

# The Potential Economic Benefits of an Appalachian Petrochemical Industry

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## Table of Contents

Executive Summary .....	1
Shale Gas – A Game Changer for U.S. Competitiveness .....	1
<i>Historic Levels of New Chemical Industry Investment</i> .....	1
New Report Adds Chapter to Shale Gas Story .....	2
Government Policies Needed to Fully Realize Potential .....	3
Key Findings.....	4
Chemical Industry Investment in Appalachia.....	6
Shale Gas Resources in Appalachia .....	6
Advantages of an Appalachian Storage Hub .....	7
Potential Economic Impact of an Appalachian Petrochemical Manufacturing Hub.....	8
Scope of the Study and Key Assumptions .....	8
Fixed Capital Investment.....	11
Economic Output from New Investments.....	12
Upstream Economic Impact .....	12
Tax Revenue Impacts.....	15
Supply Chain Impacts .....	15
Supporting an Appalachian Petrochemical Manufacturing Hub .....	16
Workforce Development.....	16
Transportation and Infrastructure .....	16
Conclusion .....	17
Acknowledgements.....	18
Sources .....	18
ACC Economics and Statistics Department .....	18
<b>Appendix A - Petrochemical Manufacturing in the U.S.</b> .....	17
<i>Background</i> .....	17
<i>The Importance of Natural Gas to Chemical Manufacturing</i> .....	17
<i>Transportation and Storage Infrastructure</i> .....	19
Downstream Plastic Products.....	19
Appendix B – Simplified Ethylene Chain .....	21
Appendix B – Simplified Propylene Chain .....	22



## **Executive Summary**

Chemistry transforms raw materials into the products and processes that make modern life possible. America's chemical industry relies on energy derived from natural gas not only to heat and power its facilities, but also as a raw material, or "feedstock," to develop the thousands of products that make American lives better, healthier, and safer.

### ***Shale Gas – A Game Changer for U.S. Competitiveness***

Access to vast, new supplies of natural gas and natural gas liquids (NGLs) from previously untapped shale deposits is one of the most exciting domestic energy developments of the past 50 years. After years of high, volatile natural gas prices, the economics of shale gas have created a decisive competitive advantage for U.S. chemical and plastics manufacturers, leading to greater investment, industry growth, and jobs.

America's chemical companies use ethane, a natural gas liquid derived from shale gas, as a feedstock in numerous applications. Dramatic growth in domestic shale gas production has helped to reduce U.S. natural gas prices, creating a more stable supply of natural gas and ethane and giving U.S. chemical manufacturers an advantage over many competitors around the world who rely on naphtha, a more expensive, oil-based feedstock.

As economic theory teaches and history shows, a reduction in the cost of inputs such as natural gas and ethane leads to enhanced competitiveness and a positive supply response. The supply curve shifts to the right and a higher quantity of output is produced at a lower cost. Economic theory also shows that the lower the cost of a good, the higher the demand by consuming industries. The new competitiveness dynamic has made the United States a cost-advantaged location for chemical and resin production, which fosters overall economic growth and job creation. Much of the investment is geared toward export markets, which can help improve the U.S. trade balance.

### ***Historic Levels of New Chemical Industry Investment***

Companies from around the world are investing in projects to expand production in the United States. Since 2010, 301 projects valued at \$181 billion have been announced nationwide, as of March 2017.<sup>1</sup> The projects include new facilities, expansions and process changes to increase capacity. Of these, 46% have been completed or are under construction, while 45% are in the planning phase. Most are geared toward expansion of production capacity for ethylene, ethylene derivatives (i.e., polyethylene, polyvinyl chloride, etc.), ammonia, methanol, propylene, and chlorine.

Fully 62% of the \$181 billion is foreign direct investment, or includes a foreign partner. The fact that such large numbers of firms based abroad are choosing to source their chemistry in the U.S. is unprecedented in recent history and a testament to the value and affordability of America's shale gas and ethane supplies. The U.S. is capturing market share from the rest of the world, and no other country or continent has as bright an outlook when it comes to natural gas.

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<sup>1</sup> ACC has been tracking announced investments in shale-advantaged chemical and plastic manufacturing resin capacity since late-2010.

### ***New Report Adds Chapter to Shale Gas Story***

This report is the fifth in a series by the American Chemistry Council (ACC) examining the potential economic and employment benefits of natural gas development from shale. The first, published in March 2011, presented the results of an analysis of the potential economic effects of increased petrochemicals production to the U.S. economy. *Shale Gas and New Petrochemicals Investment: Benefits for the Economy, Jobs, and U.S. Manufacturing* discussed the impact of a hypothetical 25 percent increase in ethane supply on growth in U.S. petrochemicals. ACC found that the increase would generate new capital investment and production in the chemical industry, job growth in the chemical industry and in its supplier sectors, expanded output throughout the U.S. economy, and increased federal, state and local tax revenues.

In May 2012, ACC extended the analysis to consider the impact of lower natural gas prices on a wider segment of the U.S. manufacturing base. The report analyzed the effects of renewed competitiveness and the supply response among eight key manufacturing industries: paper, chemicals, plastic and rubber products, glass, iron and steel, aluminum, foundries, and fabricated metal products industries. In that report -- *Shale Gas, Competitiveness and New Investment: Benefits for the Economy, Jobs, and U.S. Manufacturing* -- ACC found an opportunity for shale gas to strengthen U.S. manufacturing, boost economic output, and create jobs across multiple industries.

In May 2013, ACC published a third report -- *Shale Gas, Competitiveness and New U.S. Chemical Industry Investment: An Analysis Based on Announced Projects* -- that returned once again to the chemical industry. It was based on a detailed examination of the 97 chemical industry projects cumulatively valued at \$72 billion that had been announced as of March 2013, and their potential for job creation, increased output, and additional tax revenue at the state, local and federal levels.

In May 2015, ACC published a fourth report -- *The Rising Competitive Advantage of U.S. Plastics* -- which analyzed the economic impact of shale-advantaged resin production on the U.S. plastics industry. Specifically, it quantified the potential impact of new investment to expand capacity in plastic resin; plastics compounding, additives and colorants; and plastics products.

### ***Latest Report Focuses on Appalachian Region***

This new (and fifth) report analyzes the potential economic impacts of the development of petrochemical and plastics industries in the Appalachian region, which has the potential to become a major petrochemical and plastic resin-producing region, similar to the U.S. Gulf Coast.

While petrochemical manufacturing began in Appalachia in the 1920's, the Gulf Coast region has been the center of the U.S. petrochemical industry since the mid-20<sup>th</sup> century. With its abundant supplies of hydrocarbon raw materials and vast network of pipelines and NGL storage structures, it has been the center of chemicals production for the last six decades. Indeed, much of the industry's recent wave of shale-related investment is destined for Texas and Louisiana, with numerous projects completed, planned, or underway. However, announcements of significant petrochemical industry investment in the Appalachian region have been made, with several projects already underway.

