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Midstream Challenges and Downstream Opportunities in the Tri-State Region

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Prepared for:
Allegheny Conference

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About the Center for Economic Development

The Center for Economic Development at Cleveland State University's Maxine Goodman Levin College of Urban Affairs provides research and technical assistance to government agencies, non-profit organizations, and private industry. The Center for Economic Development serves as a designated Economic Development Administration (EDA) University Center, since 1985.

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EXECUTIVE SUMMARY

To date, much of the work evaluating economic development opportunity resulting from shale has focused primarily on the upstream (exploration and production) side of the oil gas business. However, it has been apparent for some time that regional industries that transmit, process and consume natural gas would benefit greatly from a local source of cheap and abundant natural gas. Moreover, it has also become apparent that certain locations within the Marcellus and Utica shale formations produce gas rich in natural gas liquids ("NGLs"). The result has been the rapid development of a midstream infrastructure in Ohio, Pennsylvania, and West Virginia. Further, NGLs, especially ethane, have applications as a feedstock for petrochemical companies. This in turn has led economic development experts to consider the possibility of regional growth in the downstream petrochemical industry.

The Study looked at several issues relating to the likelihood and best strategies for the development of a downstream petrochemical industry. The results of the Study are summarized below.

I. The Tri-State region is likely to see growth in wet gas production from the Marcellus and Utica Shale formations sufficient to catalyze significant growth in a regional petrochemical industry over the next five years.

Projecting potential growth for downstream oil and gas industries, including petrochemical manufacturing, requires economic development analysts to answer several key questions on the regional supply of NGLs. The Study Team examined industry data, and made the following conclusions with regard to these questions:

1. Projected natural gas production from wet gas zones in the Marcellus and Utica shale formations indicate that there will likely be ample natural gas liquids produced in the Appalachian Basin to support considerable growth in petrochemical manufacturing, including multiple ethane crackers.
2. The midstream infrastructure currently available in the Tri-State region is insufficient to support all the ethane processing that is likely to be available over the next five years in the Appalachian Basin. However, if markets develop for ethane in the region, it will be relatively easy for the midstream industry to upgrade existing infrastructure to fractionate and transport ethane to those markets.
3. Industry take-away infrastructure currently available for ethane in the Tri-State region is insufficient to transport all the ethane likely to be available over the next five years in the Appalachian Basin. Further, there are currently no announced industry plans to increase the take-away infrastructure to a level that will enable moving all likely produced ethane from the region. Accordingly, there is likely to develop, over the next five years, an excess available local ethane supply sufficient to support multiple crackers in the Tri-State region.

Ethane, however, can largely be left in the natural gas stream ("rejected") and sold on the interstate natural gas market if prices are insufficient to justify fractionation and transportation. Accordingly, availability of ethane can fluctuate greatly depending upon the rate of rejection. Likewise, ethane take away capacity may vary considerably, depending upon how certain natural gas liquids (Mariner East 2 and Utopia) lines are used. Both lines will be capable of transporting either propane or ethane, with the Mariner East 2 line also able to transport higher carbon chain hydrocarbons.

However, the most scenarios suggest that a disparity between production capacity and take away capacity will likely exist by 2020 (Table I). If development proceeds as planned by the upstream and midstream industries, and if the Utopia or the Mariner East lines are used primarily for propane, additional local markets will need to be developed to avoid large-scale ethane rejection.

Table I. Utica and Marcellus Projected Production Compared to Fractionation Capacity, 2020

	Total NGL Volume	Ethane (mbbl/d)
Industry Projected Production – wet gas	9.3 bcf/d (1) 1,400 mbbl/d (2)	638.4 (3)
Industry Projected Processing Capacity	12 bcf/d	365 (4)
Industry Projected NGL Take Away Capacity, plus local use	1,525 mbbl/d	460 (5)

(1) Blue Racer Investor Presentation – Fall 2014
(2) Williams projects 1,400 mbbl/d
(3) Assumes 60% ethane, 6 gal/mcf, 42 gal/bbl, and 20% rejection
(4) One third of C2+ fractionation (87 mbbl/d) plus de-ethanization (C2) (278 mbbl/d)
(5) The Mariner East 1 and Utopia pipelines are dedicated to ethane and propane, with capacities of 70 and 75 mbbl/d, respectively. The Mariner East 2 pipeline expansion is projected to be 275 mbbl/d, however most of the pipeline's capacity will likely be used for propane. Accordingly, all 145 mbbl/d of Mariner East 1 and Utopia's propane/ethane capacity is included to make this number, but none of Mariner East 2's 275 mbbl/d. The range of possible ethane capacity is between 315 and 735 mbbl/d.

Although it appears that there will be more ethane produced than is needed for current markets, or that can be taken away with projected infrastructure, there will be considerable uncertainty regarding whether that ethane will be fractionated. Accordingly, petrochemical companies will need to develop strategies to ensure they have sufficient ethane supplies for their facilities. The take-or-pay contract is today the primary mechanism for financing capital-intensive resource recovery and refining projects. The take-or-pay contract is fundamentally an outputs contract, requiring the buyer to take all available hydrocarbons, regardless of how that may match with needs. As such, the refinery will assume much of the risk of supply failure. However, it will be hard to finance a new cracker facility without some warranty of delivery. Accordingly, the refinery will need to either introduce warranty elements into the supply contract, or, alternatively, to have back up supply contracts and redundant pipelines in place. Most likely there will be some of both.

Back up supply contracts are also useful to deal with ethane oversupply. In the Gulf Coast, oversupply can be handled by placing ethane in underground storage facilities. In the Tri-State area, where there is no such storage available, petrochemical companies can deploy redundant pipelines and back up contracts to ensure supply and demand can be balanced. Accordingly, multiple crackers are likely to be built since they can back up each other's unmet take obligations. Another strategy, known as "line packing," can be used to resolve temporary oversupply problems. Line packing involves placing more ethane into the pipeline by adding pressure.

II. The Study Has Identified Downstream Challenges to and Opportunities for Growing a Petrochemical Industry in the Tri-State region.

The Tri-State region has an interest in seeing hydrocarbon production from its shale formations leading to more than just an "extractive economy," whereby producers extract and export hydrocarbons elsewhere. The abundance of natural gas, NGLs and ethane presents an opportunity for the regional petrochemical and chemical industries to refine NGLs and natural gas and to sell the refined more valuable commodities to local entities, as well as to consumers outside the region. Local entities that consume these commodities can then use savings realized from transportation and local price differentials to develop a market advantage in their product sales.

Falling oil prices have somewhat diminished the competitive cost advantage in processing ethylene from ethane compared to processing it from crude oil (naphtha), but the advantage continues to be significant. Indeed, there are good reasons for companies interested in investing in cracker facilities in the Tri-State region to not be discouraged. The region still holds an important competitive advantage because of its high productivity in chemical manufacturing production, highly-skilled labor force and the presence of infrastructure that supports improved manufacturing efficiency. High manufacturing productivity is supported by well-established infrastructure, sophisticated logistics, and transportation options in the Tri-State region. Proximity to eastern ports and traditional trade patterns create some additional cost advantages that allow for the export of refined products globally.

III. Supply chain gaps exist in the Tri-State region serving as opportunities for new economic development.

In order to evaluate the importance of the supply chain to the downstream petrochemical industry, the sector was defined by industries using six four-digit NAICS codes, each corresponding to portions of the overall petrochemical manufacturing industry (Table II). Using the NAICS profile for the petrochemical manufacturing industry, backward and forward linkages were observed along the supply chain. Backward linkages describe the process of how a company purchases its goods, products, or supplies (called inputs) from a company in a different sector (the suppliers). Forward linkages describe how a company sells its goods, products, or supplies (called outputs) to a company in a different sector (the customers).

Table II. NAICS Profile of the Petrochemical Manufacturing Sector

NAICS	Description
3251	Basic Chemical Manufacturing
3252	Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing
3253	Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing
3255	Paint, Coating, and Adhesive Manufacturing
3259	Other Chemical Product and Preparation Manufacturing
3261	Plastics Product Manufacturing

Further analysis in this report looked at the supply chain of the petrochemical manufacturing sector as one industry representing all six 4-digit NAICSs. To identify the gaps in the supply chain to the petrochemical industry in the Tri-State region, the analysis compared the current supply chain of the Tri-State region with the regions considered as the principal U.S. petrochemical hubs – Louisiana, Texas and California. The analysis of the U.S. petrochemical sector showed that the U.S. average data in this sector are heavily influenced by these three states, where the most petrochemical facilities are located. For this Study, the benchmark was set as the portion of the United States that does not include Ohio, Pennsylvania, and West Virginia.

Gaps in the supply chain were then identified by calculating the ratio of shares of purchased supplies (benchmark region divided by Tri-State region). For example, for every $1 spent on supplies, the petrochemical manufacturing industry purchased $0.10 worth of supplies from the petroleum refinery industry in the benchmark region, compared to $0.03 in the Tri-State region. Dividing the benchmark region's value by that of the Tri-State region establishes a ratio of 3.15. This ratio can be interpreted as follows: in the benchmark region, petroleum refinery industry services were consumed at three times the rate of that within the Tri-State region. In turn, this identifies the potential gap in the supply of refineries necessary for the petrochemical industries in the Tri-State region. Overall, the supply chain in the Tri-State region falls short in the industries illustrated in Table III.

Table III. Suppliers to the Petrochemical Manufacturing Sector in the Tri-State and Benchmark Regions

NAICS	Description	Tri-State Region (OH-PA-WV)	Benchmark Region (US less OH-PA-WV)	Benchmark to Tri-State ratio
32511	Petrochemical manufacturing	0.0599	0.3137	5.24
32411	Petroleum refineries	0.0310	0.0977	3.15
325211	Plastics material and resin manufacturing	0.0203	0.0758	3.74
32519	Other basic organic chemical manufacturing	0.0158	0.0666	4.21
42	Wholesale trade	0.0312	0.0530	1.70
55	Management of companies and enterprises	0.0316	0.0394	1.25
22112	Electric power transmission and distribution	0.0112	0.0166	1.48
32518	Other basic inorganic chemical manufacturing	0.0040	0.0147	3.64
2212	Natural gas distribution	0.0085	0.0147	1.73
482	Rail transportation	0.0067	0.0144	2.15
484	Truck transportation	0.0099	0.0122	1.23
211111	Extraction of natural gas and crude petroleum	0.0036	0.0109	2.99
32611	Plastics packaging materials and un-laminated film and sheet manufacturing	0.0035	0.0109	3.15
32513	Synthetic dye and pigment manufacturing	0.0052	0.0095	1.84
32221	Paperboard container manufacturing	0.0030	0.0088	2.91

Note: the table is ranked by the column Benchmark Region (US less OH-PA-WV).

For successful expansion of the petrochemical sector in the Tri-State region it is also important to develop a wide range of consumers within a reasonable trucking distance, making it easier to sell the products in the U.S. The assessment of forward linkages (consumers buying products from the petrochemical sector) also necessitates a comparison of the Tri-State region to the benchmark region in order to identify gaps that may currently exist in the consumer chain. The smaller consumer chain in the Tri-State region identifies opportunities to expand the pool of customers in the Tri-State Region by marketing and direct targeting for expansion the companies that consume polyethylene and other petrochemical products. The biggest shortage of consumers compared to the benchmark region was noted in sectors illustrated in Table IV.

Table IV. Buyers of the Petrochemical Manufacturing Sector in the Tri-State and Benchmark Regions

NAICS	Description	Tri-State Region (OH-PA-WV)	Benchmark Region (US less OH-PA-WV)	Benchmark to Tri-State ratio
32511	Petrochemical manufacturing	0.034	0.168	4.92
32519	Other basic organic chemical manufacturing	0.029	0.063	2.21
325211	Plastics material and resin manufacturing	0.033	0.053	1.59
326190	Other plastics product manufacturing	0.015	0.032	2.17
1111	Grain farming	0.003	0.021	7.67
32611	Plastics packaging materials and un-laminated film and sheet manufacturing	0.070	0.019	2.69
334413	Semiconductor and related device manufacturing	0.002	0.017	10.82
32411	Petroleum refineries	0.004	0.016	4.37
325412	Pharmaceutical preparation manufacturing	0.005	0.013	2.72
23*	Construction of other new residential structures	0.004	0.013	3.04
32551	Paint and coating manufacturing	0.008	0.011	1.37
23*	Maintenance and repair construction of nonresidential structures	0.004	0.010	2.83
325212	Synthetic rubber manufacturing	0.004	0.010	2.28
32522	Artificial and synthetic fibers and filaments manufacturing	0.001	0.010	18.41
312111-2	Bottled and canned soft drinks & water	0.004	0.009	2.33

Note: the table is ranked by the column Benchmark Region (US less OH-PA-WV).

IV. The Tri-State region has a robust local market for refined natural gas liquid products, providing crackers built in the region with a competitive sales advantage.

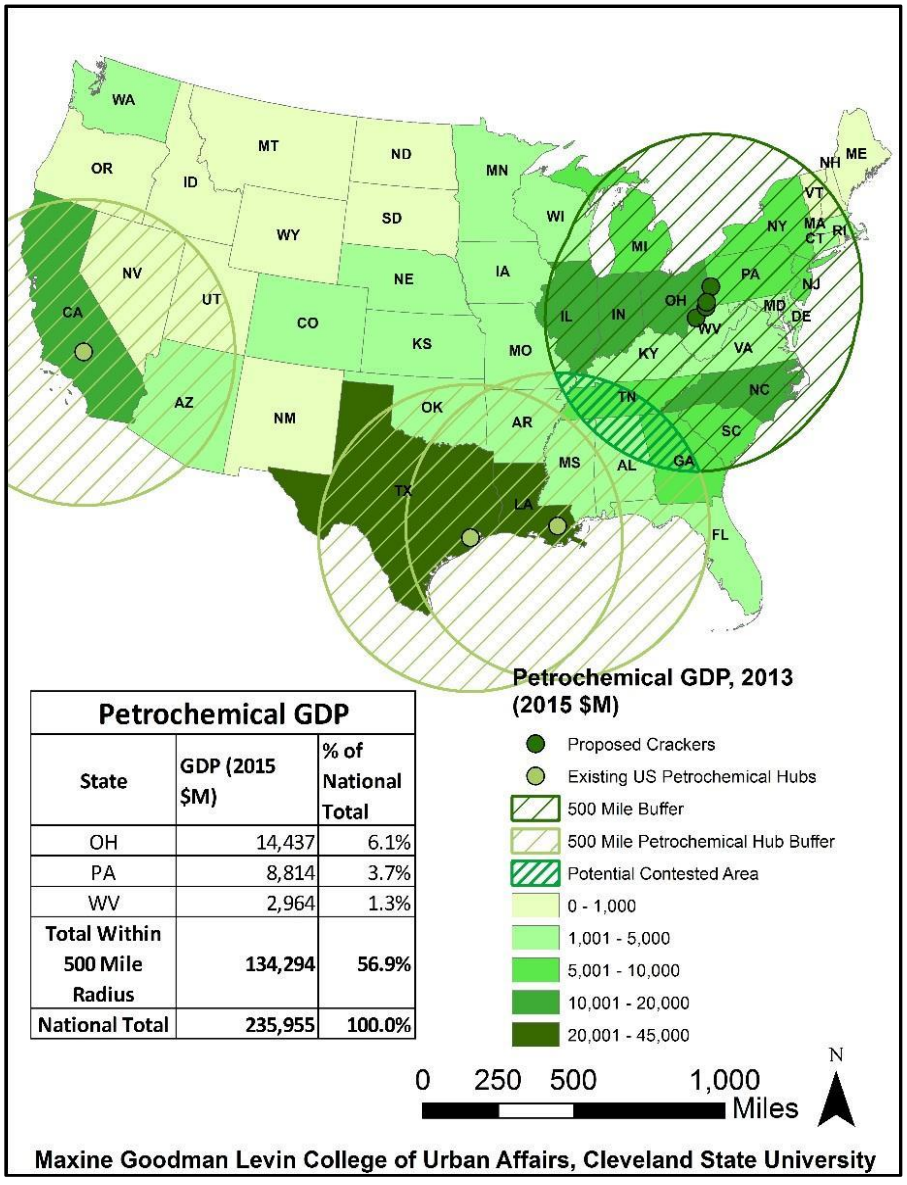
In addition to looking at the main potential consumers from individual companies, the following analysis compared the petrochemical sector's gross regional product (GRP) and employment in the Tri-State region's 500-mile radius to that of the closest competitors – the existing petrochemical hubs of Louisiana, Texas, and California. Included in the Tri-State region's 500-mile radius are 26 states, seven of which are located within the "jointly competitive area" between the Tri-State region and the Gulf Coast (overlap by the green circle and one of the yellow circles in Figure I).

The GRP of the three states comprising the Tri-State region totals to $26,215 million dollars, or 11.1% of the overall petrochemical gross domestic product (GDP) of the United States in 2013. When observing the

petrochemical GRP of the 26 states within the Tri-State region's 500-mile radius, the total jumps to $134,294 (in millions of dollars), or 56.9% of the overall petrochemical GDP in the United States (Figure I).

Within the Tri-State region, 134,914 people were employed in the petrochemical sector, or 13.9% of the overall petrochemical sector employment in the United States in 2013. The 26 states within the Tri-State region's 500-mile buffer had a total petrochemical sector employment of 665,901, or 68.8% of the national employment within this sector. Whether measured by gross product or employment, the Tri-State region's proposed crackers would have viable access to over half of the petrochemical manufacturing industry's consumer market in the United States (see Figure II).

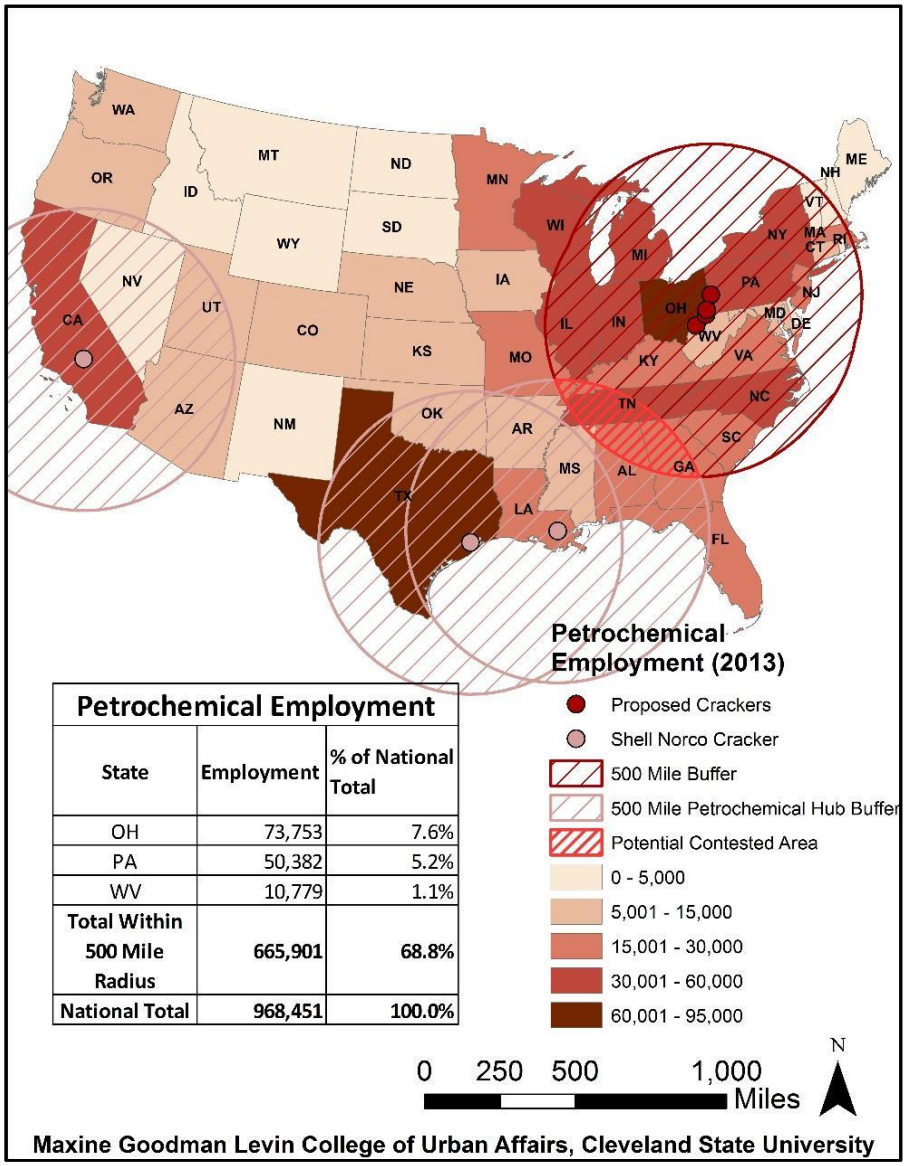
Figure I. Gross Regional Product of Petrochemical Companies within 500-mile Radii of Existing Petrochemical Hubs and the Proposed Crackers in the Tri-State Region



Petrochemical GDP		
State	GDP (2015 $M)	% of National Total
OH	14,437	6.1%
PA	8,814	3.7%
WV	2,964	1.3%
Total Within 500 Mile Radius	**134,294**	**56.9%**
National Total	**235,955**	**100.0%**

Data source: Moody's Economy.com

Figure II. Petrochemical Sector Employment within 500-mile Radii of Existing Petrochemical Hubs and the Proposed Crackers in the Tri-State Region



Petrochemical Employment

State	Employment	% of National Total
OH	73,753	7.6%
PA	50,382	5.2%
WV	10,779	1.1%
Total Within 500 Mile Radius	**665,901**	**68.8%**
National Total	**968,451**	**100.0%**

Data source: Moody's Economy.com

Of the 26 states that make up the Tri-State region's 500-mile buffer area, Ohio has the largest petrochemical sector employment (73,753 or 7.6% of the U.S. petrochemical employment), followed by Illinois (55,727), and Pennsylvania (50,382). Ohio also has the highest GRP ($14,437), North Carolina the second-most ($12,770), and Indiana the third-most ($10,434).

Not only is the concentration of the consumer market favorable to the proposed crackers in the Tri-State region, but also, many of the 26 states within the 500-mile radius have high location quotients of employment and GRP of the petrochemical sector (the petrochemical sector is comprised of six 4-digit NAICS). High location quotients indicate that this sector is a part of the regional economic base in these

states and therefore speaks to the viability of the industry and related cluster usually accompanying high concentration in employment and GRP of an industry.

V. The Tri-State region can offer sufficient labor to attract major crackers as well as their suppliers and customers.

Prior studies on labor demand in Ohio Valley's downstream companies indicated segmentation of the labor market and an overall labor shortage especially for small and medium-sized manufacturing companies offering low wages and modest benefits. The most significant effect of the shortages in petrochemical labor demand was observed in the segments of the labor market exhibiting the smallest value added per product produced – those companies that manufacture products using recycled plastics or off-spec products. There is a continuous churning of labor through different tiers within the industry as higher segments of the petrochemical industries draw labor supplies from the lower segments due to higher pay and better benefits. Additionally, the burden of teaching basic industrial skills to workers in entry-level positions is large and often unmanageable for some of the smallest companies in the industry These companies also experience higher pressures because they are only able to draw their labor from the regional pool due to the unfortunate reality that the level of salaries and benefits they can offer isn't enough to incentivize relocation. However, the labor market for the highest segments of the petrochemical labor (chemical engineers and scientists) is national. Companies hiring in high-skilled positions with commensurately high pay attract workers from other regions and states.

This Study compares the density of the occupations related to the downstream sector that are in high demand in the Tri-State region to that of the Gulf Coast region. Potential expansion of the petrochemical industry in the Tri-State region will increase demand across many categories and levels of occupations, skills, required education and pay.

This analysis was conducted in a few stages. Using the profiles of downstream industry, we identified top petrochemical occupations in the region and nationally. As a next step, we assessed the capacity of ethane crackers in petrochemical complexes in the Gulf Coast region and in the Tri-State region. When normalized by a unit of petrochemical production capacity ("cracking capacity"), the Tri-State Region is compared to the Gulf Coast region assessing regional employment necessary to sustain regional operation of three announced crackers/petrochemical complexes accounting for the overall scale of the petrochemical industry. The necessary employment in top occupations serving the petrochemical industry speaks to the future growing demand in petrochemical occupations which the region will experience when and while the crackers will start to operate. While the analysis revealed that potential shortages may be experienced only in three main petrochemical occupations, (1) Textile Winding, Twisting, and Drawing Out Machine Setters, Operators, and Tenders; (2) Petroleum Pump System Operators, Refinery Operators, and Gaugers; and (3) Chemical Plant and System Operators.

Although, this analysis speaks to optimistic results and identifies small potential shortages of labor, further investigation of potential workforce might be needed. Both workforce analyses conducted in this Study assume that existing employment will absorb new labor demand. However increased demand of labor for three potential crackers and related companies in the petrochemical industry will create a pressure on petrochemical manufacturing-related occupations and most likely will attract workers from smaller and less-paying companies moving up to larger companies offering better pay and benefits. This analysis is most useful in illustrating what occupations will be atop of the demand while the petrochemical industry expands its operations in the supply and demand chains to three crackers (Tables 23 and 26 in this report).

We know that existing companies that employs workers in petrochemical occupations will experience competition for labor and we know that workers in these occupations will be in employment advertisements while the crackers will be ready to operate.

INTRODUCTION

BACKGROUND, ISSUES PRESENTED AND SCOPE OF RESEARCH

Since 2010, Shale development has been a major economic development story for Pennsylvania, Ohio and West Virginia. To date, the work evaluating economic development opportunity resulting from shale has focused primarily on the upstream (exploration and production) side of the oil and gas business. However, it has been apparent for some time that regional industry would benefit greatly from a local source of cheap and abundant natural gas. Moreover, it has also become apparent that certain locations within the Marcellus and Utica shale formations produced gas rich in natural gas liquids ("NGLs"). The result has been the rapid development of a midstream infrastructure in Ohio, Pennsylvania and West Virginia. Further, natural gas liquids, especially ethane, have applications as a feedstock in the petrochemical business. This in turn has led economic development experts to consider the possibility of a regional renaissance in the petrochemical industry.

Downstream oil and gas industries that use ethane and other NGLs make no distinction between formations that serve as the original source of the hydrocarbons that are delivered to the plant. Both the Utica and the Marcellus formations are located in the same Appalachian basin, and both can serve regional hydrocarbon markets. Accordingly, this report was undertaken to develop a better understanding of the status of anticipated production in the Appalachian region, the regional midstream infrastructure build out and the potential downstream petrochemical opportunities for the entire footprint of the shale basins in Ohio, West Virginia and Pennsylvania.

With these developments in mind, the Study Team was asked to investigate the likely downstream opportunities that may arise in Pennsylvania, Ohio and West Virginia as a result of the Marcellus and Utica Shale drilling and infrastructure build out. The questions posed can be summarized as follows:

- What amounts of natural gas liquids are likely to be produced regionally in the next five years based upon industry projections?
- What does the midstream infrastructure look like in the Tri-State region, and will it be sufficient for projected regional natural gas liquid production, including capacity for processing, storage and take-away?
- What local markets for those liquids are available, and what is the value proposition for local downstream industries to keep these liquids in the region?
- What opportunities are there for development of downstream industries using natural gas liquids in Pennsylvania, Ohio and West Virginia, what strategies might be deployed to capture these opportunities, and when should they be deployed?
- What supply chain shortages may affect downstream development in the Tri-State region and potentially prevent new opportunities from being realized?
- What, if any, supply chain gaps exist in the Tri-State region that may serve as opportunities for new economic development?
- Workforce

The Study Team looked at these and other questions to guide its investigation. The discussion below sets forth the results of the Study Team's investigation.

