Shale Gas, Competitiveness, and New US Chemical Industry Investment: An Analysis Based on Announced Projects

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Contents

Executive Summary 5
Introduction 8
A New Competitive Advantage for US Chemical Manufacturers 8
The Development of Shale Gas 10
Energy Use and the Chemical Industry 16
US Chemical Industry Capital Spending to 2020 22
Added US Chemical Industry Output to 2020 26
Added US Chemical Industry Job Creation by 2020 31
Tax Revenues 33
Post-2020 US Chemical Industry Capital Spending and Output 34
Conclusion 35
ACC Economics & Statistics 36
Appendix 1: Methodology and Assumptions 37
Appendix 2: List of Companies that have Announced Shale-Related 41
Chemical Industry Investments 41
Appendix 3: Detailed Results from IMPLAN Modeling of Increased Chemical Industry Output in 2020 42
Appendix 4: Simplified Chemical Value Chains 43
Appendix 5: Alternative High Case 46

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 our 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 US Competitiveness

Access to vast, new supplies of natural gas 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 new economics of shale gas are creating a competitive advantage for US 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. Its relatively low price gives US manufacturers an advantage over many competitors around the world that rely on naphtha, a more expensive, oil-based feedstock. Growth in domestic shale gas production is helping to reduce US natural gas prices and create a more stable supply of natural gas and ethane.

As economic theory teaches and history shows, a reduction in the cost of factor inputs such as natural gas and ethane leads to enhanced competitiveness and a positive supply response. In other words, 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. This new competitiveness dynamic has made the United States a cost-advantaged location for investment, which fosters overall economic growth and job creation.

Chemical companies from around the world have announced plans for a significant number of new projects to build and expand their shale-advantaged capacity in the United States. Through the end of March 2013, nearly 100 chemical industry investments valued at $71.7 billion had been announced. The majority are being made to expand production capacity for ethylene, ethylene derivatives (i.e., polyethylene, polyvinyl chloride, etc.), ammonia, methanol, propylene, and chlorine. Much of the investment is geared toward export markets, which can help improve the US trade deficit.

Roughly half of the announced investments to date are from firms based outside the U.S. The fact that such large numbers of foreign-owned companies are choosing to source their chemistry in the United States 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 poised to capture 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.

New Report Adds Chapter to Shale Gas Story

This report is the third in a series examining the potential economic and employment benefits of natural gas development from shale. The first report, released in March 2011, presented the results of an analysis of the potential economic effects of increased petrochemicals production to the US economy. That report, *Shale Gas and New Petrochemicals Investment: Benefits for the Economy, Jobs, and US 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 increases in 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 US 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 US Manufacturing* -- ACC found a tremendous opportunity for shale gas to strengthen US manufacturing, boost economic output and create jobs.

This third report -- *Shale Gas, Competitiveness and New US Chemical Industry Investment: An Analysis Based on Announced Projects* -- returns once again to the chemical industry. The report is based on a detailed examination of the 97 chemical industry projects that have 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. The analysis was broken into two parts: 1) Economic impacts that occur during the ten-year *initial capital investment phase,* when new plant and equipment are purchased and plants constructed; and 2) Economic impacts as a result of *ongoing increased chemical output*, made possible by lower natural gas prices and increased availability of ethane. The two tables that follow summarize the report's key findings:

Economic Impacts During the Investment Phase (Temporary) (2010-2020)					
Chemical Industry Investment (Projects announced through March 2013)	**Direct Jobs***	**Indirect Jobs***	**Payroll-Induced Jobs***	**Total Jobs***	**Federal, State and Local Tax Collections**
$71.7 billion in chemical industry investments (**97 projects)** to build and/or expand in the U.S. will generate…	**485,000** jobs in construction and capital goods manufacturing, i.e., process equipment, tanks, pipes, valves, etc.	**258,000** jobs in firms along the supply chain, i.e., firms that supply materials, equipment, and services to contractors involved in the build-out.	Workers in direct + indirect industries will earn payrolls totaling **$47.1 billion**. Their household spending in their communities will support **442,000** *payroll-induced* jobs	**1.2 million**	**$20 billion**
**Because the investment occurs over a multi-year period, jobs should be interpreted as work-year jobs. This is done to avoid double-counting the same job in multiple years.*					

Economic Impacts From Increased Chemical Industry Output (Permanent) (By 2020)					
Increased Chemical Industry Output	**Direct Jobs**	**Indirect Jobs**	**Payroll-Induced Jobs**	**Total Jobs**	**Federal, State and Local Tax Collection**
The **$71.7 billion** in announced chemical industry investments will lead to **$66.8 billion** in increased chemical industry output. This is a **9% gain** above what output would otherwise be in 2020.	The **$66.8 billion** in new chemical industry output will require more chemical industry workers, creating more than **46,000** *direct* chemical industry jobs.	The **$66.8 billion** in new chemical industry output will generate purchases of raw materials, equipment, and services in the supply chain, creating **264,000** *indirect* jobs. Added output of these supplier sectors will lead to an additional **$100 billion** in *indirect* economic output.	The **310,000** direct + indirect jobs will earn payrolls totaling **$23.8 billion**. Household spending by these workers in their communities will support an additional **226,000** *payroll-induced* jobs.	**537,000**	**$14 billion**

Government Policies Key to Realizing the Shale Gas Opportunity

Shale gas offers the United States an enormous opportunity to become more competitive internationally, grow our economy, and create jobs. To capitalize on it, policymakers must develop balanced legislative and regulatory policies that reflect the importance of natural gas as an energy source and manufacturing feedstock, while protecting our water supplies and environment. ACC supports state-level oversight of hydraulic fracturing, as state governments have the knowledge and experience to oversee hydraulic fracturing in their jurisdictions. Furthermore, ACC is committed to transparency regarding the disclosure of the chemical ingredients of hydraulic fracturing solutions, subject to the protection of proprietary information.

A whole host of policies will influence whether domestic natural gas supplies remain robust and affordable and, in turn, whether America's manufacturing renaissance is sustained. They include:

- Access to oil and gas reserves on federal, state and private lands;
- Continuing state-based regulation of unconventional oil and gas production;
- Improving the ability to site, permit, and build infrastructure that links oil and gas production to chemical manufacturing facilities;
- Preserving coal's important role as an energy source for baseload power generation;
- Maintaining accelerated depreciation schedules for chemical industry investments in new plant and equipment;
- Expanding access to foreign markets for US goods

Right now, the chemistry industry has the confidence needed to drive new U. investment. Policymakers can help ensure that confidence continues for decades to come.

Introduction

American manufacturers use natural gas to fuel and power a wide variety of processes to produce a broad portfolio of manufactured goods. Growth in domestic shale gas production is helping to reduce US natural gas prices and create a more stable supply of natural gas for fuel and power. In addition, it is also leading to more affordable supplies of ethane, a natural gas liquid and key feedstock, or raw material, used in the chemical industry. As economic theory teaches and history shows, a reduction in the cost of a factor input such as natural gas leads to enhanced competitiveness and a positive supply response. In other words, 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. This new competitiveness dynamic has made the United States a cost-advantaged location for private sector investment, which fosters job creation.

This report is the third in a series presenting the potential economic and employment benefits of natural gas development from shale. The first report, released in March 2011, presented the results of an analysis of the potential economic effects of increased petrochemicals production to the US economy. That report, *Shale Gas and New Petrochemicals Investment: Benefits for the Economy, Jobs, and US Manufacturing,* discussed the impact of a 25 percent increase in ethane supply on growth in US 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 US economy and increases in 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 US 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 this report -- *Shale Gas, Competitiveness and New Investment: Benefits for the Economy, Jobs, and US Manufacturing* -- ACC found a tremendous opportunity for shale gas to strengthen US manufacturing, boost economic output and create jobs.

This third report -- *Shale Gas, Competitiveness and New U.S. Chemical Industry Investment* -- returns once again to the chemical industry. Chemical companies from around the world have announced new investments in US capacity to benefit from available resources and grow their businesses. We have reviewed nearly 100 project announcements. This report is based on a detailed examination of these projects and the potential effects from the wave of investment on job creation, new output, and tax implications for state, local and the Federal government. Some of these investments are being made in areas of the country that have been hardest-hit by declines in manufacturing. These investments improve the outlook in these economically depressed areas of the country. Further development of the nation's shale gas and ethane can drive an even greater expansion in domestic manufacturing capacity, provided that policymakers develop balanced regulatory policies and permitting practices.

A New Competitive Advantage for US Chemical Manufacturers

A new competitive advantage has emerged for chemical manufacturing in the United States as vast new supplies of natural gas from largely untapped shale gas resources, including the Marcellus along the Appalachian mountain chain, are leading to massive capital investment and expansion of the US chemical industry. With the development of new shale gas resources, US industry is announcing expansions of capacity, reversing a decade-long decline and providing opportunities for new jobs at a time when the United States is facing persistent high unemployment. This report presents the results of an analysis that was conducted by ACC to quantify the economic impact of the significant investment and additional production in the US chemical industry stimulated by the increased availability of low cost natural gas and the resulting gain in competitiveness.

The US chemical industry is the largest industrial consumer of natural gas for fuel and power and also for feedstock. The economic impact of the additional production in the US chemical industry invigorated by improved competitiveness resulting from an increase in the availability of low cost natural gas is game changing. Based on actual project announcements through March 2013, the US chemical industry is expected to spend at least $71.7 billion in private capital investment on new plant and equipment by 2020, to capitalize on the renewed competitiveness brought about by the shale gas revolution. Further, we expect that additional unannounced investment in chemical capacity is likely to occur. As much as $82.4 billion may be invested in new chemical industry capacity by 2020.

The $71.7 billion in capacity-expansion investments announced to date will engender an additional $66.8 billion in chemical industry output, providing a 9% gain above what output would be otherwise in 2020. In turn, this will create new chemical industry jobs and additional output in supplier (or indirect) industries. Combined, the added output of these supplier sectors of the economy will lead to an additional $100 billion in indirect economic output. On top of the direct and indirect effects, household spending as a result of the new jobs created (i.e., payroll-induced effects) will lead to an additional gains of $34 billion gain elsewhere in the economy. Looking at employment, the supply response from shale gas will directly create 46,000 jobs in the US chemical industry due to expanded chemical production. These are high-paying jobs, the type of manufacturing jobs that policy-makers would welcome in this economy. In addition to the jobs created in the US chemical industry, another 264,000 indirect jobs would be created in supplier industries, and another 226,000 payroll-induced jobs would be created elsewhere in the economy through household spending of wages, leading to a total of 537,000 new jobs. The jobs created and expanded output from the increase in chemical industry production would lead to a gain in federal, state and local tax collections, totaling nearly $14 billion in 2020.

The build-out of new chemical industry capacity actually began in 2010. During the investment phase through 2020, $71.7 billion in investments made by the US chemical industry will directly create 485,000 jobs[1] over ten years, largely in construction and capital goods industries. The ten-year investment wave will also lead to an additional $122 billion in added output via indirect and induced effects. Thus, the total economic impact during the investment phase will be $193 billion in additional output. This added output will create an additional 700,000 indirect and payroll-induced jobs, leading to a total of 1.2 million jobs during the ten-year investment wave. The jobs created and increased output resulting from the investment period will lead to a gain in federal, state and local tax collections, totaling $20 billion over the ten-year investment phase.

These estimates of job creation in the chemical industry, however, are understated. The focus of this analysis is on the supply side response arising from lower natural gas prices. On the demand side, increasing oil and gas development will have a favorable effect on the demand for oilfield chemicals. Supply-side responses in other industries such as plastic products and tire and rubber products, moreover, will respectively positively impact the demand for plastic resins, plastic additives and compounding services and the demand for synthetic rubber and rubber processing chemicals. These effects are outside the scope of and would be in addition to the estimates in this present analysis.