The Appalachian region is an ideal location for the emergence of a second major petrochemical manufacturing hub in the United States, offering benefits such as:

- **Proximity to abundant NGL resources** from the Marcellus/Utica and Rogersville shale formations
- **Proximity to manufacturing markets** in the Midwest and along much of the East Coast
- Opportunity to **strengthen the U.S. economy** by providing **employment and supply diversity**
- Opportunity to **enable high-value ethane use** to create U.S.-made products, while **avoiding ethane rejection**

This report presents a hypothetical scenario of the creation of a storage hub for NGLs and petrochemical products, pipeline distribution network, and associated petrochemical, plastics, and potentially other energy infrastructure and manufacturing in a quad-state area consisting of Kentucky, Ohio, Pennsylvania, and West Virginia. It then uses the IMPLAN model to estimate the direct, indirect, and payroll-induced job impacts, as well as tax revenue impacts, of the scenario.<sup>2</sup>

#### *Study Assumes Investment in NGL Storage, Pipelines*

The analysis assumes an initial infrastructure investment that includes a storage facility for ethane, propane, ethylene, and propylene and approximately 500 miles of pipeline running along the Ohio River valley. This storage hub and distribution network will enable market participants (NGL producers, petrochemical manufacturers, plastic resin producers, and others) to source feedstock and ship product among facilities in the region. It is similar in concept to the Mont Belvieu NGL hub in Texas that supports the Gulf Coast chemical industry, and will be the foundation of a robust petrochemical and downstream plastic products industry in the quad-state region.

#### ***Government Policies Needed to Fully Realize Potential***

Further development of the Appalachian region's shale gas and natural gas liquids (NGLs) can drive an even greater expansion in regional manufacturing capacity and job creation, provided that policymakers develop appropriate policies and regulatory permitting practices. A number of policy avenues could be pursued to support development of the Hub.

New energy infrastructure will be critical to realizing the opportunity for robust growth in petrochemicals and plastic resin production. One of the key barriers to the development of an NGL storage and distribution network in the Appalachian region is uncertainty around financing for such projects. Without existing infrastructure, it's difficult for the region to attract NGL consumers such as manufacturing facilities. At the same time, the absence of an established NGL customer base makes it difficult for pipeline developers to secure loans.

Government agencies can help reduce uncertainty and spur investment by applying existing private-public financing programs to Appalachian energy infrastructure projects. The U.S. Department of Energy (DOE)'s loan programs are important tools to address market gaps and promote energy independence and innovation in our nation's energy sector. Policymakers should affirm that development of a storage and distribution network is eligible for such programs, while taking care to preserve the federal government's overall lending authority.

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<sup>2</sup> Please see the *Methodology and Scope of Study* section for more information.

As Congress and the Administration consider infrastructure modernization legislation, we encourage them to make the Appalachian Hub a priority. Policymakers must also take steps to improve the regulatory permitting process for new infrastructure.

U.S. Senators Shelley Moore Capito (R-W.Va.), Rob Portman (R-Ohio), and Joe Manchin (D-W.Va.) have introduced bipartisan legislation to assess the feasibility and potential benefits of establishing an ethane storage and distribution hub in central Appalachia. The *Appalachian Ethane Storage Hub Study Act of 2017 (S. 1075)* will help inform efforts to maximize America’s domestic energy and manufacturing potential.

ACC supports a comprehensive energy policy that maximizes all domestic energy sources including renewables, alternatives, coal, nuclear, and oil and natural gas; prioritizes greater energy efficiency in homes, buildings and industrial facilities; and employs economically sound approaches to encourage the adoption of diverse energy sources, including energy recovery from plastics and other materials and renewable sources. The United States must ensure that our regulatory policies allow us to capitalize on shale gas as a vital energy source and manufacturing feedstock, while protecting our water supplies and environment.

**Key Findings**

Petrochemical industry investment in the Appalachian region has already begun. Several firms have announced plans to build ethylene and polyethylene facilities there. While these facilities will bring much-needed economic activity to this part of the country, there is the potential for a great deal more. The abundant supply of energy raw materials could feed at least half a dozen world-scale petrochemical complexes, in addition to a number of smaller facilities.

The contributions of a fully developed Appalachian chemical and plastics products industry could be significant, extending well beyond its direct economic footprint. The analysis found that if companies continue to invest in and build the petrochemical industry in the region, an Appalachian petrochemical hub could generate the following impacts in the quad-state region:

<b>Potential Economic Impacts of An Appalachian Chemical Industry (Permanent, By 2025)</b>				
<b>Capital Investment (\$2016)</b>	<b>Direct Output (\$2016)</b>	<b>Employment</b>	<b>Payroll (\$2016)</b>	<b>Federal, State, and Local Tax Revenue</b>
<p><b>\$32.4 billion</b> in petrochemicals, resins and derivatives</p> <p><b>\$3.4 billion</b> in plastic products</p>	<p><b>\$23 billion</b> in chemicals + plastic resins</p> <p><b>\$5.4 billion</b> in plastics compounding + plastics products</p>	<p><b>25,664</b> direct jobs (chemical and plastics products manufacturing)</p> <p><b>43,042</b> indirect (supply chain) jobs</p> <p><b>32,112</b> “payroll-induced” jobs in local communities where workers spend their wages</p>	<p><b>\$1.7 billion</b> direct</p> <p><b>\$3.0 billion</b> indirect (supply chain)</p> <p><b>\$1.5 billion</b> payroll-induced</p>	<p><b>\$1.7 billion</b> in federal tax revenue annually</p> <p><b>\$1.2 billion</b> in state and local tax revenue annually</p>
<b>TOTAL:</b> <b>\$35.8 billion</b>	<b>TOTAL:</b> <b>\$28.4 billion</b>	<b>TOTAL:</b> <b>100,818 jobs</b>	<b>TOTAL:</b> <b>\$6.2 billion</b>	<b>TOTAL:</b> <b>\$2.9 billion</b>