The Study is heavily driven by the data analysis utilizing secondary data (including U.S. Bureau of Labor Analysis, Moody's Economy.com, Reference USA, IMPLAN Data) supported by interviews and commentaries by industry representatives. The Study provides compelling arguments for the creation of a joint regional strategy not only for upstream Marcellus and Utica development, but also for mid and downstream Industries. It will inform industry, governments and economic development groups how the Tri-State region will benefit from the transformation of developed hydrocarbons into valuable supplies for regional chemical and petrochemical manufacturing. The Study provides information for companies on potential business opportunities for expanding within or relocating to the Tri-State region. In addition to providing detailed analyses on the opportunities for the downstream sector and the availability of feedstock, the Study addresses potential shortages in the supply chain and workforce development in related industries. This last information can help economic development practitioners develop strategies for closing potential gaps that may impede growth.

MIDSTREAM INDUSTRIES AND THROUGHPUT CAPACITY

Midstream oil and gas operations occur subsequent to production, and include the gathering, compressing, transporting, storing, treating, separating, processing and fractionation[1] of hydrocarbons. The separation of natural gas liquids from the gas stream occurs during midstream operations at the processing plant. Typically, an interstate gas pipeline takes the residual gas at the tailgate of the processing plant, and undifferentiated NGLs are thereafter delivered to a fractionation facility, where the liquids are segregated into "pure products," such as ethane, propane and other hydrocarbons. The pure products are then delivered by pipeline (or by truck, train or barge) to markets downstream. These markets include, among others, refining operations (e.g. reforming, cracking, or distillation), where the hydrocarbons are reformed into a product that has a commercial use. Additional operations often occur further downstream of the petrochemical plants that add additional value to the refined product, including the compounding, distribution and conversion of petrochemicals.[2] See Figure 1 below.

In order to build sufficient infrastructure, midstream companies must estimate the likely volume of hydrocarbons to be produced. Pipelines and processing plants are built based upon an expected volume of production likely to be passing through their facilities ("throughput") on a daily basis.

Midstream investment can cost hundreds of millions of dollars. Some midstream facilities are financed based upon a contractual dedication of production from certain wells or fields to those facilities.[3] Others are financed based upon "speculation" on the likely needed midstream infrastructure in a given region.

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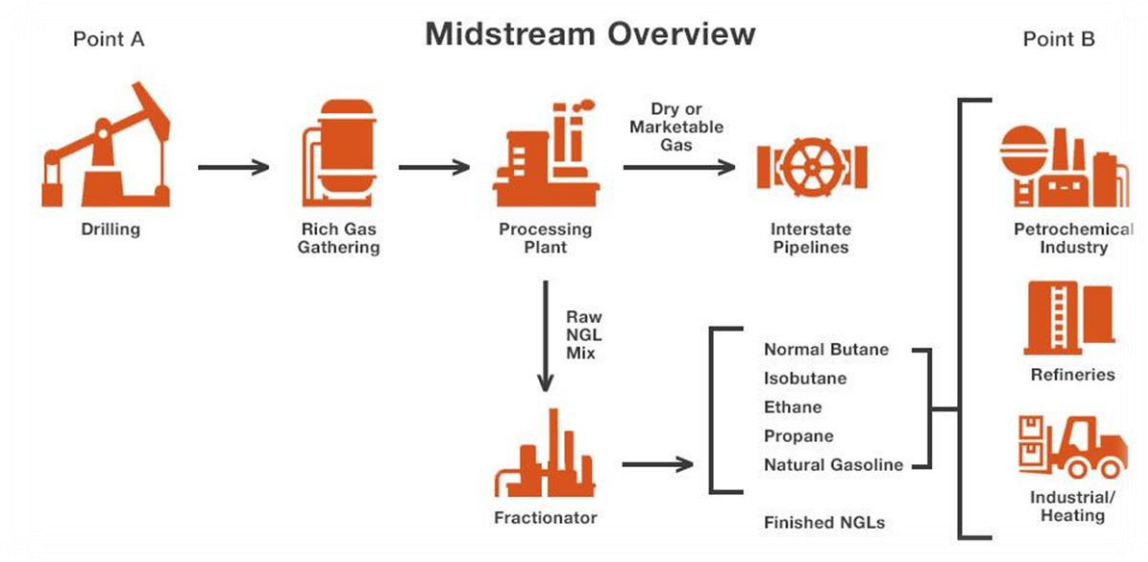
[1] Fractionation facilities are generally divided into three categories: C2, C2+, and C3+. C2 fractionators (de-ethanizers) separate ethane from the NGL stream. C2+ fractionators have the ability to separate out ethane as well as "heavier" NGLs (propane, butane, isobutane, and natural gasoline). C3+ fractionators cannot separate ethane from the NGL stream, but can remove the heavier NGLs.

[2] The North American Industry Classification System (NAICS) classifies upstream companies as those found within the mineral extraction industries. Midstream companies are those found within the oil and gas transportation business. Companies engaged in downstream activities usually are included in NAICS as manufacturing industries, primarily in petroleum, petrochemical and chemical manufacturing.

[3] Sales of natural gas are usually based upon a "daily contract quantity," and contracts to sell natural gas tend to be far more complex than those for sales of liquids due to the difficulty in storing natural gas. Industry trade associations, such as the Association of International Petroleum Negotiators, have developed forms for gas sales agreements.

Either way, midstream companies must make major capital investment into their facilities, and throughput estimates must be accurate.[4]

Figure 1. Midstream Overview



Source: Gas Processors Association

Refining of Natural Gas Liquids and the Petrochemical Industry

Downstream companies face similar investment decisions. These companies must make investments, often times in the billions of dollars, into facilities based upon not only the likely available throughput, but also upon the likely market for their refined or reformed products.

Investment into natural gas liquid refining, such as for ethane crackers, requires not only a secure supply of hydrocarbon raw products, it also requires a certain market for the product being refined. Accordingly, long-term supply contracts, either from producers or from those midstream companies that take title to the liquids after processing, will be critical to enabling downstream facility investment. Of course long-term contracts for sales of refined products from the facility would likewise be important to obtaining investment capital. However downstream companies may have to find capital willing to speculate on sales. Much of the market for refined products made from natural gas liquids is sold through spot, rather than long-term, contracts.

Natural gas liquid refineries take pure product liquids derived from the natural gas stream and, using processes like catalytic cracking, reform the liquid into a new product that can be compounded, distributed and consumed by various operations further downstream. The most common example of this is refining ethane into ethylene, which is then polymerized into polyethylene pellets. Polyethylene is then

[4] The midstream industry has introduced flexibility to its planning by making processing facilities modular. Processing plants can be built on skids in standard capacity units (typically 200 mmcf/d), and installed or uninstalled for redeployment elsewhere.

distributed to various converter companies for molding into plastics that are consumed in an assortment of commercial applications.

Investment by chemical companies into crackers and other refineries in the Marcellus/Utica Shale region will be controlled by a number of factors besides feedstock supply. These include such things as access to downstream markets, transportation costs, labor costs, and storage capacity. However, securing a long-term feedstock supply at attractive prices will be the first and perhaps most important step to enabling NGL refining to be built in the Tri-State region.

RESEARCH METHODOLOGY

The research for this Study included several undertakings. The first undertaking consisted of a review of industry production projections for the Marcellus and the Utica. Industry projections for development and throughput were acquired through literature searches, interviews, and conference presentations.

A second undertaking was to assess of the status of the midstream oil and gas infrastructure in the Tri-State region. To obtain this data, the Study Team interviewed major midstream and upstream players in the Marcellus/Utica region, and conducted a literature search for industry projections. The Study Team then compared the existing and projected infrastructure to the anticipated production as determined by the industry to assess the likely availability of natural gas liquids for possible downstream industries.

A similar investigation was undertaken to determine the downstream markets for natural gas liquids, with a principal focus on ethane. For this the Study Team undertook literature searches, attended industry conferences, and conducted interviews with downstream companies, especially those in the petrochemical business downstream of the refinery. The Study Team then identified potential opportunities for downstream petrochemical businesses to develop in the Marcellus/Utica basin, and considered strategies and relevant time frames for investment.

Finally, the Study Team examined industry employment and supply chain benchmarking the Tri-State region to the national averages for the petrochemical industry and identified potential gaps. To address the gaps, there is a list of potential companies that could relocate or expand into the Tri-State region and the list of competencies and appropriate levels of education listed for the labor in short supply. Both findings may serve as a resource for economic development organizations, governments and industries to identify business opportunities and create strategies and public policies for supporting regional growth in petrochemical industries.

UTICA AND MARCELLUS SHALE PRODUCTION PROJECTIONS

FACTORS CONTROLLING PRODUCTION

The Study Team considered the influence of several factors controlling regional production of natural gas liquids, including natural gas and NGL prices, pace of development in regional midstream infrastructure, and the 2015-16 business strategies of the principal upstream players in the Marcellus/Utica basin.

Natural Gas and Natural Gas Liquid Prices

The volume of natural gas liquids produced from the Appalachian Basin will be principally a function of prices for natural gas and natural gas liquids. Natural gas production from the Marcellus and Utica has already been so significant that it is changing not only how we use gas, but also how we assess natural gas

markets. Appalachian natural gas hubs have become, for the first time, as relevant as the traditional Gulf Coast trading locations, such as the Henry Hub.

Indeed, as production in the Appalachian region continues to overwhelm regional consumption, regional hub prices have dropped consistently below the spot price of natural gas at Henry Hub in Louisiana (Figure 2). In the spring of 2016, natural gas produced from the Marcellus and Utica basin was still trading locally nearly $0.50/mmbtu (million British Thermal Units) below the Henry Hub price.[5]

The regional differences with Henry Hub natural gas prices reflect not only an oversupply of natural gas from the Marcellus and Utica Shale plays, but also a constrained pipeline take-away capacity. Without additional new consumption or take away infrastructure, prices in the regional hubs will remain depressed, resulting in a sustained slowdown in drilling.

Columbia Gas Transmission Corporation's Appalachian Index (TCO Appalachia Pool) has maintained prices comparable to those found for Henry Hub, notwithstanding the surplus (Figure 2). This is apparently because there are less contractual and pipeline restrictions for gas traded on the TCO Appalachia Pool. For instance, Columbia Gas was able to back out take obligations from the Gulf Coast production to accommodate its West Virginia and Southwest Pennsylvania gas production.[6] By spring 2016, Henry Hub, and TCO Pool were trading around $2.00/mmbtu (thousand cubic feet of gas), while Dominion North and Dominion South were trading around $1.50/mmbtu.[7]

Natural gas liquid prices also affect drilling and production rates in the Marcellus/Utica basin. Falling oil prices in the fall of 2014 caused NGL prices to likewise drop. The result is that in those areas where natural gas liquids are more prevalent -- the "wet gas" windows -- drilling had slowed by the spring of 2015, and continued to be slow through the summer of 2016.

Depressed ethane markets have further slowed drilling. By July 2015, ethane was selling at slightly above $2.50/mmbtu – comparable to the price received for dry natural gas.[8] Propane, butane and natural gasoline have local markets and usually retrieve prices that are higher than methane. See Figure 2. However ethane makes up over half of natural gas liquids produced in the Utica and Marcellus, and it may or may not retrieve a higher price than methane. Ethane and methane prices tend to be related, since both exist as gas at normal temperatures and pressures, and can often be mixed together when delivered to a natural gas interstate pipeline. The decision to not remove ethane from the natural gas stream is known in the industry as "ethane rejection." Ethane is rejected whenever the price of methane is the same or higher than ethane, or when there is no market or available infrastructure to take the ethane.

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[5] "Spread Between Henry Hub, Marcellus natural gas prices narrows as pipeline capacity grows," Energy Information Agency, January 27, 2016, http://www.eia.gov/todayinenergy/detail.cfm?id=24712. Natural gas is often measure as volume (thousand cubic feet, or mcf) or by its energy content (million British Thermal Units). Generally speaking, the higher the btu content, the more valuable the gas stream. Natural gas liquids increase the energy content in the gas stream. One mcf of gas is roughly equivalent to one mmbtu of gas.

[6] *See*, "Some Appalachian Natural Gas Spot Prices Are Well Below the Henry Hub National Benchmark," *Today in Energy*, U.S. Energy Information Administration, October 15, 2014, found at: http://www.eia.gov/todayinenergy/detail.cfm?id=18391

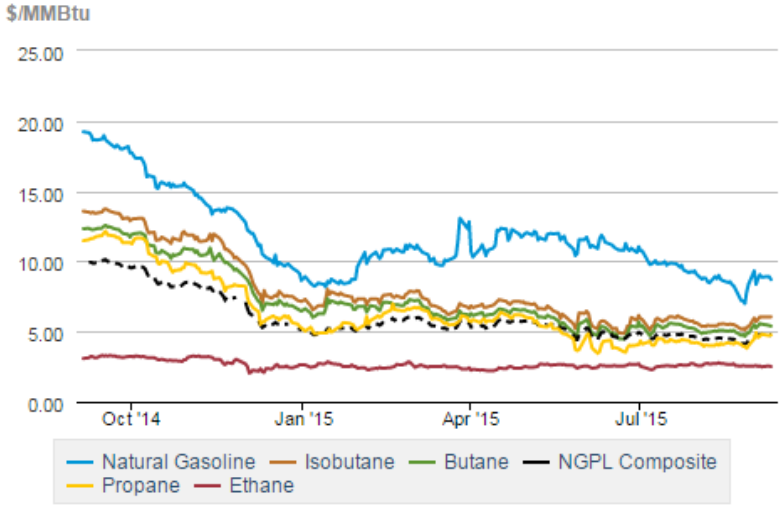
[7] *See e.g.* "Spread Between Henry Hub," footnote 5, *supra*. By late summer 2016, Appalachian prices had begun to rebound to over $2.50/mmbtu for TCO Pool, but Dominion Index remained at $1.22/mcf. *See* "Market Report," Ohio Oil and Gas Association, September 22, 2016, http://www.ooga.org/?page=marketreport.

[8] "Natural gas liquids spot prices" U.S. Energy Information Administration 7/15.

However, not all the ethane can be rejected. Interstate pipelines have limits to how much ethane can be placed into the gas stream before the BTU content becomes too "hot." In such instances, ethane may have to be sold into inferior markets. These cases provide the most advantageous circumstances for a refiner looking to lock up supplies of ethane.

Appalachian produced ethane currently is being shipped through pipelines to the Gulf Coast, Ontario and to the East Coast, where it is used in petrochemical applications. These markets set the price for ethane. Appalachian produced ethane can also be sold to international markets, where ethane brings a higher price. However transportation of ethane overseas as a liquid is more costly than by pipeline, so it is yet unclear how much this market will help the oversupply problem in the Marcellus/Utica basin. Currently international supplies for ethane are expected to be sufficient to meet demand beyond 2017. In 2015, Enterprise Products Partners estimated that Europe could provide an incremental 415,000 b/d ethane demand.[9] If this was insufficient, naphtha could be produced from conventional oil plays, and could substitute as the feedstock for Europe-driven ethane demand.

Figure 2. Natural Gas Liquids Spot Prices



eia Source: NGL spot prices from Bloomberg, L.P., and weights for NGPL composite price from EIA-816, Monthly Natural Gas Liquids Report.

Note: NGL spot prices at Mont Belvieu, Texas. Monthly volumes from EIA-816 used to calculate weights for the NGPL composite price. EIA-816 volume weights are constant throughout a given month, and the latest available weights are applied to the three most recent months. Natural gasoline is the term used in the spot and futures markets to describe pentanes and hexanes, the primary components of pentanes plus.

(July 2015)

Strategies of Key Marcellus and Utica Players

Development of the Marcellus and Utica within the Appalachian Basin will depend principally upon the investment strategies of a handful of key oil and gas operating companies. Most large and mid-size oil and gas producers mitigate their risk by investing in multiple plays. Some will also invest in midstream

[9] Marcellus/Utica produced ethane to reach USGC markets in January: Enterprise. Houston (Platts)--5Dec2013/437 pm EST/2137 GMT. http://www.platts.com/latest-news/natural-gas/houston/marcellusutica-produced-ethane-to-reach-usgc-21914284

and even downstream projects to further mitigate risk, but also to ensure that there will be a market for their production. Companies investing into the Marcellus and Utica are no different in this regard; they all have investments that cross multiple regions and markets, and that compete internally for financial resources.

The Study Team examined Ohio Department of Natural Resources, Pennsylvania Department of Environmental Protection, and West Virginia Department of Environmental Protection data for drilling permits and actual drilling to identify the principal players in the Marcellus and Utica. This resulted in a list of the top four companies by drilling activity between January 2014 and April 2015:

- Chesapeake
- EQT
- Range Resources
- Southwestern Energy Production Co.

As reported as of the end of April 2015, overall capital budgets of Marcellus and Utica upstream operators have commonly been reduced by 40-50%. In addition, overall rig counts have also fallen, decreasing by 44% in the Utica and 42% in the Marcellus. Similarly, capital budgets of those operating in oil plays have also been reduced by 40-50%, with an overall rig count decline of 56%.[10] Prices remained depressed through May of 2016, when natural gas prices finally began to show signs of improvement.

Chesapeake is the second largest producer of natural gas and the 11th largest producer of oil and natural gas liquids in the United States. The company has operations in eight plays across the country, including the Marcellus and Utica in Ohio, Pennsylvania, and West Virginia.[11] Chesapeake reduced its 2015 capital expenditures by 45% versus 2014, including the announcement of an additional $500 million in cuts since February 2015. Correspondingly, Chesapeake reduced its average number of Utica operating rigs from 3-5 to 1 in 2016,[12] and from 1-2 to 0-1 in the Marcellus. The company's reduction in capital expenditures partly stems from increasing efficiencies in drilling. Compared to 2011, Chesapeake has seen a 65% decrease in drilling days and a 30% reduction in CAPEX per well, while the company has adjusted well spacing in the Utica to optimize field recovery. In 2014, Chesapeake operated 220 wells in the Utica and 90 in the Marcellus, compared to 47 and 223 in 2011, respectively.[13]

Chesapeake made successful moves to the wet gas play within the Utica, growing this segment over 65% in 2013-2014 and forming two joint ventures, with French TOTAL and Houston-based EnerVest (EV). The company's plans to unlock an oil window announced in 2015 may prove to be less appealing if liquids prices remain as low as they were in the first half of 2016. Chesapeake Energy recently sold its assets in the South Marcellus Shale and a part of the assets in Eastern Utica Shale to Southwestern Energy. This

[10] "Company Presentation" Range Resources 4/28/15. http://ir.rangeresources.com/phoenix.zhtml?c=101196&p=irol-presentations

[11] "Corporate Fact Sheet" Chesapeake Energy 3/15. http://www.chk.com/documents/operations/corporate-fact-sheet.pdf

[12] citation

[13] "Leadership Performance Value" Chesapeake Energy 3/24/15. http://www.chk.com/Documents/investors/20150323_Latest_IR_Presentation.pdf

move was followed by an announcement of the company's plans to repurchase $1 billion worth of its own shares. [14]

EQT continues to focus its activity in four areas: central Pennsylvania, southwest Pennsylvania, and the dry and wet gas portions of northern West Virginia. Southwest Pennsylvania's dry gas area will remain EQT's primary focus in 2015, adding 79 wells to its existing 260. Northern West Virginia's wet gas area will also see activity, with 178 current wells and an additional 45 planned for 2015. Central Pennsylvania (72 wells) and northern West Virginia's dry portions (50 wells) are emerging areas of opportunity for EQT, seeing additions of 9 and 8 wells in 2015, respectively.[15]

Unlike most other upstream companies operating in the Marcellus and Utica, EQT increased its 2015 capital expenditures from 2014. The company's CAPEX of $2.5 billion included $2.3 billion for EQT Production and $225-250 million for EQT Midstream, with the overwhelming majority of EQT Production's $2.3 billion being put towards well development.[16] This compares to the 2014 CAPEX of $2.4 billion, where $1.9 billion was dedicated to EQT Production and $475 million for EQT Midstream.[17]

Range Resources controls the largest acreage position in the core of the Marcellus, Upper Devonian, and Utica shale plays. Range initially announced its capital budget to be $1.3 billion for 2015, however soon revised the number to $870 million to account for reductions in service costs.[18] 95% of Range's 2015 budget was focused in the Marcellus play, and the vast majority was used towards drilling activities. Range increased its average lateral length by over 100%, allowing for decreases in well, drilling, and completion costs, while production is planned to grow 20-25%. The company has also engaged in exploratory tests in the Utica shale, with results that have warranted the construction of two wells in 2015.[19] The company reported that its test well achieved an initial flow rate of 59 mmcf/d, which company officials believed was an Appalachian basin record. In addition to the Utica, Range's acreage also sits directly on top of the Marcellus and Upper Devonian plays, allowing resources to be extracted from all three with a single well pad.[20]

Southwestern Energy is the fourth largest producer of natural gas in the lower 48 states (as of 4Q 2014), and operates in Appalachia as well as Arkansas, Texas, and Louisiana. Within Appalachia, Southwestern holds 413,000 net acres in southwest Pennsylvania and West Virginia, and recently purchased an

[14] Fukushima, Kurumi. "Chesapeake Energy (CHK) Stock Closed Up Today on $1 Billion Share Buyback Following Asset Sale" The Street 12/23/14. http://www.thestreet.com/story/12994764/1/chesapeake-energy-chk-stock-closed-up-today-on-1-billion-share-buyback-following-asset-sale.html

[15] "Analyst Presentation" EQT 4/15. http://ir.eqt.com/sites/eqt.investorhq.businesswire.com/files/doc_library/file/Analyst_Presentation_APRIL_-_PRINT.pdf

[16] "EQT Announces 2015 Operational Forecast" EQT 12/8/14. http://ir.eqt.com/press-release/eqt-announces-2015-operational-forecast

[17] "EQT Announces 2014 Operational Forecast" EQT 12/18/13. http://ir.eqt.com/press-release/eqt-announces-2014-operational-forecast

[18] "Range Resources Reduced Original 2015 Capital Budget to $870 Million" Oil & Gas Financial Journal 1/16/15. http://www.ogfj.com/articles/2015/01/range-resources-reduces-original-2015-capital-budget-to-870m.html

[19] "Company Presentation" Range Resources 4/28/15.

[20] "Range Resources' Utica Shale well hits a sweet spot" Pittsburgh Business Times, Energy Inc. 12/15/14. http://www.bizjournals.com/pittsburgh/blog/energy/2014/12/range-resources-utica-shalewell-hits-a-sweet-spot.html

additional 30,000 acres. The company primarily works in the Marcellus wet gas window and plans to operate 50-55 wells in 2015. In addition, the company holds 312,000 acres in northeast Pennsylvania, and plans to drill 88-92 wells there in 2015. Southwestern's 2015 capital budget was $2 billion, the lowest out of the last six years, and represented a drop from 2014's $2.4 billion budget. 64% of Southwestern's 2015 budget was put towards its operations in Appalachia, with 37% ($700 million) in the northeastern portion and 27% ($520 million) in the southwestern portion. This was a substantial shift from the company's 2014 budget, in which 33% was dedicated towards Appalachian operations.[21]

INDUSTRY THROUGHPUT PROJECTIONS

Even with today's mature American natural gas markets, relatively new natural gas provinces such as that of the Marcellus/Utica basin require major new investment into a midstream infrastructure. Without that infrastructure in place, production must be shut in. Operators prefer to not expend resources on drilling and completing wells when there is no expectation of immediately producing hydrocarbons. On the other hand, because much of the infrastructure is built based upon speculation by midstream companies, these companies must be careful to not overbuild. Planning and investment is deliberate. Even so, midstream companies are investing heavily in the region, and production has to date not been sitting behind pipe for more than a year. Total Utica and Marcellus midstream investments are projected to exceed $30 billion.[22]

To help them evaluate these investments, midstream companies have been making throughput projections based upon their discussions with producing companies, together with their own observations and analyses. Throughput is the basic metric controlling midstream investment. It is defined as the volume of gas or liquid that that moves through a facility or pipeline per day, usually represented as thousands (or millions and billions) of cubic feet per day, or, in the case of liquids, as thousands of barrels per day.

Midstream company throughput projections are frequently presented at investor conferences and are made available for public review on company websites. For purposes of building midstream facilities, companies tend to build facilities that integrate regional production, and as a result throughput projections often aggregate Marcellus and Utica production. The Study Team reviewed publicly available literature and presentations made by midstream companies projecting throughput. This section compiles the various views provided by industry experts as to the likely production to be found from the Marcellus/Utica basin over the next five years.

As set forth in section 2.1.2 above, most producing companies active in the Marcellus/Utica basin have materially cut back capital expenditures for shale development in the region. However as of the date of this report, midstream companies had not yet announced any major changes to their throughput projections.

According to midstream and upstream companies operating in the region, typical natural gas wells producing from the Utica and Marcellus wet gas corridors will incur about 30% shrinkage after processing,

[21] "May 2015 Update" Southwestern Energy 5/15.
http://www.swn.com/investors/LIP/latestinvestorpresentation.pdf

[22] "North American Midstream Infrastructure through 2035: Capitalizing on Our Energy Abundance" An INGAA Foundation Report, Prepared by ICF International Executive Summary March 18, 2014

generating approximately 6 gallons of liquids per mcf of produced wet natural gas. Of these liquids, the typical make up is approximately:

- 60% ethane,
- 22% propane,
- 11% butane, and
- 7% other, more complex hydrocarbons.[23]

According to midstream company Blue Racer, 2014 natural gas production was about 13 bcf/d for the two shale plays.[24] Blue Racer projects total "wet gas" production from the basin in 2020 to be around 9.3 bcf/d. Of this, Blue Racer projects about 3.6 bcf/d will be from the Utica, and about 5.7 bcf/d from the Marcellus.[25] Using the following "rule of thumb" formula:[26]

Wet gas volume x 6 gal/mcf x 0.60/42 gal/bbl = ethane volume

One can obtain from Blue Racer's estimates a throughput projection of approximately 247 mbbl/d by 2020 from the Utica, plus 391 mbbl/day (both assuming 20% ethane rejection)[27] from the Marcellus, for a total ethane output of 638 mbbl/d from the combined Utica/Marcellus basin.

MIDSTREAM COMPANY ACTIVITIES IN THE MARCELLUS/UTICA BASIN

GATHERING LINES

Once a well is completed and available to be produced, it is temporarily shut in pending a market. The next step is to build a line from the wellhead to a trunk line that feeds into either an interstate pipeline (if the gas is dry) or into a processing plant (if the gas is wet). These activities – called gas gathering - are often the specialty of companies that have particular skills in transportation, processing, or both. The result is that many of the midstream activities in the Marcellus/Utica basin are carried out by joint ventures (JV) between companies that pool together expertise and capital.[28]

[23] The Study Team interviewed a number of major midstream and upstream companies during the course of the research. Based upon these interviews ethane content was found to be around 60% of the NGLs produced, and this number was used for the "rule of thumb" ethane throughput calculation.

[24] "From Importer to Exporter" Blue Racer 1/30/14.
http://www.caimanenergy.com/sites/default/files/resources/resources0114Presentation.pdf

[25] Blue Racer, January 2014.

[26] The formula (6 gallons of liquids per mcf of wet gas produced, 60% ethane, and 42 gallons per barrel) was obtained from interviews with midstream companies working in the Utica and Marcellus wet gas regions.

[27] New processing technology allows for recovery of 90% or more, however industry projections typically use the 80% number because recovery of ethane over 80% becomes increasingly expensive. This number was obtained from industry interviews.

[28] There are two principal JV business models for marketing of liquids that may affect downstream industry development. One model envisions transporting and processing natural gas on a "fee" basis, tying the fee to the volume of gas transported or processed. The other model allows the midstream company to take title to the natural gas liquids upon processing. In this case, the midstream company assumes the risk of marketing or any loss of the liquids. Normally, whoever has the most expertise at marketing liquids will take title to the production after processing.