Thus, based on a large private investment initiative driven by newly abundant domestic supplies of natural gas, a significant strengthening of the vital US manufacturing is possible. A reasonable regulatory regime will facilitate this development, while the wrong policy initiatives could derail this recovery and expansion and the associated job creation.

[1] Because the investment occurs over a multi-year period, total jobs should be interpreted as *work-year* jobs. This is done to avoid double counting the same job in multiple years.

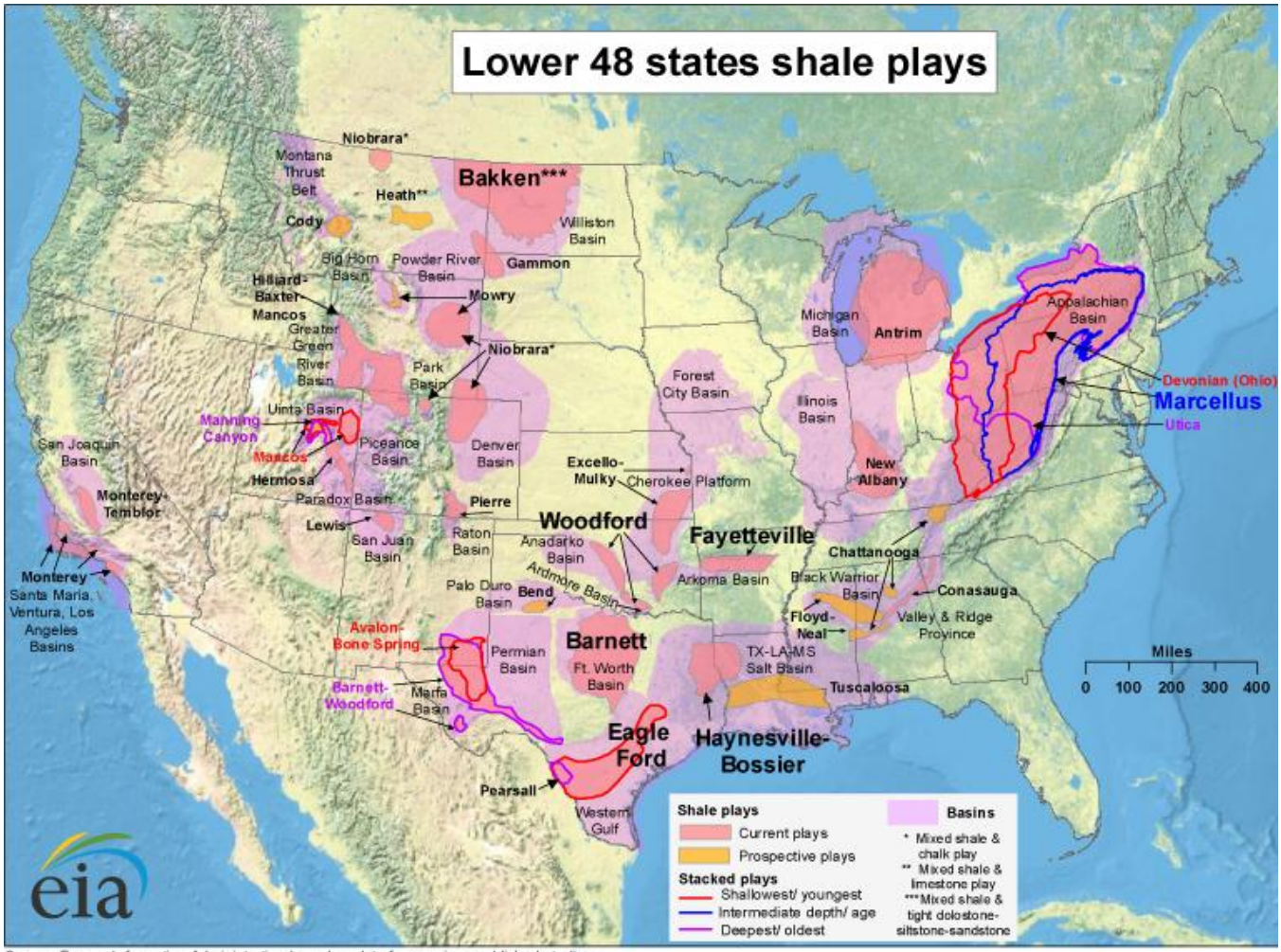
The Development of Shale Gas

One of the more interesting developments in the last five years has been the dynamic shift in natural gas markets. Between the mid-1960s and the mid-2000s, proved natural gas reserves in the United States fell by one-third, the result of restrictions on drilling and other supply constraints. Starting in the 1990s, government promoted the use of natural gas as a clean fuel, and with fixed supply and rising demand from electric utilities, a natural gas supply shortage occurred, causing prices to rise from an average of $1.92 per thousand cubic feet in the 1990s to $7.33 in 2005. The rising trend in prices were exacerbated by the effects of hurricanes Katrina and Rita in 2005, which sent prices over $12.00 per thousand cubic feet for several months due to damage to gas production facilities.

Shale and other non-conventional gas were always present geologically in the United States. Figure 1 illustrates where shale gas resources are located in the United States. These geological formations have been known for decades to contain significant amounts of natural gas, but it was not economically feasible to develop given the technology available. However, uneconomic resources often become marketable assets as a result of technological innovation, and shale gas is a prime example.

Over the last five years, several factors have combined to stimulate the development of shale gas resources. First was a new way of gathering natural gas from tight-rock deposits of organic shale through horizontal drilling combined with hydraulic fracturing. Horizontal drilling allows producers to drill vertically several thousand feet and then turn 90 degrees and drill horizontally, expanding the amount of shale exposed for extraction. With the ability to drill horizontally, multiple wells from one drilling pad (much likes spokes on a wheel) are possible, resulting in a dramatic expansion of shale available for extraction, which significantly boosts productivity. A typical well might drill 1½ miles beneath the surface and then laterally 2,000-9,000 feet.

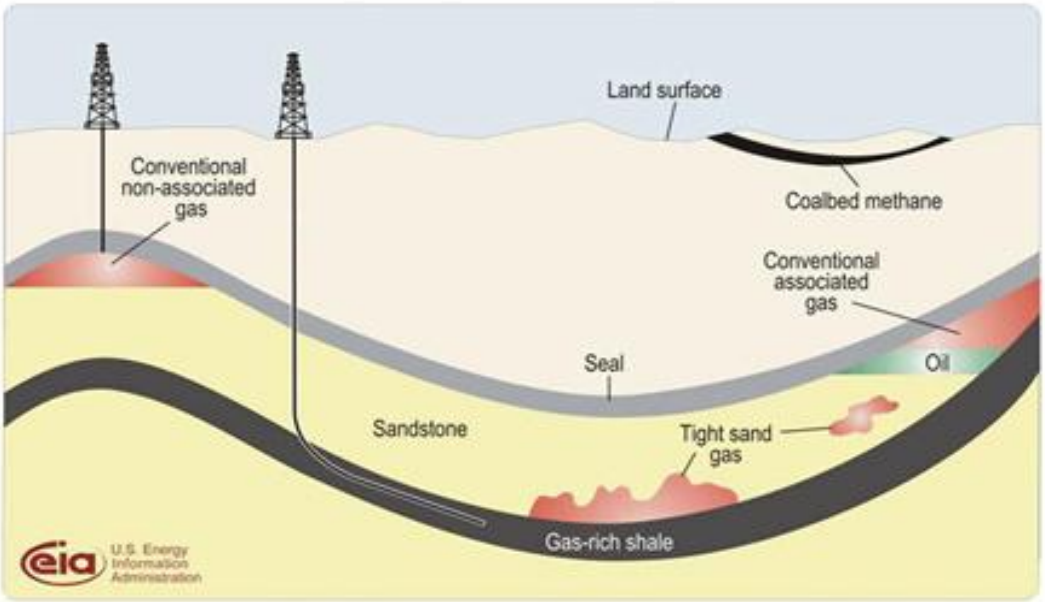
FIGURE 1: SHALE GAS RESOURCES



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

The second innovation entailed improvements to hydraulic fracturing (or fracking). This involves fracturing the low-permeability shale rock by using water pressure. Although these well stimulation techniques have been around for nearly 50 years, the technology has significantly improved. A water solution injected under high pressure cracks the shale formation. Small particles, usually sand, in the solution hold the cracks open, greatly increasing the amount of natural gas that can be extracted. Fracturing the rock using water pressure is often aided by chemistry (polymers, gelling agents, foaming agents, etc.). A typical well requires two to three million gallons of water and 1.5 million pounds of sand. About 99.5% of the mixture is sand and water. Figure 2 provides a simple illustration of these technologies. Another important technology is multi-seismology that allows a more accurate view of potential shale gas deposits.

FIGURE 2: GEOLOGY OF SHALE GAS AND CONVENTIONAL NATURAL GAS



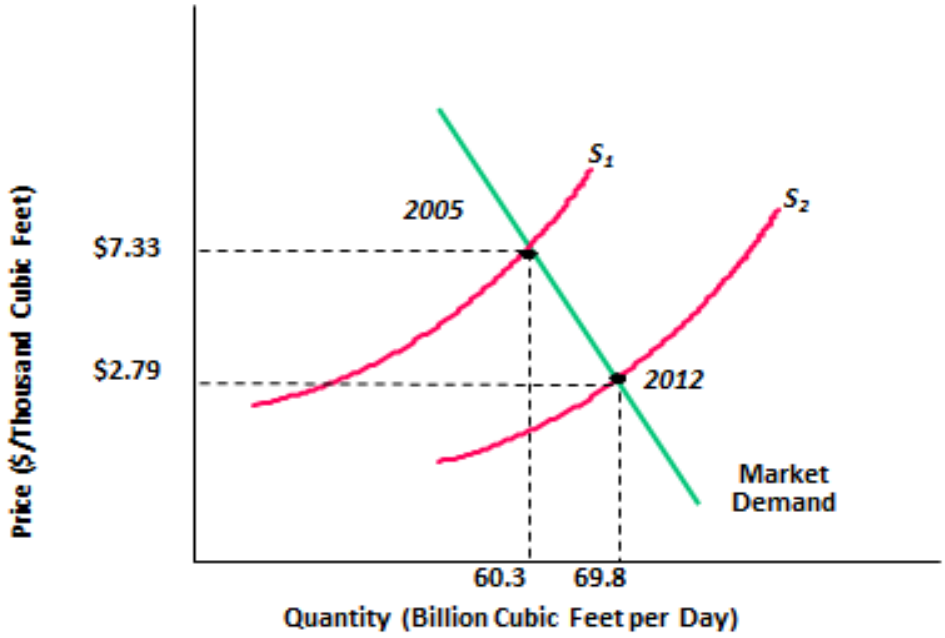
With these innovations in natural gas drilling and production, the productivity and profitability of extracting natural gas from shale deposits became possible. Further, unlike traditional associated and non-associated gas deposits that are discrete in nature, shale gas often occurs in continuous formations. While shale gas production is complex and subject to steep production declines, shale gas supply is potentially less volatile because of the continuous nature of shale formations. Many industry observers suggest that the current state of shale gas operations is more closely analogous to manufacturing operations than traditional oil and gas exploration, development and production.

These new technical discoveries have vastly expanded estimates of natural gas resources and will offset expected declines in conventional associated-gas production. Estimates of technically recoverable shale gas were first assessed by the National Petroleum Council (NPC) at 38 trillion cubic feet (TCF) in 2003. More recently, the Potential Gas Committee (PGC) estimated US shale gas resources of 1,073 TCF at the end of 2012. The United States is now estimated to possess nearly 2,700 TCF of potential (or future) natural gas supply, 40% of which is shale gas that could not be extracted economically as recently as eight years ago. This translates into an additional supply of 47 years at current rates of consumption of about 23 TCF per year. Total US natural gas resources are estimated to be large enough to meet over 115 years of demand. Due to the emergence of new shale gas supplies, the US sharply reduced gas imports from Canada and liquefied natural gas (LNG) receipts, over the past several years.