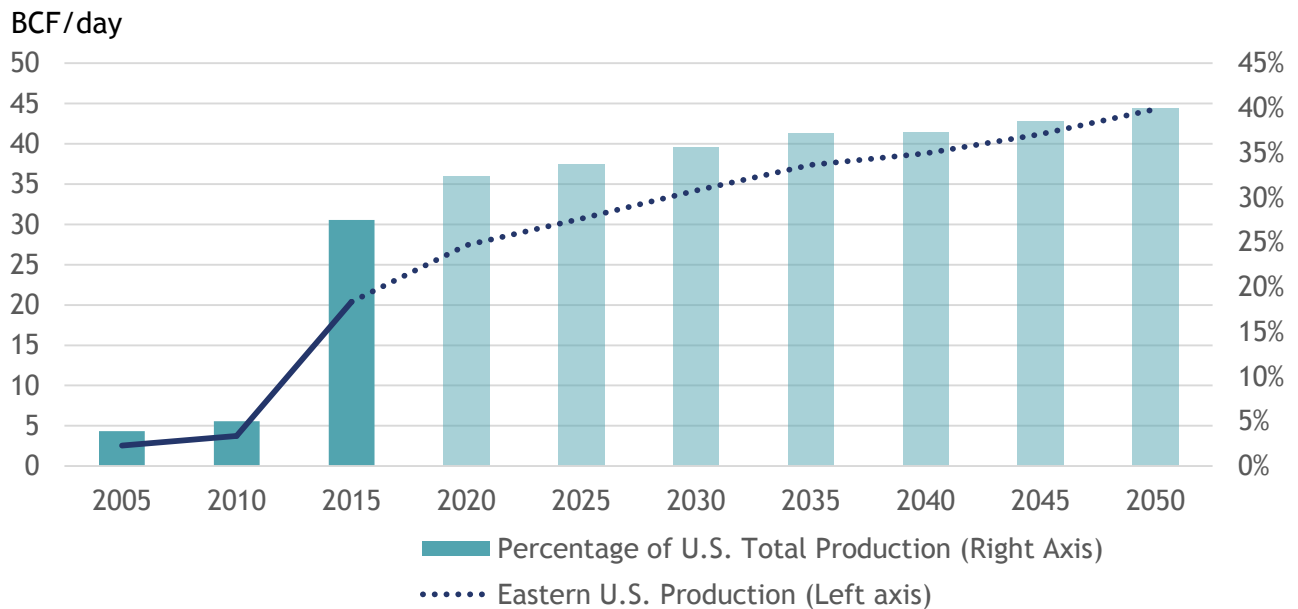


## Chemical Industry Investment in Appalachia

### Shale Gas Resources in Appalachia

Two massive shale formations run along the Appalachian chain from Quebec down through Kentucky. These formations – the Marcellus and Utica shales – are said to be among the world’s largest known gas reserves. In addition, while less developed, the Rogersville shale formation in Kentucky is thought to be a major resource, as well. As natural gas is pulled out of the well, it is processed to separate the dry natural gas (i.e., mostly methane) from the natural gas liquids (NGLs) such as ethane, propane, butane, iso-butane, and natural gasoline (also called pentanes plus). The natural gas contained in the Marcellus and Utica shales is considered to be “wet,” because it contains a relatively high percentage of NGLs. This resource base offers a tremendous opportunity to reenergize manufacturing in the Appalachian region, which includes West Virginia, eastern Kentucky, eastern Ohio and western Pennsylvania.

**Figure 1 - Natural Gas Production Outlook in the Eastern United States**



Source: Energy Information Administration

Production of natural gas is motivated by demand for pipeline supplies of dry natural gas for fuel and power and, increasingly, exports. The Marcellus and Utica shales are already major contributors to U.S. natural gas supply, and growth in the region’s production is expected to continue. According to the Energy Information Administration, natural gas produced in the Eastern U.S. (predominantly from the Marcellus and Utica shales) has already grown from next to nothing to more than 20 billion cubic feet (BCF) per day. Over the next 35 years, production from this region is expected to more than double, accounting for 40% of total U.S. natural gas production.

Because of the vast resource available in Appalachia, several petrochemical producers have announced plans to build ethylene and polyethylene facilities in the region. These facilities will bring much needed economic activity to this part of the country. There is potential, however, for much more. The abundant ethane and propane supply from the Appalachian region could feed at least five world scale

ethylene complexes (ethane cracker and derivative units) and a handful of propane dehydrogenation and polypropylene facilities.

Companies need to be assured of continuous supply of feedstock and other raw materials and opportunities to transport products because these complexes are billion dollar investments. The feedstock is there: the Marcellus and Utica shales are rich with natural gas liquids, in particular, ethane and propane. The Appalachian region has already invested tens of billions of dollars in separation (separating dry natural gas from impurities and NGLs) and fractionation (separating mixed NGLs into purity products, i.e., ethane) capacity. Because the renaissance of the Appalachian petrochemical industry is in its early stages, NGLs produced in the region are being transported to petrochemical producers in the Gulf Coast and are even being exported to petrochemical producers in Canada, Europe, and India. The abundance of ethane has led gas processors to leave significant amounts of ethane in the natural gas stream, a phenomenon called “ethane rejection.” Platts Bentek estimates that in mid-2016, around 40% -- 125,000 barrels per day (BPD) -- of Northeast ethane produced at the wellhead was being rejected, down from an estimated 65% in 2015.<sup>3</sup> By building petrochemical facilities in the Appalachian region, ethane that is currently being rejected into the fuel stream could be used to create jobs and value to workers and businesses in and around the Appalachian region.

### ***Advantages of an Appalachian Storage Hub***

The creation of a storage hub including the network of pipeline infrastructure could enable the Appalachian region to develop a community of petrochemical and derivative producers modeled after that on the U.S. Gulf Coast.<sup>4</sup> By investing in this infrastructure, companies would have access to the resources they need to build an industry in the region that provides high-paying jobs and supports a supply chain of supplier industries throughout the region.

There are many advantages to building a storage hub in Appalachia. Currently, the vast quantities of ethane produced in the area are being sent out of the region to other parts of the country and the world. In addition, there is so much ethane that processors are “rejecting” significant quantities in the natural gas stream to be burned as fuel. There is a clear opportunity to create economic value and jobs by encouraging petrochemical manufacturers and their downstream producers to locate in the quad-state region. In addition, developing the petrochemical industry in Appalachia will foster a more robust national supply chain, and increased opportunities to export chemicals and plastics along the East Coast. The supply chain including other manufacturing and services in the region will also grow in direct response to the economic activity generated by a new petrochemical industry in the region. As business activity and hiring increase, household earnings should also grow supporting additional spending, reenergizing local economies in the quad-state region.

Supporting the creation of a petrochemical and plastic resin manufacturing community in the region provides supply-chain redundancy. To date, the center of the U.S. petrochemical and plastic manufacturing industry has been in the Gulf Coast region. During 2005, the disruptions from the hurricanes Katrina and Rita had a ripple effect on manufacturing and businesses around the country. Manufacturing facilities as far north as Pennsylvania and Ontario were disrupted. As the largest supplying region of high density polyethylene resin, the temporary disruption of supply meant that

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<sup>3</sup> <http://blogs.platts.com/2016/03/30/long-short-ethane-northeast-us/>

<sup>4</sup> See Appendix A - Petrochemical Manufacturing in the U.S. for background and history of chemical manufacturing.

dairy producers in the Midwest could not package milk in plastic gallon jugs. By diversifying the supply base for these materials, manufacturers across the nation will benefit from increased supply security.

In addition, petrochemicals, intermediates, and plastic resins produced in Appalachia are close to end-use customer industries in the Midwest and along the East Coast. Proximity to East Coast ports serving European markets is also an advantage, as much of the products produced in the region will be competitive on a global basis; the export potential is high. In addition, the availability of locally-produced resin would likely encourage downstream plastics processors to locate in the region.

### **Potential Economic Impact of an Appalachian Petrochemical Manufacturing Hub**

In an effort to quantify the potential impact of an Appalachian petrochemical manufacturing hub, ACC developed a scenario that captures the potential development of petrochemicals, intermediate chemicals, plastics, and other manufacturing expected to come to Appalachia. The scenario is based on announced investments to date in addition to discussions with industry experts on how the industry might develop around an NGL and liquid chemicals hub in the region.

ACC expects continued growth in both natural gas and NGL production in the Marcellus and Utica shales based on projections by EIA and industry experts. EIA projects dry natural gas production in the Eastern region of the U.S. (dominated by production in the Appalachian region) to grow by a third between 2015 and 2025. As additional volumes of dry natural gas are produced, NGLs will need to be stripped to create pipeline-ready natural gas. Thus, NGL production should continue increase. Researchers at West Virginia University believe that with the additional natural gas production, between 1.1 and 1.3 million BPD of NGLs will be produced in the combined Marcellus/Utica region by 2022. Of that, 650,000 to 750,000 BPD is ethane. Even after factoring in growth in pipeline shipments of ethane out of the region to chemical producers along the Gulf Coast, Canada and beyond, an estimated 350,000 to 400,000 BPD of ethane would remain available for petrochemical feedstock within the quad-state region. In addition, propane production is set to surge, as well. The conversion of this ethane and propane into chemicals and plastics within the quad-state region offers tremendous economic opportunities and is the motivation for this analysis.