The Appalachian basin had a significant gathering line infrastructure that pre-existed the development of shale. Dominion, for instance, contributed almost 600 miles of gathering lines (with a capacity of 1.5 bcf/d) to its Blue Racer joint venture with Caiman Energy, most of which predated Utica development.[29] However Dominion's pre-existing infrastructure was insufficient to support the significant new production coming into Blue Racer's processing facilities, so 200 miles of new gathering lines are being built.[30] Other midstream companies that have gathering line capacity include: MarkWest (400 miles),[31] Williams Partners (1,400 miles),[32] NiSource (55 miles),[33] Antero (233 miles),[34] EQT (70 miles; 100 additional miles by 2018),[35] Magnum Hunter (175 miles),[36] Crestwood (65 miles),[37] M3 Momentum (150 miles,[38] with 67 additional miles planned),[39] and Summit (49 miles;[40] with 115 additional miles by the end of 2015).[41] In 2015, MarkWest announced plans to develop 250 additional miles of dry gas gathering lines in Jefferson County Ohio.[42]

[29] "From Importer to Exporter," Blue Racer 1/30/14.

[30] Nikoloric, Casey. "Blue Racer Midstream Provides Update on Operations in the Utica and Marcellus Shale" Blue Racer Midstream 6/24/15. http://www.blueracermidstream.com/news/blue-racer-midstream-provides-update-operations-utica-and-marcellus-shale

[31] "2015 Investor & Analyst Day" MarkWest 6/3/15. http://investor.markwest.com/phoenix.zhtml?c=135034&p=irol-presentations

[32] "Northeast Gathering & processing" Williams 2015. http://co.williams.com/operations/northeast-gathering-and-processing/

[33] "Pennant Midstream Hickory Bend Processing Plant and Gathering System Project" Columbia Pipeline Group 2014. https://www.columbiapipelinegroup.com/current-projects/pennant-midstream-hickory-bend-processing-plant-and-gathering-system

[34] "Antero Midstream Partners LP Announces 2015 Guidance and Operational Update" Antero Midstream Partners LP 1/20/15. http://www.prnewswire.com/news-releases/antero-midstream-partners-lp-announces-2015-guidance-and-operational-update-300023194.html

[35] Kusic, Sam. "EQT Midstream to Invest $370 million in Pipeline Expansion Project" Pittsburgh Business Times 3/11/15. http://www.bizjournals.com/pittsburgh/blog/energy/2015/03/eqt-midstream-to-invest-370-million-in-pipeline.html

[36] "Investor Presentation" Magnum Hunter 7/15. http://www.magnumhunterresources.com/MagnumHunterResources.pdf

[37] "Gathering & Processing: Marcellus" Crestwood 2015. http://www.crestwoodlp.com/operations/gathering-processing/marcellus.asp

[38] "Appalachian Gathering System Brochure" M3 Momentum. http://www.m3midstream.com/appalachia-gathering-system/AGS%20Brochure-3.pdf

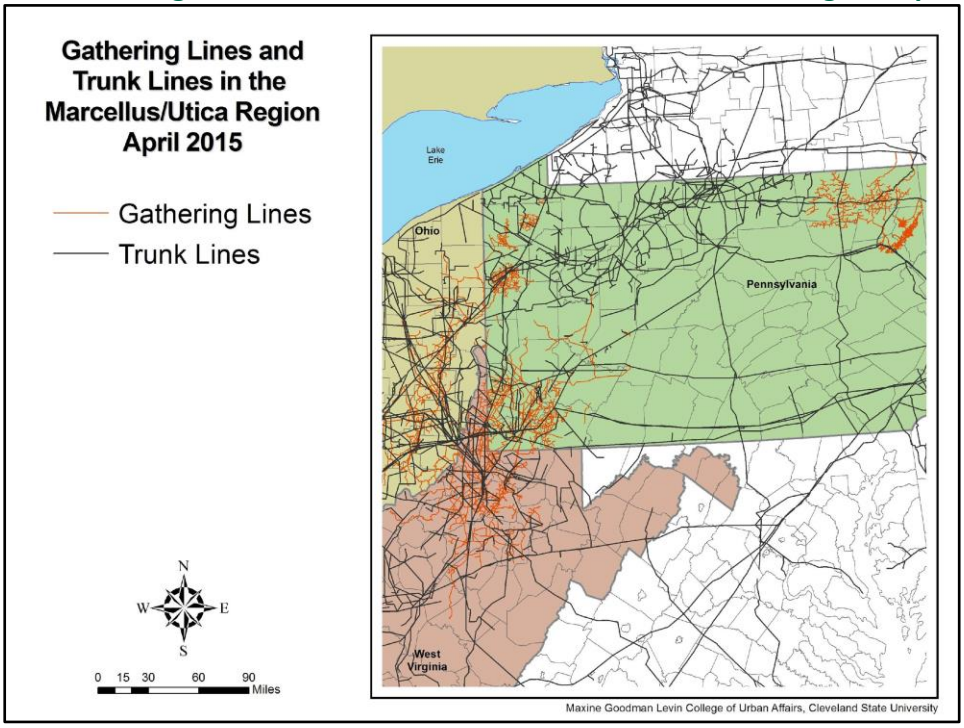
[39] "M3's New Stonewall Gathering System Extends Existing AGS in WV" Marcellus Drilling News 4/15. http://marcellusdrilling.com/2015/04/m3s-new-stonewall-gathering-system-extends-existing-ags-in-wv/

[40] "Areas of Operation" Summit Midstream 2013. http://www.summitmidstream.com/operations

[41] "General Partner of Summit Midstream Partners, LP to Develop Natural Gas Gathering System for XTO Energy Inc. in the Utica Shale" Summit Midstream 12/15/14. http://www.summitmidstream.com/docs/xto%20utica%20announcement%20%2812%2015%2014%29vf.pdf

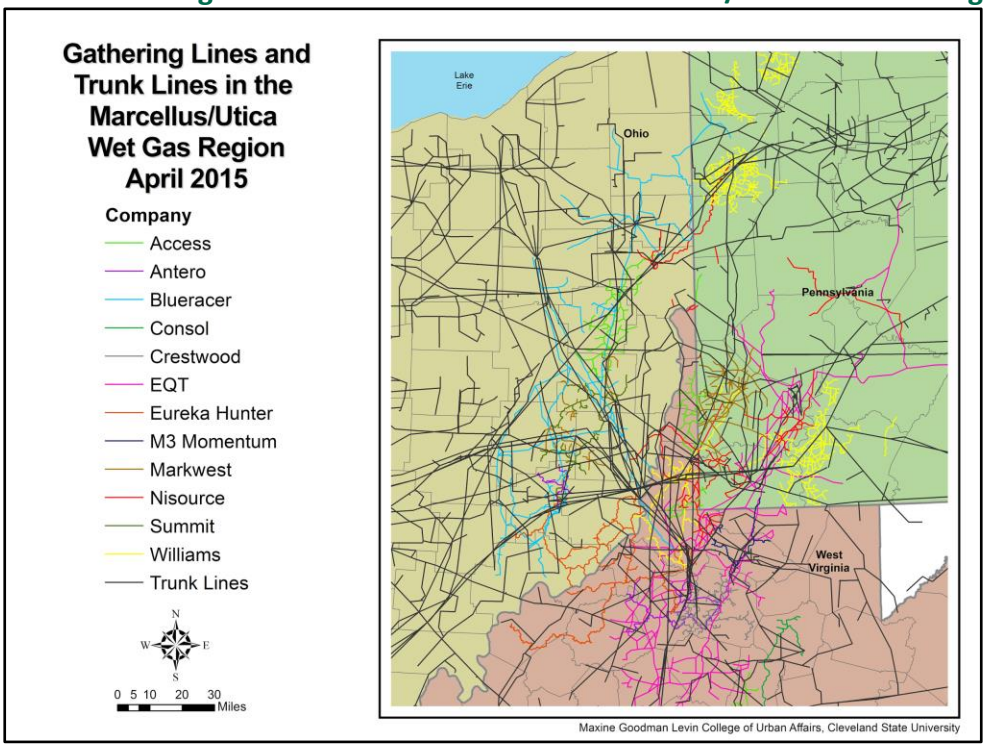
[42] "Third Quarter 2015 Conference Call Presentation" MarkWest 11/4/15. http://investor.markwest.com/phoenix.zhtml?c=135034&p=irol-presentations

Figure 3. Gathering Lines and Trunk Lines in the Marcellus/Utica Region, April 2015



Source: Midstream company investor presentations and other public sources

Figure 4. Gathering Lines and Trunk Lines in the Marcellus/Utica Wet Gas Region



Source: Midstream company investor presentations and other public sources

CRYOGENIC PROCESSING AND FRACTIONATION CAPACITY

The wet gas windows for the Utica and the Marcellus are located principally in SE Ohio, SW Pennsylvania and northern West Virginia. Accordingly, most of the processing facilities are located in this Tri-State region. In 2015, there were nine processing companies in the core Marcellus-Utica region, including the following key companies:[43]

- M3-Momentum (Utica East Ohio Midstream)
- MarkWest
- Blue Racer (processing by Caiman)
- Pennant (processing by NiSource)
- Williams Partners
- XTO Energy
- Several Smaller Operations

These midstream processing company operations can be described as follows:

Utica East Ohio Midstream. Access Midstream collaborated with M3-Momentum and EV Energy Partners (EnerVest) to create Utica East Ohio Midstream (UEO). Williams Partners acquired Access in February 2015 and EV Energy Partners in April of 2015, increasing its stake in UEO to over 70%.[44] The joint venture gathers, compresses, dehydrates, processes and fractionates natural gas and natural gas liquids. Utica East Ohio Midstream has 1.0 bcf/d of cryogenic processing capacity. UEO also has 135 mbbl/d of C2+ fractionation (ethane and up), 90 mbbl/d of C3+ fractionation (propane and up), 1 million barrels of NGL storage, a high capacity rail and truck terminal and multiple purity product pipelines to distribute natural gas liquids to the premium markets in the region. Utica East Ohio Midstream producers include Chesapeake, Total, Hilcorp, Halcon, and Atlas.[45]

Blue Racer. Caiman (of which Williams Partners owns 58%)[46] has partnered with Dominion to create Blue Racer. It processes gas for such operators as Hess, Consol, Rex and Chesapeake. As of spring 2015 Caiman had cryogenic processing capability of 400 mmcf/d in Natrium, West Virginia and 400 mmcf/d in Berne, Ohio. With Dominion, an additional 288 mmcf/d is located in the Hastings, WV facility. Blue Racer has a C2+ fractionation capacity of 46 mbbl/d in Natrium, with another 80 mbbl/d under construction at that location.[47] 14 mbbl/d more of C3+ fractionation capacity is located in Blue Racer's Hastings facility.[48] Blue Racer also had 200 mmcf/d of cryogenic processing planned for a new facility in Petersburg, Ohio, but has since cancelled plans citing poor production in the northern reaches of the Utica.[49]

[43] There is additional processing capacity in the Marcellus region that may, with some additional pipeline infrastructure, be used to process wet gas from either the Marcellus or Utica.

[44] Carr, Housley. "Join Together With Demand-Five Marcellus/Utica Midstream Players" RBN Energy LLC 4/12/15.

[45] Industry interviews

[46] Carr, Housley. "Join Together With Demand-Five Marcellus/Utica Midstream Players" RBN Energy LLC 4/12/15.

[47] "From Importer to Exporter" Blue Racer 1/30/14.

[48] Meyers, Dave. "NGL Gold Rush: Processing, Fractionation, Pipelines, and Storage Infrastructure" Dominion 9/10/14.

[49] "Blue Racer Shelves Petersburg Gas Project" The Business Journal 1/30/15. http://businessjournaldaily.com/blue-racer-shelves-petersburg-gas-project/

MarkWest. MarkWest has midstream operations in Ohio, West Virginia, New York and Pennsylvania. It takes production from Gulfport, Antero, Chesapeake, Range, Chevron, Consol and others. Its cryogenic processing capacity as of November 2015 for the Utica and Marcellus was 5,345 mmcf/d, divided among nine facilities. 1,200 mmcf/d of this capacity is located at the Sherwood, WV facility, 1,070 mmcf/d in Majorsville, PA, 720 mmcf/d in Mobley, WV, 800 mmcf/d at the Seneca, OH facility, 555 mmcf/d in Houston, PA, 525 in Cadiz, OH, and 210 at the Keystone facility in Pennsylvania. MarkWest's three remaining cryogenic processing facilities, Kenova, Cobb, and Kermit, have a combined capacity of 265 mmcf/d.[50] MarkWest's C3+ fractionation capacity in 2014 was 192 mbbl/d, 120 mbbl/d of which is located in Hopedale, OH, 60 in Houston, PA, and 12 at the Keystone facility. The company also operates 134 mbbl/d of de-ethanization (C2) capacity, 40 of which is located at Cadiz, 40 located at Houston, 40 in Majorsville, and 14 at Keystone. MarkWest anticipates expansions to 7,145 mmcf/d of cryogenic processing capacity, 283 mbbl/d of C3+ fractionation, and 238 mbbl/d of de-ethanization capacity.[51]

In August of 2013, MarkWest announced that it planned to pursue a joint venture with Kinder Morgan to construct a cryogenic processing facility in Tuscarawas County, Ohio. This plant will have an initial capacity of 200 mmcf/d, with a planned expansion to 400 mmcf/d (included in the projection numbers above).[52] In mid-2015 it was announced that MarkWest will be acquired by Marathon Petroleum Corp.'s pipeline unit, MPLX, for $15.8 billion. The acquisition was completed in 2015.[53]

Pennant. NiSource, through its Columbia Midstream Group, operates midstream gathering and processing as Pennant in a joint venture with Hilcorp at the Hickory Bend cryogenic processing facility in Mahoning County, Ohio. Pennant has processing capacity of 200 mmcf/d[54] and plans to add another 200 mmcf/d.[55]

Williams Partners. Williams Partners operates two cryogenic processing facilities, Ft Beeler and Oak Grove in West Virginia, which have capacities of 520 mmcf/d and 400 mmcf/d, respectively. The Oak Grove complex also has 40 mbbl/d of de-ethanization capacity, along with 42.5 mbbl/d of C3+ fractionation

[50] "West Virginia: Profile Overview" United States Energy Information Administration 3/27/14. http://www.eia.gov/state/?sid=WV

[51] "Third Quarter 2015 Conference Call Presentation" MarkWest 11/4/15. http://investor.markwest.com/phoenix.zhtml?c=135034&p=irol-presentations

[52] "Kinder Morgan, MarkWest Utica EMG Announce Plans to Form Joint Venture to Support Northern Ohio Rich-Gas Development and NGL Takeaway from the Utica and Marcellus Shale Resource Plays" Business Wire 8/7/13. http://www.businesswire.com/news/home/20130807006090/en/Kinder-Morgan-MarkWest-Utica-EMG-Announce-Plans#.VHzHWcnzi1g

[53] Polson, Jim. "Marathon to Buy Gas-Rich MarkWest for $15.8 billion" Bloomberg Business 7/14/15. http://www.bloomberg.com/news/articles/2015-07-13/mplx-to-buy-markwest-energy-partners-for-about-20-billion

[54] "Pennant Midstream Announces Hickory Bend Cryogenic Processing Plant Ready for Service" Columbia Pipeline Group 1/6/14. https://www.columbiapipelinegroup.com/about-us/news-room/2014/01/06/pennant-midstream-announces-hickory-bend-cryogenic-processing-plant-ready-for-service

[55] "Pennant Midstream Hickory Bend Processing Plant and Gathering System Project" Columbia Pipeline Group 2014.

capacity at Williams Partners' Moundsville, WV facility.[56] The company added an additional 17.5 mbbl/d of C3+ fractionation capacity at its Moundsville facility in 2015.[57]

XTO Energy. Having merged with the Exxon Mobil Corporation in 2010, XTO Energy operates one cryogenic processing plant in Pennsylvania. This Butler County facility has a 125 mmcf/d processing capacity.[58]

Smaller Operations. Three companies manage smaller cryogenic processing operations in the core Marcellus and Utica region: Dominion, Exterran Energy, and Laurel Mountain. Dominion has a cryogenic processing capacity of 94 mmcf/d, split among its three plants: Lightburn, Copley, and West Union. Exterran Energy operates a small facility in Schultz, WV with a capacity of 10 mmcf/d. Laurel Mountain has two facilities, Stewart and Robin Hill, that each have cryogenic processing capacities of 18 mmcf/d. Other small operations exist in the greater Marcellus/Utica region, contributing another 80 mmcf/d of capacity.[59]

Through the end of 2015, MarkWest had the largest cryogenic processing capacity in the region with 5,345 mmcf/d, and a projected 7,145 mmcf/d by 2020. Blue Racer had 1,088 mmcf/d of cryogenic processing, with plans to expand to 1,688 mmcf/d. Utica East Ohio Midstream had a total of 1,000 mmcf/d in cryogenic processing capacity, and plans to add at least 500 mmcf/d of additional processing capacity with the timing dependent upon its customers' production growth over the next few years.[60] With Hickory Bend as its only current processing facility, Pennant will increase its capacity from 200 mmcf/d to 400 mmcf/d by 2020. The total 2015 cryogenic processing capacity for the Marcellus and Utica was about 7,898 mmcf/d, which is expected to increase to about 11,998 mmcf/d by 2020.

Projected wet gas production from the Marcellus and the Utica by 2020, according to Blue Racer, will be about 9.3 bcf/d.[61] The liquids derived from processing this volume establishes the number that should be compared to anticipated total regional processing capacity. That analysis is set forth in Table 1 below.

[56] Meyers, Dave. "NGL Gold Rush: Processing, Fractionation, Pipelines, and Storage Infrastructure" Dominion 9/10/14.
[57] Bull, Darrell. "More Growth Stories, and another NGL Solution" Williams 1/30/13.
[58] "Pennsylvania Activities and Operations" XTO Energy 2/14.
http://xtoenergy.com/areasofoperation/pennsylvania
[59] "West Virginia: Profile Overview" United States Energy Information Administration 3/27/14.
[60] Industry Interviews
[61] "From Importer to Exporter," Blue Racer 1/30/14.

Table 1. Existing Processing Capacity in the Marcellus and Utica

Company	Type of Processing			
	Cryogenic Processing (Mmcf/d)	C3+ Fractionation (mbbl/d)	C2+ Fractionation (Mbbl/d)	De-Ethanization (C2) (mbbl/d)
M3 Momentum	1,000	90	135	0
Caiman	1,088	14	46	0
MarkWest	5,345	192	0	134
NiSource	200	0	0	0
Williams	920	42.5	0	40
XTO	125	0	0	0
Grand Total	**8,898 including 220 mmcf/d of capacity from small operations**	**338.5**	**181**	**174**

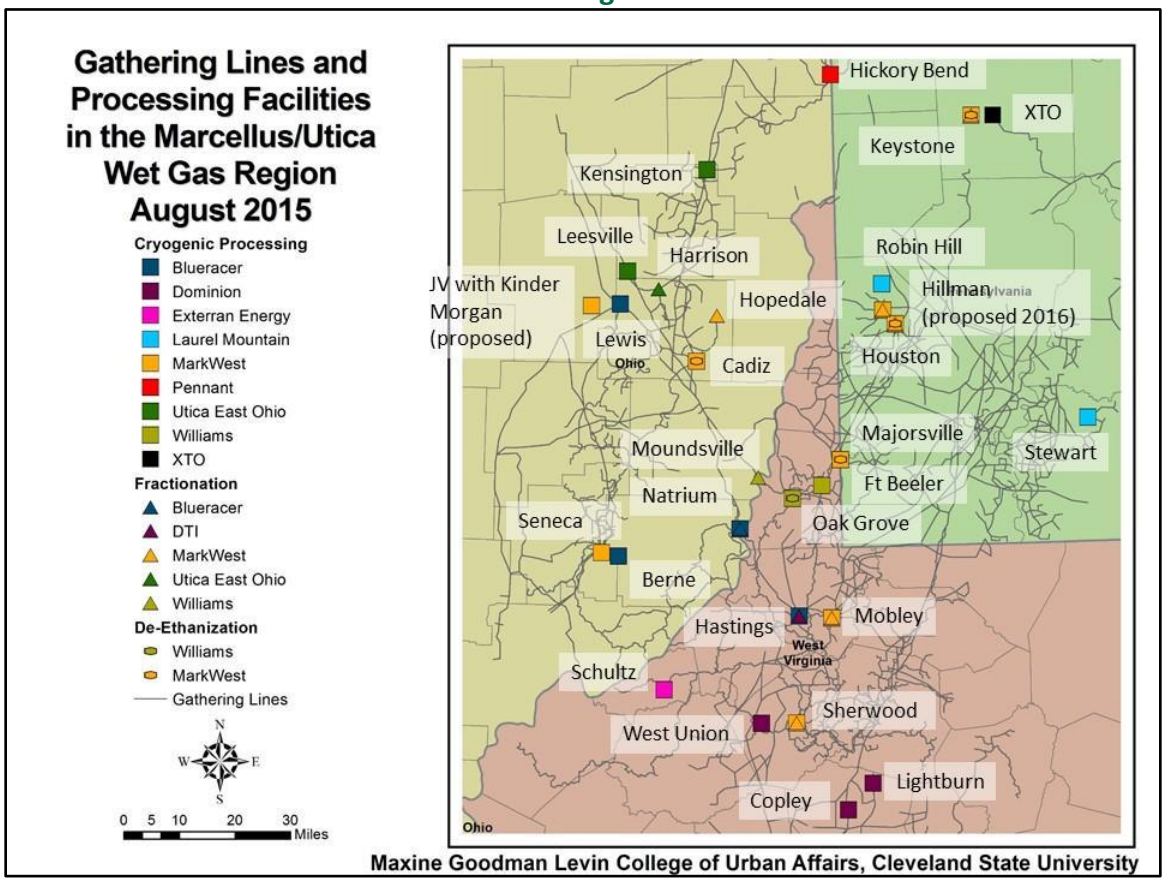
(June 2015)

Table 2. Planned Processing Capacity Expansions plus Existing Capacity in the Marcellus and Utica

Company	Type of Processing			
	Cryogenic Processing (Mmcf/d)	C3+ Fractionation (mbbl/d)	C2+ Fractionation (Mbbl/d)	De-Ethanization (C2) (mbbl/d)
M3 Momentum				
Existing	1,000	90	135	0
Total After Expansion	1,500	90	135	0
Caiman				
Existing	1,088	14	46	0
Total After Expansion	1,688	14	126	0
MarkWest				
Existing	5,345	192	0	134
Total After Expansion	7,145	283	0	238
NiSource				
Existing	200	0	0	0
Total After Expansion	400	0	0	0
Williams				
Existing	920	42.5	0	40
Total After Expansion	920	60	0	40
XTO				
Existing	125	0	0	0
Total After Expansion	125	0	0	0
Grand Total After Expansion	**11,998 including 220 mmcf/d of capacity from small operations**	**447**	**261**	**278**

(June 2015)

Figure 5. Cryogenic Processing, Fractionation, and De-Ethanization in the Marcellus/Utica Wet Gas Region



Source: Midstream company investor presentations and other public sources (2015)

NATURAL GAS LIQUIDS TAKE AWAY CAPACITY

Natural Gas Liquids must be transported to markets after processing. This important midstream company activity occurs downstream of the cryogenic or fractionation plants. In addition to transporting natural gas, pipeline companies also have lines dedicated to natural gas liquids and oil. These lines can carry undifferentiated natural gas liquids or carry a pure product. Unlike for natural gas, liquids normally have alternative take away transportation strategies available: truck, rail and barge. Ethane, however, is the exception to this: pure product ethane is typically still a gas after fractionation, and as such requires a pipeline for take away.

For the Appalachian Basin, there are several existing pipelines with natural gas liquid take away capacity. There are also plans to expand some of these lines and to build new ones. The ATEX pipeline, owned by Enterprise Products Partners, has the ability to transport 125 mbbl/d of ethane to the Gulf Coast (ethane is commonly measured in barrels instead of cubic feet, notwithstanding that is usually a gas). These 1,205-mile (16" and 20") lines can be expanded to 265 mbbl/d.[62]

[62] "Scotia Howard Weil Energy Conference" Enterprise Products Partners L.P. 3/23/15. http://phx.corporate-ir.net/phoenix.zhtml?c=80547&p=irol-presentations2015

In addition to its ATEX line, Enterprise Products Partners operates the TEPPCO pipeline, running from the Gulf Coast to the northeastern United States. With a design capacity (adjusting for seasonal differences) of 60 mbbl/d, the line can transport propane and refined products from the Utica/Marcellus region, in addition to points further northeast.[63]

Sunoco Logistics owns two pipelines: the Mariner East and West lines. The Mariner East line runs between Houston, PA and the Marcus Hook industrial complex near Philadelphia, carrying a mixture of propane and ethane. Transportation of propane on the Mariner East line began at the end of 2014, with an initial capacity of 10 mbbl/d, growing to 20 mbbl/d by the second quarter of 2015. These additions are part of Sunoco Logistics' Mariner East 1 project, and became fully operational in 2015 with a total capacity of 70 mbbl/d.[64] An expanded ethane and propane capacity of 275 mbbl/d will be offered when Sunoco Logistics' Mariner East 2 project is completed in 2016.[65] The Mariner West line, which became operational at the end of 2013, travels from Houston, PA to Sarnia, Ontario and has a 50 mbbl/d ethane capacity.[66]

Another pipeline has been proposed by Kinder Morgan that will carry ethane and propane west to Sarnia. The proposed Utopia line (50 mbbl/d capacity, expandable to 75 mbbl/d) is scheduled to be complete in 2018.[67] In addition, Kinder Morgan plans to construct a batched system pipeline (propane, butane, natural gasoline and condensate) - the Utica-Marcellus Texas Pipeline- with an initial capacity of 150 mbbl/d.[68] This project would convert over 950 miles of Kinder Morgan's Tennessee Gas Pipeline for NGL transportation, and would connect to nine Marcellus/Utica processing facilities.[69] It would have a maximum design capacity of 430 mbbl/d. The Utica-Marcellus Texas Pipeline is scheduled to be in-service by the end of 2018.[70]

One system that was contemplated, but has been since suspended, was the William's Bluegrass NGL pipeline, which was to have around 200 mbbl/d capacity.[71]

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[63] "Enterprise increasing TEPPCO propane shipments following US FERC order" Platts 2/10/14. http://www.platts.com/latest-news/oil/houston/enterprise-increasing-teppco-propane-shipments-21198473; "Northeast Propane Infrastructure, Supply Shortages & High Cost to Consumers" Crestwood 4/15. http://energy.gov/sites/prod/files/2014/04/f15/Remarksof_AndyRonald_Crestwood_ppt_April21_0.pdf

[64] "Fourth Quarter 2014 Earnings Conference Call" Sunoco Logistics Partners L.P. 2/19/15. http://www.sunocologistics.com/SiteData/docs/Q42014SXLE/4607d6ca1f788aab/Q4%202014%20SXL%20Earnings%20Conference%20Call%20Slides%20-%20FINAL3.pdf

[65] "About Sunoco Logistics and the Mariner East Project" Sunoco Logistics 11/14. http://sxlpipelineprojects.com/wp-content/uploads/2014/11/SXL_Frequently_Asked_Questions.pdf

[66] "Citi MLP/ Midstream Infrastructure Conference" Sunoco Logistics Partners L.P. 8/20/14. http://www.sunocologistics.com/SiteData/docs/August2014/b68372a93583dc3e/August%202014%20Investor%20Presentation%20-%20v3.pdf

[67] "Kinder Morgan Announces Binding Open Season for Ethane/Propane Movements Out of the Utica Shale" Kinder Morgan 9/4/14. http://www.kindermorgan.com/content/docs/UtopiaPress_Release.pdf

[68] "Kinder Morgan Energy Partners- Targa Resources Partners to Expand Fractionation Capacity in Texas to Support the Utica Marcellus Texas NGL Pipeline" Kinder Morgan 12/20/13. http://www.kindermorgan.com/content/docs/KMP_Targa_Ext_Open_Season.pdf

[69] "Utica Marcellus Texas Pipeline Project" Kinder Morgan 2015. http://www.kindermorgan.com/projects/ygrade

[70] "Kinder Morgan Announces Binding Open Season for Utica Marcellus Texas Pipeline" Business Wire 6/17/15. http://www.businesswire.com/news/home/20150617005877/en/Kinder-Morgan-Announces-Binding-Open-Season-Utica#.VYlcFhDzi1g

[71] "From Importer to Exporter" Blue Racer 1/30/14.

