Williamsport	Blow molding	131,000	326160	85	PE
Bardot Plastics Inc.	Easton	Injection molding	80,000	326199	104	HDPE & LLDPE
C&J Industries Inc.	Meadville	Injection molding	125,000	326199	277	HDPE
Crescent Industries Inc.	New Freedom	Injection molding	154,000	326199	114	HDPE
Drug Plastics Closures Inc.	Boyertown	Injection molding	12,000	326199	62	HDPE
FPI Topcraft LLC	Warminster	Injection molding	22,000	326199	20	HDPE
George Ko Industries Inc.	Erie	Injection molding	22,000	326199	20	HDPE & LLDPE
Greif, L.L.C.	Hazelton	Blow molding	31,943	326199	40	HDPE
Plastek Group, The	Erie	Injection molding	200,000	326199	80	LLDPE
Port Erie Plastics Inc.	Harborcreek	Injection molding	300,000	326199	250	HDPE
Rehrig Pacific Co.	Erie	Injection molding	51,932	326199	100	HDPE
Remcon Plastics Inc.	Reading	Roto	78,000	326199	79	HDPE & LLDPE
Selmax Corp.	Selinsgrove	Injection molding	16,000	326199	21	HDPE
Silgan Holdings Co.	New Castle	Injection molding	12,922	326199	75	LLDPE
Sterling Technologies Inc.	Lake City	Roto	24,000	326199	103	HDPE
Tech Molded Plastics LP	Meadville	Injection molding	74,192	326199	150	HDPE
True Precision Plastics LLC	Lancaster	Injection molding	85,581	326199	25	HDPE & LLDPE
Valley Extrusions Inc.	Allentown	Pipe	10,350	326199	42	HDPE
Viking Plastics	Corry	Injection molding	64,000	326199	110	HDPE
Westmoreland Plastics Co.	Latrobe	Injection molding	35,600	326199	45	HDPE
York Imperial Plastics Inc.	York	Injection molding	45,000	326199	40	HDPE & LLDPE
General Cable	Williamsport	Wire & cable	80,809	331420	250	LLDPE
Graham Recycling Co.	York	Recyclers	12,000	562920	80	HDPE

Note: The list includes four compounding firms assigned to NAICs code 325991.

Source: IHS Markit

These firms listed in Table 4.2 are located across many different counties throughout the Commonwealth of Pennsylvania. Furthermore, these firms use a variety of plastics processing technologies—e.g. blow molding for bottles, injection molding for shapes and containers, film extrusion for packaging film, and wire and cable for electrical applications.

Identification of Pennsylvania's secondary use sectors

In the roadmap for Pennsylvania's petrochemical value chain, the secondary use sectors are those ubiquitous manufacturing and service sectors that use plastic products as inputs to make another type of goods or deliver a different type of service. Some examples include pharmaceutical manufacturers that use plastic containers for pills, food companies that wrap their products in plastics, retail stores that provide carryout bags, dairies that sell milk, and homebuilders that use plastic pipes and conduit. In fact, IHS Markit analysis reveals that plastic products are used as an input by 82 of the 86 four-digit NAICS manufacturing sub-sectors. However, even though plastic products are used in nearly all of the NAICS manufacturing subsectors, it is important to note that the general public may not realize that these secondary use sectors have a clear connection to plastics manufacturers since these secondary use sectors' main products are food and beverages, healthcare, hospitality, agriculture, construction, and consumer goods.

Because of the diversity of these secondary use sectors and the varied characteristics of the individual firms among them, it is difficult to generalize about the likelihood of which firms may decide to locate new production activities in Pennsylvania. The opportunity will certainly exist for firms in the secondary use sectors to increase their purchases of plastics product inputs from Pennsylvania firms because of their potentially lower prices, shorter lead times, and increased availability.

How can Pennsylvania be more attractive to petrochemical and plastics manufacturers?

Site selection criteria

In order to design effective economic development strategies to attract new petrochemical plants like ethane crackers and plastics manufacturing plants, it is necessary to understand two other important issues.

First, what are the factors that go into determining where to locate a plant, and how do project developers perceive them for new sites? The 10 highest ranked site selection factors from *Area Development* magazine's most recent survey of site selectors, in descending order of importance, are:

- Supply of skilled labor
- Highway accessibility
- Quality of life
- Occupancy or construction costs
- Supply of available building sites
- Labor costs
- Corporate tax rates
- Proximity to major markets
- Availability of state and local economic development incentives
- Energy supply and costs

The site selection factors generally apply to both crackers and plastics manufacturing plants, but their relative importance for an individual project will depend on its specific characteristics. Ethane crackers are more difficult to site because of their size, complexity, environmental and safety concerns, and requirements for infrastructure than plastics manufacturing plants. For example, energy supply and costs will be much more important for crackers because of their very high demands for natural gas (as a fuel) and electric power rather than for plastics manufacturing plants. In contrast, plastic manufacturing plants typically require less space and are less complex. Hence, highway accessibility and proximity to major markets are likely to be more important when determining a location for these types of plants.

Some location factors cannot be directly affected by state and local government actions (i.e., proximity to customers or raw materials, market conditions, some quality of life aspects), while others can. It is important to note that state and local governments can affect some of these factors in the short run, such as changing the types of economic incentives available and the size of awards, while others can only occur over a longer period, such as improving transportation infrastructure. Successful state economic development agencies understand the key location factors that the primary use sectors will consider in siting plants so that they can design and implement effective policies and programs and provide the required investment in supporting infrastructure.