### ***Scope of the Study and Key Assumptions***

This study assumes that a storage hub and associated pipeline network will be built in the Appalachian region on a scale comparable to that in the Gulf Coast. A scenario for an Appalachian storage hub builds on the tens of billions of dollars of separation and fractionation capacity that has already been built, though additional fractionation capacity will be needed to process growing volumes of raw natural gas produced in the region. The assumptions used in this report are consistent with the development of an Appalachian Storage Hub as proposed by the Mid-Atlantic Technology and Innovation Center (MATRIC)<sup>5</sup> and the Chemical Alliance Zone (CAZ).<sup>6</sup> This storage and distribution system includes feedstock and product storage in addition to distribution along an arc stretching from Monaca, Pennsylvania to Cattletsburg, Kentucky, including a spur to serve the Charleston, WV area. As a result of the infrastructure that is put in place, the scenario includes a detailed view of the petrochemical and derivatives industry that could develop in the Appalachian area:

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<sup>5</sup> An independent, nonprofit 501(c)(3) contract R&D corporation located in South Charleston, West Virginia.

<sup>6</sup> A nonprofit economic development group working to boost and maintain investment and jobs in West Virginia's chemical industry and related industries, including natural gas, manufacturing, and technology.

*Petrochemicals & Derivatives* – To date, four crackers (with a combined capacity of 4.0 million metric tons) have been announced. Additional ethane cracker capacity is likely although differing scenarios of ethane development suggest that as many as nine (9) crackers could be supported in the region. All estimates of the fixed capital costs are based on current industry cost data and cost engineering methodologies.

- *Ethane Crackers* -- The analysis assumes five (5) ethane crackers will be built in the Appalachian region (including several already announced). These five projects will all be world scale projects with a combined ethylene capacity of 6.25 million metric tons. The estimated ethane demand for the five ethane crackers is approximately 350,000 bpd.
- *Polyethylene* -- The analysis also assumes that associated derivative units will be built. It is assumed that three (3) of the five ethylene projects will largely be focused on supplying ethylene for manufacturing polyethylene. These projects will have a combined ethylene capacity of 3.75 million metric tons and include downstream derivative plants to produce high density polyethylene (HDPE) and linear low density polyethylene (LLDPE) resin plants. All ethylene is assumed to be consumed internally within the facility. Along with the output from the other two crackers which are assumed to have a broader portfolio of derivatives (discussed below), total polyethylene capacity is 4.9 million metric tons.
- *Other Derivatives* -- The analysis assumes that two (2) projects -- with a combined ethylene capacity of 2.5 million metric tons -- will be more fully integrated, supplying a wider variety of downstream petrochemical derivatives and other chemical products. In addition to HDPE and LLDPE, these integrated complexes could include the manufacturing facilities for products such as ethylene oxide/glycol, ethylene dichloride (EDC), vinyl chloride monomer (VCM), polyvinyl chloride (PVC), and chlorine/caustic soda, among others.
- *Propane Dehydrogenation* - The analysis also assumes that two (2) propane dehydrogenation (PDH) plants of 500,000 metric tons capacity each will be built in the Appalachian region. In addition, each plant is assumed to include a polypropylene (PP) resin plant with 490,000 metric tons capacity.

*Storage Hub* – The storage hub and associated pipeline envisioned by MATRIC and CAZ represents approximately \$10 billion in investment.<sup>7</sup> This investment includes a storage facility for NGLs and petrochemical products in naturally occurring underground caverns and/or spent well systems. In addition, there will be a pipeline system to move these materials around the region. It does not include additional fractionation capacity that would likely be required to process growing volumes of natural gas.

- *NGL and Petrochemical Products Storage* – The scenario assumes that underground storage with a capacity of 75 million to 100 million barrels for ethane, ethylene, propane, and propylene is built to serve the region.

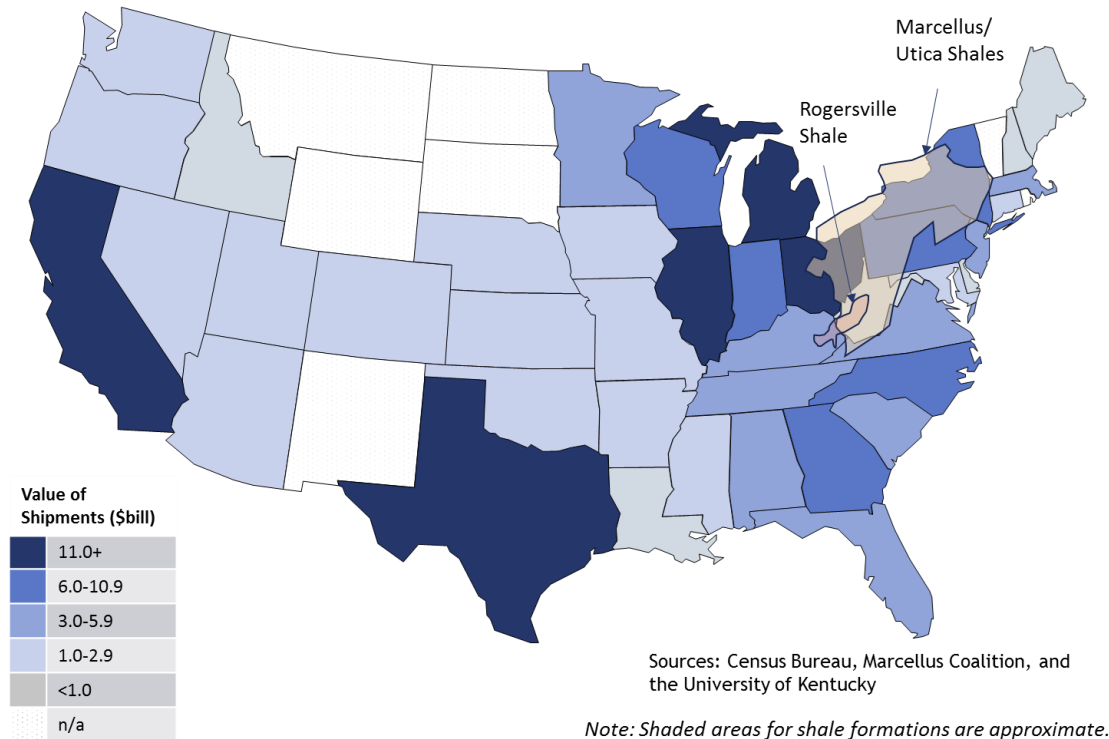
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<sup>7</sup> [http://www.rigzone.com/news/oil\\_gas/a/146478/the\\_10\\_billion\\_petchem\\_growth\\_engine\\_for\\_appalachia](http://www.rigzone.com/news/oil_gas/a/146478/the_10_billion_petchem_growth_engine_for_appalachia)

- *Pipelines* – The analysis assumes construction of approximately 500 miles of pipeline running from Monaca, Pennsylvania to Cattletsburg, Kentucky, including a spur to serve the Charleston, WV area. The pipeline would be configured to run six materials concurrently in a “six-pack” configuration. Those six materials are: methane (dry natural gas), ethane, propane, ethylene, propylene, and chlorine.

*Plastic Products* – Based on the configuration of the downstream portfolios of the five ethane crackers and two PDH units assumed in the analysis, nearly 7.0 million metric tons of plastic resin capacity (polyethylene, polypropylene and polyvinyl chloride) will be constructed in the region. Of this, the scenario assumes that 6.3 million metric tons (90%) will be shipped to customers outside the Appalachian region (including exports to Canada, Europe and other global customers). As manufacturers take advantage of available plastic resin supply, this will lead to continued investment in downstream plastic products operations across the United States. Significant plastic processing capacity already exists in the states closest to the Appalachian region. According to data from Townsend Solutions, nearly two-thirds (64%) of the total resin (polyethylene, polypropylene and PVC) consumed in the production of plastic products in the U.S. was in states within approximately 500 miles of the Appalachian region. Figure 3 shows shipments (production value) of plastic products (NAICS 3261) by state.