Higher prices for natural gas in the last decade (especially after hurricanes Katrina and Rita) and the advances in horizontal drilling and hydraulic fracturing (i.e., chemistry in action) changed the dynamics for economic shale gas extraction. These technologies allowed extraction of shale gas at about $7.00 per thousand cubic feet, which was well below the historical trend. With new economic viability, natural gas producers have responded by drilling, setting off a “shale gas rush”. As learning curve effects took hold, the cost to extract shale gas (including return on capital) fell, making even more supply (and demand) available at lower cost. Moreover, natural gas liquids have become paramount in changing the economics of shale gas production. It is the sales of ethane and other liquids that have enabled producers to extract and sell natural gas at less than $3.50 per thousand cubic feet. Although the path was irregular, average daily consumption of natural gas rose from 60.3 billion cubic feet

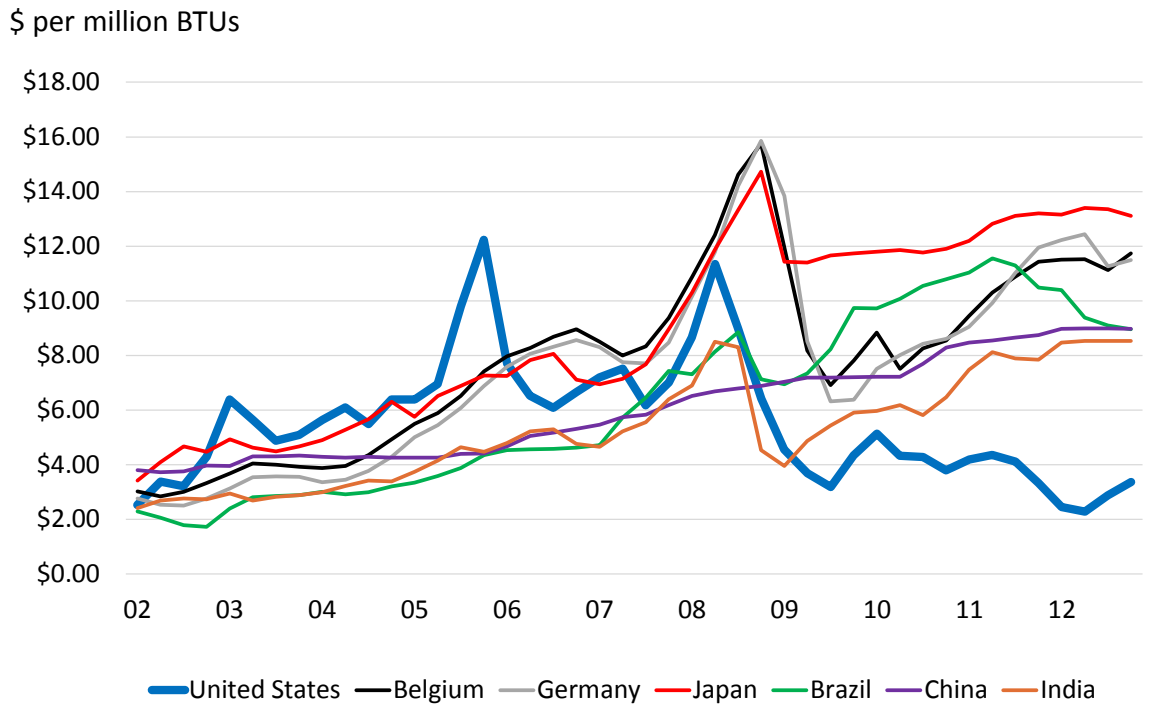
(BCF) per day in 2005 to 62.0 BCF per day in 2009. Moreover, since the mid-2000s, US-proved natural gas reserves have risen by one-third. In economists' terms, the supply curve has shifted to the right, resulting in lower prices and greater availability. As a result, average natural gas prices fell from $7.33 per thousand cubic feet in 2005 to $3.65 per thousand cubic feet in 2009. In 2010 and 2011, a recovery of gas-consuming industries and prices occurred. Average daily consumption rose to 66.9 BCF and prices strengthened to $4.12 per thousand cubic feet. But the mild winter of 2011-12 resulted in a record level of stocks and pushed prices even lower to $2.79 per thousand cubic feet. Figure 3 illustrates how this new technology's entrance into the market expanded supply and pushed prices lower.

FIGURE 3
THE ADVENT OF SHALE GAS RESULTED IN MORE, LESS COSTLY SUPPLY OF US NATURAL GAS



Before the development of shale gas, the US was a gas importing nation. The US is now a gas surplus nation and has become the leading global producer. Shale gas is thus a "game changer". In the decades to come, unconventional gas could provide half of US natural gas needs, compared to only 8% in 2008. The US's favorable position is illustrated in Figure 4. As natural gas prices have fallen in the US in wake of the emerging shale gas revolution, prices in other major nations have risen.

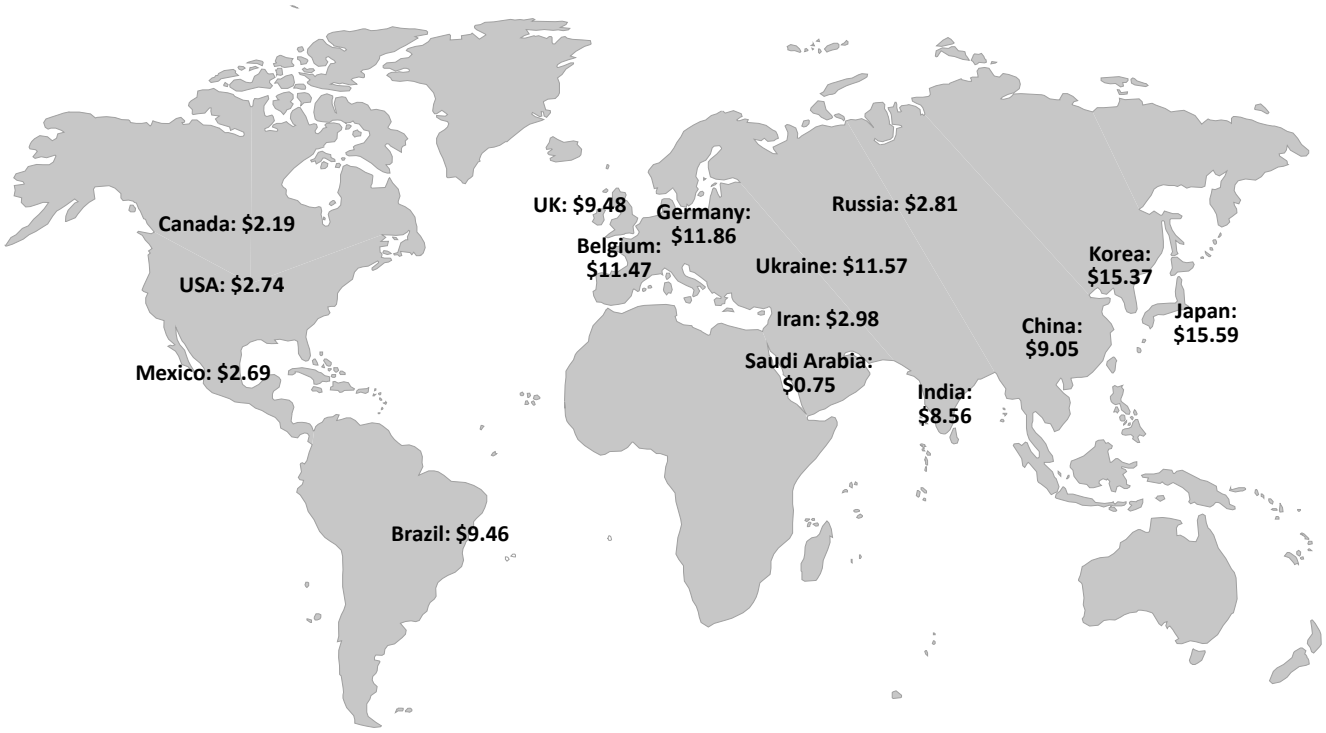
FIGURE 4
TRENDS IN NATURAL GAS PRICES ACROSS THE WORLD



Sources: EIA, Petrobas, IMF, World Bank, various national statistical agencies

By 2012, North America featured some of the lowest cost natural gas in the world. Figure 5 illustrates this. Prices in Russia and Iran have appreciated beyond that of the United States. Prices in Saudi Arabia are set at $0.75 per million BTUs by government decree. These prices were originally due for adjustment in 2012 but a decision on this has been delayed. Prices at this level are artificial and would actually be around $3.00 per million BTUs if a free market existed.

FIGURE 5
AVERAGE 2012 NATURAL GAS PRICES BY NATION
($ per million BTUs)



Note: Prices generally reflect domestic wellhead/hub prices or imported prices via pipeline. Some nations (e.g., Japan and Korea) import LNG. Thus, the higher prices. Other nations import LNG if it's a minor share of demand but these prices aren't generally reflected in the above.

The availability of low priced natural gas improves US industry competitiveness. Lower natural gas prices mean lower input prices for major US manufacturing industries. Leading industries, including aluminum, chemicals, iron and steel, glass, and paper, are large consumers of natural gas and thus, benefit from shale gas developments. Lower input costs have boosted capital investments and expanded output. These manufacturers add a great deal of value to the natural gas they consume.

Manufacturers in these industries compete globally and small cost advantages can be all it takes to tip the balance for some companies. In their recent study, study -- *U.S. Manufacturing Nears the Tipping Point: Which Industries, Why, and How Much?* – the Boston Consulting Group uncovered a "tipping point" in cost-risk among seven key industries (computers and electronics, appliances and electrical equipment, machinery, furniture, fabricated metal products, plastic and rubber products, and transportation goods). They found that as these industries "re-shore" to the US, the US economy will gain $80 billion to $120 billion in added annual output and two million to three million jobs.

With a growing and increasingly affluent population and economic growth, demand for electricity will rise in the US. In addition, clean air regulations are promoting natural gas use in electricity generation. This will increase natural gas demand and economic theory suggests that barring any increase in supply, market prices will rise. There is a risk that higher gas prices could partially offset some of the positive gains achieved during the

past five years. Further technological developments in drilling and fracturing, however, could generate additional low-cost natural gas supplies.

The use of hydraulic fracturing in conjunction with horizontal drilling has opened up resources in low permeability formations that would not be commercially viable without this technology and has led to many positive gains in US industry and the economy. However, there are some policy risks as there is public concern regarding hydraulic fracturing due to the large volumes of water and potential contamination of underground aquifers used for drinking water. The concern exists even though fracturing occurs well below drinking water resources. Limiting the use of hydraulic fracturing would impact natural gas production from low permeability reservoirs. Ill-conceived policies that restrict supply or artificially boost demand are also risks. Local bans or moratoria could present barriers to private sector investment. A final issue is the need for additional gathering, transport and processing infrastructure. The Marcellus and some other shale gas deposits are located outside the traditional natural gas supply infrastructure to access the shale gas.

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. ACC supports state-level oversight of hydraulic fracturing, as state governments have the knowledge and experience to oversee hydraulic fracturing in their jurisdictions. Furthermore, ACC is committed to transparency regarding the disclosure of the chemical ingredients of hydraulic fracturing solutions, subject to the protection of proprietary information.

Energy Use and the Chemical Industry

Excluding pharmaceuticals, firms in the $587 billion chemical industry produce a variety of chemistry products including chlorine, caustic soda, soda ash and other inorganic chemicals, bulk petrochemicals and organic chemical intermediates, industrial gases, carbon black, colorants, pine chemicals, other basic chemicals, adhesives and sealants, coatings, other specialty chemicals and additives, plastic compounding services, fertilizers, crop protection products, soaps and detergents, and other consumer chemistry products. Although pharmaceuticals are classified by the government as part of chemicals, for the purposes of this analysis, pharmaceuticals were excluded because of the different industry dynamics.