Both the ATEX and Mariner West Pipelines were constructed solely for ethane transportation purposes, while the Mariner East 1 and Utopia pipelines, as well as the proposed Mariner East 2 pipeline, were or will be designed for both ethane and propane use (see Table 3 below).

In addition to these pipeline systems, there is about 200 mbbl/d of railroad take-away capacity in the region.[72] However railroad capacity, as is the case for trucking capacity, is principally limited to those natural gas liquids that are easy to transport in a liquid state, such as propane.

There is also a robust local demand for propane. Propane is a popular fuel used for residential heating, and is also used as a feedstock for the petrochemical industry. As of 2014, most propane produced from the Utica/Marcellus region was consumed locally. Local propane demand in the Utica/Marcellus basin is around 100 mbbl/d.[73]

Total liquids projected for 2020 from the Marcellus and the Utica are around 1,400 mbbl/d.[74] Assuming the Enterprise Products, Kinder Morgan, and Sunoco expansions occur, take away capacity plus local usage for the basin could reach 1,525 mbbl/d by 2020. This suggests that the take away capacity being built will be sufficient for total natural gas liquids production.

Industry projections call for around 638 mbbl/d of ethane throughput, assuming a 20% rate of rejection (Marcellus: 391 mbbl/d and Utica: 247 mbbl/d). Regional ethane processing capacity is calculated as the sum of de-ethanization (or C2 fractionation) capacity and the amount of C2+ fractionation capacity dedicated for ethane-specific processing. This C2+ value is gathered using an industry rule of thumb, estimating that one third of C2+ fractionation capacity will be reserved for ethane processing. Accordingly, 2020 regional ethane processing capacity will total 365 mbbl/d, combining de-ethanization (278 mbbl/d) and one third of C2+ fractionation (87 mbbl/d). Since ethane can be rejected, these fractionation capacities may well be sufficient for the region's projected ethane throughput. However, if there is a market for ethane, additional capacity can be built quickly. The midstream industry was able to build processing capacity to handle the wet Utica gas within two years. It is unlikely that fractionation capacity will create a bottleneck for ethane supply.

Ethane take away capacity, however, could fall short if production reaches projected numbers, and if ethane is rejected at a rate of 20%. Ethane take away capacity may vary considerably, depending upon how the Mariner East 2 and Utopia lines are used. Both lines will be capable of transporting either propane or ethane, with the Mariner East 2 line also able to transport higher carbon chain hydrocarbons. Sunoco Logistics has stated that it anticipates that the Mariner East 2 pipeline (capacity 275 mbbl/d for mixed NGLs) will likely be used primarily for propane. Accordingly, for purposes of projecting total ethane take away capacity for 2020, we include Utopia's 50-75 mbbl/d and Mariner East 1's 70 mbbl/d, but not Mariner East 2's 275 mbbl/d capacity. This leaves a projected total capacity of around 460 mbbl/d for ethane by 2020 (see Table 3 below), with a possible capacity ranging between 315 and 735 mbbl/d. [75]

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[72] "Credit Suisse 2014 Energy Summit" Williams 2/11/14. http://www.energy.williams.com/Profiles/Investor/Investor.asp?BzID=630&from=du&ID=64367&myID=13611&L=I&Validate=3&I=

[73] *Id*.

[74] "Credit Suisse 2014 Energy Summit" Williams 2/11/14.

[75] This 460 mbbl/d figure does not include the Mariner East 2 pipeline (with 275 mbbl/d of propane, ethane, and butane capacity) because the pipeline will primarily be used for propane transportation (*see* Sunoco Logistics,

Table 3. Marcellus/Utica NGL Take Away Capacity

Pipeline	Company	Type	Existing 2014 (mbbl/d)	Projected (mbbl/d)
ATEX	Enterprise Products	Ethane	125	265
Mariner East	Sunoco	Ethane and Propane	70	345*
Mariner West	Sunoco	Ethane	50	50
Utopia	Kinder Morgan	Ethane and Propane	0	75
Ethane Total			**245**	**460 (excluding Mariner East 2)**
TEPPCO	Enterprise Products	Propane	60	60
Utica Marcellus Texas	Kinder Morgan	Y-grade	0	430
Total			305	1,225
Grand Total			**605 including local demand and rail capacity**	**1,525 including local demand and rail capacity**

The Mariner East 2 pipeline will have a capacity of 275 mbbl/d of mixed NGLs, including propane, ethane, and butane. Because of this, its capacity is not included in the "Ethane Total" figure, but is included in the "Grand Total" figure. (June 2015)

This suggests that a disparity between production capacity and take away capacity may exist by 2020 (Table 4). If development proceeds as planned by the upstream and midstream industries, and if the Utopia or the Mariner East lines are used primarily for propane, additional local markets will need to be developed to avoid large-scale ethane rejection.

supra). However, this figure does include the Mariner East 1 and Utopia pipelines with a combined 145 mbbl/d of ethane and propane capacity. Because of this, ethane take away capacity for the Utica and Marcellus could theoretically range from 315 mbbl/d (if no Mariner East 1, Mariner East 2, and Utopia capacity is dedicated for ethane) to 735 mbbl/d (if all Mariner East 1, Mariner East 2, and Utopia capacity is dedicated for ethane).

Table 4. Utica and Marcellus Projected Production Compared to Fractionation Capacity, 2020

	Total NGL Volume	Ethane (mbbl/d)
Industry Projected Production – wet gas	9.3 bcf/d (1) 1,400 mbbl/d (2)	638.4 (3)
Industry Projected Processing Capacity	12 bcf/d	365 (4)
Industry Projected NGL Take Away Capacity, plus local use	1,525 mbbl/d	460 (5)

(6) Blue Racer Investor Presentation (Fall 2014)

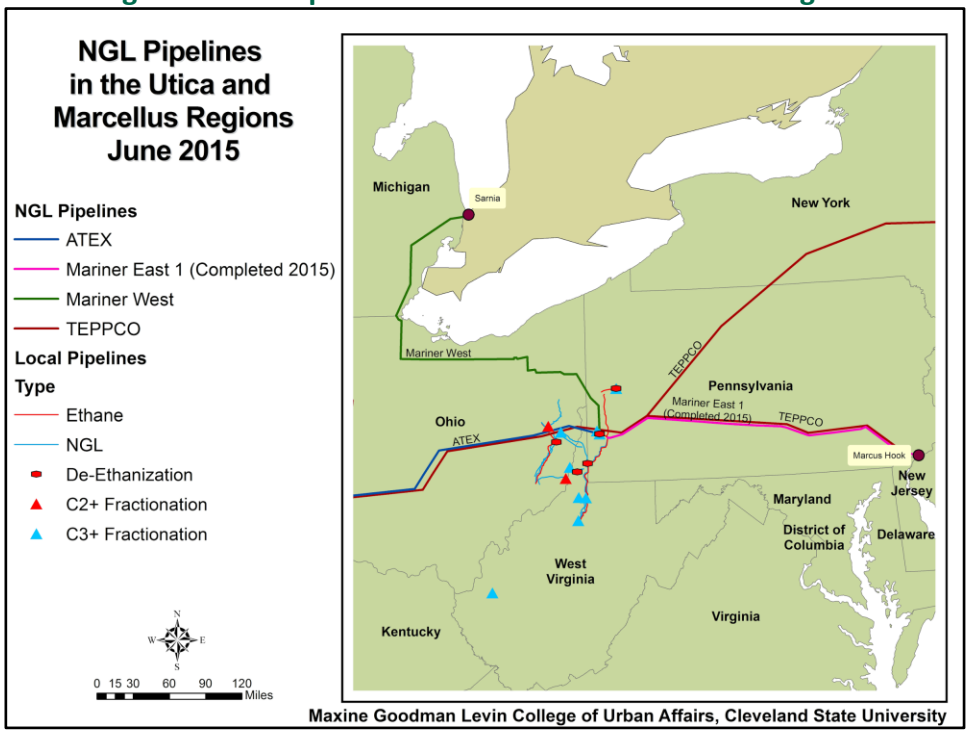
(7) Williams projects 1,400 mbbl/d

(8) Assumes 60% ethane, 6 gal/mcf, 42 gal/bbl, and 20% rejection

(9) One third of C2+ fractionation (87 mbbl/d) plus de-ethanization (C2) (278 mbbl/d)

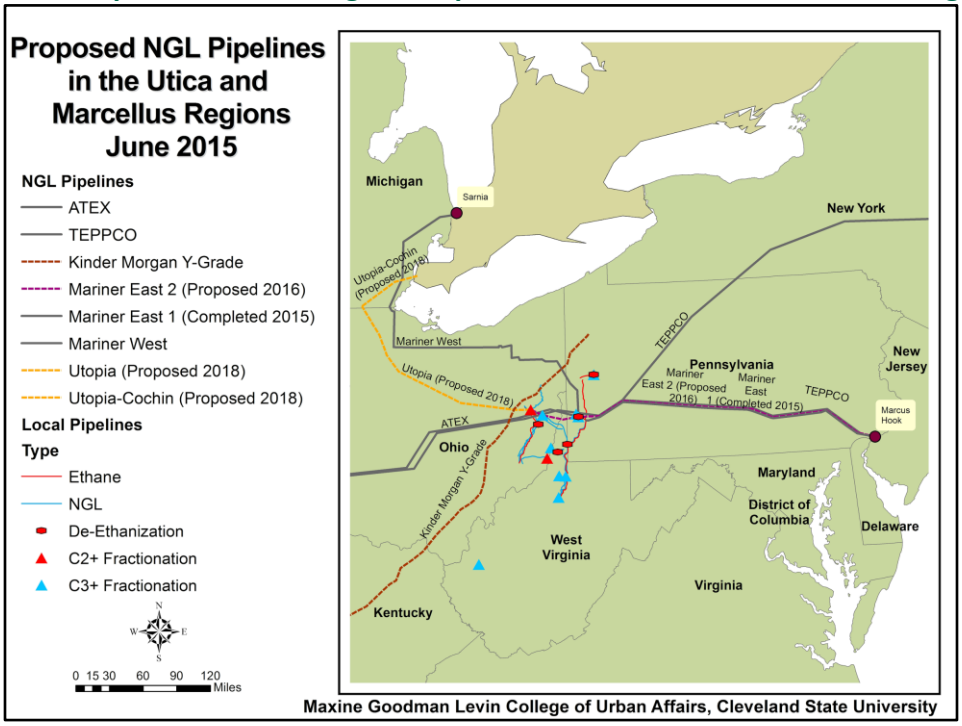
(10) The Mariner East 1 and Utopia pipelines are dedicated to ethane and propane, with capacities of 70 and 75 mbbl/d, respectively. The Mariner East 2 pipeline expansion is projected to be 275 mbbl/d, however most of the pipeline's capacity will likely be used for propane. Accordingly, all 145 mbbl/d of Mariner East 1 and Utopia's propane/ethane capacity is included to make this number, but none of Mariner East 2's 275 mbbl/d. The range of possible ethane capacity is between 315 and 735 mbbl/d.

Figure 6. NGL Pipelines in the Utica and Marcellus Regions



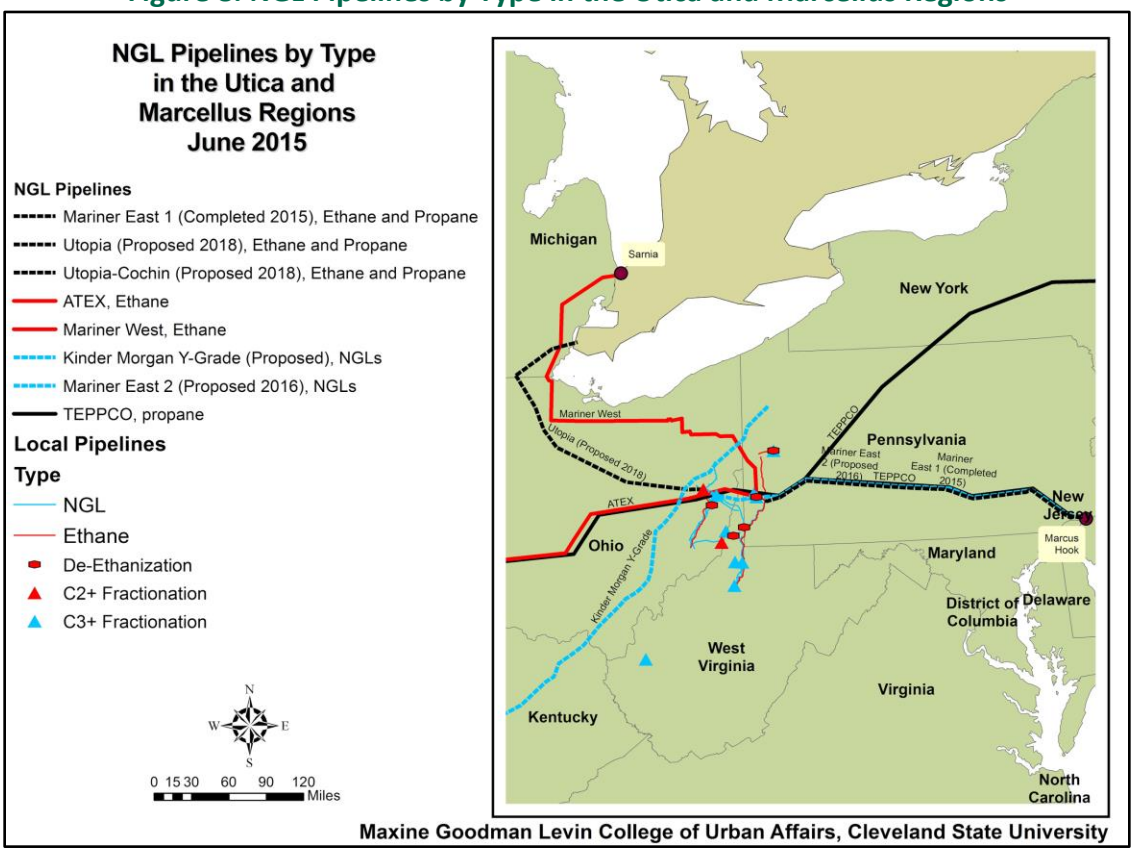
Source: Midstream company investor presentations and other public sources. (June 2015)

Figure 7. Proposed and Existing NGL Pipelines in the Utica and Marcellus Regions



Source: Midstream company investor presentations and other public sources. (June 2015)

Figure 8. NGL Pipelines by Type in the Utica and Marcellus Regions



Source: Midstream company investor presentations and other public sources. (June 2015)

REGIONAL STORAGE AND SUPPLY CONTRACTING CONSIDERATIONS FOR ETHANE

Storage Supplies

Natural gas liquids are commonly transported in the US by pipeline. However, when pipelines are unavailable, NGLs can also be transported via truck or rail. Heavier NGLs are more likely to be transported in this manner.

Lighter liquids, especially ethane, are more volatile, and as a result more difficult to transport by truck or rail. Ethane boils off at a temperature of a negative 127 degrees F. To keep it in the liquid state for easy transportation, it has to be chilled and maintained under great pressure. This makes ethane transportation by truck or rail expensive.[76]

Above ground storage of ethane is, for the same reason, more expensive than for heavier liquids. The most common strategy for large-scale ethane storage is the same as that used for dry natural gas: pumping it into underground natural gas storage facilities. Storage serves as insurance against unexpected market events, such as interruptions in production, pipeline mechanical failure, and natural disasters.[77] It is also used to maintain balance between supply and demand. However, because ethane does not incur the large daily and seasonal swings in demand that dry natural gas incurs, far less storage is required. Yet ethane demand is nonetheless dynamic enough that storage strategies are important to avoid supply interruption or oversupply.[78]

As of December 2013, total United States domestic natural gas storage capacity was over 9,100 bcf,[79] located in more than 400 facilities across the country.[80] Many of those facilities are located in the Appalachian region (Figure 9 below). However, as of 2016, all underground storage facilities in the Appalachian Region are dedicated to methane storage. Both salt dome and hard rock storage facilities are full. Geologic studies have been undertaken to find new storage locations, and so far no economically viable locations have been identified.[81] As a result, ethane storage of this nature would have to be

[76] Propane and butane are also gases at atmospheric temperatures and pressures, but cost less to liquefy. Propane and butane (together, Liquefied Petroleum Gas) are liquefied at 15 degrees Celsius, and 1.7-7.5 bars of pressure. *See*, "CNG vs. LPG," http://www.diffen.com/difference/CNG_vs_LPG.

[77] Natural gas storage historically has followed the same pattern: put gas into storage during the summer, and take it out during the winter. However, it has recently become more complicated in the Appalachians due to shale development. Now storage is more than just a flywheel for gas usage fluctuation; with production overwhelming demand, storage may be needed to avoid flaring.

[78] "C. Mitchell, "Catch a Hydrocarbon, Put it in Your Cavern, Save It for a Wintry Day," RBN Energy, LLC, April 8, 2013, found at: https://rbnenergy.com/catch-a-hydrocarbon-put-it-in-your-cavern-save-it-for-a-wintry-day-natural-gas-storage

[79] "Oil & Natural Gas Transportation & Storage Infrastructure: Status, Trends, & Economic Benefits" IHS Global Inc. 12/13. There are three types of natural gas storage facilities: depleted natural gas reservoirs, aquifers, and salt caverns. Depleted natural gas reservoirs make up the largest share of storage in the United States, at over 80%, and also comprise the majority of facilities in the Appalachian region. *See* "Energy Primer: A Handbook of Energy Market Basics" Office of Enforcement, Federal Energy Regulatory Commission 7/12. Salt cavern storage is also found in Ohio. Aquifer storage exists west of Ohio, and also tends to be more expensive. *Id.*

[80] "Energy: Securing Our Natural Gas Supply Chain" American Petroleum Institute.

[81] Industry interviews. For an example of such studies, *see* slide 24, G. Dettinger, http://www.wvcommerce.org/App_Media/assets/doc/energy/Energy_Summits/presentations_2011/GKurtDettinger_StateofWV.pdf. However there has been discussion in 2016 around an effort to reexamine developing regional

contained in on-site, above-ground refrigerated storage tanks similar to those used for shipping ethane overseas.

The U.S. Gulf Coast, by contrast, has ample underground storage capacity, especially at its Mont Belvieu, Texas fractionation facility, located 30 miles east of Houston. Enterprise Product Partners maintains 35 storage caverns with a capacity of 110 million bbls. Targa Resources, Oneok Partners and other companies own additional storage capacity in the area. While storage is just one consideration for choosing a location to build a cracker, this does provide the Gulf Coast with a strategic advantage.[82]

Nevertheless, the lack of underground ethane storage facilities should not be a deterrent to building crackers in Appalachia.[83] The oil and gas industry has developed strategies for dealing with storage requirements when no underground storage is available. One strategy, known as "line packing," involves placing more ethane into the pipeline by adding pressure. Another strategy common to the oil and gas industry is to mitigate the need for storage by deploying redundant pipelines and back up contracts to ensure supply and demand can be balanced.

Line Packing has long been common to the natural gas transportation business. Gas can be stored for short-term purposes within pipelines by increasing pipeline pressure to "pack" a greater number of molecules into the same amount of space. For natural gas, a pipeline is packed when the withdrawal of gas is minimum and pressure is at a maximum (warmer months), and is unpacked when withdrawal is at a maximum and pressure is at a minimum (colder months). Therefore, the storage capacity of a natural gas pipeline is the difference between its packed condition and its unpacked condition.[84]

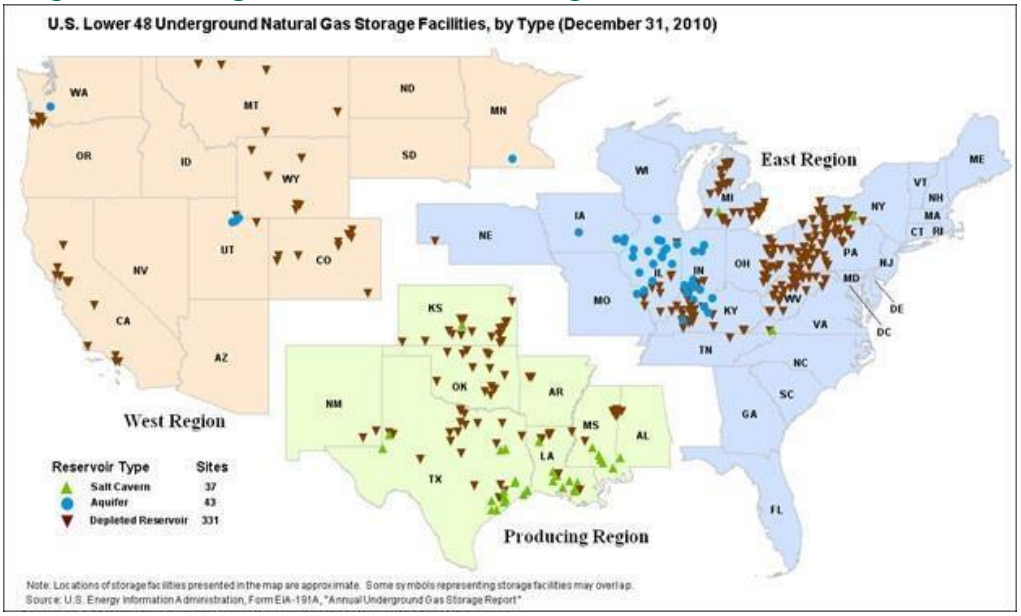
NGL storage. *See e.g.* "WV, OH, PA, KY Should Cooperate on $10B NGL Storage Hub," Marcellus Drilling News, September 2016, found at: http://marcellusdrilling.com/2016/07/wv-oh-pa-ky-should-cooperate-on-10b-ngl-storage-hub/.

[82] *See, e.g.* R. Brelsford, "What's at Mont Belvieu," Oil and Gas Journal, June 2, 2014, http://www.ogj.com/articles/print/volume-112/issue-6/speical-report-worldwide-gas-processing/what-s-at-mont-belvieu.html; *see also* C. Junkins, "MarkWest Official Says Storage Needed for Ethane Cracker," The Intelligencer Wheeling News-Register, October 1, 2015, http://www.theintelligencer.net/page/content.detail/id/643571/MarkWest-Official-Says-Storage-Needed-for-Ethane-Cracker.html?nav=526

[83] *See* Junkens, *supra*, (MarkWest executive Greg Floerke states that a lack of underground storage should not discourage a company looking to build a cracker). Furthermore, Shell Oil Company has committed to building a cracker in Pittsburgh, PA.

[84] "LP model uses line-pack to optimize gas pipeline operation," Oil & Gas Journal 2/24/03. http://www.ogj.com/articles/print/volume-101/issue-8/transportation/lp-model-uses-line-pack-to-optimize-gas-pipeline-operation.html

Figure 9. Underground Natural Gas Storage Facilities in the United States



(2010)

Unless rejected, ethane is not commonly used as a heating fuel, and as a result is not as affected by seasonality or by severe weather demands. Nevertheless, ethane pipelines can be packed in the same way as natural gas for purposes of short-term storage. Storage capacity will depend upon the pipeline length and pressure specifications. Line packing is relatively inexpensive. The marginal cost of building pipelines capable of packing is low – the cost of larger diameter or thicker walled pipelines – compared to the cost of above ground storage. Further, incremental capacity or pump stations can be built to supply additional storage as needed.[85]

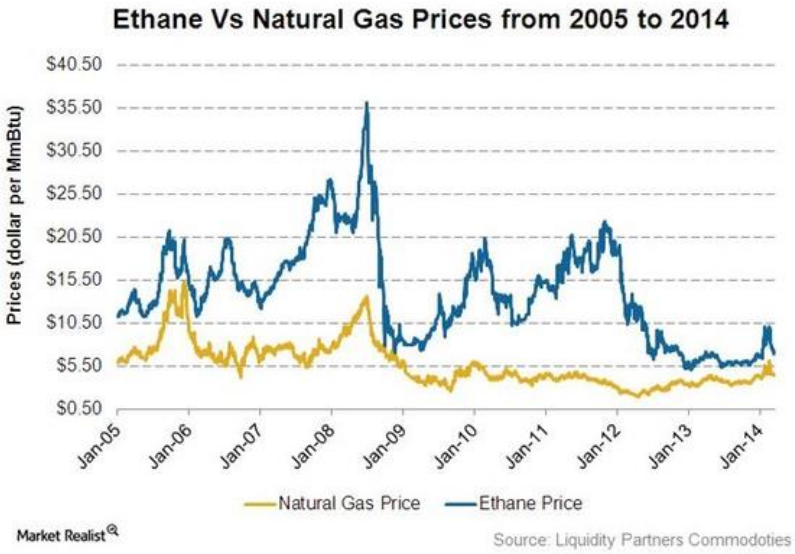
Storage requirements can also be mitigated through the use of multiple ethane feeder lines. Multiple pipelines serving one facility can be built such that when one line fails for some reason, the other lines are capable of supplying close to 100% of the total daily requirement from the facility. This scenario can be anticipated through back up delivery contracts. If the supplier warrants delivery, it will trigger a backup delivery contract between the supplier and a third party. If delivery is not warranted, it will trigger a backup delivery contract between the consumer and a third party.

If the current oversupply market survives past the building of local crackers, or if the polyethylene market becomes oversupplied, the storage problem could be more complicated. Under this scenario, producers may want sales contracts to have "take or pay" features that ensure a market for the ethane. Under a take of pay contract, the consumer (or midstream company) agrees to pay for ethane not taken. To avoid take or pay obligations for natural gas contracts, midstream companies usually require maximum daily take obligations in their contracts, and producers usually have back up sales contracts for this scenario. Alternatively, producers can use gas-balancing agreements with their working interest partners to sell to a partner's buyer.

[85] Industry interviews. Adding 1 inch to the diameter of an ethane pipeline costs around $150,000/mile. *See* Dettinger, *supra*, at slide 23.

Ethane sales contracts can also include these strategies for balancing supply and demand. However, ethane rejection may be a better solution for producers looking to mitigate an oversupply problem. Rejection will only be a problem if the additional ethane load makes the natural gas heat content too high for commercial and residential use. The real cost of rejection will be the difference between ethane and natural gas prices. During times of oversupply, as was the case for Appalachia in 2015, this difference in price will be relatively small.

Figure 10. Ethane vs. Natural Gas Prices



Long-term Sales Contract Strategies

There have traditionally been two types of contracts to sell natural gas: contracts to supply all the needs of the buyer ("requirements" contract) or contracts to take all the production supplied by the seller ("outputs" contract). The first sort of contract is often called a "warranty" contract, and it is usually the sort of contract a gas distribution company would enter into with an end user. However, producing companies have, from time to time, and to stimulate the market, entered into long-term, fixed price warranty contracts directly with end users, sometimes with catastrophic results. Texaco, for instance, went into bankruptcy in the 1990s in part due to a system of long-term natural gas warranty contracts it entered into with petrochemical companies in Louisiana.

The preferred, and more common, type of gas sales contract used by producers is the outputs contract – where the pipeline company agrees to take, or if they fail to take, to pay anyway, for all production supplied by the pipeline company, usually from a particular field or reservoir. These contracts have become known in the industry as "take or pay" contracts.

Take or pay contracts have their own history of litigation, however. In the late 1980s and early 1990s, following the collapse of oil and gas prices, pipeline companies found themselves having to take or pay for large volumes of gas that they were forced to then resell at a small fraction of the price paid. Take or pay-contracts cause problems when the commodity market rapidly shifts, making opting out of a contract, or if no opt-out is available, protracted litigation, a more attractive choice than continuing to pay above market rates. In markets as volatile as natural gas, this risk has been especially acute.

As a result, execution of take or pay contracts can be a significant hurdle for the development of downstream projects. There will always be risk and uncertainty when tying a large capital project to a commodity market like natural gas. However, principles of risk mitigation have found their way into modern long-term hydrocarbon sales agreements. Today, while the take or pay contract is the more common form of gas sales arrangements, some of risk can be contractually mitigated.