**Figure 3 – Plastic Products Manufacturing Shipments by State (2015)**



Of the resin that remains in the U.S. to be available to domestic markets, a portion of that will remain within the Appalachian region. In 2015, the four states included in the Appalachian region (Kentucky, Ohio, Pennsylvania, and West Virginia) produced \$32.1 billion of plastic products, accounting for nearly 17% of the U.S. plastics products industry. Given expected supplies of resin available in the Appalachian region, it is likely that downstream plastic processing manufacturers will locate to the region. For purposes of analysis, it is assumed that 10% of the incremental resin produced in the region will remain in the Appalachian states and converted into plastic products. Thus, this analysis includes \$3.4 billion in incremental compounding and plastics processing capacity through 2025. This new capacity would produce \$5.4 billion in compounded resin and new plastic products made in the Appalachian region and used throughout the economy.

*Other Infrastructure* – To a very large degree, site specific infrastructure and other project costs are included in the cost estimates. This includes costs such as water treatment, steam and other utilities; logistics (marine terminals, docks, etc.); freight and insurance in transit and import duties; transport equipment (barges, railcars, tank trucks, bulk shipping containers, and plant vehicles, etc.); administrative; financing; technology licensing and royalties; land, right of way, permits, etc.; and working capital, etc. It is impossible to assess the public and private-sector capital investment needed in these areas. However, the indirect supply chain effects and induced effects from the private sector capital investment in ethane recovery and storage, pipeline, chemical industry, and downstream plastic products output can be assessed and are included within the scope of this study.

### **Fixed Capital Investment**

Based on the above assumptions regarding investment in new chemical capacity, compounding and downstream plastic products within the region, it is likely that development of a fully developed Appalachian petrochemical and plastics industry would necessitate \$35.8 billion in capital investment.<sup>8</sup> These investments are summarized in the subsequent table.

**Table 1: Summary of Fixed Capital Investment**

<b>Type of Investment</b>	<b>Capital Investment (billions of \$2016)</b>
<b>Petrochemicals &amp; Derivatives</b>	32.4

<sup>8</sup> Fixed capital costs include inside battery limit (ISBL), outside battery limit (OSBL), and other project costs. ISBL (also referred to as process units or production units) costs include all process equipment for unit operations to engender the required process conversions. That is, the main process blocks of the chemical process plant necessary to manufacture products. Cost also include purchased equipment-delivered (including fabricated equipment and process machinery), purchased-equipment installation, instrumentation and controls (installed), piping (installed), electrical (installed), buildings and structures within the battery limits, yard improvements, service facilities within the battery limits, construction expenditures, contractor’s fees, and engineering and construction. The installed cost also include construction overhead, fringe benefits, payroll burdens, field supervision, equipment rentals, small tools and expendables, field office expenses, site support services, and temporary facilities, among related costs occurred within the battery limits. Outside battery limit costs include equipment and structures necessary to support the process plant but are shared with other process units. These are auxiliary plant items that are needed to the functioning of the process unit, but perform a supporting role rather than a direct role in production. Within a large site, these offsite facilities are shared among several process units. The investment cost for these shared facilities are allocated or pro-rated among the various process units. These shared facilities include broader yard improvement, storage, loading stations, maintenance, water treatment, other utilities, firefighting, security, administrative, etc. that are not specific to process units.

<b>Plastic Products</b>	3.4
<b>Total</b>	<b>\$35.8</b>

The Appalachian storage hub and pipeline system like the one outlined above is expected to motivate substantial investment by chemical and plastics manufacturers in the Appalachian region. Chemical industry fixed investment to develop the regional petrochemical industry – five crackers, two PDH plants, and related plastic resin, derivatives, and other chemical process units – will require an estimated \$32.4 billion in capital investment. Finally, a portion of the plastic resin produced would be processed within the region and will lead to development of a downstream compounding and plastic products industry. This would be expected to generate another \$3.4 billion in fixed capital investment. These capital investments are currently underway and will likely continue through the mid-2020s.

### **Economic Output from New Investments**

Should these new investments become operational, around 2025, significant new output of chemicals, resins, compounded plastics, and plastic products would be manufactured in the region. In fact, more than \$23 billion of chemical and plastic resin output could be generated by these facilities by 2025. As such, Appalachia would emerge as a major hub for petrochemicals and related downstream manufacturing activity. This economic activity is substantial and is expected to support tens of thousands of jobs within the region.

**Table 2: Summary of Output (billions of \$2016)**

<b>Type of Output</b>	<b>Value of Output (billions of \$2016)</b>
Petrochemicals	4.90
Organic Intermediates and Chlor-Alkali	4.95
Plastic Resins	13.18
<b>Subtotal Chemicals and Resins</b>	<b>\$23.03</b>
Plastics Compounding	0.62
Plastic Products	4.82
<b>Total</b>	<b>\$28.47</b>

### **Upstream Economic Impact**

The economic contributions of an Appalachian petrochemical industry will be numerous, though often overlooked in traditional analyses that consider only the direct jobs and output of the industry. In addition to the jobs created directly by the industry, additional jobs are supported by Appalachian petrochemical industry and by the subsequent expenditure-induced activity (i.e., “upstream impact”). Chemical and plastics manufacturers pay its employees’ wages and salaries and purchased supplies and services (including transportation, contract workers, warehousing, maintenance, accounting, etc.).



These supplier businesses, in turn, make purchases and pay their employees. Thus, a fully developed Appalachian petrochemical industry and downstream plastic products industry generates several rounds of economic spending and re-spending.

In addition to the direct effects of the emerging Appalachian petrochemical industry, the indirect and induced effects on other sectors of the economy can also be quantified. The economic impact of an industry is generally manifested through four channels:

- *Direct impacts* - such as the employment, output and fiscal contributions generated by the sector itself
- *Indirect impacts* - employment and output supported by the sector via purchases from its supply chain
- *Induced impacts* - employment and output supported by the spending of those employed directly or indirectly by the sector
- *Spillover (or catalytic) impacts* - the extent to which the activities of the relevant sector contribute to improved productivity and performance in other sectors of the economy

This report presents the economic contributions related to the first three channels. Spillover (or catalytic) effects do occur from petrochemical industry development, but these positive externalities are difficult to quantify and thus were not examined in the analysis.

To estimate the economic impacts from the development of the Appalachian petrochemical industry, the IMPLAN model was used.<sup>9</sup> The IMPLAN model is an input-output model based on a social accounting matrix that incorporates all flows within an economy. The IMPLAN model includes detailed flow information for 440 industries. As a result, it is possible to estimate the economic impact of a change in final demand for an industry at a relatively fine level of granularity. For a single change in final demand (i.e., change in industry spending), IMPLAN can generate estimates of the direct, indirect and induced economic impacts. Direct impacts refer to the response of the economy to the change in the final demand of a given industry to those directly involved in the activity. Indirect impacts (or supplier impacts) refer to the response of the economy to the change in the final demand of the industries that are dependent on the direct spending industries for their input. Induced impacts refer to the response of the economy to changes in household expenditure as a result of labor income generated by the direct and indirect effects.