The chemical industry transforms natural raw materials from earth, water, and air into valuable products that enable safer and healthier lifestyles. Chemistry unlocks nature's potential to improve the quality of life for a growing and prospering world population by creating materials used in a multitude of consumer, industrial and construction applications. The transformation of simple compounds into valuable and useful materials requires large amounts of energy.

The business of chemistry is energy-intensive. This is especially the case for basic chemicals, as well as certain specialty chemical segments (e.g., industrial gases). The largest user of energy is the petrochemical and downstream chemical derivatives business. Inorganic chemicals and agricultural chemicals also are energy-intensive.

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.

Petrochemical Feedstocks

There are several methods of separating or "cracking" the large hydrocarbon chains found in fossil fuels (natural gas and petroleum). Natural gas is processed to produce methane and natural gas liquids (NGLs) that are contained in the natural gas. These natural gas liquids include ethane, propane, and butane, and are produced mostly via natural gas processing. That is, stripping the NGLs out of the natural gas (which is mostly methane) that is shipped to consumers via pipelines. This largely occurs in the Gulf Coast region and is the major reason the US petrochemicals industry developed in that region. Ethane is a saturated C_2 light hydrocarbon; a colorless and odorless gas. It is the primary raw material used as a feedstock in the production of ethylene and competes with other steam cracker feedstocks. Propane is also used as a feedstock but it is also used primarily as a fuel. Butane is another NGL feedstock. The revolution in shale gas has pushed ethane prices down from a peak of 93 cents per gallon in 2008 to an average of 41 cents per gallon during 2012. That is a 56% decline. In recent months the price fell to as low as 23 cents per gallon.

Petroleum is refined to produce a variety of petroleum products, including naphtha and gas oil, which are the primary heavy liquid feedstocks. Naphtha is a generic term for hydrocarbon mixtures that distill at a boiling range between 70°C and 190°C. The major components include normal and isoparaffins, naphthenes and other aromatics. Light or paraffinic naphtha is the preferred feedstock for steam cracking to produce ethylene, while heavier grades are preferred for gasoline manufacture. Gas oil is another distillate of petroleum. It is an important feedstock for production of middle distillate fuels—kerosene jet fuel, diesel fuel and heating oil—usually after desulfurization. Some gas oil is used as olefin feedstock. Naphtha is the preferred feedstock in Western Europe, Japan, and China. The price of naphtha is highly correlated with the price of Brent oil. As a result, naphtha prices in Western Europe rose from an average of $793 per metric ton in 2008 to $942 per metric ton in 2008. That is a 19% increase.

Petrochemical Products and their Derivatives

Naphtha, gas oil, ethane, propane and butane are processed in large vessels or "crackers", which are heated and pressurized to crack the hydrocarbon chains into smaller ones. These smaller hydrocarbons are the gaseous petrochemical feedstocks used to make the products of chemistry. In the US petrochemical industry, the organic chemicals with the largest production volumes are methanol, ethylene, propylene, butadiene, benzene, toluene and xylenes. Ethylene, propylene and butadiene are collectively known as olefins, which belong to a class of unsaturated aliphatic hydrocarbons. Olefins contain one or more double bonds, which make them chemically reactive. Benzene, toluene and xylenes are commonly referred to as aromatics, which are unsaturated cyclic hydrocarbons containing one or more rings. The figures in Appendix 4 illustrate supply chains of several building block chemicals from feedstock through intermediates and final end-use products.

Ethane and propane derived from natural gas liquids are the primary feedstocks used in the United States to produce ethylene, a building block chemical used in thousands of products, such as adhesives, tires, plastics, and more. While propane has additional non-feedstock uses, the primary use for ethane is to produce petrochemicals; in particular, ethylene.

Ethane is difficult to transport, so it is unlikely that the majority of excess ethane supply would be exported out of the United States. As a result, it is also reasonable to assume that the additional ethane supply will be consumed domestically by the petrochemical sector to produce ethylene. In turn, the additional ethylene and other materials produced from the ethylene are expected to be consumed downstream, for example, by plastic resin producers.

Increased ethane production is already occurring as gas processors build the infrastructure to process and distribute production from shale gas formations. Chemical producers are starting to take advantage of these new ethane supplies with crackers running at 95% of capacity, and several large chemical companies have announced plans to build additional capacity. And because the price of ethane is low relative to oil-based

feedstocks used in other parts of the world, US-based chemical manufacturers are contributing to strong exports of petrochemical derivatives and plastics.

Another key petrochemical feedstock -- methane -- is directly converted from the methane in natural gas and does not undergo the cracking process. Methane is directly converted into methanol. Methanol is generally referred to as a primary petrochemical, and is the chemical starting point for plastics, pharmaceuticals, electronic materials, and thousands of other products that improve the lives of a growing population. Methane is also directly converted into ammonia. Ammonia is a starting point for a variety of chemical intermediates used in manufacturing synthetic fibers used in apparel, home furnishing and other applications. Ammonia is also the starting point for a variety of nitrogenous fertilizers used to enhance crop growth and feed a growing population.

The Shale Advantage

Energy represents a significant share of manufacturing costs for the US business of chemistry. For some energy-intensive products, energy for both fuel and power needs and feedstocks account can represent 85% of total production costs. Because energy is a vital component of the industry's cost structure, higher energy prices can have a substantial impact on the business of chemistry. Figure 9 illustrates the energy intensity of some of these products.

FIGURE 9
FUEL, POWER AND FEEDSTOCK COSTS AS A PERCENT OF TOTAL COSTS FOR SELECTED CHEMICAL PRODUCTS

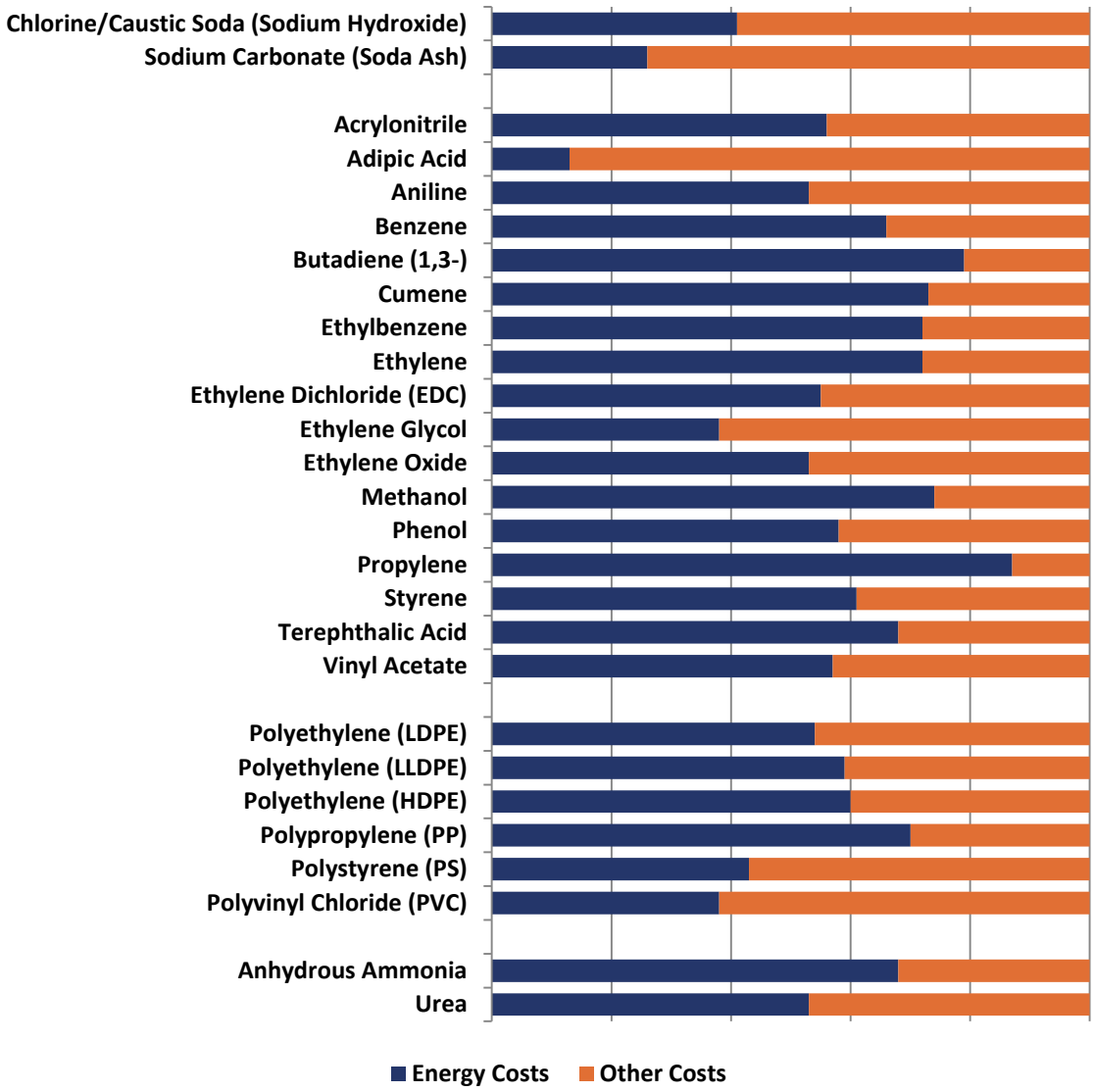
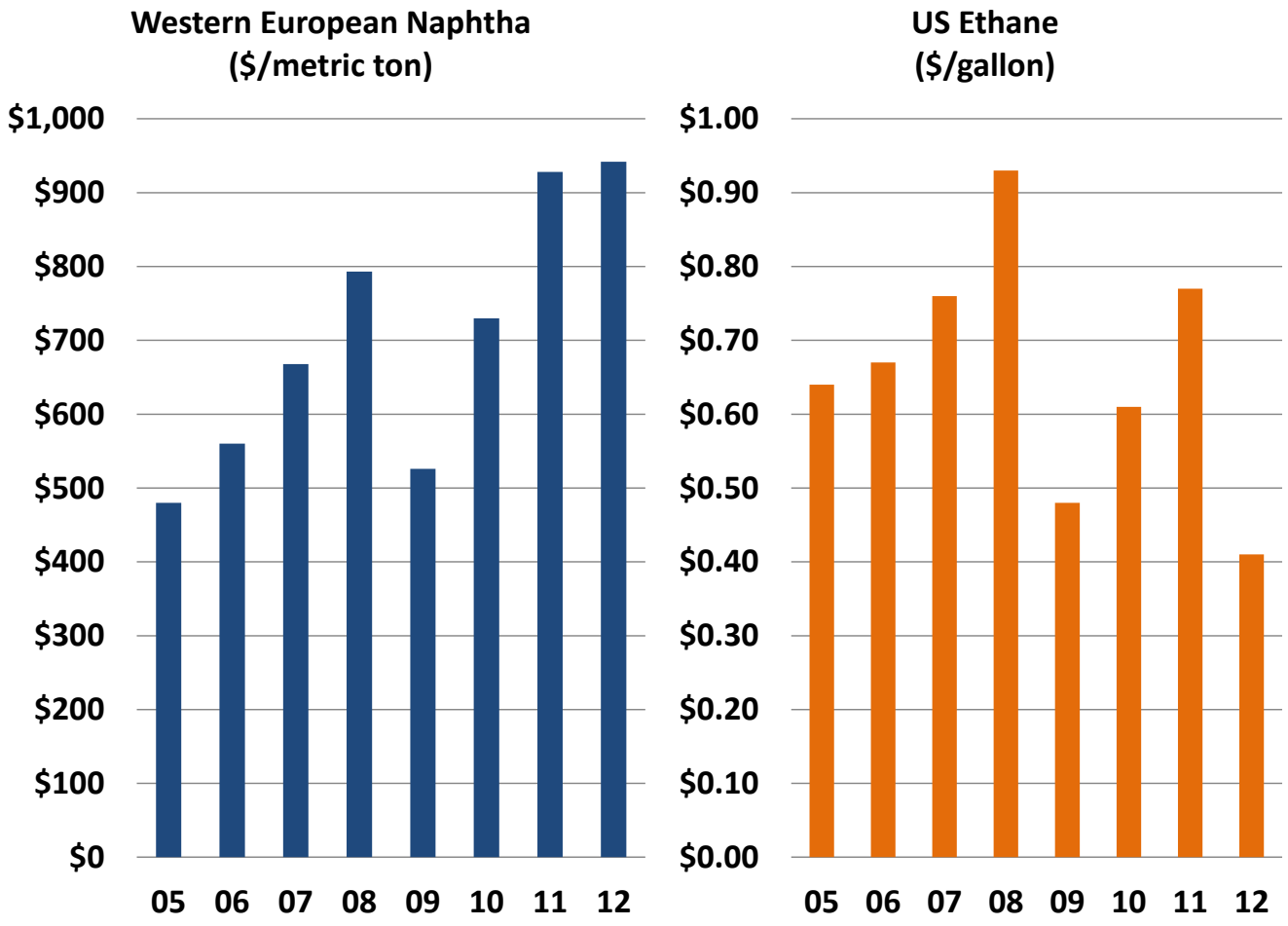
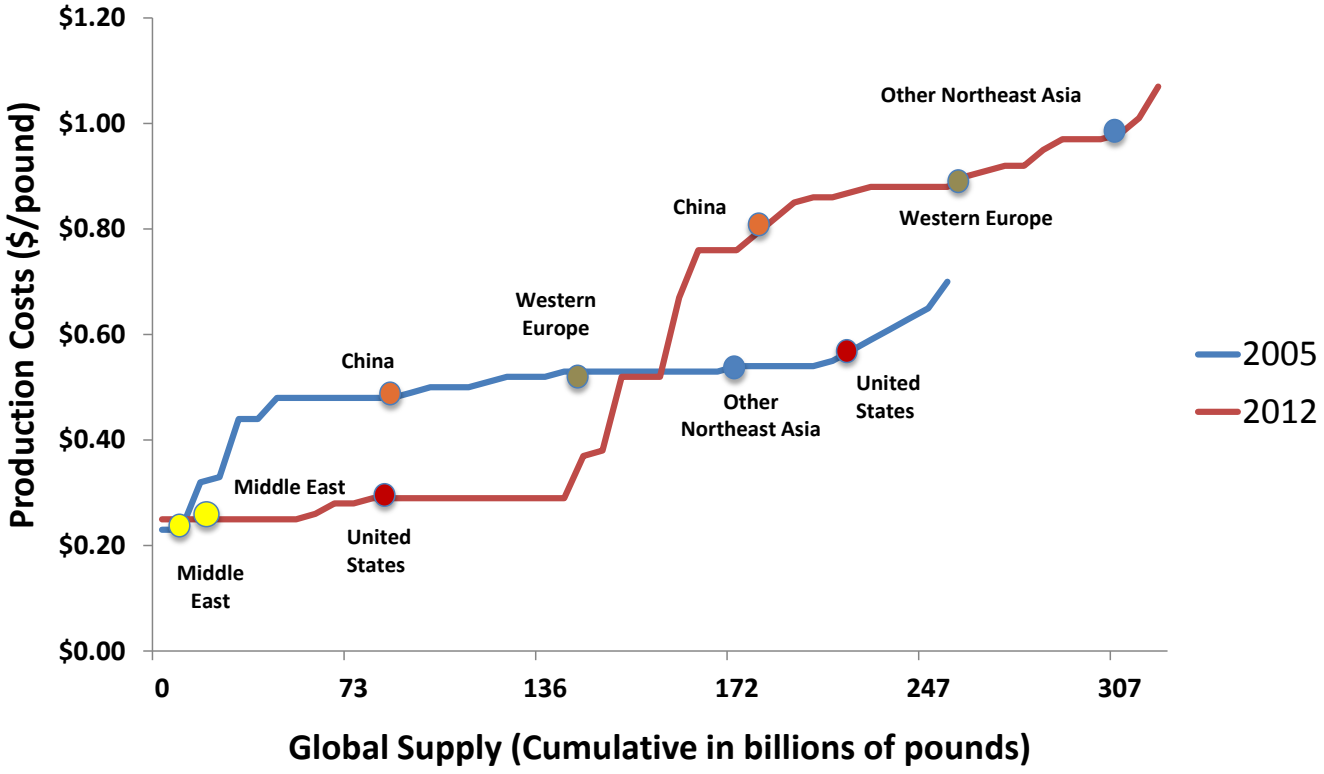