Cost of doing business

Second, what is the overall cost of doing business in the Pennsylvania compared with alternative locations? The overall cost is clearly a major consideration when deciding where to locate a new petrochemical or plastics manufacturing plant. A reputable source of cost information is KPMG's Competitive Alternatives study, which evaluates metropolitan areas in the United States and internationally based on 26 location-sensitive criteria in the following areas: labor, facilities, transportation, utilities, capital, non-income taxes, and income taxes. The study estimates a cost-of-doing-business index (US average = 100) for the manufacturing sector, which is comprised of 12 sub-sectors including chemicals and plastics. A lower cost index value is preferred (a value of less than 100 shows that the cost of doing business is below the US average and vice versa). The cost index values can be directly compared to each other. The index values are presented in Table 4.3 for metropolitan areas located in and adjacent to the Marcellus and Utica formations, and for several competing locations.

Table 4.3

Manufacturing cost of doing business index in selected metropolitan areas

City	Cost of doing business index
Baton Rouge, Louisiana	96.2
Youngstown, Ohio	96.7
Charleston, West Virginia	97.4
Pittsburgh, Pennsylvania	**98.0**
Houston, Texas	98.7
Chicago, Illinois	99.1
Philadelphia, Pennsylvania	99.4
New Orleans, Louisiana	96.6

Source: KPMG, 2016. 2015 Competitive Alternatives Study

The overall cost of operating a plastic manufacturing plant in Western Pennsylvania (Pittsburgh) is comparable to the costs along the Gulf Coast. The relatively small cost difference between Pittsburgh and the other metropolitan areas indicates that the site location factors, which include proximity to raw materials, availability/proximity to the transportation network and utility connections, and the value of the economic development incentives available (as a tiebreaker), will often be the determining factors in selecting a specific site.

Economic incentives

All states use economic incentives to promote economic development by enabling existing firms to expand or by attracting new facilities. Economic incentives are the means by which states can reduce the cost of doing business so they can compete with other states for new plants. Shell Pennsylvania Chemicals was attracted to Pennsylvania, in part, because of the creation of the Resource Manufacturing Tax Credit in 2012, which was written specifically for a project that purchased ethane for the production of ethylene within the Commonwealth. The act provides a significant tax benefit to Shell Pennsylvania Chemicals. The total value of the incentive package is estimated to be $1.65 billion between 2017 and 2042.

The major types of economic incentives offered across all states include:

- Financial tax incentives, including credits, deductions, abatements, tax increment financing districts (TIFs), and payments in lieu of taxes (PILOTs). These can be designed to promote new job creation, encourage investments or research and development (R&D) spending, targeted at specific industries, or available in defined districts such as enterprise zones.

- Financial capital incentives, including grants that provide low-interest loans through the issuance of bonds, interest rate subsidies, and loan guarantees. Financial incentives are often designed based on the amount of capital investment, number and wage level of jobs created, industry sector, or for specific types of purchases such as manufacturing equipment.

- In-kind services, including paying for site improvements, acquiring sites, providing job training and offering permit assistance.

- Special districts including empowerment and enterprise zones (e.g. Keystone Opportunity Zones and Keystone Opportunity Expansion Zones).

An individual project's eligibility for economic development incentives can vary greatly. Economic incentives ranked only ninth among the 10 highest ranked site selection factors. Experienced economic development planners know that incentives come into play when attempting to attract a major industry only if the other important locational criteria have been met. In instances where adjacent states with similar locational advantages are vying for the same facility, the value of the economic incentive package offered can be a crucial tiebreaker.[8] In such situations, it is not uncommon for a project's owner to play off competing states against each other in order to extract the most incentives. In summary, well before economic incentives become crucial, a potential host state must have the right set of competitive advantages based on an industry sector's unique set of regional and local site selection factors.

Conclusion

Pennsylvania has, and will continue to have, a large supply of NGL to support the emergence of a world-class petrochemical industry. Its major competitive advantage is access to an expanding supply of low-cost natural gas and NGL, especially ethane and propane that can support four additional, world-scale, integrated ethane crackers similar in size to the Shell Pennsylvania Chemicals. The Commonwealth has a large installed base of plastics plants that are potential customers of Shell Pennsylvania Chemicals. As these plants expand output and new ones move in, they both will benefit and receive significant reductions in operating expenditures because of their close proximity to the large supplies of low-cost plastic resins, which in turn will increase employment and output in Pennsylvania's manufacturing sector. Southwestern Pennsylvania has other locational advantages for petrochemicals, including being within 700 miles of 73% of US and Canada demand for PE and 67% of the demand for PP, competitive costs of doing business for manufacturing, and closer proximity to the large markets in the US Northeast and Midwest than the USGC. Even with these current and emerging advantages, Pennsylvania must begin immediately to plan and implement strategies to maximize the potential long-term economic development benefits that will accompany the growth of a petrochemical cluster. Potential threats and weaknesses that will need to be addressed by the Commonwealth include constraints on pipeline capacity, insufficient NGL storage capacity, increasing the supply of large developable sites zoned for industrial activity, and reducing the length of time to obtain regulatory approvals for NGL infrastructure projects. Finally, insuring that a greater share of the locally-produced ethane and propane is transformed in Pennsylvania instead of exported will maximize the economic development benefits in Pennsylvania.

8 Shell was also considering sites in Ohio and West Virginia with similar access to the Marcellus shale resource base.

IHS Markit Customer Care

CustomerCare@ihsmarkit.com
Americas: +1 800 IHS CARE (+1 800 447 2273)
Europe, Middle East, and Africa: +44 (0) 1344 328 300
Asia and the Pacific Rim: +604 291 3600

IHS Markit™