Liquids, however, do not generally have the same problems with warranty and take or pay obligations that natural gas has. Oil has historically been sold on short-term spot markets for. Heavier natural gas liquids are largely treated like oil; they are easily transported, stored, and sold on spot markets. Lighter natural gas liquids, however, are more like natural gas. Ethane is expensive to store and transport, and can often be a by-product of oil or natural gas production, and as a result is not susceptible to being shut in. Consequently, ethane sales contracts are more likely to resemble natural gas contracts than oil contracts, and are more likely to incur some of same risks inherent in take or pay and in warranty natural gas contracts.

The lack of familiarity within the region for projecting long-term supplies of hydrocarbons, together with a shortage of pipeline and storage infrastructure, can make the contracting difficult. Compounding the problem is that contracts must not only be long term (typically 10-20 years in length), delivery under the contracts may not start for another five – the usual amount of time it takes to permit and build a large cracker. The result is that producers and end users must negotiate for supply commitments that may be required from 2020 to 2040 – a highly speculative timeframe for even big oil companies.

Overcoming the financial risks associated with take or pay contracts will be a critical step to locating crackers in the Ohio, Pennsylvania and West Virginia region. With some creativity, take or pay contracts can allow for risk management for both the oil company and the end user. It can also enable each party to focus on its core competency – for producers, this would be the extraction of hydrocarbons; for midstream companies, it would be the storage and delivery of hydrocarbons; and for end users, the manufacturing of plastics feedstock.

The take-or-pay contract is today the primary mechanism for financing capital-intensive resource recovery and refining projects. A properly constructed take-or-pay contract provides the seller with a revenue stream that ensures an adequate return on the significant project capital investment, including the risks to which it is exposed.[86] However the take-or-pay contract remains, fundamentally, an outputs contract. As such, the refinery will likely assume most of the risk of supply failure. However, it will be hard to finance a new cracker facility without some warranty of delivery. Accordingly, the refinery will need to either introduce warranty elements into the supply contract, or, alternatively, to have back up supply contracts in place.

The most common strategy to reduce risk in take or pay contracts is to tie the sales price to commodity indices. Another strategy is to include price reopeners, which allow the price term to be renegotiated if it moves out of an agreed upon range. Parties can also reduce risk through market devices such as hedging or call options.

[86]http://www.forbes.com/sites/richardlevick/2014/09/17/natural-gas-innovative-financing-breaks-distribution-barriers/

Another way to mitigate risk, from the buyer's perspective, is to limit the obligation to take (or, from the seller's perspective, the obligation to deliver). Many gas sales contracts today contemplate back up sales agreements, such that when a "daily contract quantity" is reached, the seller has to look to another buyer. That back up buyer usually acquires the excess at a reduced price, which provides them with the incentive to serve as a backup purchaser. Today's gas sales contracts often have a complex set of purchasers, all with limited obligations, tied in part to a gas balancing agreement between an operator and its working interest partners.[87]

For those looking to finance refineries, multiple and back up sources of ethane sufficient to supply the refinery may be necessary. Ideally, these contracts will be tied to indices or hedged in a way to assure low prices at least for the early years of refinery operations.

Finally, those investing in crackers would, ideally, like to also have long-term contracts to sell their product, usually either ethylene or polyethylene, to distributors and plastics converters. However, there is no evidence, at least domestically, that there is a market for long-term commitments to purchase either of these products. Polyethylene, like oil, is easily stored and transported, and as such, subject to a robust, worldwide spot market.

As a result, companies that build crackers in the Appalachian region will likely do so with much speculation as to their ability to sell the product being manufactured at a profit. Investors in this arena must have deep pockets to withstand this sort of risk. Those investing in new cracker facilities in the Appalachian region will certainly be careful with long-term contracts, under such circumstances. However, it does not appear that an inability by ethane consumers to constrain risk from long-term supply contracts will be an obstacle to the investment.

Petrochemical companies downstream of the cracker may, however, have reason to consider long-term supply contracts. Appalachian ethane refiners will have no incentive to pass along savings to their customers from local ethane price differentials and from reduced transportation costs unless they receive long-term sales commitments. If the downstream users continue the current practice of using the spot market to acquire polyethylene,[88] the refiners will sell their product on the spot market, and most of the savings associated with refining in Appalachia will inure to the benefit of the refiner.

DOWNSTREAM OPPORTUNITIES IN SUPPLY CHAIN AND WORKFORCE

Downstream opportunities for the Tri-State region will be defined by a value proposition offered to businesses along the entire shale development product value chain. Seven major economic considerations[89] are at the focus of regional economic development organizations in the Tri-State region. These considerations include (1) availability of low-cost natural gas, NGL and derived ethane; (2) improved manufacturing efficiency; (3) established infrastructure, (4) logistics and transport, (5) proximity of

[87] Industry interviews.

[88] Petrochemical company interviews. Many petrochemical companies downstream of the cracker operate on thin margins, and as a result do not like to store polyethylene on site. As a result, they tend to tie their feedstock supply contracts to their imminent needs as dictated by sales.

[89] As outlined by TeamNEO – one of a major economic development organization supporting Tri-State shale development, http://www.teamneo.org/.

petrochemical products to consumer markets; (6) strong export potential and (7) availability of skilled labor and local talent.

Each of these factors was chosen based on its respective underlying regional competitive advantage. The abundance of natural gas, NGLs and ethane, discussed in previous sections, presents an opportunity for the petrochemical and chemical industries to further refine NGLs and natural gas and sell them with higher value added to local entities, as well as consumers outside the region. Falling oil and gas commodity prices have somewhat diminished the competitive cost difference in processing ethylene from ethane compared to processing it from crude oil (naphtha), but have not discouraged prospective stockholders from investing in petrochemical processing plants. The region still holds an important competitive advantage because of its high productivity in manufacturing production, highly-skilled labor force and the presence of infrastructure that supports improved manufacturing efficiency. High manufacturing productivity is supported by well-established infrastructure, sophisticated logistics, and transportation options in the Tri-State region. Proximity to eastern ports and traditional trade patterns create some additional cost advantages that allow for the export of refined products globally.

The process of building a petrochemical cluster anchored with ethane steam crackers in the Tri-State region will require developing a supply chain of aligned companies operating in the markets of derivative chemicals, rubber, metals, and converted products. Establishing significant supporting infrastructure, especially in pipeline and natural gas processing capacity for taking products to markets and storage, will create a demand for construction labor and materials for years to come.

This Study evaluates data relevant to two important ingredients to growth in the Tri-State petrochemical manufacturing sector: the proximity of petrochemical products to consumer markets and the availability of skilled labor. In addition, the following sections identify supply shortages for the production of petrochemical products using an industrial input-output relations model – the model reflecting regional buy-sell relationships between the companies of different industries.

SHORTAGES IN THE DOWNSTREAM SUPPLY CHAIN IN THE TRI-STATE REGION

In order to evaluate the importance of the supply chain to the downstream petrochemical industry, the sector was defined by industries using six four-digit NAICS codes, each corresponding to portions of the overall petrochemical manufacturing industry (*see* Table 5 below).[90] Using the NAICS profile for the petrochemical manufacturing industry, backward and forward linkages were observed along the supply chain. Backward linkages describe the process of how a company purchases its goods, products, or supplies (called inputs) from a company in a different sector (the suppliers). Forward linkages describe how a company sells its goods, products, or supplies (called outputs) to a company in a different sector (the customers).

[90] The industries profile of the downstream sector is defined in the previous study "Mapping the Opportunities of Shale Development in Ohio", p.102.
http://engagedscholarship.csuohio.edu/cgi/viewcontent.cgi?article=2332&context=urban_facpub

Table 5. NAICS Profile of the Petrochemical Manufacturing Sector

NAICS Code	Description
3251	Basic Chemical Manufacturing
3252	Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing
3253	Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing
3255	Paint, Coating, and Adhesive Manufacturing
3259	Other Chemical Product and Preparation Manufacturing
3261	Plastics Product Manufacturing

Further analysis looked at the supply chain of the petrochemical manufacturing sector as one industry representing all six 4-digit NAICS industries identified in Table 5.[91] To identify the gaps in the supply chain to the petrochemical industry in the Tri-State region, the analysis compared the current supply chain of the Tri-State region with the regions considered as the principal U.S. petrochemical hubs – Louisiana, Texas and California. The analysis of the U.S. petrochemical sector showed that the U.S. average data in this sector are heavily influenced by these three states, where the most petrochemical facilities are located. For this Study, the benchmark was set as the portion of the United States that does not include Ohio, Pennsylvania, and West Virginia.

The comparison between the Tri-State and the benchmark region is centered on the amount of supplies that are bought for every $1.00 spent by the downstream sector in each region. Gaps in the supply chain were then identified by calculating the ratio of shares of purchased supplies (benchmark region divided by Tri-State region). For example, for every $1 spent on supplies, the petrochemical manufacturing industry purchased $0.10 worth of supplies from the petroleum refinery industry in the benchmark region, compared to $0.03 in the Tri-State region. Dividing the benchmark region's value by that of the Tri-State region establishes a ratio of 3.15. This ratio can be interpreted as follows: in the benchmark region, petroleum refinery industry services were consumed at three times the rate of that within the Tri-State region. In turn, this identifies the potential gap in the supply of refineries necessary for the petrochemical industries in the Tri-State region.

Highlighted in Table 6 below are industries that have high benchmark region-to- Tri-State-region ratios in shares of purchased supplies, representing potential gaps in the Tri-State region's supply chain. The petrochemical manufacturing sector (NAICS 32511) divides segments of petrochemical processing into many discrete productions; therefore, companies within this industry have many horizontal relationships, buying and supplying products to each other. The very high benchmark to Tri-State ratio of this industry (5.24) indicates that there is a significantly smaller concentration of this industry in the Tri-State region compared to the benchmark. Simply, there are more companies identified as NAICS 32511 in the benchmark region that trade products than in the Tri-State region. For every dollar spent by this industry buying supplies from other companies within NAICS 32511, companies within the benchmark region buy

[91] In this report, the petrochemical manufacturing sector, interchangeably called petrochemical manufacturing industry, is identified as six 5-digit NAICS industries illustrated in Table 5.

supplies for 31.4 cents compared to companies making similar purchases within the Tri-State region for just shy of 6 cents.

In addition to the petrochemical manufacturing industry (NAICS 32511), five industries were identified as representing large gaps in the Tri-State region's petrochemical manufacturing supply chain: other basic organic chemical manufacturing (NAICS 32519) – 4.21, plastics material and resin manufacturing (NAICS 325211) – 3.74, other basic inorganic chemical manufacturing (NAICS 32518) – 3.64, petroleum refineries (NAICS 32411) – 3.15, and plastics packaging materials and un-laminated film and sheet manufacturing (NAICS 32611) – 3.15. All other industries in this table (with a ratio greater than one), point to higher consumption of their product and services by the downstream sector in the benchmark region compared to the Tri-State region and therefore point to potential shortages of supplies from companies classified within these industries.

Table 6. Suppliers to the Petrochemical Manufacturing Industry in the Tri-State Region and in the Benchmark Region

NAICS	Description	Tri-State Region (OH-PA-WV)	Benchmark Region (US less OH-PA-WV)	Benchmark to Tri-State ratio
32511	Petrochemical manufacturing	0.0599	0.3137	5.24
32411	Petroleum refineries	0.0310	0.0977	3.15
325211	Plastics material and resin manufacturing	0.0203	0.0758	3.74
32519	Other basic organic chemical manufacturing	0.0158	0.0666	4.21
42	Wholesale trade	0.0312	0.0530	1.70
55	Management of companies and enterprises	0.0316	0.0394	1.25
22112	Electric power transmission and distribution	0.0112	0.0166	1.48
32518	Other basic inorganic chemical manufacturing	0.0040	0.0147	3.64
2212	Natural gas distribution	0.0085	0.0147	1.73
482	Rail transportation	0.0067	0.0144	2.15
484	Truck transportation	0.0099	0.0122	1.23
211111	Extraction of natural gas and crude petroleum	0.0036	0.0109	2.99
32611	Plastics packaging materials and un-laminated film and sheet manufacturing	0.0035	0.0109	3.15
32513	Synthetic dye and pigment manufacturing	0.0052	0.0095	1.84
32221	Paperboard container manufacturing	0.0030	0.0088	2.91

Note: the table is ranked by the column Benchmark Region (US less OH-PA-WV).

The Benchmark Region column (US less OH-PA-WV) presents a pattern of supplies the Tri-State region is aiming for, as the benchmark region reflects economies with a more developed petrochemical sector.

After the supply chain gap industries were established for the Tri-State region, out-of-region companies in these potentially "thin" supply areas were identified (ranked by employment in Tables 7-11 and Figures 11-16 below). These companies could be targeted by economic development organizations for potential expansions or relocations within the Tri-State region in response to potential supply chain gaps.

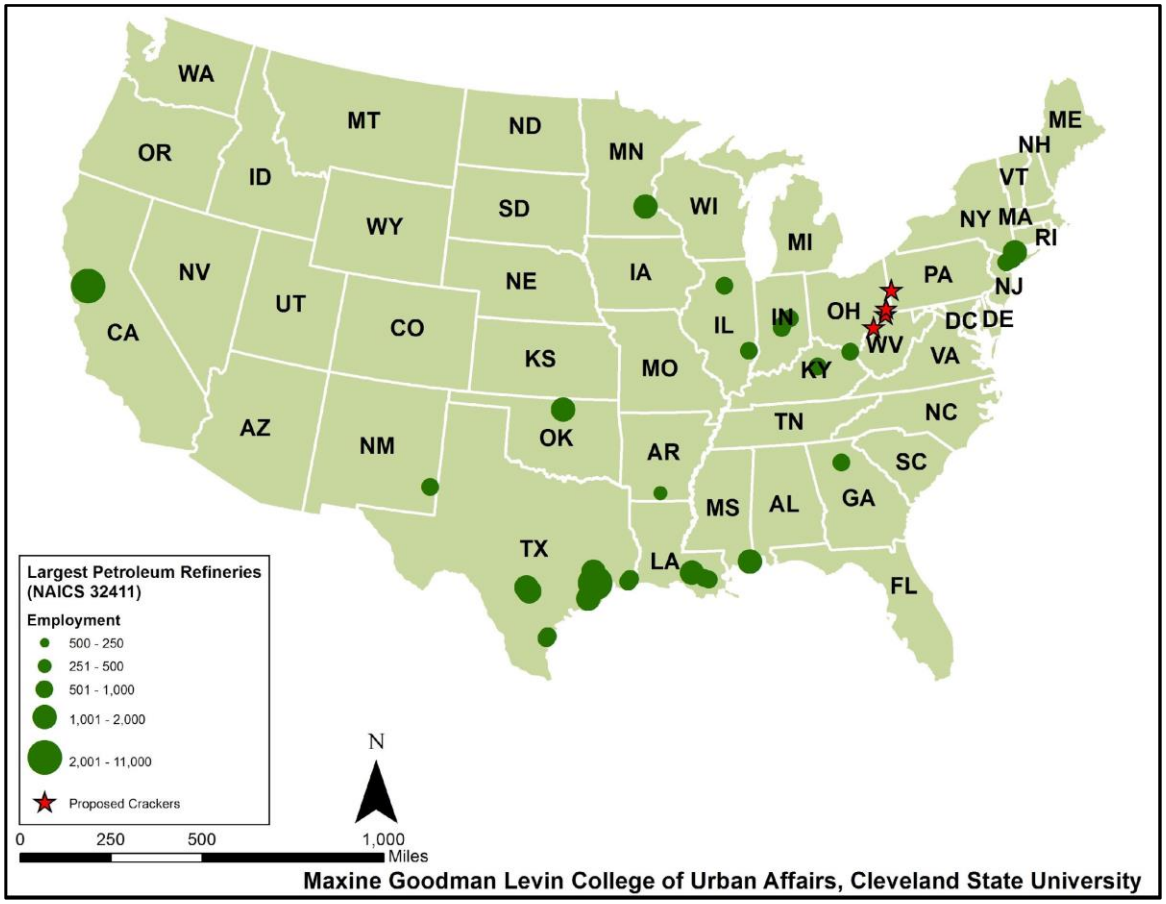
Based on data retrieved from Reference USA, the largest companies in the petroleum refineries industry (NAICS 32411) - demonstrating those with the highest expansion/relocation potential - are Chevron, BP, and Valero. While the single largest petroleum refinery (ranked by employment) is located in California (with nearly 11,000 employees), the largest geographic concentration exists along the Gulf Coast, with several also located in the Mississippi and Ohio River valleys. The Phillips 66 Bayway Refinery in Linden, New Jersey; Marathon Petroleum's facility in Catlettsburg, Kentucky; and Marathon's Robinson Refinery in Robinson, Illinois, represent the largest companies within geographic proximity of the Tri-State region.

Table 7. Largest Companies in the Petroleum Refineries Industry, Sorted by Employment

NAICS	Company Name	City	State	Employment
32411	Chevron Corp	San Ramon	CA	10,976
32411	BP America Inc	Houston	TX	5,000
32411	Valero Marketing & Supply Co	San Antonio	TX	2,000
32411	Valero Energy Corp	San Antonio	TX	2,000
32411	Phillips 66 Refinery	Ponca City	OK	2,000
32411	Premcor Inc	Old Greenwich	CT	1,770
32411	Anadarko Petroleum Corp	The Woodlands	TX	1,500
32411	Phillips 66 Sweeny Refinery	Old Ocean	TX	1,300
32411	Chevron Pascagoula Refinery	Pascagoula	MS	1,290
32411	Flint Hills Resources	Rosemount	MN	1,200
32411	Chalmette Refinery LLC	Chalmette	LA	1,200
32411	Phillips 66 Bayway Refinery	Linden	NJ	1,000
32411	Marathan Petroleum Co	Catlettsburg	KY	1,000
32411	Motiva Enterprises	Port Arthur	TX	980
32411	Valero Port Arthur Refinery	Port Arthur	TX	850
32411	Valero Bill Greehey Refinery	Corpus Christi	TX	820
32411	Valero Refining Co	Corpus Christi	TX	801
32411	Motiva Enterprises	Convent	LA	700
32411	Marathon Robinson Refinery	Robinson	IL	700
32411	Valero St Charles Refinery	Destrehan	LA	600
32411	Marathon Petroleum Corp	Duluth	GA	600
32411	Marathon Petroleum Corp	Indianapolis	IN	600
32411	Marathon Petroleum Corp	Indianapolis	IN	600
32411	Marathon Petroleum Corp	Muncie	IN	600
32411	Marathon Petroleum Corp	New York	NY	600
32411	Marathon Petroleum Corp	Utica	IL	600
32411	Marathon Petroleum Corp	Lovington	NM	600
32411	Marathon Petroleum Corp	Lexington	KY	600
32411	Saudi Refining Inc	Houston	TX	500
32411	Murphy Oil Corp	El Dorado	AR	500

Source: Reference USA

Figure 11. Location of Largest Companies in the Petroleum Refineries Industry



Map Data Source: Reference USA

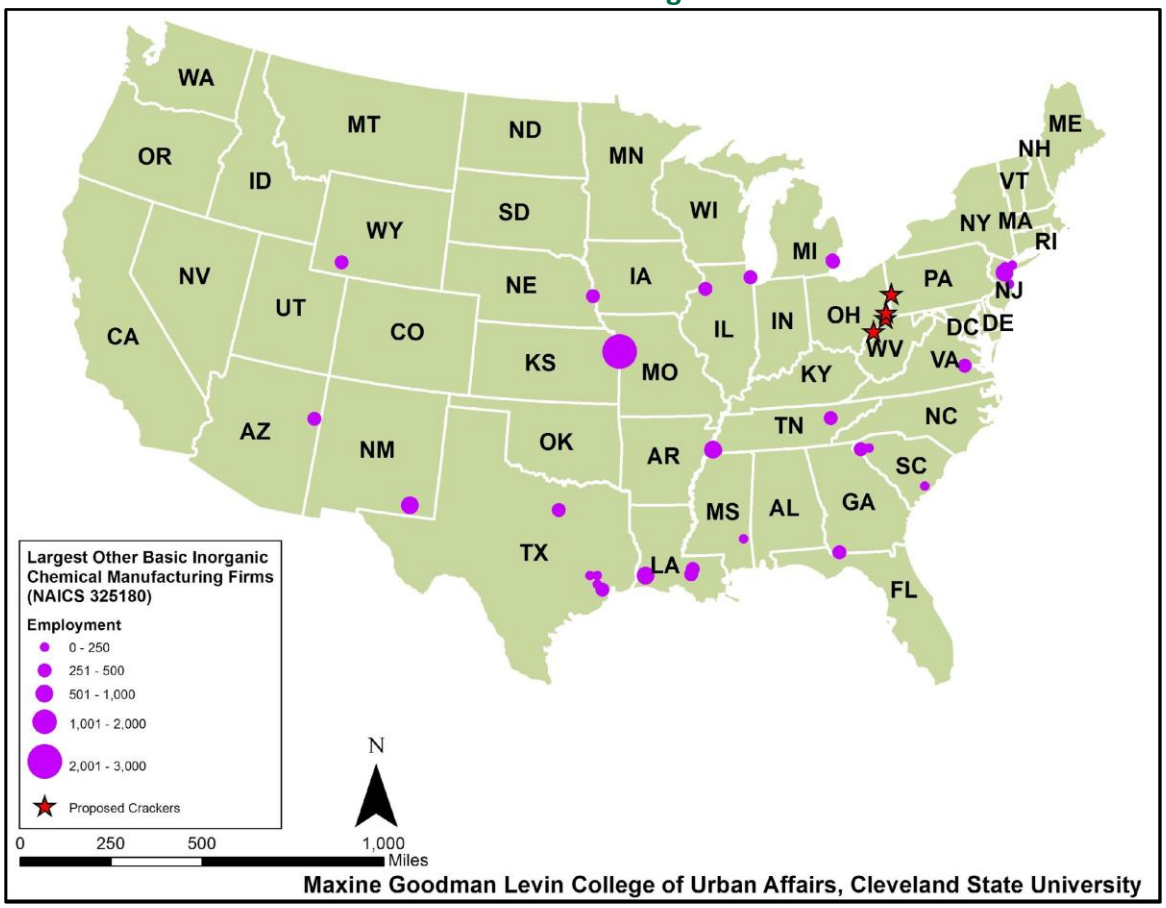
The largest companies in the other basic inorganic chemical manufacturing industry (NAICS 325180) are Honeywell, BASF, and Sasol North America. While these companies are more geographically dispersed than petroleum refineries, some clustering can be seen along the Gulf Coast as well as in the New York City metropolitan area. Large companies in close proximity to the Tri-State region include BASF in Iselin, New Jersey; Nalco in Chicago, Illinois; and 3M in Cordova, Illinois.

Table 8. Largest Companies in the Other Basic Inorganic Chemical Manufacturing Industry, Sorted by Employment

NAICS	Company Name	City	State	Employment
325180	Honeywell Federal Mfg & Tech	Kansas City	MO	3,000
325180	BASF Corp Catalyst Div	Iselin	NJ	900
325180	Sasol North America Inc	Westlake	LA	550
325180	Mosaic Potash Carlsbad	Carlsbad	NM	550
325180	Bulab Holdings Inc	Memphis	TN	525
325180	US Department Of Energy	Oak Ridge	TN	500
325180	OCI Wyoming LP	Green River	WY	425
325180	Nalco Co	Chicago	IL	415
325180	3M Co	Cordova	IL	413
325180	Buckman Laboratories Intl Inc	Memphis	TN	350
325180	BASF Corp Catalyst Div	Seneca	SC	340
325180	William H Harvey Co	Omaha	NE	330
325180	Solvay	Baton Rouge	LA	300
325180	Sid Richardson Carbon & Energy	Fort Worth	TX	300
325180	BASF Corp Catalyst Div	Wyandotte	MI	300
325180	Axiall Corp	Plaquemine	LA	300
325180	Ashland Specialty Ingredients	Hopewell	VA	270
325180	BASF Corp Catalyst Div	Pasadena	TX	251
325180	BASF Corp Catalyst Div	Sanders	AZ	251
325180	BASF Corp Catalyst Div	Lincoln Park	MI	251
325180	BASF Corp Catalyst Div	Attapulgus	GA	251
325180	Solvay	North Charleston	SC	245
325180	TETRA Chemicals Div	The Woodlands	TX	200
325180	KIK Custom Products	Houston	TX	200
325180	Ortec Inc	Easley	SC	130
325180	Odom Industries	Waynesboro	MS	113
325180	Sasol North America Inc	Houston	TX	101
325180	Phibro-Tech Inc	Teaneck	NJ	100
325180	Minerals Technologies Inc	New York	NY	100
325180	Madison Industrial	Old Bridge	NJ	100

Source: Reference USA

Figure 12. Location of Largest Companies in the Other Basic Inorganic Chemical Manufacturing



Map Data Source: Reference USA

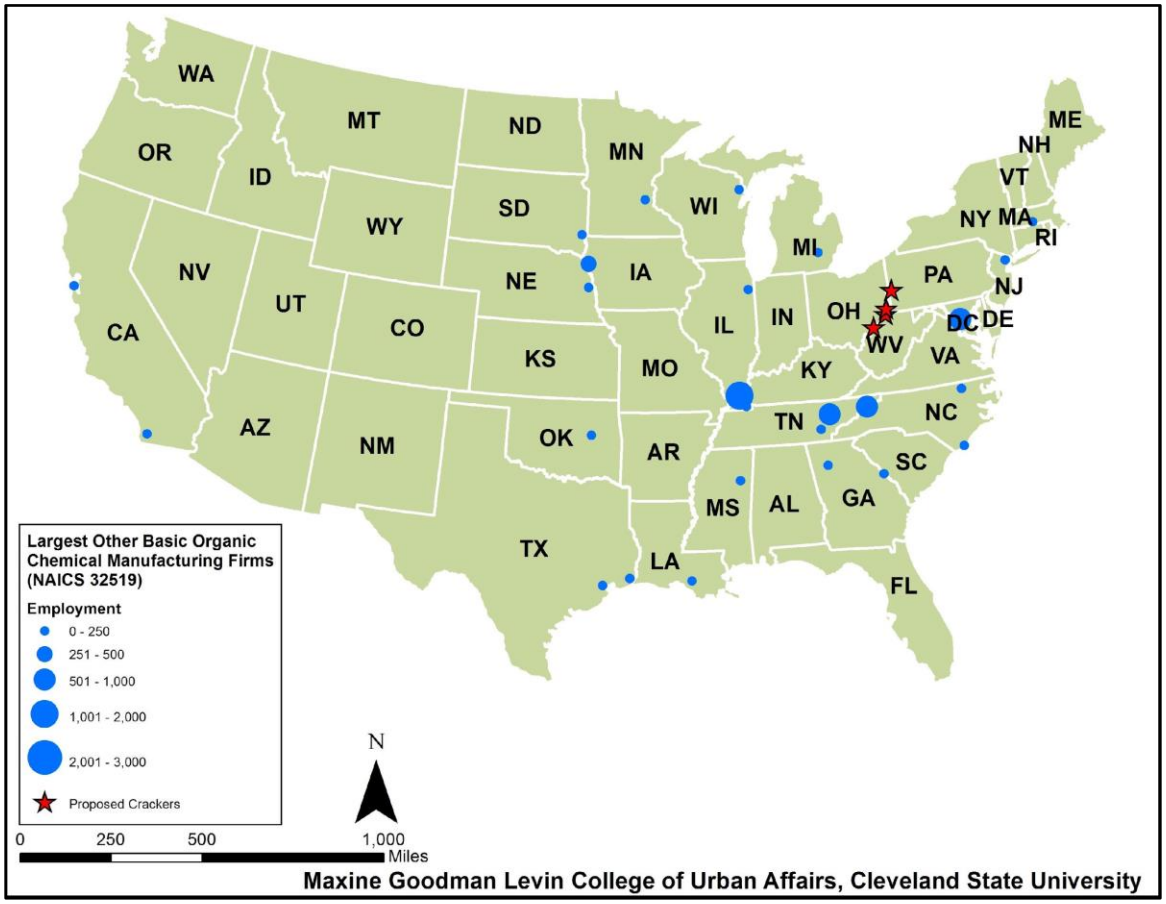
The largest companies in the other basic organic chemical manufacturing industry (NAICS 32519) are United States Enrichment, Nuclear Fuel Service, and American Centrifuge. Geographic clustering of the largest firms falling under the NAICS 32519 classification can be seen in the states of Kentucky and Tennessee, as well as the Washington, D.C. metropolitan area. United States Enrichment in Paducah, Kentucky; Chem-TREND in Howell, Michigan; and Merisant in Manteno, Illinois represent large companies with existing facilities close to the Tri-State region.