FIGURE 10
US ETHANE PRICES VS. WESTERN EUROPEAN NAPHTHA PRICES



The falling cost of ethane and other light feedstocks (propane, butane, etc.) in the United States since 2008 contrasts with rising costs for naphtha and other heavy liquid feedstocks in Western Europe. Indeed, prices for North American NGL feedstocks have fallen in half since 2008. This has advantaged US production of ethylene, the main product for which these two feedstocks are used. As a result, the production cost to manufacture ethylene in the United States is 35% of that in Western Europe. As Figure 11 illustrates the United States is now one of the low cost producing nations for ethylene, the bellwether petrochemical. Because of US shale gas resources, this position will likely be maintained placing low production costs as a strong incentive to invest in the US chemical industry.

FIGURE 11
CHANGE IN THE GLOBAL COST CURVE FOR ETHYLENE AND RENEWED US COMPETITIVENESS

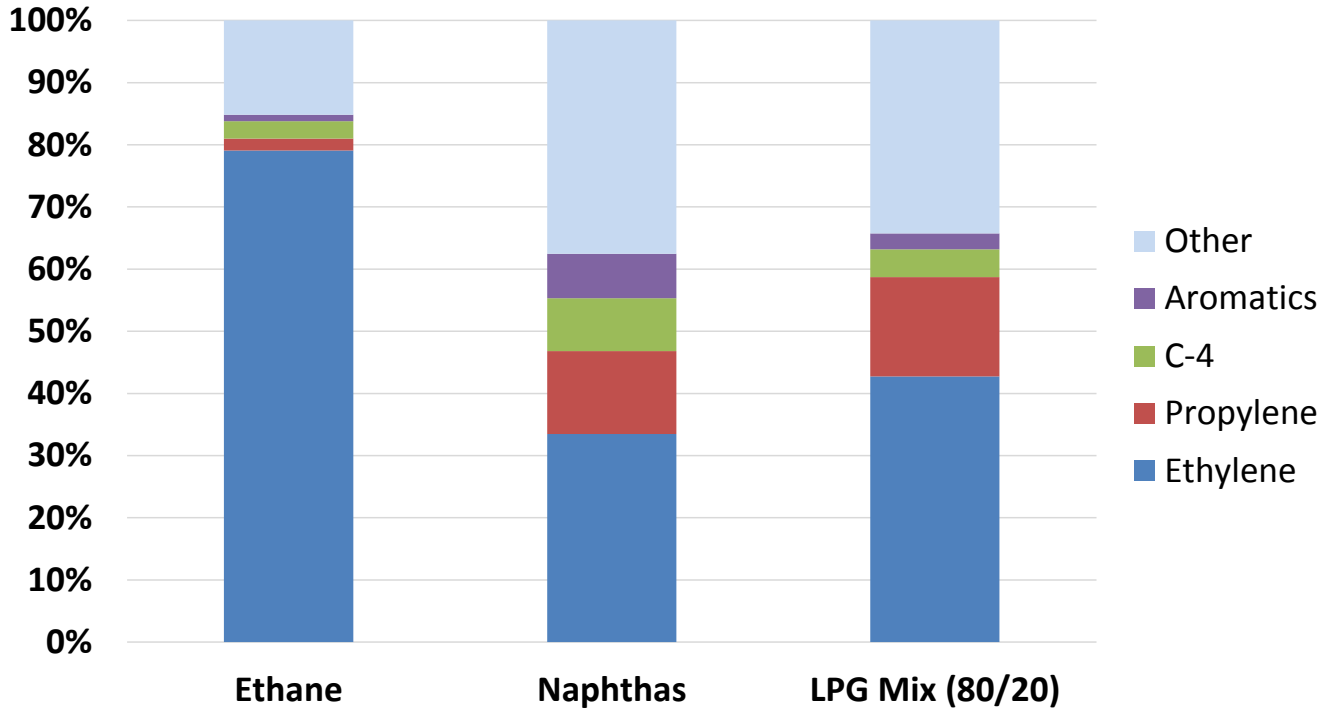


Moreover, falling energy costs and renewed competitiveness are not limited to ethylene but encompass a broad variety of downstream derivative products (plastic resins, synthetic rubber, etc.) and other chemical products. For example, chlorine (and co-product caustic soda) production uses large amounts of electricity in what is an electrolytic process and with low natural gas prices favorably affecting electricity costs, chlor-alkali production in the United States is favored. These cost advantages have improved margins, which provide the funding for capital investment.

The shift toward ethane cracking in the United States has reduced supplies of propylene and butadiene, two important petrochemical products. As seen in Figure 12, while ethane cracking has higher ethylene yields, cracking ethane yields comparatively less propylene, butadiene and other chemical products. Because of lower propane and butane costs (from shale gas) and reduced supply of these chemicals from the shift to ethane steam cracking, a number of "on-purpose"[2] propylene and butadiene projects have also been announced.

[2] Typically, propylene and butadiene are produced as co-products of ethylene production or in refineries. "On purpose" production refers to facilities that produce these materials as the primary output, rather than as a co-product.

FIGURE 12
RELATIVE OLEFIN YIELDS BY FEEDSTOCK



Abundant and low cost natural gas plays a key role for a low cost feedstock and production cost position. This is engendering a massive expansion of the US chemical industry. Abundant supplies of ethane are destined for ethylene production while new supplies of propane will be used to produce on-purpose propylene among other uses.

US Chemical Industry Capital Spending to 2020

Leading companies in the business of chemistry, a number of ACC member companies have announced new investments in US petrochemical and derivatives capacity to benefit from available resources and grow their chemical businesses. Other chemical companies are making similar announcements in petrochemicals and derivatives. In addition, investments are being made in inorganic chemicals and fertilizers. In total, nearly 100 major projects have been announced. ACC examined the details of these announced projects. Some of these represent foreign direct investment (FDI) from chemical companies in Brazil, Canada, Germany, Indonesia, Saudi Arabia, South Africa, Taiwan, and elsewhere. A list of projects is presented in the appendix. These projects are slated to produce nearly 60 million metric tons of bulk petrochemicals, plastic resins, other downstream products, inorganic chemicals, fertilizers, and other products.

Examining the economic impact of these projects which are the direct result of low cost abundant feedstocks in the United States, ACC considered only actual projects rather than conjecture. The estimated cumulative capital investment totals $71.7 billion[3] through 2020. The annual incremental gains in US chemical industry capital investment are presented in Table 1.

[3] Estimate is presented in 2012 dollars.

TABLE 1
INCREMENTAL US CHEMICAL INDUSTRY CAPITAL EXPENDITURES THROUGH 2020 ARISING FROM SHALE GAS-INDUCED RENEWED COMPETITIVENESS
(billions of 2012 dollars)

	2010-12	2013	2014	2015	2016	2017	2018	2019	2020	Total
Investment	$5.7	$7.8	$11.3	$14.6	$12.4	$7.1	$4.4	$4.7	$3.7	$71.7

The data in Table 1 reflect the US chemical industry's incremental capital expenditures arising because of renewed competitiveness from shale gas. That is, the supply-side effects. Demand-side effects are excluded. These expenditures include new greenfield crackers in addition to capital investments to expand capacity for other existing products, capacity for new products, replacing existing plant and equipment, improving operating efficiencies, energy savings, health and safety, environmental production and other projects. In 2012, the US chemical industry (excluding pharmaceuticals) invested $31.8 billion in capital spending. Over $3.2 billion of this was related to shale gas as some plant restarts, debottlenecking projects, and expansions that occurred during 2012. Chemical industry investments related to shale gas actually began in 2010. Between 2010 and 2011, another $2.5 billion had been invested in these shale gas-related projects. Thus, a total of $5.7 billion of shale-related capital expenditures has already been spent. The remaining $66.0 billion in spending will occur between 2013 and 2020.The scheduled start-up dates of announced projects indicate that capital spending will peak at $14.6 billion (in 2012 dollars) in 2015 as seen in Figure 13. It will then taper off as many of the announced projects seem to be centered with 2016 or 2017 start-up dates.