**Table 3 – Economic Impact of New Chemical and Plastic Products Manufacturing (\$2016)**

<b>Impact Type</b>	<b>Employment</b>	<b>Payroll (\$ Billion)</b>	<b>Output (\$ Billion)</b>	<b>Federal Tax Revenues</b>	<b>State &amp; Local Tax Revenues</b>
Direct	25,664	1.7	28.5	0.6	0.5
Indirect (Supply Chain)	43,042	3.0	10.0	0.7	0.5

<sup>9</sup> [www.implan.com](http://www.implan.com)

Payroll-Induced	32,112	1.5	4.5	0.4	0.2
<b>Total</b>	<b>100,818</b>	<b>\$6.2</b>	<b>\$43.0</b>	<b>\$1.7</b>	<b>\$1.2</b>

The combined \$28.5 in new chemical and plastics products manufacturing output is expected to result in approximately 25,700 direct jobs in chemical and plastics products manufacturing. In addition, as these facilities purchase materials, supplies, and services, more than 43,000 indirect (supply-chain) jobs would be supported. Finally as wages and salaries paid to workers directly employed at facilities and throughout the supply chain are spent by workers' households, another 32,000 payroll-induced jobs would be supported in local communities. Thus, new chemical and plastic products manufacturing is expected to support more than 100,000 jobs in Kentucky, Ohio, Pennsylvania, and West Virginia. This is a permanent shift in the level of employment in the region that occurs due to the economic activity of these facilities. Additional employment is generated outside these four states, but is not included in this analysis.

### ***Tax Revenue Impacts***

The IMPLAN model also generates estimates of federal, state, and local tax revenue flows from multiple sources including, employee compensation, corporate income tax, property taxes, etc. Tax revenues from direct economic activity associated with new chemical and plastics production are expected to generate \$0.6 billion in federal tax revenues and \$0.5 billion in state and local tax revenues. Including supply chain and payroll-induced impacts, \$1.7 billion in federal tax revenue and \$1.2 billion in state & local tax revenue are expected to be generated.

### ***Supply Chain Impacts***

To support the production of \$28.5 billion of new chemicals, plastic resins, compounded plastics, and plastic products, these facilities would purchase materials, supplies and services from suppliers within the four state region. The businesses that provide these supplies and services and the downstream businesses that they, in turn, make purchases from are expected to support an additional 43,000 jobs in the region. More than 8,000 jobs are expected to be supported in the mining sector which includes oil and natural gas extraction, services to the oil and gas sector, and natural gas liquids separation and fractionation. In addition, nearly 2,700 jobs are expected to be supported in the manufacturing sector industries, such metal products, machinery, and rubber products. Nearly 6,800 wholesale and retail trade jobs are expected to be supported in the distribution of supplies and materials to these facilities and their supply chain.

**Table 4 – Indirect (Supply-Chain) Jobs Supported by New Chemical and Plastic Products Manufacturing**

<b>Sector</b>	<b>Number of Jobs</b>
Agriculture	1,195
Mining	8,045
Utilities	909
Maintenance & Repair	1,298
Manufacturing	2,693
Durable Manufacturing	1,104
Nondurable Manufacturing	1,590
Trade	6,778
Information	504
Transportation	4,013
Financial Services	2,326
Waste Management and Business Support Services	4,679
Professional & Technical Services	3,791
Management of Companies	3,567
Other Services & Gov't	3,244
<b>Total</b>	<b>43,042</b>

## Supporting an Appalachian Petrochemical Manufacturing Hub

### *Workforce Development*

According to this analysis, more than 25,000 direct chemical and plastic products manufacturing jobs generated in the region and an additional 43,000 jobs in supply-chain industries will develop in the region. Communities need to be ready to provide the skills needed to bring this scenario to its fullest potential. Chemical manufacturing, in particular, requires a portfolio of STEM (science, technology, engineering, and math) skills at all occupational levels. An emphasis on STEM education, development of regionally-tailored curricula at community colleges and technical schools, and increasing training opportunities are just some of the ways to develop the skilled labor force that will be required in the region. Within Kentucky, Ohio, Pennsylvania, and West Virginia, the average annual earnings of chemical industry employees averages more than \$88,200, nearly 50% more than the manufacturing average.

### *Transportation and Infrastructure*

As chemical and plastic resin production grows sharply over the next decade, new investments in transportation and infrastructure will be needed to move products from producers to consumers in the U.S. and around the world. A recent study by PwC<sup>10</sup> found that production from new chemical and

<sup>10</sup> <https://www.americanchemistry.com/Transporting-Growth-Delivering-a-Chemical-Manufacturing-Renaissance.pdf>

plastic resin projects are expected to increase by 53 million metric tons nationally, requiring an additional 1.8 million shipments per year. The study goes on to project that given challenges already present in the transportation network, manufacturers will likely face additional transportation-related costs that challenge the extent of future growth. While much of the report focused on constraints along the Gulf Coast, some of the same challenges exist in the quad-state region and need to be addressed in order to fully realize the benefits of chemical and plastics expansion in the region.

## **Conclusion**

The analysis presented in this study by ACC has shown significant and extensive contributions of the potential development of the Appalachian petrochemical industry, including the development of downstream compounding and plastic products. In addition to generating economic output that is expected to support over 100,000 jobs in the quad-state region, development of the industry has several other advantages, including:

- Strengthening U.S. economy by providing employment, supply diversity.
- Proximity to manufacturing markets in the Midwest and along much of the East Coast
- Avoidance of ethane rejection, thereby adding value to otherwise wasted resource
- Taking advantage of the nearby resource potential of Marcellus/Utica and Rogersville shales

These jobs and economic benefits will only come about with the right tax and energy policies that will drive innovation, increase productivity, expand supply, and promote manufacturing competitiveness. Access to plentiful and affordable natural gas supplies is essential in allowing the United States to capture an increasing share of global chemical industry investment.

## Acknowledgements

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## Sources

This report presents an assessment of potential for an Appalachian petrochemicals industry. The analysis uses economic data and publicly available information through mid-March 2017.

- Energy Information Administration, *2017 Annual Energy Outlook*
- IHS Markit, *Chemical Economics Handbook: Ethane* (January 2017)
- Townsend Solutions, *Plastic Buyers Database*

In addition, ACC takes into account insight and analysis made by energy, economic development, economists and others (whose expertise ACC gratefully acknowledges) and from energy and economic consultants and non-profit institutions.

## ACC Economics and Statistics Department

The Economics & Statistics Department provides a full range of statistical and economic advice and services for ACC and its members and other partners. The group works to improve overall ACC advocacy impact by providing statistics on American Chemistry as well as preparing information about the economic value and contributions of American Chemistry to our economy and society. They function as an in-house consultant, providing survey, economic analysis and other statistical expertise, as well as monitoring business conditions and changing industry dynamics. The group also offers extensive industry knowledge, a network of leading academic organizations and think tanks, and a dedication to making analysis relevant and comprehensible to a wide audience. The lead authors of this report were Kevin Swift and Martha Gilchrist Moore.

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## **Appendix A - Petrochemical Manufacturing in the U.S.**

### ***Background***

The Appalachian region of the United States has long been a hydrocarbon resource, the hills rich with coal, oil and natural gas. In 1859, Edwin Drake drilled the first oil well in Titusville, Pennsylvania and launched the petroleum industry in the United States. In 1901, the Spindletop well was drilled in Texas, shifting the center of gravity in oil and gas south and westward. With discovery of the Permian Basin and later formations in the Gulf of Mexico, Texas, Oklahoma, and Louisiana became the dominant producers of oil and natural gas by the mid-20<sup>th</sup> century. Around the same time, chemists had refined methods to make building block chemical materials from the hydrocarbons in oil and natural gas. As the hydrocarbon raw materials were readily abundant in the Gulf Coast, this is where the new petrochemical industry laid its roots. As the industry grew in sync with the oil and gas industry along the Gulf Coast, a network arose to move hydrocarbon feedstocks and petrochemical products among industry participants. Over the past 60 years, a vast network of pipelines and storage structures were built to supply the region's producers and consumers.