Table 9. Largest Companies in the Other Basic Organic Chemical Manufacturing Industry, Sorted by Employment

NAICS	Company Name	City	State	Employment
32519	United States Enrichment Corp	Paducah	KY	1,200
32519	Nuclear Fuel Svc Inc.	Erwin	TN	700
32519	United States Enrichment Corp	Bethesda	MD	608
32519	United States Enrichment Corp	Oak Ridge	TN	608
32519	American Centrifuge Hldng LLC	Bethesda	MD	608
32519	American Centrifuge Enrchmnt	Bethesda	MD	608
32519	Gelita USA Inc	Sergeant Bluff	IA	300
32519	POET LLC	Sioux Falls	SD	250
32519	Chem Design Products Inc	Marinette	WI	230
32519	United States Enrichment Corp	Oak Ridge	TN	215
32519	Axiall Corp	Aberdeen	MS	210
32519	Chem-TREND LP	Howell	MI	203
32519	Solazyme Inc	S San Francisco	CA	200
32519	Rousselot	Peabody	MA	200
32519	Cp Kelco Us Inc	Okmulgee	OK	200
32519	ADM	Southport	NC	200
32519	Cp Kelco Us Inc	San Diego	CA	190
32519	Nutra Sweet Co	Augusta	GA	185
32519	Kaneka Texas Corp	Pasadena	TX	185
32519	Hawkins Industrial Group	Minneapolis	MN	150
32519	Occidental Chemical Corp	Convent	LA	130
32519	Georgia-Pacific Corp	Conway	NC	125
32519	Merisant	Manteno	IL	120
32519	OCI Partners LP	Nederland	TX	119
32519	OCI Beaumont LLC	Nederland	TX	119
32519	Vanderbilt Chemical Corp	Murray	KY	118
32519	ITW Chemtronics	Kennesaw	GA	110
32519	Green Plains Inc	Omaha	NE	102
32519	Fujifilm Hunt Chemicals USA	Dayton	TN	100
32519	Fujifilm Hunt Chemicals USA	Allendale	NJ	100

Source: Reference USA

Figure 13. Location of Largest Companies in the Other Basic Organic Chemical Manufacturing



Map Data Source: Reference USA

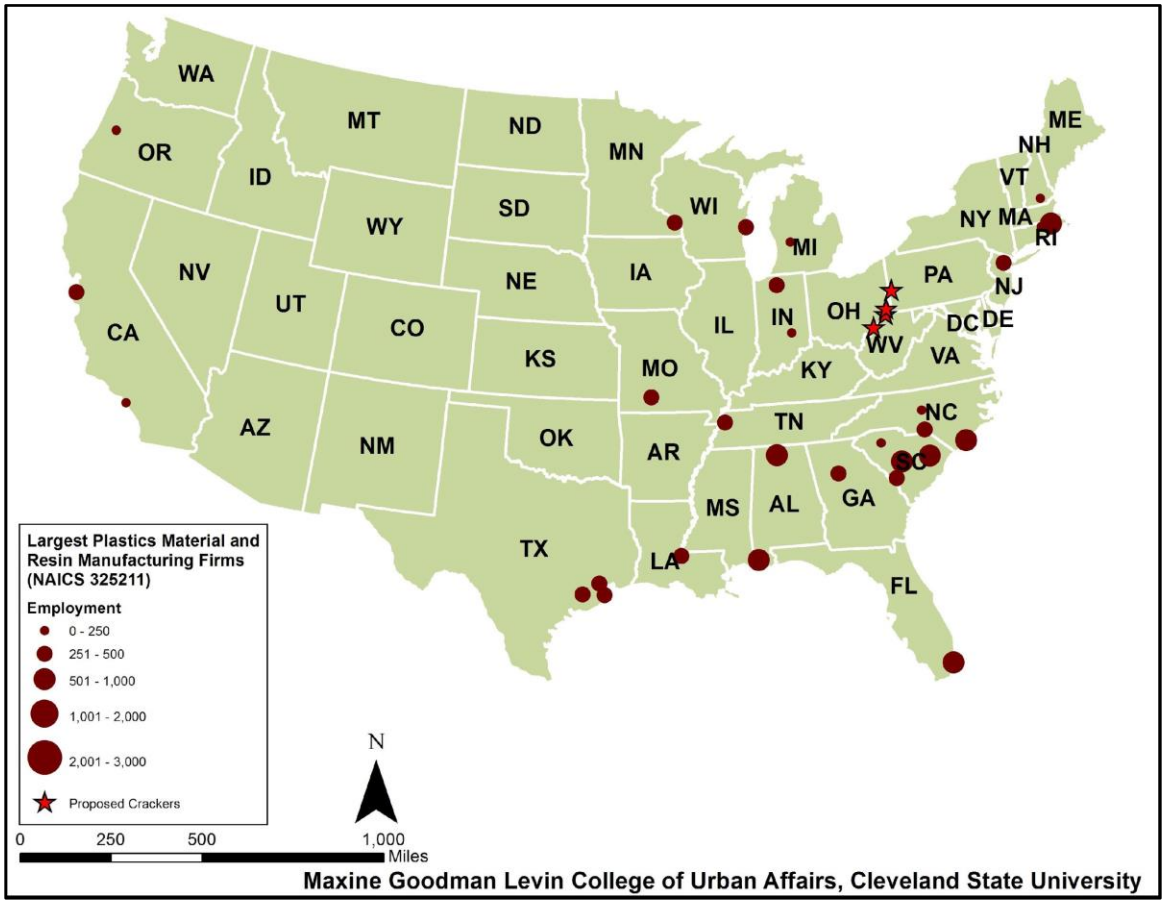
The largest companies in the plastics material and resin manufacturing industry (NAICS 325211) are Innocor, 3M, and Nan Ya Plastics. The companies that are categorized under NAICS 325211 are almost exclusively located in the eastern half of the country, primarily in the southeast. Large companies located in close geographic proximity to the Tri-State region include Maax USA in Plymouth, Indiana; Colorite Polymers in Ridgefield, New Jersey; and Williams Industries in Shelby, Indiana.

Table 10. Largest Companies in the Plastics Material and Resin Manufacturing Industry, Sorted by Employment

NAICS	Company Name	City	State	Employment
325211	Innocor Inc	Miami	FL	1,000
325211	3M Co	Decatur	AL	930
325211	Nan Ya Plastics Corp	Lake City	SC	901
325211	Teknor Apex Co	Pawtucket	RI	800
325211	Evonik Corp	Theodore	AL	700
325211	DAK Americas LLC	Wilmington	NC	700
325211	DAK Americas LLC	Gaston	SC	600
325211	Plastics Engineering Co	Sheboygan	WI	400
325211	AM Topp Corp	Livingston	NJ	400
325211	Nan Ya Plastics Corp	Wharton	TX	360
325211	Maax USA Corp	Plymouth	IN	350
325211	Diversified Plastics Corp	Nixa	MO	350
325211	RTP Co	Winona	MN	325
325211	Solvay America	Houston	TX	300
325211	Nan Ya Plastics Corp	Batchelor	LA	300
325211	Landec Corp	Menlo Park	CA	300
325211	Ineos Americas LLC	League City	TX	300
325211	Clariant Corp	Charlotte	NC	300
325211	Poly One Corp	Dyersburg	TN	299
325211	Clariant Corp	Martin	SC	275
325211	AEP Industries Inc	Griffin	GA	260
325211	Willamette Valley Co	Eugene	OR	250
325211	Techmer PM	Compton	CA	250
325211	Rogers Corp	Rogers	CT	250
325211	Prestige Fabricators Inc	Asheboro	NC	250
325211	National Starch & Chemical Co	Enoree	SC	250
325211	Colorite Polymers	Ridgefield	NJ	250
325211	Worthen Industries Inc	Nashua	NH	150
325211	Williams Industries Inc	Shelbyville	IN	150
325211	VI-Chem Corp	Grand Rapids	MI	101

Source: Reference USA

Figure 14. Location of Largest Companies in the Plastics Material and Resin Manufacturing



Map Data Source: Reference USA

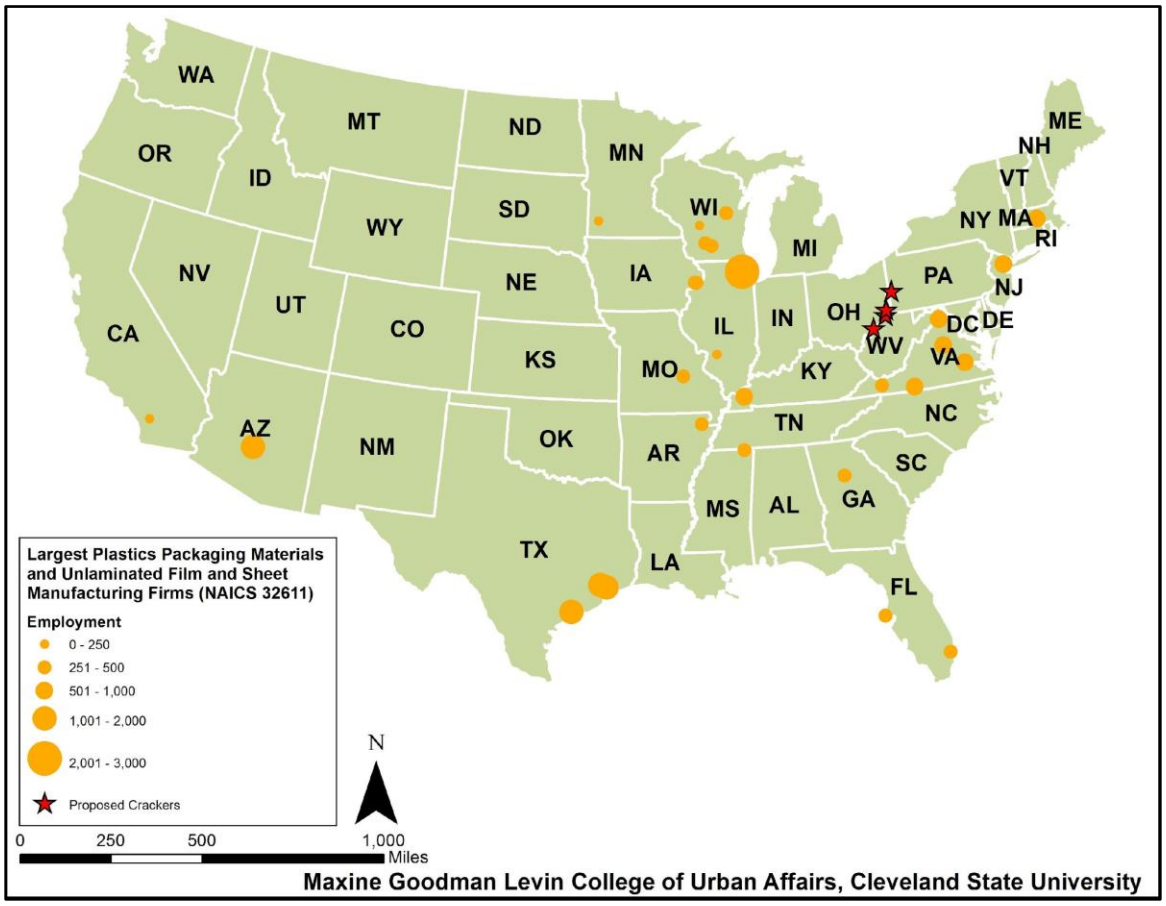
The largest companies in the plastics packaging materials and un-laminated film and sheet manufacturing industries (NAICS 32611) are Berry Plastics, Equistar Chemicals, and Formosa Plastics. These companies are geographically clustered in the Gulf Coast, the Mississippi Valley, and Mid-Atlantic Regions. Berry Plastics in Schaumburg, Illinois; Formosa Plastics in Livingston, New Jersey; and Westlake Monomers in Calvert City, Kentucky are large companies with existing facilities located adjacent to the Tri-State region.

Table 11. Largest Companies in the Plastics Packaging Materials and Un-laminated Film and Sheet Manufacturing Industry, Sorted by Employment

NAICS	Company Name	City	State	Employment
32611	Berry Plastics	Schaumburg	IL	2,940
32611	Equistar Chemicals LP	La Porte	TX	1,500
32611	Formosa Plastics Corp	Point Comfort	TX	1,453
32611	Veri Fone Inc	Scottsdale	AZ	1,431
32611	Equistar Chemicals LP	Houston	TX	1,200
32611	FLEX Con Corp	Spencer	MA	900
32611	O'Sullivan Films Inc	Winchester	VA	800
32611	Solutia Inc Performance Films	Fieldale	VA	701
32611	Klockner Pentaplast Of America	Gordonsville	VA	700
32611	Formosa Plastics Corp USA	Livingston	NJ	650
32611	Westlake Monomers	Calvert City	KY	600
32611	Du Pont	Hopewell	VA	550
32611	Bemis Co Inc	New London	WI	500
32611	Anchor Packaging Inc	Paragould	AR	500
32611	Veri Fone Inc	Clearwater	FL	380
32611	Clysar LLC	Clinton	IA	375
32611	Cardinal CG Co	Spring Green	WI	360
32611	Meramec Group Inc	Sullivan	MO	351
32611	Plastic Ingenuity	Cross Plains	WI	350
32611	Equistar Chemicals LP	Clinton	IA	350
32611	Klockner Pentaplast Of America	Rural Retreat	VA	320
32611	Viskase Co Inc	Darien	IL	300
32611	SKC Inc	Covington	GA	300
32611	Flex Sol Packaging Corp	Pompano Beach	FL	300
32611	Mississippi Polymers Inc	Corinth	MS	275
32611	Westlake Chemical Corp	Houston	TX	250
32611	Highland Supply Corp	Highland	IL	250
32611	First American Card Svc	Murrieta	CA	250
32611	COVERIS	Tomah	WI	250
32611	Blackbourn	Edgerton	MN	250

Source: Reference USA

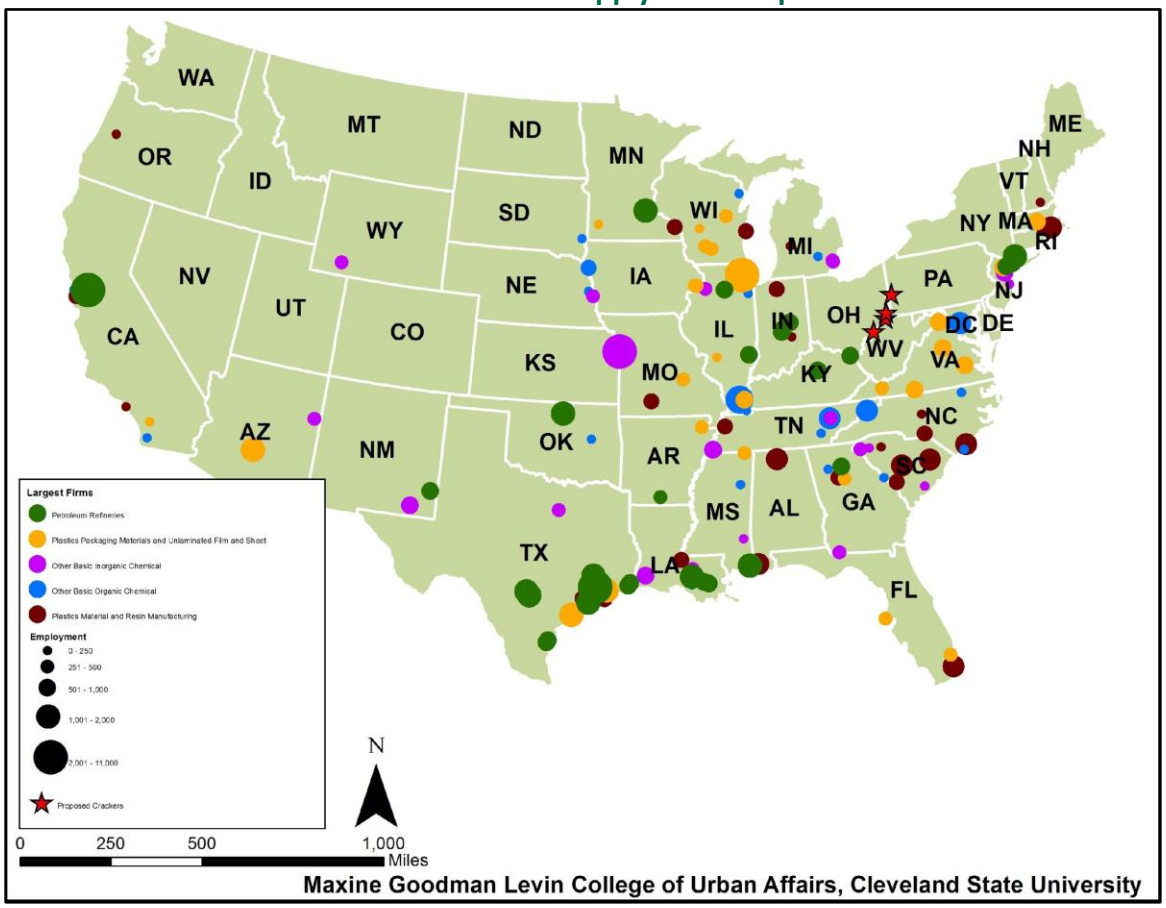
Figure 15. Location of Largest Companies in the Plastics Packaging Materials and Unlaminated Film and Sheet Manufacturing



Map Data Source: Reference USA

Figure 16 below displays an overview map combining companies from the five maps above that have the potential to respond to any supply chain gaps for the petrochemical industry within the Tri-State region. This map demonstrates that these companies, regardless of individual industry, are primarily located in the eastern half of the United States, specifically along the Gulf Coast and in the Mississippi Valley and Mid-Atlantic Regions. The relatively close proximity of these geographic areas to the Tri-State region could potentially benefit the supply chain of the petrochemical manufacturing industry. Nevertheless, the benefits would be even greater if the companies were located within the Tri-State region itself, leveraging transportation cost advantages and any workforce or other advantages.

Figure 16. Location of Companies outside the Tri-State Region Capable of Responding to Tri-State Potential Supply Chain Gaps



Map Data Source: Reference USA

CONSUMER MARKET FOR THE PETROCHEMICAL MANUFACTURING SECTOR IN THE TRI-STATE REGION

For successful expansion of the petrochemical sector in the Tri-State region it is also important to develop a wide range of consumers within a reasonable trucking distance, making it easier to sell the products in the U.S. The assessment of forward linkages (consumers buying products from the petrochemical sector) also necessitates a comparison of the Tri-State region to the benchmark region in order to identify gaps that may currently exist in the consumer chain. This comparison between the two regions focuses on the amount of products that are bought from the petrochemical manufacturing sector (six industries from Table 5 together) for each $1.00 spent by different industrial sectors in the Tri-State and the benchmark regions. Gaps in the consumer chain were identified by calculating the ratio of shares of purchased products (benchmark region divided by Tri-State region). For example, the other basic organic chemical manufacturing industry purchased $0.06 worth of products from the petrochemical manufacturing industry in the benchmark region, compared to $0.03 in the Tri-State region. Dividing the benchmark region's value by that of the Tri-State region establishes a ratio of 2.21. This ratio indicates that in the benchmark region, industries purchased 2.2 times as many products from the petrochemical sector than did the Tri-State region. Therefore, it was much easier for those petrochemical companies to sell their products to other companies in the benchmark region than for petrochemical companies to do the same

within the Tri-State region. The potential gap of consumers can be filled by companies residing outside of the Tri-State region that relocate to the Tri-State region, or by companies already in the region that expand their business.

As set forth earlier, the petrochemical manufacturing (NAICS 32511) is both a supplier and a consumer to itself. Companies within this industry actively trade with each other, specializing in a narrow technological process, specific product, or a service. The benchmark to Tri-State ratio of 4.92 for this industry indicates that in the benchmark region, for every dollar spent on supplies, other industries were buying almost 5 times more supplies from petrochemical manufacturers (NAICS 32511) than in the Tri-State region (Table 12).

Table 12. Buyers from the Petrochemical Manufacturing Sector in the Tri-State Region and in the U.S. less Tri-State Region

NAICS	Description	Tri-State Region (OH-PA-WV)	Benchmark Region (US less OH-PA-WV)	Benchmark to Tri-State ratio
32511	Petrochemical manufacturing	0.034	0.168	4.92
32519	Other basic organic chemical manufacturing	0.029	0.063	2.21
325211	Plastics material and resin manufacturing	0.033	0.053	1.59
326190	Other plastics product manufacturing	0.015	0.032	2.17
1111	Grain farming	0.003	0.021	7.67
32611	Plastics packaging materials and un-laminated film and sheet manufacturing	0.070	0.019	2.69
334413	Semiconductor and related device manufacturing	0.002	0.017	10.82
32411	Petroleum refineries	0.004	0.016	4.37
325412	Pharmaceutical preparation manufacturing	0.005	0.013	2.72
23*	Construction of other new residential structures	0.004	0.013	3.04
32551	Paint and coating manufacturing	0.008	0.011	1.37
23*	Maintenance and repair construction of nonresidential structures	0.004	0.010	2.83
325212	Synthetic rubber manufacturing	0.004	0.010	2.28
32522	Artificial and synthetic fibers and filaments manufacturing	0.001	0.010	18.41
312111-2	Bottled and canned soft drinks & water	0.004	0.009	2.33

Note: the table is ranked by the column Benchmark Region (US less OH-PA-WV).

In the benchmark region, for every dollar spent on supplies, other industries spent about 17 cents on petrochemical manufacturing products and services while in the Tri-State region, similar companies only spent between 3 and 4 cents on similar supplies from the petrochemical manufacturing. The column of Benchmark Region (US less OH-PA-WV) presents a pattern of consumption the Tri-State region could aim

for, as the benchmark region reflects an economy with a more developed petrochemical sector and an established consumer market.

In addition to petrochemical manufacturing (NAICS 32511), the largest gaps existing in the consumer chain for the petrochemical sector are highlighted in Table 12. Five more industries were identified as having large gaps in the Tri-State region's petrochemical manufacturing consumer chain: artificial and synthetic fibers and filaments manufacturing (NAICS 32522) – 18.41, semiconductor and related device manufacturing (NAICS 334413) – 10.82, grain farming (NAICS 1111) – 7.67, petroleum refineries (NAICS 32411) – 4.37, and the construction of other new residential structures (NAICS 23) – 3.04. All other industries in this table (with a ratio greater than one), point to higher consumption by these industries of the products and services of the downstream sector in the benchmark region compared to the Tri-State region, pointing to potential consumption shortages by companies classified within these industries.

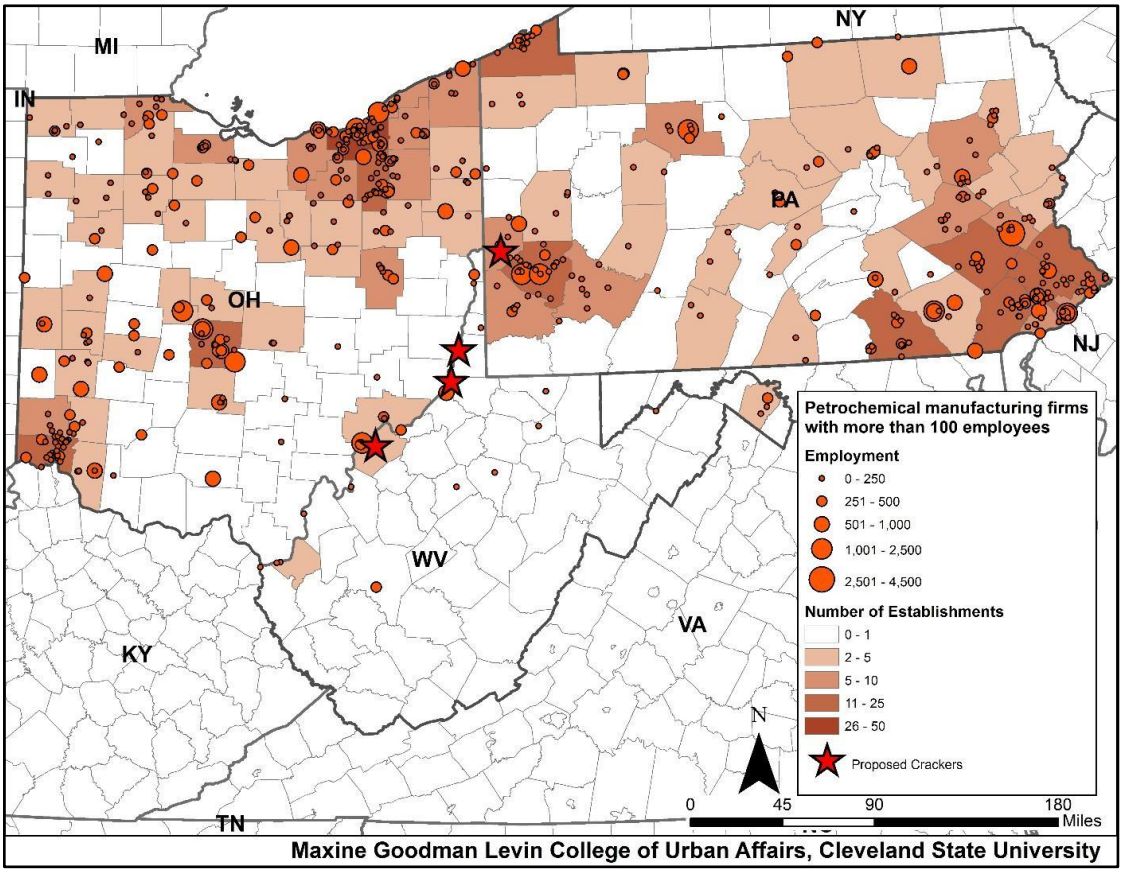
It is important to the analysis of forward linkages in the supply chain to identify preexisting polyethylene consumers within the Tri-State region, as proximity to markets is crucial for investment decisions. Figure 17 shows the geographic distribution of firms with at least 100 employees in the Tri-State region that match the NAICS profile for the petrochemical manufacturing sector, while Table 13 lists the top 20 of such firms, ranked by employment. Because these firms are already located within the region, the introduction of a cracker facility in the Tri-State region could induce an expansion of their operations. Several clusters of petrochemical manufacturing activity already exist in the Tri-State region, including the Cleveland, Philadelphia, Pittsburgh, Columbus, and Cincinnati metropolitan areas.