FIGURE 13
INCREMENTAL SHALE-RELATED US CHEMICAL INDUSTRY CAPITAL EXPENDITURES THROUGH 2020

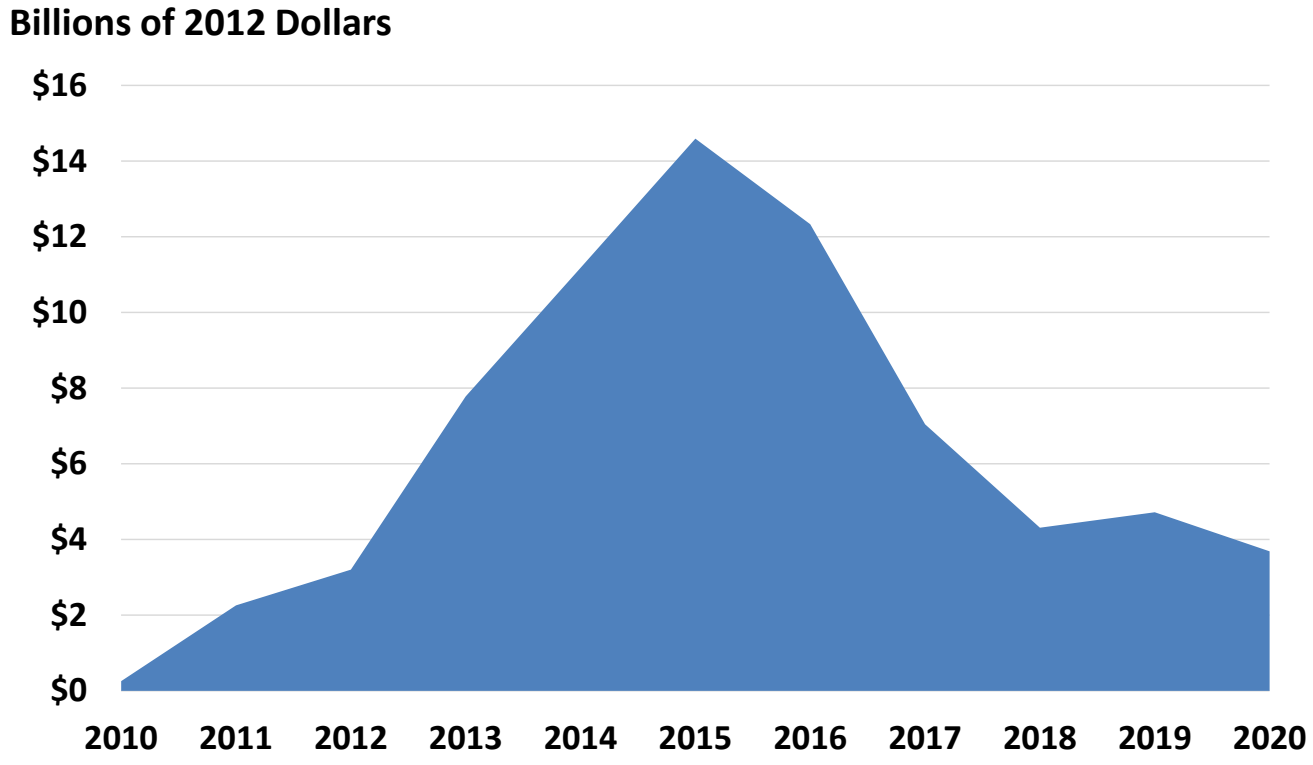
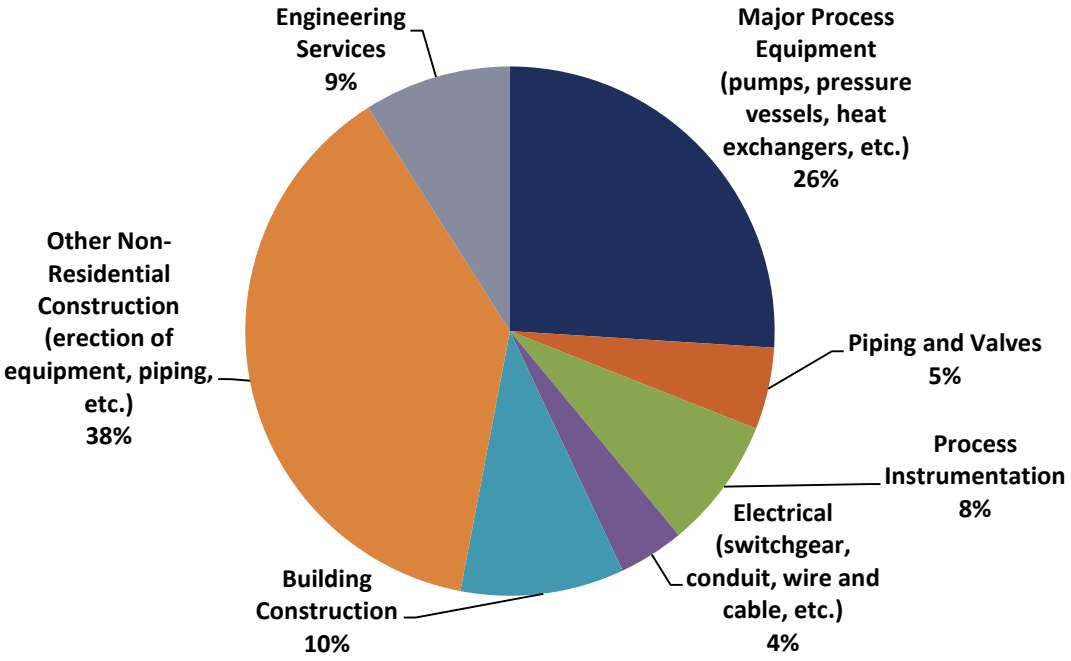
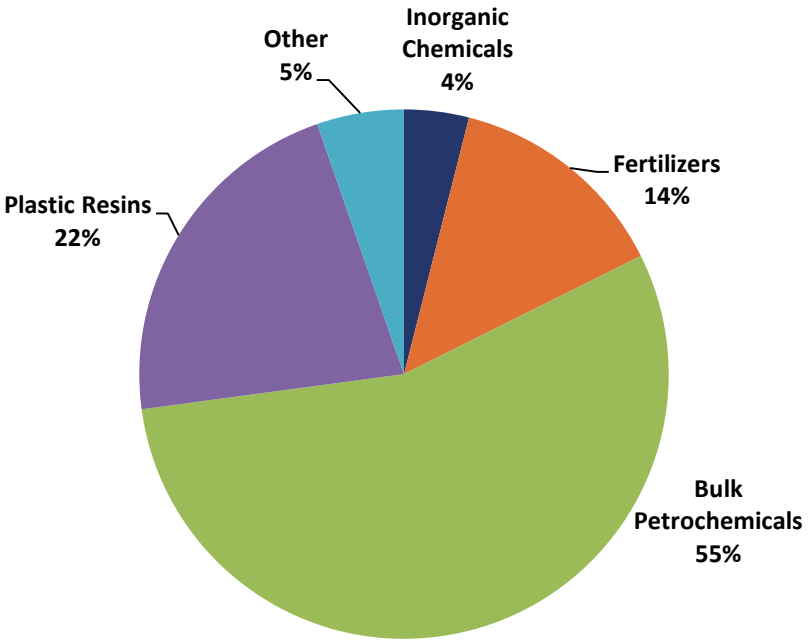


FIGURE 14
COMPOSITION OF NEW CAPITAL INVESTMENT BY ASSET TYPE



Pressure vessels, distillation columns, reactors, heat exchangers, pumps, compressors, and other major process equipment will represent about 26% of the capital spending. Other major goods categories include piping and valves (5%), process instrumentation (8%), and switchgear, transformers, conduit, wire and cable, and other electrical (4%). Building construction will represent about 10% and other non-residential construction will account for 38% of the total. Engineering services account for the balance.

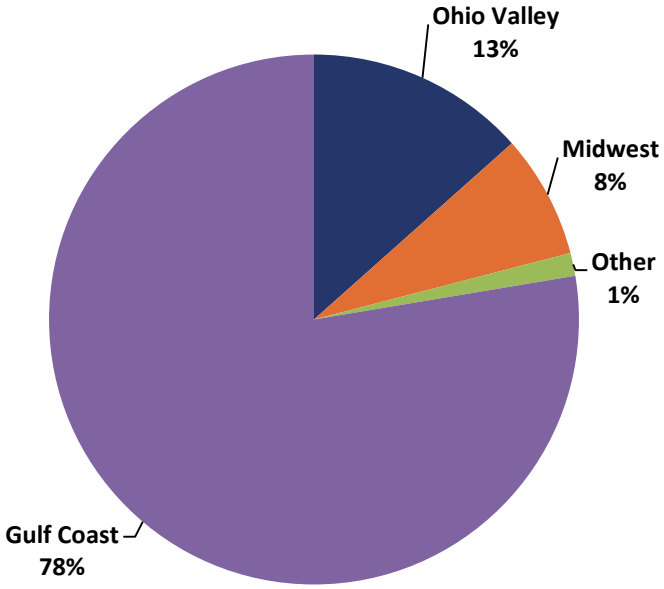
FIGURE 15
COMPOSITION OF NEW CAPITAL INVESTMENT BY CHEMICAL INDUSTRY SEGMENT



The mix of projects announced so far has been heavily slanted towards bulk petrochemicals, mainly steam crackers for ethylene and also on-purpose propylene. During the past six months a slew of projects for producing methanol and ammonia as well as fertilizer products and downstream plastic resins have been announced. Since the output of steam crackers is primarily for plastic resins we expect that more of the future announcements will be for these products as well as other downstream derivatives. Figure 15 provides our estimate of the incremental capital expenditures arising renewed competitiveness from shale gas by chemical industry segment. These shares will likely evolve through time as future investment announcements will increasingly expand capacity for downstream petrochemical derivatives such as plastic resins. As a result, the composition of actual capital investment will evolve to include a greater share in downstream, higher-value-added products. In addition, greater production of all of these chemical materials will generate demand for other chemistry (e.g., catalysts). Catalyst production shows up in the indirect (i.e., supplier) effects in this analysis.

The geographic spread of the chemical industry is highly concentrated on the Gulf Coast as well as other major industrial states. Major producing states include Texas and Louisiana as well as California, Florida, Georgia, Illinois, Iowa, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, and Virginia. The new investments arising from the renewed competitiveness arising from shale gas will largely occur in the Gulf Coast. Nonetheless, a cluster of projects will likely occur in the Ohio Valley and in the Midwest.

FIGURE 16
NEW CHEMICAL INDUSTRY CAPITAL INVESTMENT BY REGION



With the advent of abundant low-cost feedstocks, the US chemical industry is presented with the most significant opportunity in 75 years. Significant capital investments are planned with the nearly 100 projects we evaluated. The US competitive advantage is presenting challenges for the global industry. The United States is now viewed as the region to locate production. A large number of European and Asian companies are planning or evaluating investments in the United States. Even one large Middle Eastern chemical company is in talks about a possible investment in the United States. Indeed, nearly 50 of the 97 projects evaluated for this analysis are by foreign-controlled companies, and represent 51% of estimated capital investment. Although serving expanding US domestic markets remains important, many of the projects will be built for exports.