Prior to 1978, federal regulations restricted the interstate movement of natural gas, so the petrochemical industry concentrated along the Gulf Coast close to its feedstock supply. Among the key petrochemical products produced in the Gulf Coast are ethylene and propylene. These petrochemicals are then shipped via pipeline to downstream producers to make intermediate chemical products and plastic resins.

Production of downstream intermediate chemicals and plastic resin manufacturing consume not only petrochemicals, but other chemical products (i.e., additives, industrial gases, inorganic chemicals, etc.). In economics, these are referred to as "complementary" products. As a result many producers of these materials also located along the Gulf Coast to be near their petrochemical-consuming customers.

Ethylene and propylene are also consumed by plastic resin manufacturers in the Gulf Coast region. Pipeline deliveries of petrochemicals are used to produce plastic pellets that are then shipped from the Gulf Coast to customers around the United States and the world. Plastic resins are converted into a huge variety of products, including car parts, building materials, and packaging, to name a few. Over the last six decades, the Gulf Coast chemical industry hub has grown from a disconnected collection of small operations to a world-class materials manufacturing hub connected by a network of pipelines and other transportation infrastructure.

### ***The Importance of Natural Gas to Chemical Manufacturing***

Unique among manufacturers, the business of chemistry relies upon energy inputs, not only as fuel and power for its operations, but also as raw materials in the manufacture of many of its products. For example, oil and natural gas are raw materials (termed "feedstocks") for the manufacture of organic chemicals. Petroleum and natural gas contain hydrocarbon molecules that are split apart during processing and then recombined into useful chemistry products. Feedstock use is concentrated in bulk petrochemicals and fertilizers.

In North America and the Middle East where natural gas (and co-produced natural liquids) have historically been abundant, petrochemical producers in these regions use predominantly NGLs as feedstock. In Europe and Asia, however, producers there typically use naphtha, a petroleum refinery product as their primary feedstock. Thus, differences in feedstock costs drive differences in competitiveness across regions. Because the price of naphtha is closely tied to the global oil price and

the price of ethane is related to the price of regionally-produced natural gas, the ratio of the price of oil to natural gas is a rough proxy for regional petrochemical competitiveness. When the ratio is above 7-to-1, Gulf Coast petrochemicals (and derivative product) are relatively advantaged vis-a-vis other global producers. When the ratio is below 7, as it was during much of the early 2000's, Gulf Coast petrochemicals and their derivatives are relatively disadvantaged.

During the early 2000's, the United States was among the highest cost producers of ethylene and derivative products, such as polyethylene resin. Because it was less expensive to source these materials from naphtha-producing regions and the Middle East where the natural gas price was set by the government, U.S. production declined.

Following the devastating hurricanes of 2005 which disrupted natural gas production in and near the Gulf of Mexico, natural gas prices soared above \$12 per million BTUs compared to an average of \$2 the preceding two decades. This provided an incentive for producers to try a new technique in the Barnett shale in Texas – hydraulic fracturing of shale – in an effort to provide more natural gas supply. The industry quickly learned how to produce more for less and the cost of producing gas from hydraulic fracturing fell sharply. At the same time, geologists across the country renewed efforts to identify shale formations and companies rushed in to produce from them. Thus, the shale gas era was born. Natural gas from shale now accounts for half of U.S. natural gas production.

Development of shale resources in the U.S. has reversed the competitive dynamics of the chemical industry in the United States compared with a decade ago. As a result, companies from around the world have announced investments in new U.S. chemical and plastic resin manufacturing capacity. ACC began tracking these announcements at the end of 2010. As of March 2017, 301 projects have been announced with a cumulative investment of \$181 billion. While much of the announced investment will be located along the U.S. Gulf Coast, more than \$16 billion has been announced to date in Appalachia along the Ohio River. These announcements form the basis for a scenario of an Appalachian chemical and plastics manufacturing industry that is examined in this analysis.

#### *Natural Gas Liquids*

When raw natural gas is produced from the wellhead, in addition to methane it contains ethane, propane, butanes, other hydrocarbons, water vapor, helium, nitrogen, and other organic and inorganic compounds. Natural gas pipelines have strict requirements on the composition of the natural gas that moves through the natural gas transportation network. Pipeline-quality natural gas delivered to customers is almost entirely methane with small amount of ethane permitted to stay in the gas stream. As a result, raw natural gas is processed close to where it is produced to separate “dry” natural gas (methane) from the various hydrocarbons and other materials that come up from the wellhead. Because natural gas liquids have valuable uses as chemical feedstock and fuel, they are further processed via a process called fractionation to separate NGLs into their individual components and sold.

While propane and butane have uses as fuel, ethane is primarily consumed as chemical feedstock to produce a family of petrochemicals, mostly ethylene with smaller quantities of propylene, and butadiene. Propane is also used to produce petrochemicals. It can also be cracked to produce ethylene, propylene and other petrochemicals. In addition, a relatively new process called propane dehydrogenation (PDH) directly converts propane to propylene.



Ethylene and propylene are two key building block chemicals that are the foundation of a large and diverse portfolio of chemistry products. Appendix B includes simplified chemical chains showing how ethylene and propylene are used to produce thousands of goods for households and businesses. Like their feedstocks, ethylene and propylene are liquid products.

Two of the main uses for ethylene and propylene are in plastic resins used in car parts, building materials, and packaging. Through a process called polymerization, ethylene molecules are joined together in a chain to produce polyethylene. Similarly, propylene is polymerized into polypropylene. Ethylene and propylene are sent to resin manufacturing facilities via pipeline where they are polymerized into plastic resins that are then shipped to plastic processing facilities where they are manufactured into products we use every day.

### ***Transportation and Storage Infrastructure***

In addition to fractionation capacity, a functioning NGL network requires storage (to ensure continuous supply) and transportation (to move NGLs and petrochemicals from where they are produced to where to manufacturing facilities where they are consumed). Adding storage and pipelines to the existing fractionation facilities completes this network.

A robust storage and distribution system is the backbone of the chemical manufacturing industry. The Gulf Coast petrochemical industry located there to be close to the feedstock supply, but the dramatic growth of the downstream industries (intermediates and plastic resins) was enabled by the storage and transportation infrastructure that allowed companies to bring in feedstocks, produce building block petrochemicals (i.e., ethylene and propylene) and pipe those petrochemicals to downstream producers.

### ***Downstream Plastic Products***

Firms in this industry convert plastic resins into a variety of products. These firms engage in converting plastic resins into plastic bags and forming, coating or laminating plastics film and sheets into single-wall or multiwall plastic bags; producing plastic pipes, plastic fittings for plastic pipes, and plastic profile shapes such as rods, tubes, plates and automotive parts; laminated plastic shapes, plates and sheets; foam products such as bedding, cushioning, food containers and cups, insulation, packaging products and other applications; and bottles and containers for soft drinks, milk, condiments, food, and household and automotive chemicals. Plastic products flow through to end-use markets, such as building and construction, transportation, furniture and furnishings, packaging, medical, and others.