Table 13. Top 20 Petrochemical Companies within OH, PA, and WV, Ranked by Employment

Company Name	City	State	Employment
Air Products & Chemicals Inc	Allentown	PA	4,500
Du Pont Washington Works	Washington	WV	2,400
Armstrong Holdings Inc	Lancaster	PA	2,000
Sherwin-Williams Co	Cleveland	OH	2,000
Bayer Material Science LLC	Pittsburgh	PA	1,800
Ashland Performance Materials	Dublin	OH	1,500
Lubrizol Corp	Wickliffe	OH	1,500
Scotts Miracle-Gro Co	Marysville	OH	1,500
Keystone Powdered Metal Co	St Marys	PA	1,300
Lubrizol Laboratories	Wickliffe	OH	1,250
PPG Industries Inc	Pittsburgh	PA	1,200
Dow Chemical Co	Philadelphia	PA	1,100
HFI LLC	Canal Winchester	OH	1,001
Dart Container Corp	Leola	PA	1,000
United States Enrichment Corp	Piketon	OH	1,000
Armstrong World Industries Inc	Lancaster	PA	900
D&H Distributing Co	Harrisburg	PA	900
Global Tungsten & Powders	Towanda	PA	900
Lyondell Basell Industries	Newtown Square	PA	900
Plastek Group	Erie	PA	900

Source: Reference USA

Figure 17. Geographic Distribution of Petrochemical Manufacturing Firms within OH, PA, and WV, by Employment and Number of Establishments per County*



*Note that data for petrochemical manufacturing firms in West Virginia may be incomplete.
Map data source: Reference USA

A search of the largest petrochemical manufacturing firms was also performed using two other geographies to further identify potential consumers of polyethylene: those within 500 miles of the Tri-State region's proposed cracker facilities, as well as those within the United States overall. We hypothesized that the companies that operate in more than one state might be more receptive to opening another branch within the Tri-State region compared to those that operate within one state, i.e. under one state's regulations.

We also suggest that the 500-mile radius identifies a maximum 1-day truck delivery distance, which would likely be the most favorable area for the proposed crackers to sell their product directly to consumers. Table 14 lists the top 30 petrochemical manufacturing companies within the 500-mile radius, while Table 15 lists the top 30 within the United States, ranked by employment.

Table 14. Top 30 Petrochemical Companies within 500 miles of Proposed Crackers, Ranked by Employment

Company Name	City	State	Employment
General Motors Technical Ctr	Warren	MI	17,096
Eastman Chemical Co	Kingsport	TN	8,000
Air Products & Chemicals Inc	Allentown	PA	4,500
Monsanto Co	St Louis	MO	4,000
BP Chemical Co	Warrenville	IL	4,000
B&W Technical Svc Y-12 LLC	Oak Ridge	TN	4,000
Pfizer Inc	Groton	CT	3,800
Cristal USA	Cockeysville	MD	3,600
Hospira Inc	Lake Forest	IL	3,000
Dow Chemical Co	Midland	MI	3,000
Berry Plastics	Schaumburg	IL	2,940
Berry Plastics Group Inc	Evansville	IN	2,800
Sonoco Adhesives Div	Hartsville	SC	2,500
Sonoco Plastics Inc	Hartsville	SC	2,500
Georgia-Pacific Corp	Green Bay	WI	2,500
Caterpillar Inc	Peoria	IL	2,500
Du Pont Washington Works	Washington	WV	2,400
Automotive Components Holdings	Saline	MI	2,400
INVISTA	Seaford	DE	2,100
Rubbermaid Home & Family Prods	Huntersville	NC	2,000
Linde North America Inc	New Providence	NJ	2,000
Sherwin-Williams Co	Cleveland	OH	2,000
Precision Global	Rye Brook	NY	2,000
Armstrong Holdings Inc	Lancaster	PA	2,000
Berry Plastics Corp	Evansville	IN	1,900
Acuity Specialty Products Inc	Atlanta	GA	1,800
Bayer Material Science LLC	Pittsburgh	PA	1,800
International Paper Co	Franklin	VA	1,800
Du Pont	Grifton	NC	1,750
Momentive Performance Mtrls	Waterford	NY	1,700

Source: Reference USA

Table 15. Top 30 Petrochemical Companies within the United States, Ranked by Employment

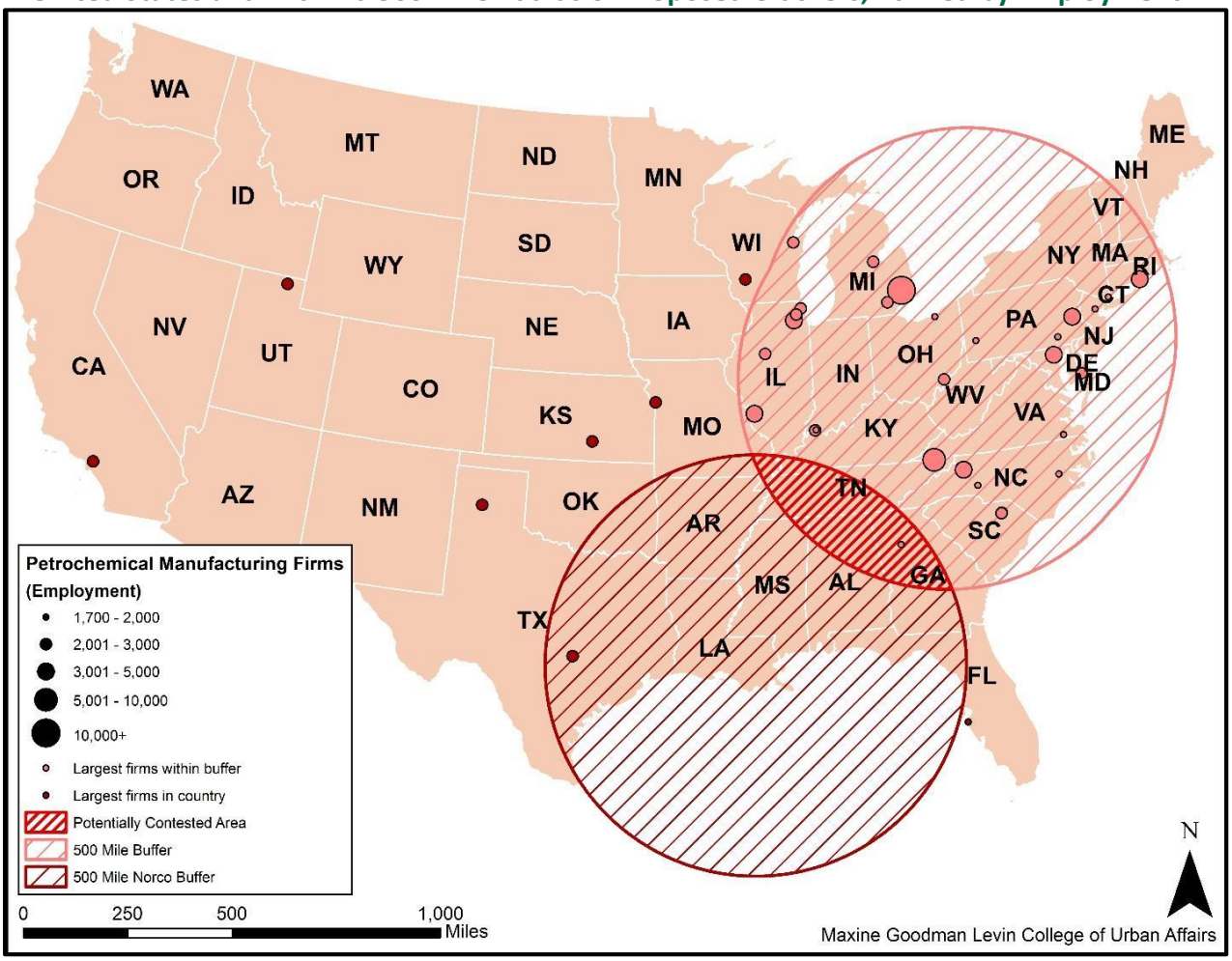
Company Name	City	State	Employment
General Motors Technical Ctr	Warren	MI	17,096
Eastman Chemical Co	Kingsport	TN	8,000
Air Products & Chemicals Inc	Allentown	PA	4,500
Monsanto Co	St Louis	MO	4,000
BP Chemical Co	Warrenville	IL	4,000
B&W Technical Svc Y-12 LLC	Oak Ridge	TN	4,000
Pfizer Inc	Groton	CT	3,800
Cristal USA	Cockeysville	MD	3,600
Hospira Inc	Lake Forest	IL	3,000
Koch Industries Inc	Wichita	KS	3,000
Dow Chemical Co	Midland	MI	3,000
Honeywell Federal Mfg & Tech	Kansas City	MO	3,000
ICON Health & Fitness Inc	Logan	UT	3,000
Berry Plastics	Schaumburg	IL	2,940
Derek Steele Co	Richland Center	WI	2,900
Berry Plastics Group Inc	Evansville	IN	2,800
B&W Technical Svc Pantex	Amarillo	TX	2,600
Sonoco Adhesives Div	Hartsville	SC	2,500
Sonoco Plastics Inc	Hartsville	SC	2,500
Freescale Semiconductor Inc	Austin	TX	2,500
Georgia-Pacific Corp	Green Bay	WI	2,500
Caterpillar Inc	Peoria	IL	2,500
Du Pont Washington Works	Washington	WV	2,400
Automotive Components Holdings	Saline	MI	2,400
Ameron International Corp	Pasadena	CA	2,300
INVISTA	Seaford	DE	2,100
Tropicana Products Inc	Bradenton	FL	2,000
Rubbermaid Home & Family Prods	Huntersville	NC	2,000
Linde North America Inc	New Providence	NJ	2,000
Sherwin-Williams Co	Cleveland	OH	2,000

Source: Reference USA

Figure 18 shows the geographic distribution of the top petrochemical companies within the 500-mile radius from the proposed Tri-State regional crackers. Also displayed in Figure 18 is a 500-mile buffer around the Norco, Louisiana cracker, the northernmost cracking facility in the Gulf Coast region. The overlap portion of the Tri-State region's proposed cracker buffer and the Gulf Coast buffer is identified as a "jointly competitive area" where competition for customers between petrochemical hubs may exist.

The map shows that the majority of the largest petrochemical companies, when ranked by employment, are located within 500 miles of the proposed crackers in the Tri-State region, while only two are located within 500 miles of the Norco cracker.

Figure 18. Geographic Distribution of the Top Petrochemical Manufacturing Firms within the United States and within a 500-mile Radius of Proposed Crackers, Ranked by Employment



Map data source: Reference USA

Table 16 lists the top 30 petrochemical manufacturing firms that are located within the 500-mile radius, while Table 17 lists the top 30 within the United States, this time ranked by sales. Figure 19 shows the geographic distribution of such firms, again displaying a "jointly competitive area" between the Tri-State and Gulf Coast regions. When ranked by sales, many more top petrochemical companies appear to be located in the Gulf Coast region, as opposed to when companies are ranked by employment. Still, clusters of large petrochemical companies exist in Chicago and Detroit, including General Motors Technical Center and BP Chemical.

Table 16. Top 30 Petrochemical Companies within 500 miles of Proposed Crackers, Ranked by Sales

Company Name	City	State	Sales
General Motors Technical Ctr	Warren	MI	$13,078,440,000
BP Chemical Co	Warrenville	IL	$12,405,640,000
United States Enrichment Corp	Paducah	KY	$2,703,473,000
Sonoco Adhesives Div	Hartsville	SC	$2,218,486,000
INVISTA	Seaford	DE	$2,169,519,000
PCS Phosphate	Aurora	NC	$1,920,043,000
Calumet Penreco	Karns City	PA	$1,901,907,000
Solutia Inc	Indian Orchard	MA	$1,874,258,000
Dow Chemical Co	Piscataway	NJ	$1,764,530,000
Du Pont	Grifton	NC	$1,627,971,000
Dow Corning Corp	Carrollton	KY	$1,471,708,000
Pfizer Inc	Groton	CT	$1,455,200,000
Dow Chemical Co	Philadelphia	PA	$1,407,393,000
American Water Heater Co	Johnson City	TN	$1,320,811,000
Nuclear Fuel Svc Inc	Erwin	TN	$1,244,707,000
Nan Ya Plastics Corp	Lake City	SC	$1,239,819,000
Henkel Corp	Westlake	OH	$1,211,853,000
Solutia Inc	Anniston	AL	$1,202,868,000
Berry Plastics	Schaumburg	IL	$1,160,000,000
B&W Technical Svc Y-12 LLC	Oak Ridge	TN	$1,157,332,000
BASF-Chemical Co	Tarrytown	NY	$1,141,000,000
Lubrizol Laboratories	Wickliffe	OH	$1,112,394,000
International Paper Co	Franklin	VA	$1,087,086,000
United States Enrichment Corp	Oak Ridge	TN	$1,081,117,000
Vi-Jon Inc	Smyrna	TN	$1,072,832,000
Henkel Corp	Madison Heights	MI	$1,047,340,000
Solutia Inc	Trenton	MI	$1,044,118,000
BP Chemical Co	Decatur	AL	$1,037,675,000
DAK Americas LLC	Wilmington	NC	$1,009,772,000
Dart Container Solo	North Andover	MA	$988,560,000

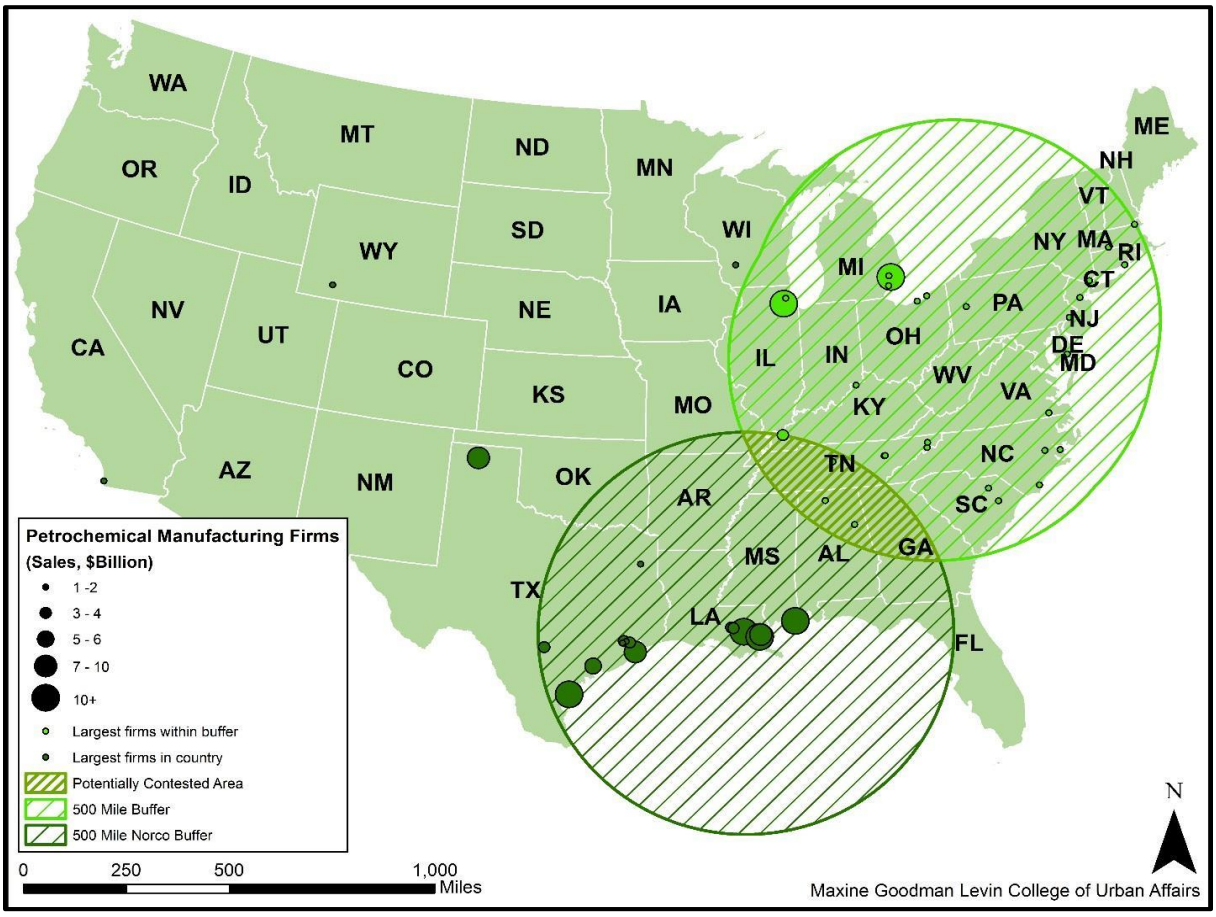
Source: Reference USA

Table 17. Top 30 Petrochemical Companies within the United States, Ranked by Sales

Company Name	City	State	Sales
Marathon Garyville Refinery	Garyville	LA	$21,895,808,000
Flint Hills Resources	Corpus Christi	TX	$15,749,587,000
Chevron Oronite Co LLC	Belle Chasse	LA	$15,327,065,000
General Motors Technical Ctr	Warren	MI	$13,078,440,000
Chevron Pascagoula Refinery	Pascagoula	MS	$12,781,819,000
BP Chemical Co	Warrenville	IL	$12,405,640,000
Murphy Oil USA	Meraux	LA	$9,123,253,000
Eastman Chemical Co	Texas City	TX	$8,749,770,000
Valero Mc Kee Refinery	Sunray	TX	$7,874,793,000
World-Pak Corp	Lolita	TX	$5,599,430,000
CVS Caremark Prescription Svc	San Antonio	TX	$4,095,598,000
Syngenta	St Gabriel	LA	$3,234,330,000
BASF-Chemical Co	Geismar	LA	$3,166,331,000
Chevron Kapolei Refinery	Kapolei	HI	$3,069,548,000
United States Enrichment Corp	Paducah	KY	$2,703,473,000
Chevron Phillips Chemical Co	Houston	TX	$2,628,734,000
Lubrizol Corp	Deer Park	TX	$2,628,734,000
FMC Corp	Green River	WY	$2,468,797,000
Haltermann Custom Production	Houston	TX	$2,362,438,000
Eastman Chemical Co	Longview	TX	$2,277,532,000
Derek Steele Co	Richland Center	WI	$2,224,472,000
Sonoco Adhesives Div	Hartsville	SC	$2,218,486,000
INVISTA	Seaford	DE	$2,169,519,000
Cardinal Health	San Diego	CA	$2,021,821,000
PCS Phosphate	Aurora	NC	$1,920,043,000
Calumet Penreco	Karns City	PA	$1,901,907,000
Solutia Inc	Indian Orchard	MA	$1,874,258,000
Dow Chemical Co	Piscataway	NJ	$1,764,530,000
South Coast Terminals Inc	Houston	TX	$1,679,955,000
Du Pont	Grifton	NC	$1,627,971,000

Source: Reference USA

Figure 19. Geographic Distribution of the Top Petrochemical Manufacturing Firms within the United States and within a 500-mile Radius of Proposed Crackers



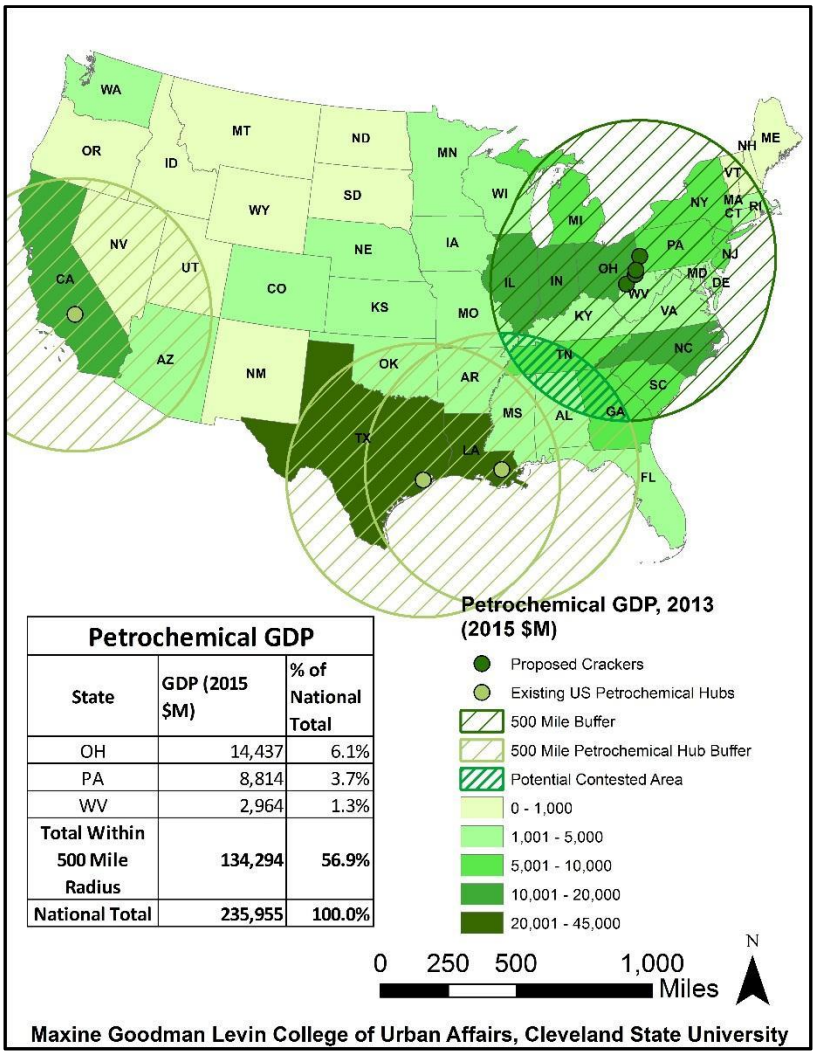
Map data source: Reference USA
Note: Ranked by Sales

In addition to looking at the main potential consumers from individual companies, the following analysis compared the petrochemical sector's gross regional product (GRP) and employment in the Tri-State region's 500-mile radius to that of the closest competitors – the existing petrochemical hubs of Louisiana, Texas, and California. Included in the Tri-State region's 500-mile radius are 26 states, seven of which are located within the "jointly competitive area" between the Tri-State region and the Gulf Coast (overlap by the green circle and one of the yellow circles in Figure 20).

The GRP of the three states comprising the Tri-State region totals to $26,215 million dollars, or 11.1% of the overall petrochemical gross domestic product (GDP) of the United States in 2013.[92] When observing the petrochemical GRP of the 26 states within the Tri-State region's 500-mile radius, the total jumps to $134,294 (in millions of dollars), or 56.9% of the overall petrochemical GDP of the United States (see Figure 20).

[92] Source: Moody's Economy.com.

Figure 20. Gross Regional Product of Petrochemical Companies within 500-mile Radii of Existing Petrochemical Hubs and the Proposed Crackers in the Tri-State Region



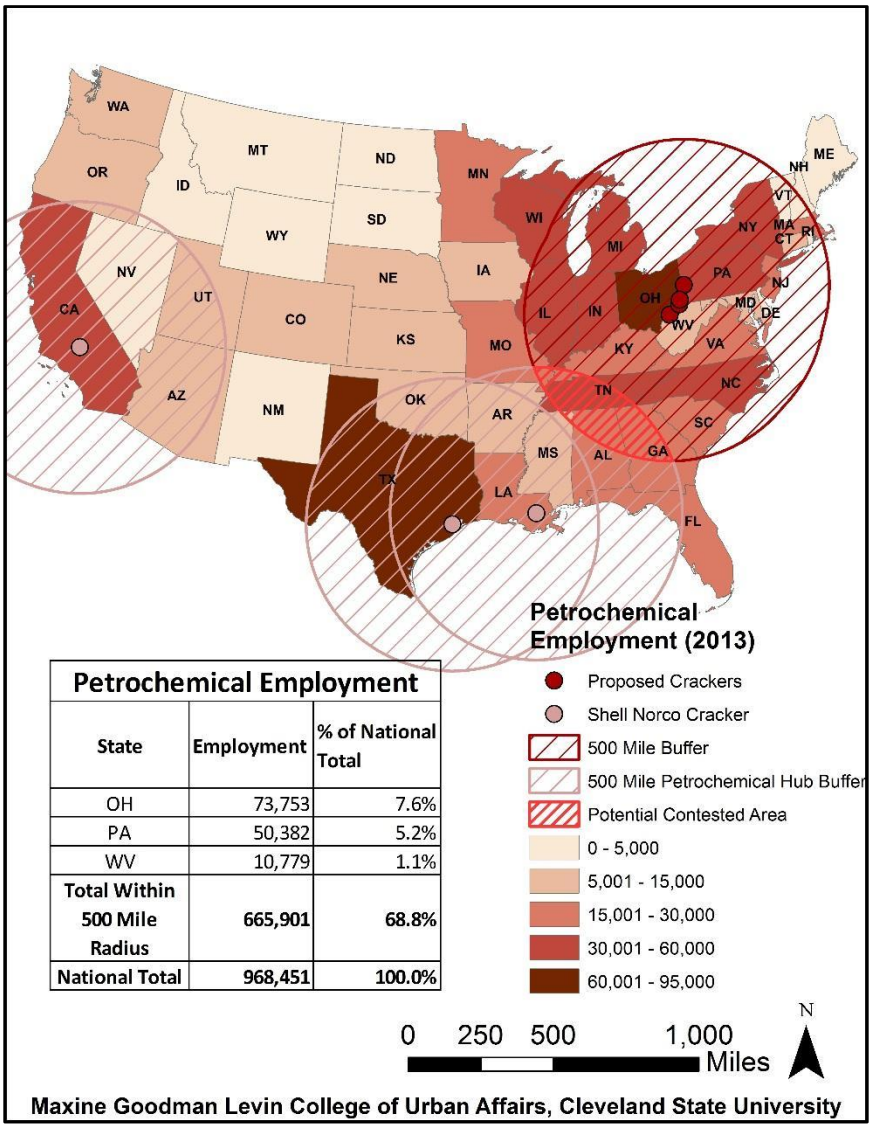
Petrochemical GDP

State	GDP (2015 $M)	% of National Total
OH	14,437	6.1%
PA	8,814	3.7%
WV	2,964	1.3%
Total Within 500 Mile Radius	**134,294**	**56.9%**
National Total	**235,955**	**100.0%**

Data source: Moody's Economy.com

Within the Tri-State region, 134,914 people were employed in the petrochemical sector, or 13.9% of the overall petrochemical sector employment in the United States in 2013. The 26 states within the Tri-State region's 500-mile buffer had a total petrochemical sector employment of 665,901, or 68.8% of the national employment within this sector. Whether measured by gross product or employment, the Tri-State region's proposed crackers would have viable access to over half of the petrochemical manufacturing industry's consumer market in the United States (see Figure 21).

Figure 21. Petrochemical Sector Employment within 500-mile Radii of Existing Petrochemical Hubs and the Proposed Crackers in the Tri-State Region



Petrochemical Employment

State	Employment	% of National Total
OH	73,753	7.6%
PA	50,382	5.2%
WV	10,779	1.1%
Total Within 500 Mile Radius	**665,901**	**68.8%**
National Total	**968,451**	**100.0%**

Map data source: Moody's Economy.com

Of the 26 states that make up the Tri-State region's 500-mile buffer area, Ohio has the largest petrochemical sector employment (73,753 or 7.6% of the U.S. petrochemical employment), followed by Illinois (55,727), and Pennsylvania (50,382). Ohio also has the highest GRP ($14,437), North Carolina the second-most ($12,770), and Indiana the third-most ($10,434).

Not only is the concentration of the consumer market favorable to the proposed crackers in the Tri-State region, but also, many of the 26 states within the 500-mile radius have high location quotients of employment and GRP of the petrochemical sector (the petrochemical sector is comprised of six 4-digit NAICS). High location quotients indicate that this sector is a part of the regional economic base in these states and therefore speaks to the viability of the industry and related cluster usually accompanying high concentration in employment and GRP of an industry.

Moreover, there is a high likelihood that these industries receive close attention in state public policies and from economic development intermediaries. Table 18 displays the states' location quotient of petrochemical sector employment and GRP, measuring the sector's concentration within the states compared to the nation overall. A location quotient greater than 1.2 indicates that a higher than average concentration of that industry is located within the state.[93] For example, Ohio's petrochemical sector has an employment location quotient of 2, meaning that the sector is 2 times more concentrated in the state than the concentration of the petrochemical sector in the national economy.

[93] A location quotient (LQ) is an analytical statistic that measures a region's industrial specialization relative to a larger geographic unit (usually the nation). An LQ is computed as an industry's share of a regional total for some economic statistic (earnings, GDP by metropolitan area, employment, etc.) divided by the industry's share of the national total for the same statistic. For example, an LQ of 1.0 in mining means that the region and the nation are equally specialized in mining; while an LQ of 1.8 means that the region has a 1.8 times (or 80%) higher concentration in mining than the nation.