Added US Chemical Industry Output to 2020

The output generated by renewed competitiveness and expanded production of the chemical industry is significant. The nearly 100 project announcements examined in detail are slated to produce 55.9 million metric tons of bulk petrochemicals, plastic resins, other downstream products, inorganic chemicals, fertilizers, and other products. Extrapolating from the start-up dates of these projects and using average 2012 selling prices along with the assumption of 90% operating rates, it was possible to measure the incremental value of output of these projects (as measured in constant 2012 dollars) and compare them to a baseline projection.

The outlook for the chemical industry in the baseline projection presented here reflects the consensus of several economic models that are demand-driven. That is, they do not account fully for changes on the supply side. However, based on announced projects, it's our contention that the growth profile from the supply-side response scenario should be much greater than that of the consensus forecast of the mainstream forecasting models. Our results reflect most of these investment announcements proceeding. Thus, the estimated incremental production from these announced projects is shown in addition to the baseline consensus forecast of production volume.

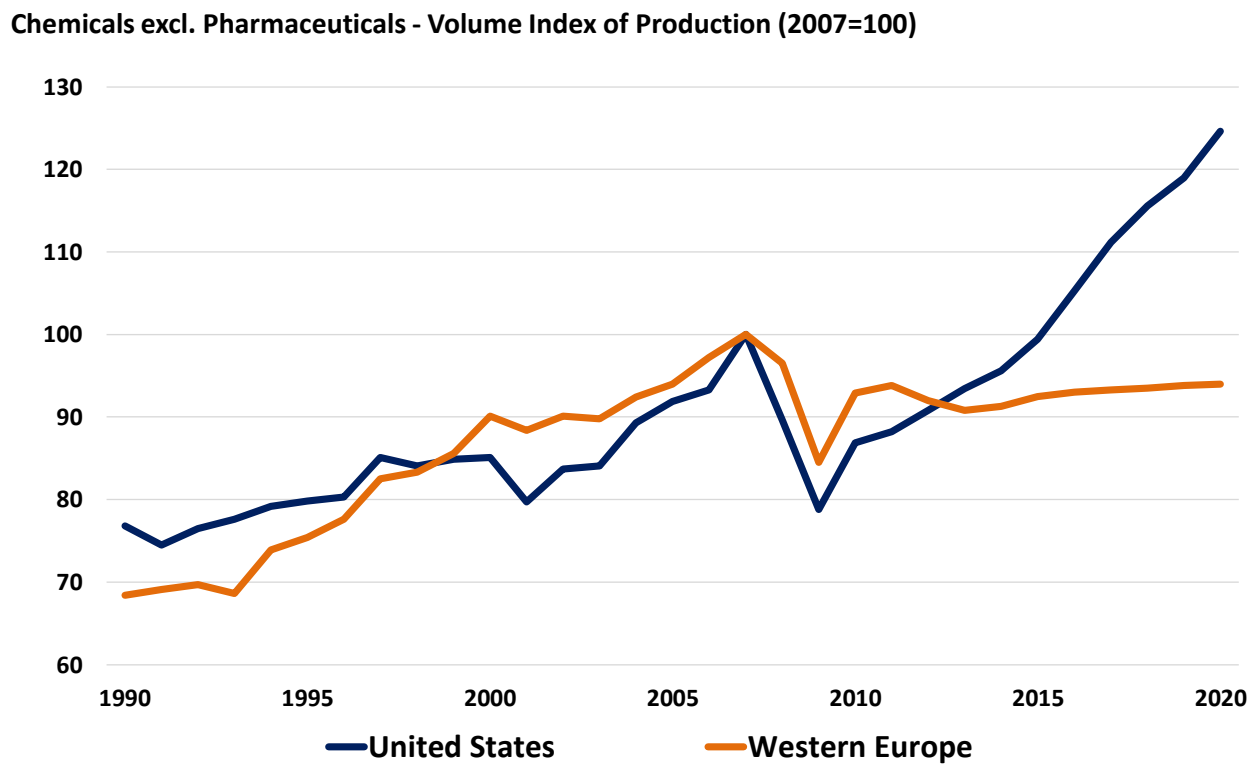
TABLE 2
INCREMENTAL US CHEMICAL INDUSTRY OUTPUT THROUGH 2020 ARISING FROM SHALE GAS-INDUCED RENEWED COMPETITIVENESS
(billions of 2012 dollars)

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Baseline	$587.2	$603.2	$614.8	$631.5	$655.9	$680.1	$700.1	$720.8	$743.0
New Investment	$589.4	$606.5	$620.6	$645.8	$683.8	$721.8	$750.7	$773.2	$809.8
% Δ from Base	0.4%	0.5%	0.9%	2.3%	4.3%	6.1%	7.2%	7.3%	9.0%

Some of the incremental output arising from capital investment due to renewed competitiveness from shale gas is already occurring. A number of plant restarts, debottlenecking projects, and plant expansions have already occurred. The added value of output from these projects amounted to $2.2 billion in 2012. As a result, there is already some deviation from the baseline.

Including production from these new investments, growth in the chemical industry will likely average 4.0% per year through 2020, 50% higher than the 3.0% average annual growth projected in the baseline consensus forecast. These projections are in real terms. Growth in basic chemicals and plastics will be even faster. The output of the US chemical industry will be 9.0% above the baseline projection in 2020. This represents $66.8 billion (2012 dollars) in additional output at that time. The supply response varies among segments. In ethylene, for example, by 2020, the expansion of US capacity is anticipated to approach 40% above the levels of 2010. The large supply response reflects that in addition to improved competitiveness from lower fuel and power cost, competitiveness is especially enhanced because the industry's feedstock and raw materials are energy-intensive as well. Expansion in fertilizers is expected to be significant and a revival in the methanol segment is also expected. The growth of more downstream production will also evolve.

FIGURE 17
US CHEMICAL INDUSTRY GROWTH COMPARED WITH GROWTH IN WESTERN EUROPE



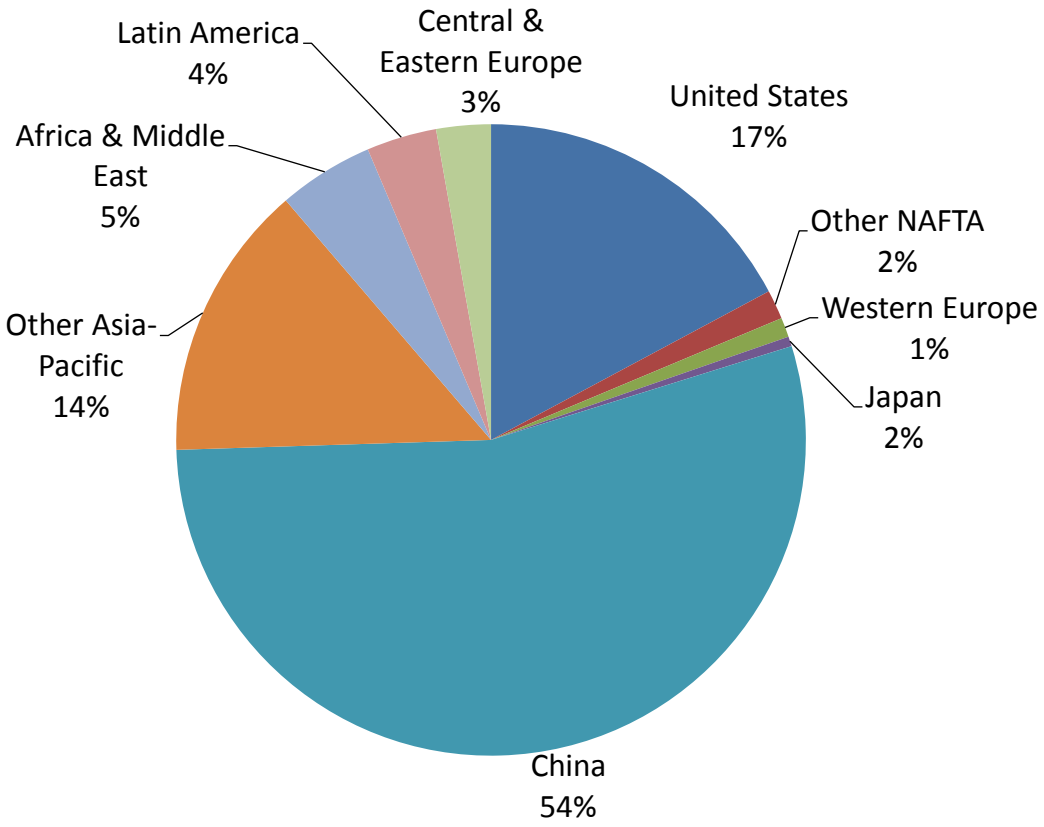
Sources: Eurostat, Federal Reserve, ACC analysis

Renewed competitiveness due to shale gas will accelerate chemical industry growth in the United States. US chemical industry growth will surpass that in Western Europe. Figure 17 presents this comparison between the likely growth of the US chemical industry and baseline projections for the chemical industry in Western Europe. As production from new investments comes online over the next several years, the United States will capture market share away from Europe. This analysis extends the "Re-Emerging America" scenario in the October 2011 study *Scenarios: Possible Futures for the US Chemical Industry through 2030.*

Global demand for (and supply of) chemicals excluding pharmaceuticals is expand at a pace 1.2 times that of global economic activity. As a result, production of chemicals excluding pharmaceuticals will incrementally expand by $1.35 trillion (in constant US dollars) between 2012 and 2020. China already represents the largest producing nations, with output twice that of the United States. As a result, China's sheer size (33% of the global total compared to 15% for the United States) suggests that even if growth were to severely slow, China will continue to dominate future incremental gains. Thus, China will account for 54% of the incremental gain in global production. But with the renewed competitiveness and wave of capital investment arising from shale gas, the US chemical industry will experience a renaissance, and will also account for the second largest share (at 17%) of the incremental gain in global production. These shares (by nation and region) of the incremental gain in global production are illustrated in Figure 18.

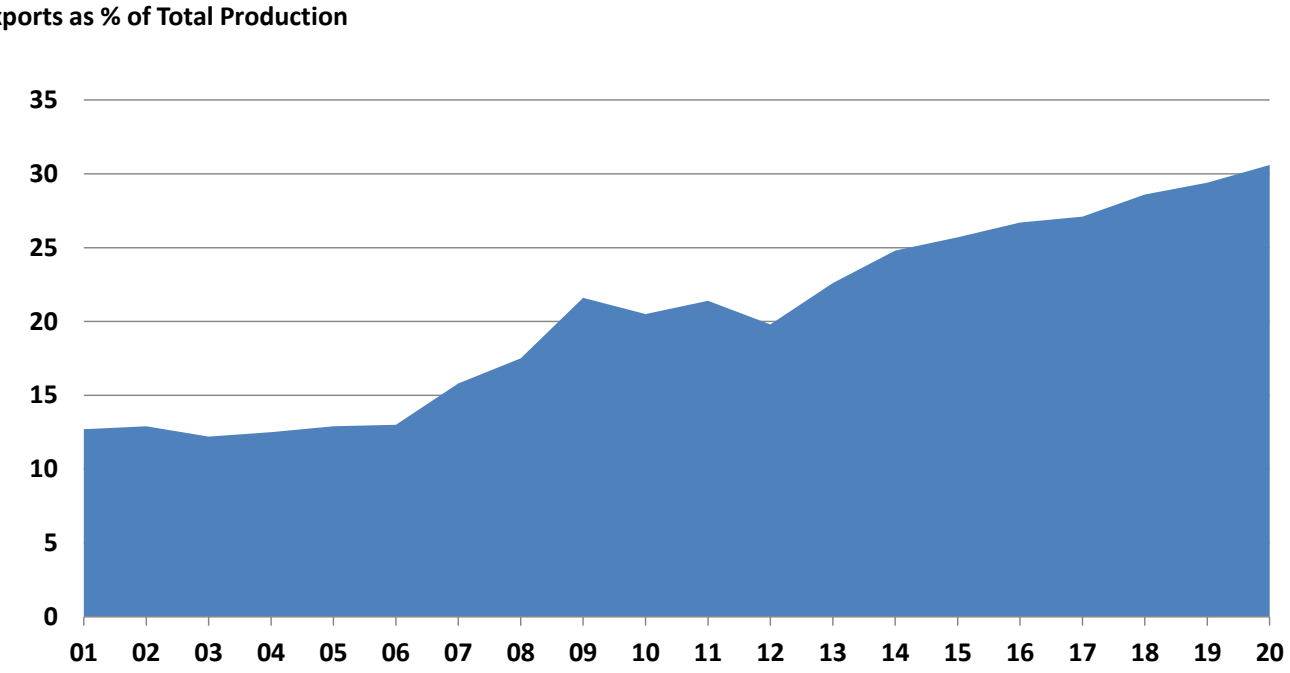
FIGURE 18

SHARE OF THE GLOBAL INCREMENTAL GAIN IN THE PRODUCTION OF CHEMICALS EXCLUDING PHARMACEUTICALS FROM 2012 THROUGH 2020



The chemical industry is not the only American industry benefiting from the manufacturing renaissance. ACC's May 2012 shale gas study presents 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. ACC found a tremendous opportunity for shale gas to strengthen US manufacturing, boost economic output and create jobs. One of the industries clearly benefiting is plastic and rubber products, and this industry will feature strong growth and absorb much of the incremental gains in chemical industry output arising from the shale gas-induced renewed competitiveness. But an increasing share of US chemical industry output will be exported because the US chemical industry is emerging as a low cost producer of plastic resins and other chemical products globally traded.