**Figure 2 – Major End-Uses by Resin**

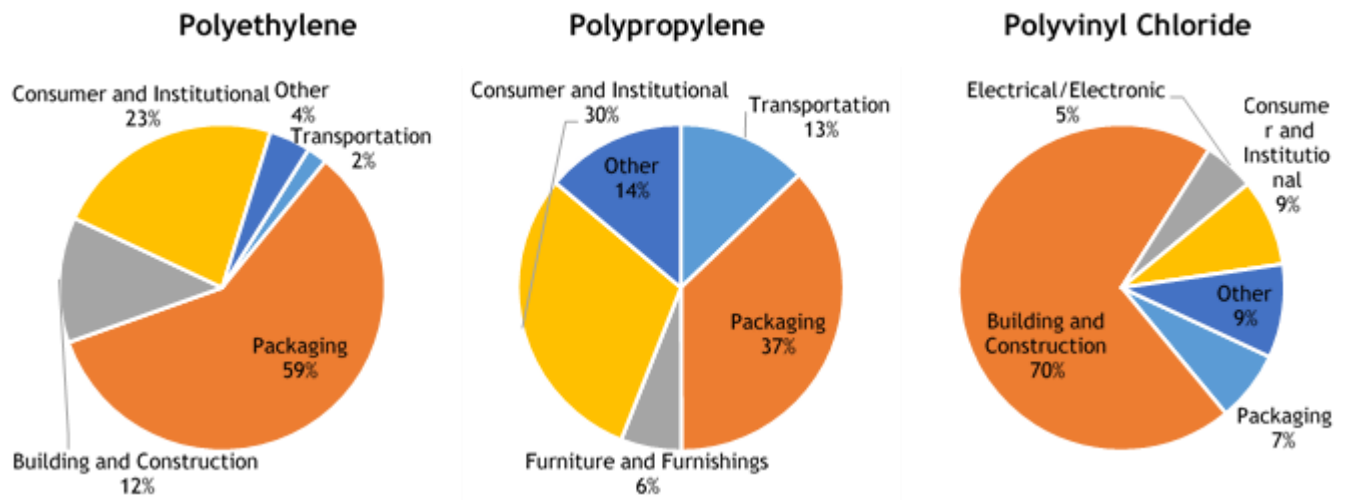
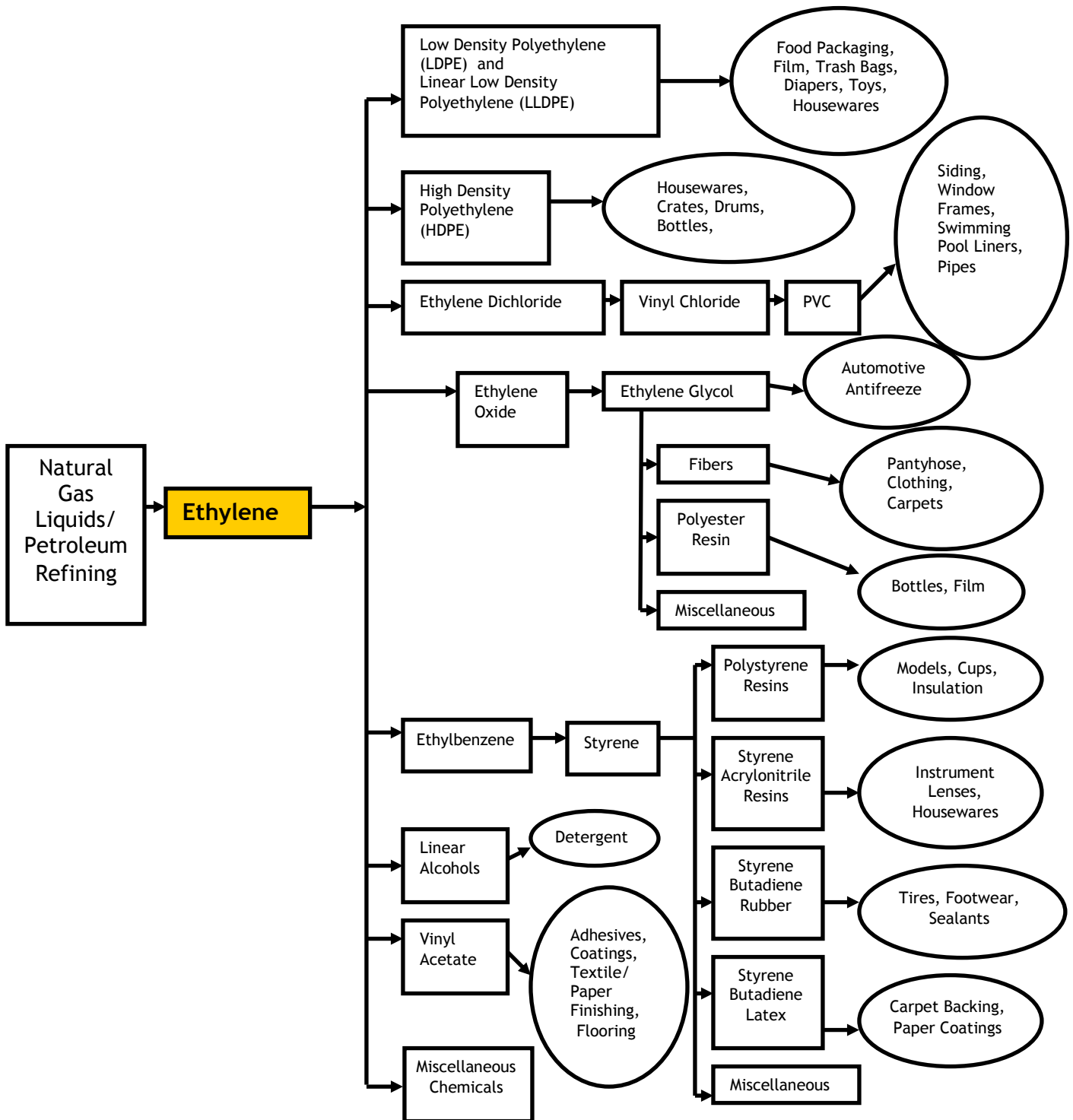


Figure 2 shows some of the key end-use markets for polyethylene, polypropylene, and polyvinyl chloride in the United States. Each resin type serves a different portfolio of end-use markets with their own demand drivers. For example, nearly 60% of polyethylene is consumed as packaging, i.e., food and beverage containers and wraps that keep foods fresher for longer. Another large end use for polyethylene is building and construction where polyethylene is used in energy saving housewrap and, pipe, and conduit. While polypropylene is also used in packaging, it also used in automotive interior trim, upholstery, medical fabrics, and outdoor furniture. The largest use for polyvinyl chloride (70%) is in building and construction where it is fabricated into vinyl siding, window and door frames, pipe, and other materials. As the U.S. economy grows in the coming years, demand for plastic products will also increase as key end-use markets expand. In the U.S., ACC expects production of plastic products to grow by nearly 3% per year over the next five years.

Demand for plastic resins is also growing globally as the world’s population increases and becomes more affluent. Global demand for polyethylene, the largest resin by volume, is expected to grow by 3.9% per year over the next decade, according to Townsend Solutions. Because of the competitive advantage of U.S. producers, more than half of new U.S. resin supplies are expected to be exported to markets in Asia, Latin America, and Europe.

## Appendix B – Simplified Ethylene Chain



## Appendix B – Simplified Propylene Chain