Table 18. Petrochemical Sector as Economic Base Industry for 26 States within 500 miles of Tri-State Region's Proposed Crackers

26 states within 500-mile area	Employment	Employment Location Quotient	GRP, $M	GRP Location Quotient
Ohio	73,753	2.00	14,437	1.81
Illinois	55,727	1.37	10,370	1.02
Pennsylvania	50,382	1.25	8,814	0.97
Michigan	47,491	1.66	5,904	0.97
Indiana	44,501	2.15	10,434	2.33
North Carolina	37,788	1.29	12,770	1.92
Wisconsin	36,154	1.80	4,681	1.17
New York	32,909	0.53	6,978	0.38
Tennessee	32,632	1.67	6,063	1.49
Georgia	29,818	1.04	6,032	0.94
South Carolina	26,668	1.96	5,135	1.98
New Jersey	25,271	0.93	5,960	0.78
Virginia	23,426	0.86	4,740	0.74
Kentucky	23,093	1.70	3,784	1.46
Alabama	21,353	1.57	4,277	1.56
Missouri	20,846	1.06	4,109	1.05
Massachusetts	17,933	0.77	3,798	0.60
Iowa	12,860	1.15	3,848	1.64
Maryland	10,840	0.59	2,459	0.51
West Virginia	10,779	1.98	2,964	2.84
Connecticut	9,517	0.82	2,241	0.64
Mississippi	8,902	1.10	2,052	1.38
New Hampshire	4,763	1.07	464	0.48
Delaware	4,062	1.34	1,432	1.62
Rhode Island	3,688	1.12	481	0.64
Vermont	745	0.34	64	0.15
TOTAL	**665,901**		**134,294**	
Pct. Of US Total	**68.8%**		**56.9%**	

Source: Moody's Economy.com

The petrochemical sector GRP and employment for the 26 states within the Tri-State region's 500-mile buffer area are greater than those of the 500-mile areas surrounding the existing petrochemical hubs of Louisiana, Texas, and California. Louisiana's 500-mile area covers 11 states (including Texas) and has a total petrochemical employment of 292,561 and GRP of $99,213 million dollars, or 30.2% and 42% of national totals, respectively (see Table 19).

Table 19. Petrochemical Sector Employment and GRP for 500-mile Area Surrounding Louisiana Hub

States within 500-mile area	Employment	GRP, $M
Texas	92,245	44,183
Tennessee	32,632	6,063
Georgia	29,818	6,032
Louisiana	24,516	21,662
Kentucky	23,093	3,784
Alabama	21,353	4,277
Missouri	20,846	4,109
Florida	20,385	3,911
Arkansas	9,954	1,631
Mississippi	8,902	2,052
Oklahoma	8,817	1,508
TOTAL	**292,561**	**99,213**
Pct. Of US Total	**30.2%**	**42.0%**

Source: Moody's Economy.com

Texas' 500-mile radius includes eight states with a petrochemical employment total of 207,018 and GRP of $83,333, or 21.4% and 35.3% of national totals, respectively (see Table 20). The 500-mile radii drawn around the Louisiana and Texas petrochemical hubs largely overlap, showing direct competition for the market. California's 500-mile radius includes six states, with petrochemical employment only totaling 81,963 and GRP $16,765, or 8.5% and 7.1% of national totals, respectively (see Table 21).

Table 20. Petrochemical Sector Employment and GRP for 500-mile Buffer Area Surrounding Texas Hub

States within 500-mile area	Employment	GRP, $M
Texas	92,245	44,183
Louisiana	24,516	21,662
Alabama	21,353	4,277
Missouri	20,846	4,109
Florida	20,385	3,911
Arkansas	9,954	1,631
Mississippi	8,902	2,052
Oklahoma	8,817	1,508
TOTAL	**207,018**	**83,333**
Pct. Of US Total	**21.4%**	**35.3%**

Source: Moody's Economy.com

Table 21. Petrochemical Sector Employment and GRP for 500-mile Buffer Area Surrounding California Hub

States within 500-mile area	Employment	GRP, $M
California	56,865	12,789
Oregon	6,522	931
Arizona	6,229	1,252
Utah	5,804	910
Idaho	3,299	524
Nevada	3,244	360
TOTAL	**81,963**	**16,765**
Pct. Of US Total	**8.5%**	**7.1%**

Source: Moody's Economy.com

ANALYSIS OF THE DOWNSTREAM INDUSTRIES LABOR DEMAND

Prior study[94] on labor demand for the Ohio Valley's downstream companies suggest a segmentation of the labor market and an overall labor shortage, especially for small and medium-sized manufacturing companies offering low wages and modest benefits. The most significant effect of the shortages in petrochemical labor demand was observed in the segments of the labor market exhibiting the smallest value-added per product produced: those companies that manufacture products using recycled plastics or off-spec products. There is a continuous churning of labor through different tiers within the industry as higher, more specialized, segments of the petrochemical industries draw labor supplies from the lower segments - those requiring lower labor skills. More specialized petrochemical manufacturing offers higher pay and better benefits, like any highly specialized companies in other manufacturing sectors.

Additionally, the burden of teaching basic industrial skills to workers in entry-level, low skill positions is large and often unmanageable for some of the smaller companies in the industry. These companies also experience additional economic pressure because they are only able to draw their labor from the regional pool. Moreover, regionally, these companies compete for labor with upstream and midstream oil and gas businesses hiring local labor for low-skill jobs. Salary levels and benefits in these circumstances are insufficient to incentivize relocation of workers from other regions. However, the labor market for the highest segments of the petrochemical labor (chemical engineers and scientists) is national. Companies hiring highly-skilled workers with commensurately high pay attract workers from other regions and states.

This part of the Study compares the density of the downstream occupations that are in high demand in the Tri-State region to the same occupations for the Gulf Coast region.[95] Potential expansion of the petrochemical industry in the Tri-State region will increase demand across many categories and levels of occupations, skills, required education and pay. The goal of this analysis is to assess the Tri-State region's

[94] Lendel, Iryna; Thomas, Andrew R.; Townley, Bryan; Murphy, Thomas; and Kalynchuk, Ken, "Economics of Utica Shale in Ohio: Workforce Analysis" (2015). Urban Publications. Paper 1330. http://engagedscholarship.csuohio.edu/urban_facpub/1330.

[95] For this Study, the Gulf Coast region is defined to include the states of AL, AR, LA, MS, OK, TX, and 36 MSAs outside of these states – Appendix 1.

ability to use its workforce to attract major crackers and affiliated companies from their supply and demand chains, and to consider strategies for how this might be done.

This analysis was conducted in several stages. Using the profiles of downstream industries discussed in the previous chapters, we identified top petrochemical occupations through the cross-walk employment matrix from industrial classification to occupational categories using the U.S. Bureau of Labor Analysis' matrix of national occupations.[96] Workers classified within 234 occupational categories are working in six four-digit NAICS industries identified as the profile of petrochemical industry.

To conduct an analysis on a workforce necessary to attract the crackers, we assessed the ethane cracking capacity for petrochemical complexes in the Gulf Coast region and compared these to the ethane cracking capacity proposed through the construction of three regional crackers for the Tri-State region. This was done because cracking capacity can provide insights into labor requirements downstream of the cracker. For the Gulf Coast we used existing capacity plus additional capacity anticipated from committed expansion plans. In the Tri-State region, we aggregated the cracking capacity of three prospective crackers announced by the beginning of 2015: ASCENT in Wood County, WV; Royal Dutch Shell in Monaca, PA; and PTT Global in Belmont County, OH.

If built, these petrochemical complexes would have a significant impact on the Tri-State regional workforce. This impact will be not only from operation of these crackers, but from attracting a significant number of petrochemical suppliers and customers to the region, all of whom would hire. Having a diverse manufacturing economic base, we can expect that all three states would benefit from the regional production of chemical products derived from ethane. As the following data demonstrates, the effect would be wide-spread throughout the supply chain and the downstream customer pool in Ohio, Pennsylvania and West Virginia.

Table 22 identifies rates of growth of employment in occupations directly involved in the petrochemical downstream sector in the Tri-State and the Gulf Coast regions. In this table, the occupations are grouped into major occupational classes (Column SOC). In petrochemical industries, managerial occupations (raw SOC 11) were growing by 15.6% in the Gulf Coast and by 26.4% in the Tri-State regions between 2009 and 2014. This is the only petrochemical occupational employment that was growing faster in the Tri-State region than in the Gulf Coast region. All other petrochemical occupations were growing faster in the Gulf Coast. Moreover, in six major occupational sectors -- Maintenance; Sales and Related Occupations; Office and Administrative Support; Construction and Extraction; Installation, Maintenance and Repair; and Transportation and Material Moving -- occupational employment was growing in the Gulf Coast region while, at the same time, these sectors were declining in the Tri-State area. The largest disparity was observed in the Installation, Maintenance and Repair sector (SOC 49) where the occupational employment of the petrochemical sector of the Gulf Coast region was growing by 14.2% while declining in the Tri-State region by -11.1%.

[96] A cross-walk matrix provides occupational details across industrial employment. U.S. Bureau of Labor Statistics, http://www.bls.gov/emp/ep_crosswalks.htm

Table 22. Growth of Petrochemical-Related Occupational Employment

SOC	Description	2009 Employment		2014 Employment		Employment Change		% Change Employment	
		Gulf Region	Tri-State Region	Gulf Region	Tri-State Region	Gulf Region	Tri-State Region	Gulf Region	Tri-State Region
11	Management	851,040	277,500	984,100	350,850	133,060	73,350	15.6%	26.4%
13	Business and Financial Operations	714,170	298,530	897,920	342,630	183,750	44,100	25.7%	14.8%
15	Computer and Mathematical	171,610	72,480	317,640	122,650	146,030	50,170	85.1%	69.2%
17	Architecture and Engineering	161,570	84,280	174,600	86,460	13,030	2,180	8.1%	2.6%
19	Life, Physical, and Social Science	27,740	20,720	28,770	21,150	1,030	430	3.7%	2.1%
29	Healthcare Practitioners and Technical	11,580	5,150	15,330	5,910	3,750	760	32.4%	14.8%
37	Building and Grounds Cleaning and Maintenance	376,730	191,390	424,170	182,430	47,440	-8,960	12.6%	-4.7%
41	Sales and Related	435,390	200,310	452,450	164,570	17,060	-35,740	3.9%	-17.8%
43	Office and Administrative Support	3,376,330	1,397,260	3,589,860	1,362,740	213,530	-34,520	6.3%	-2.5%
47	Construction and Extraction	116,850	51,020	129,600	48,300	12,750	-2,720	10.9%	-5.3%
49	Installation, Maintenance, and Repair	463,990	204,330	529,830	181,590	65,840	-22,740	14.2%	-11.1%
51	Production	1,160,860	639,300	1,296,020	654,560	135,160	15,260	11.6%	2.4%
53	Transportation and Material Moving	1,345,750	647,350	1,513,860	622,270	168,110	-25,080	12.5%	-3.9%

Source: U.S. Bureau of Labor Statistics' Standard Occupational Classification

To assess regional capacity offering labor for prospective ethane crackers, we calculated indices of (1) occupational employment per unit of ethane and (2) per unit of ethane and propane cracking in the Gulf Coast region (called ethane occupational density and total occupational density, respectively). The capacity of production was measured per 1,000 tonnes a year. After calculating the indices of occupational capacity in the Gulf Coast region, we applied them to the prospective ethane cracking capacity in the Tri-State region. Table 23 presents the calculation of required labor in the Tri-State region assuming that all three crackers will be built. The multiplications of prospective Tri-State cracking capacity by occupational density indices resulted in the column called "required employment," which represents the required demand for employment for each top occupation in the petrochemical industry. As a next step, we compared the required employment calculation with existing 2014 employment within each occupation, and determined the required growth within that particular occupational employment ("Required % Change Employment" column).

In 2014, the Tri-State regional employment in the Petroleum Pump System Operators, Refinery Operators, and Gaugers was 2,740 employees (raw SOC 51-8093 in Table 23). This employment declined 16.5% over 2009-2014. The occupational density of ethane in the Gulf Coast region in this occupation is 2.18, which means that for every 1,000 tonnes/year of produced ethane in that region, there are 2.18 workers employed in this occupation. To support the Tri-State regional capacity of ethane production from the three projected crackers we would need to employ 13,000 workers in this occupation. By having only 2,740 employees in this occupation in 2014, the downstream industry in the Tri-State region is potentially short 10,260 workers to handle the Petroleum Pump System Operators jobs. The Tri-State region would need to increase this occupational employment by 587% as these crackers were brought on line. Interpreting the rest of Table 23 in this manner we can see significant shortages in a number of occupations required for petrochemical production. The top occupations that might experiencing the largest shortages include:

- Textile Winding, Twisting, and Drawing Out Machine Setters, Operators, and Tenders
- Petroleum Pump System Operators, Refinery Operators, and Gaugers
- Chemical Plant and System Operators
- Fiberglass Laminators and Fabricators
- Industrial Machinery Mechanics
- Business Operations Specialists, All Other
- Chemical Engineers
- Welders, Cutters, Solderers, and Brazers
- General and Operations Managers
- Weighers, Measurers, Checkers, and Samplers, Recordkeeping
- Electrical and Electronics Repairers, Commercial and Industrial Equipment
- First-Line Supervisors of Non-Retail Sales Workers
- Health and Safety Engineers, Except Mining Safety Engineers and Inspectors
- First-Line Supervisors of Mechanics, Installers, and Repairers
- Computer User Support Specialists

Table 23. Petrochemical Occupational Employment in the Tri-State Region by Ethane Density

SOC	Description	Tri-State Employment	2009-2014	Gulf Occupational Density 2014	Required Employment	Employment Shortage	Required
		2014	% Change Employment	Ethane Occupational Density*			% Change Employment
51-6064	Textile Winding, Twisting, and Drawing Out Machine Setters, Operators, and Tenders	590	-4.8%	0.68	4,051	-3,461	586.7%
51-8093	Petroleum Pump System Operators, Refinery Operators, and Gaugers	2,740	-16.5%	2.18	13,000	-10,260	374.4%
51-8091	Chemical Plant and System Operators	1,940	-56.8%	1.36	8,109	-6,169	318.0%
51-2091	Fiberglass Laminators and Fabricators	940	-26.6%	0.42	2,490	-1,550	164.9%
49-9041	Industrial Machinery Mechanics	18,800	-42.1%	8.17	48,711	-29,911	159.1%
13-1199	Business Operations Specialists, All Other	46,500	-15.8%	17.45	104,016	-57,516	123.7%
17-2041	Chemical Engineers	3,080	-4.6%	1.15	6,855	-3,775	122.6%
51-4121	Welders, Cutters, Solderers, and Brazers	35,510	9.9%	11.71	69,784	-34,274	96.5%
11-1021	General and Operations Managers	140,090	69.4%	46.09	274,675	-134,585	96.1%
43-5111	Weighers, Measurers, Checkers, and Samplers, Recordkeeping	5,170	2.4%	1.68	10,031	-4,861	94.0%
49-2094	Electrical and Electronics Repairers, Commercial and Industrial Equipment	5,660	-36.2%	1.84	10,971	-5,311	93.8%
41-1012	First-Line Supervisors of Non-Retail Sales Workers	17,490	-12.6%	5.54	33,002	-15,512	88.7%
17-2111	Health and Safety Engineers, Except Mining Safety Engineers and Inspectors	2,090	-8.7%	0.64	3,833	-1,743	83.4%
49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	34,940	4.0%	10.59	63,112	-28,172	80.6%
15-1151	Computer User Support Specialists	43,200	0.0%	13.04	77,744	-34,544	80.0%
11-3011	Administrative Services Managers	20,350	6.5%	6.11	36,397	-16,047	78.9%
51-9031	Cutters and Trimmers, Hand	730	-51.7%	0.22	1,295	-565	77.4%
43-4051	Customer Service Representatives	199,860	6.7%	58.31	347,540	-147,680	73.9%
43-1011	First-Line Supervisors of Office and Administrative Support Workers	104,690	1.1%	30.37	181,021	-76,331	72.9%
53-3032	Heavy and Tractor-Trailer Truck Drivers	150,630	2.9%	43.43	258,830	-108,200	71.8%
13-1041	Compliance Officers	18,510	12.0%	5.31	31,665	-13,155	71.1%
53-1021	First-Line Supervisors of Helpers, Laborers, and Material Movers, Hand	14,560	-3.5%	4.15	24,746	-10,186	70.0%
41-4012	Sales Representatives Wholesale and Manufacturing Except Technical and Scientific Products	114,110	-20.9%	32.27	192,317	-78,207	68.5%
53-1031	First-Line Supervisors of Transportation and Material-Moving Machine and Vehicle Operators	17,110	-5.4%	4.78	28,484	-11,374	66.5%
13-1151	Training and Development Specialists	19,320	3.0%	5.33	31,772	-12,452	64.5%
11-2022	Sales Managers	24,240	9.4%	6.63	39,532	-15,292	63.1%
43-6011	Executive Secretaries and Executive Administrative Assistants	52,320	-41.7%	14.23	84,812	-32,492	62.1%
43-9061	Office Clerks, General	251,090	-11.3%	67.86	404,436	-153,346	61.1%
49-9043	Maintenance Workers, Machinery	9,380	56.9%	2.53	15,082	-5,702	60.8%
43-6014	Secretaries and Administrative Assistants, Except Legal, Medical, and Executive	187,430	23.1%	50.28	299,675	-112,245	59.9%

Note: Based on Gulf Coast occupational density (per 1,000 tonnes/yr ethane cracker capacity)

Similar shortages in potential workforce can be identified in this manner for occupations across many educational and skill levels. Table 24 illustrates these occupations by the required rates in change of employment, hourly and annual pay, and so called "Job Zone."

Table 24. Required Education and Skills for the Workforce in Potentially Growing Occupational Sectors in the Tri-State Region

SOC	Description	% Change Emp	Hourly	Annual	Job Zone
11-1011	Chief Executives	32.5%	$ 83.33	$ 173,320	**5**
11-9041	Architectural and Engineering Managers	46.7%	$ 62.80	$ 130,620	**5**
11-3021	Computer and Information Systems Managers	39.5%	$ 61.37	$ 127,640	**4**
11-2021	Marketing Managers	42.1%	$ 61.12	$ 127,130	**4**
11-3031	Financial Managers	36.4%	$ 55.44	$ 115,320	**5**
11-2022	Sales Managers	63.1%	$ 53.20	$ 110,660	**4**
11-3061	Purchasing Managers	56.6%	$ 51.01	$ 106,090	**4**
11-9199	Managers, All Other	56.2%	$ 50.51	$ 105,060	**4**
11-3121	Human Resources Managers	56.8%	$ 49.41	$ 102,780	**4**
11-1021	General and Operations Managers	96.1%	$ 46.77	$ 97,270	**4**
17-2041	Chemical Engineers	122.6%	$ 46.60	$ 96,940	**4**
17-2199	Engineers, All Other	9.2%	$ 45.31	$ 94,240	**4**
11-3051	Industrial Production Managers	6.3%	$ 44.46	$ 92,470	**4**
11-3071	Transportation, Storage, and Distribution Managers	56.8%	$ 41.06	$ 85,400	**4**
11-3011	Administrative Services Managers	78.9%	$ 40.28	$ 83,790	**3**
17-2141	Mechanical Engineers	10.8%	$ 39.93	$ 83,060	**4**
15-1121	Computer Systems Analysts	28.3%	$ 39.76	$ 82,710	**4**
17-2111	Health and Safety Engineers, Except Mining Safety Engineers and Inspectors	83.4%	$ 39.34	$ 81,830	**4**
17-2112	Industrial Engineers	15.3%	$ 39.18	$ 81,490	**4**
13-1111	Management Analysts	46.5%	$ 38.89	$ 80,880	**4**
15-1142	Network and Computer Systems Administrators	56.5%	$ 36.44	$ 75,790	**4**
41-4011	Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products	28.2%	$ 36.13	$ 75,140	**4**
13-1081	Logisticians	47.5%	$ 35.51	$ 73,870	**4**
41-1012	First-Line Supervisors of Non-Retail Sales Workers	88.7%	$ 34.42	$ 71,600	**4**
29-9011	Occupational Health and Safety Specialists	53.4%	$ 33.27	$ 69,210	**4**
13-1199	Business Operations Specialists, All Other	123.7%	$ 32.35	$ 67,280	**3**
13-2011	Accountants and Auditors	55.8%	$ 31.70	$ 65,940	**4**
13-1041	Compliance Officers	71.1%	$ 31.23	$ 64,950	**4**
51-8093	Petroleum Pump System Operators, Refinery Operators, and Guagers	374.4%	$ 30.21	$ 62,830	**2**
49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	80.6%	$ 29.88	$ 62,150	**3**

The following Table 25 describes requirements for Education, Experience and Training by Job Zone.

Table 25. Requirements to Education, Experience and Training by Job Zone

Job Zone	Education	Experience	Training
1	HS Diploma/ GED certificate	Little or none	Days-Months
2	HS Diploma	Some	Months-1 Year
3	Vocational/ Associate's degree	Medium	1 Year-2 Years
4	Bachelor's degree	Considerable	Several Years
5	Master's/ Professional degree	Extensive	Some (should already be skilled)

For example, as illustrated in Table 24, the occupation of General and Operations Managers (SOC 11-1021) has a demand of employment at 96.1% growth. This occupation pays $46.77 per hour or $97,270 annually according to the national average, and has a Job Zone 4. According to Table 25, Job Zone 4 requires at least a Bachelor's degree with considerable experience and several years of on-the-job training.

While the analysis illustrates labor shortages in many occupations, it significantly overstates these shortages due to the additional demand for petrochemical workers in companies similar to ethane crackers in the Gulf Coast. Petrochemical complexes that crack propane and butane require similar workers to those employed at ethane steam cracker facilities.

Table 25 illustrates the results of a similar labor demand analysis calculated based on total occupational density – the index calculated as occupational employment per unit of ethane and propane cracking in the Gulf Coast region. In this analysis, the occupational density was also calculated per 1,000 tonnes/year accounting for a cumulative production of ethane and propane. While the occupational employment number was divided by larger ethane and propane capacity volumes, indices of density were significantly lower for the Gulf Coast region. In turn, these lower indices yielded smaller occupational employment demand for different occupations. Only three occupations have lower employment than needed to produce ethane in the Tri-State region.

Those occupations are illustrated in the first three rows in Table 26:

- 51-6064 - Textile Winding, Twisting, and Drawing Out Machine Setters, Operators, and Tenders
- 51-8093 - Petroleum Pump System Operators, Refinery Operators, and Gaugers
- 51-8091 - Chemical Plant and System Operators

Table 26. Petrochemical Occupational Employment in the Tri-State Region by Total Density

SOC	Description	Tri-State 2014 Employment	2009-2014 % Change Employment	Gulf Coast Occupational Density 2014*	Required Employment****	Employment Shortage*****	Required % Change Employment*
51-6064	Textile Winding, Twisting, and Drawing Out Machine Setters, Operators, and Tenders	590	-4.8%	0.25	1,518	-928	157.3%
51-8093	Petroleum Pump System Operators, Refinery Operators, and Gaugers	2,740	-16.5%	0.82	4,872	-2,132	77.8%
51-8091	Chemical Plant and System Operators	1,940	-56.8%	0.51	3,039	-1,099	56.6%
51-2091	Fiberglass Laminators and Fabricators	940	-26.6%	0.16	933	7	-0.7%
49-9041	Industrial Machinery Mechanics	18,800	-42.1%	3.06	18,254	546	-2.9%
13-1199	Business Operations Specialists, All Other	46,500	-15.8%	6.54	38,979	7,521	-16.2%
17-2041	Chemical Engineers	3,080	-4.6%	0.43	2,569	511	-16.6%
51-4121	Welders, Cutters, Solderers, and Brazers	35,510	9.9%	4.39	26,151	9,359	-26.4%
11-1021	General and Operations Managers	140,090	69.4%	17.27	102,932	37,158	-26.5%
43-5111	Weighers, Measurers, Checkers, and Samplers, Recordkeeping	5,170	2.4%	0.63	3,759	1,411	-27.3%
49-2094	Electrical and Electronics Repairers, Commercial and Industrial Equipment	5,660	-36.2%	0.69	4,111	1,549	-27.4%
41-1012	First-Line Supervisors of Non-Retail Sales Workers	17,490	-12.6%	2.08	12,367	5,123	-29.3%
17-2111	Health and Safety Engineers, Except Mining Safety Engineers and Inspectors	2,090	-8.7%	0.24	1,436	654	-31.3%
49-1011	First-Line Supervisors of Mechanics, Installers, and Repairers	34,940	4.0%	3.97	23,651	11,289	-32.3%
15-1151	Computer User Support Specialists	43,200	0.0%	4.89	29,134	14,066	-32.6%
11-3011	Administrative Services Managers	20,350	6.5%	2.29	13,639	6,711	-33.0%
51-9031	Cutters and Trimmers, Hand	730	-51.7%	0.08	485	245	-33.5%

The total occupational density of the Petroleum Pump System Operators, Refinery Operators, and Gaugers (SOC 51-8093) is only 0.82 compared to an ethane occupational density of 2.18 (Table 23). Producing the ethane estimated for the three crackers in the Tri-State region would require 4,872 workers in this occupation. Compared to the employment of 2014, this occupation would need to attract or educate an additional 2,132 workers if and when the three crackers are built.

Similar shortages were identified for the Textile Winding, Twisting, and Drawing Out Machine Setters, Operators, and Tenders occupation (1,518 workers) and for the Chemical Plant and System Operators occupation (1,099 workers). All other occupations have a projected surplus of occupational employment (negative percent change of required employment) compared to existing 2014 employment in these occupations in the Tri-State region.

Although, this analysis speaks to optimistic results and identifies small potential shortages of labor, further investigation of potential workforce might be needed. Both workforce analyses conducted in this Study assume that existing employment will absorb new labor demand. However increased demand of labor for three potential crackers and related companies in the petrochemical industry will create a pressure on petrochemical manufacturing-related occupations and most likely will attract workers from smaller and less-paying companies moving up to larger companies offering better pay and benefits. This analysis is most useful in illustrating what occupations will be atop of the demand while the petrochemical industry expands its operations in the supply and demand chains to three crackers (Tables 23 and 26 in this report).

We know that existing companies that employ workers of these occupations will experience competition for labor. We can also expect that workers in these occupations will be the subject of employment recruitments as the crackers begin operations. We might also expect that local community colleges will roll out training programs responsive to the employment needs of the downstream supply chain and polyethylene consumer community.

APPENDIX 1

Appendix Table 1.1. Definition of the Gulf Coast Region

Whole State	MSA	State(s)
Alabama	Fayetteville-Springdale-Rogers	AR-MO
Arkansas	Crestview-Fort Walton Beach-Destin	FL
Louisiana	Gainesville	FL
Mississippi	Ocala	FL
Oklahoma	Panama City-Lynn Haven-Panama City Beach	FL
Texas	Pensacola-Ferry Pass-Brent	FL
	Tallahassee	FL
	Tampa-St. Petersburg-Clearwater	FL
	Albany	GA
	Athens-Clarke County	GA
	Atlanta-Sandy Springs-Marietta	GA
	Dalton	GA
	Gainesville	GA
	Macon	GA
	Rome	GA
	Valdosta	GA
	Warner Robins	GA
	Columbus	GA-AL
	Lawrence	KS
	Manhattan	KS
	Topeka	KS
	Wichita	KS
	Joplin	MO
	Springfield	MO
	Jefferson City	MO
	Cape Girardeau-Jackson	MO-IL
	Columbia	MO-IL
	St. Louis	MO-IL
	Kansas City	MO-KS
	St. Joseph	MO-KS
	Cleveland	TN
	Jackson	TN
	Nashville-Davidson--Murfreesboro--Franklin	TN
	Chattanooga	TN-GA
	Clarksville	TN-KY
	Memphis	TN-MS-AR