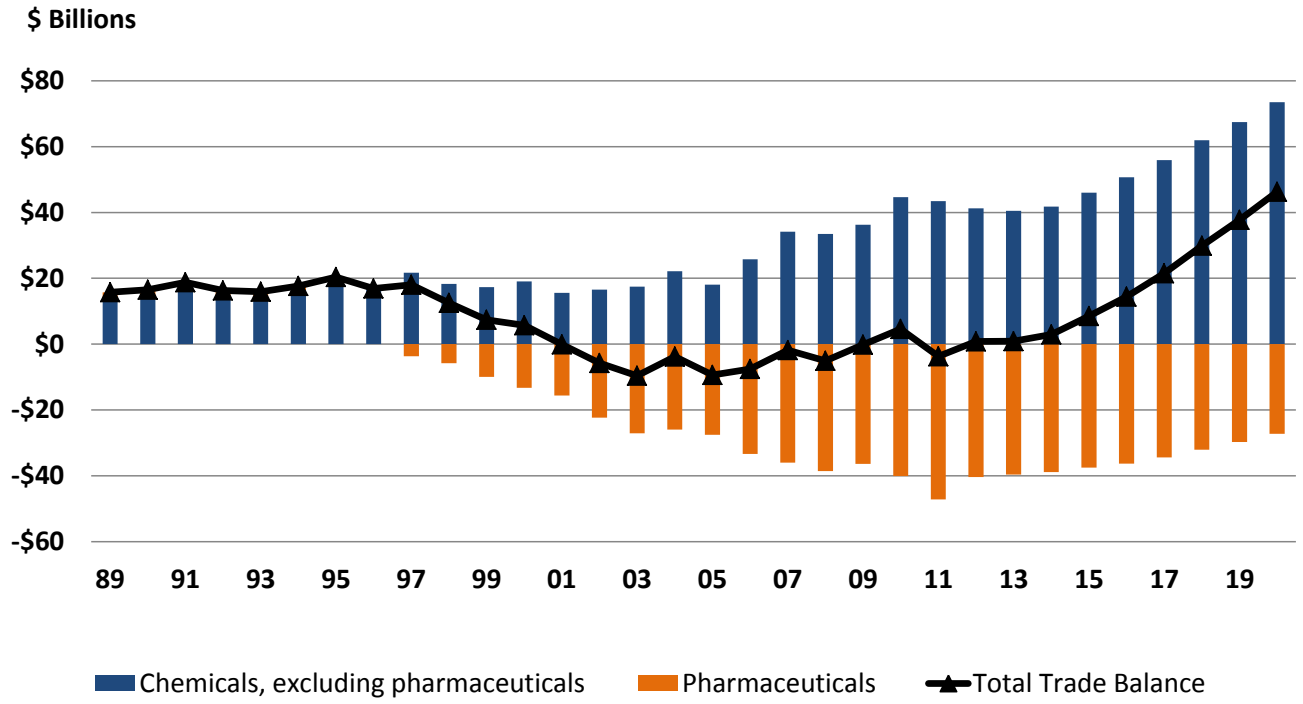
FIGURE 19
EXPORTS GAINING AS A SHARE OF NORTH AMERICAN THERMOPLASTICS OUTPUT



One tangible form of petrochemical competitiveness lies in trade of thermoplastics. In the period from 2001 through 2006 exports of thermoplastics as a share of North American production averaged less than 13%. However, as the shale gas revolution improved the competitiveness of US production this share began to rise, reaching 22% by 2009. This was during the Great Recession when global trade and industrial production severely slumped. A strong US economy since then has absorbed a slightly larger share of North American output but when Europe and Japan recover from their current weakness, the combination of this growth in demand and the renewed competitiveness will push the export share in excess of 30% by 2020.

In addition to thermoplastic exports, other shale-advantaged chemistry products will become increasingly competitive in world markets. In fact, many of the announced investments are export-oriented. Through 2020, growth in chemistry exports outpaces growth in imports and the $800 million trade surplus in 2012 grows to more than $46 billion by 2020. This is in contrast to the trade deficits the industry faced during the last decade as competitively disadvantaged basic chemical exports failed to offset large and growing imports of pharmaceuticals.

FIGURE 20
CHEMISTRY TRADE BALANCE GROWS DUE TO THE SHIFT IN COMPETITIVENESS



Added US Chemical Industry Job Creation by 2020

The additional output and employment generated by renewed competitiveness and expanded production of the chemical industry is significant. The investments announced to date will bring substantial advantaged production capacity online over the next decade. Because of shale gas, the US is among the low-cost chemical producers worldwide. As a result, capacity utilization rates for the new investments are expected to remain high, and the new investments are expected to produce $66.8 billion in new chemical output. The additional $66.8 billion (2012 dollars) in US chemical industry output would directly generate roughly 46,000 high-paying, desirable jobs in the chemical industry. Because these jobs provide high incomes, the induced effects are especially large.

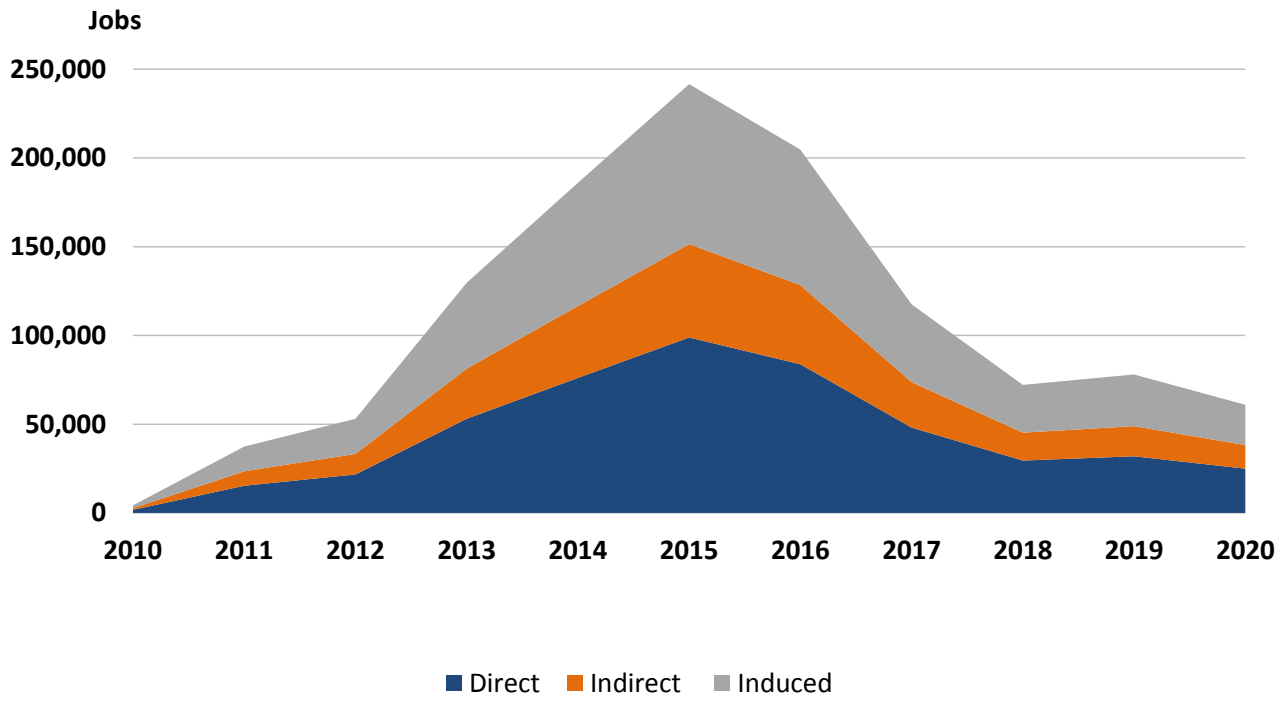
TABLE 3
ECONOMIC IMPACT FROM EXPANDED PRODUCTION OF THE US CHEMICAL INDUSTRY FROM RENEWED COMPETITIVENESS ARISING FROM SHALE GAS, 2020

	Employment	Payroll ($ Billion)	Output ($ Billion)
Direct Effect	46,359	$4.9	$66.8
Indirect Effect	264,111	$18.9	$100.4
Induced Effect	226,272	$10.6	$33.9
Total Effect	**536,741**	**$34.4**	**$201.1**

In addition, the increased competitiveness arising from shale gas and expanded output by the US chemical industry would generate purchases of raw materials, services, and other supplies throughout the supply chain. Thus, through indirect effects, another 264,000 supply chain jobs would be supported by the boost in the output of the chemical industry.

Finally, the wages earned by new workers in the chemical industry and workers throughout the supply chain are spent on household purchases and taxes generating nearly 226,000 jobs induced by the response of the economy to changes in household spending as a result of labor income generated by the direct and indirect effects. All told, the additional $66.8 billion in the output of the chemical industry (from renewed competitiveness of the shale gas revolution) would generate $201 billion in output to the economy and nearly 537,000 jobs in the United States generating a payroll of $34 billion. This comes at a time when millions of Americans remain out of work. Moreover, the new jobs would primarily be in the private sector.

FIGURE 21
JOBS PER YEAR DURING INVESTMENT PHASE



Following a decade of deindustrialization, new plant and equipment are required to support the expansion of the chemical industry. The $71.7 billion in needed investments would generate an average of 44,000 direct jobs annually, mostly in the construction and capital equipment-producing industries. During 2015, when investment activity is projected to peak, nearly 100,000 direct jobs will be created. Over the ten-year period, a total of 485,000 direct jobs[4] will be supported by the ethane-advantaged build out of the chemical industry (see details presented in Table 4). Furthermore, through supply-chain impacts, chemical industry investment will support an additional 23,000 indirect jobs per year on average. Thus, a total of 258,000 jobs will be supported in supply chain industries over the ten year period. These are jobs in industries that supply materials and services to the companies building new chemical facilities and manufacturing the process equipment. Finally, the payrolls generated by workers throughout the investment supply chain support an additional 40,000 jobs per year on average, largely in local communities. Over the ten-year investment period, a total of 442,000 of these payroll-induced jobs are supported through the household spending of workers supported directly and indirectly by chemical industry investment. All told, the ten-year $71.7 billion investment in the US chemical industry would support 1.2 million jobs over the ten-year investment wave and $67.9 billion in payrolls.

TABLE 4
ECONOMIC IMPACT FROM CHEMICAL INDUSTRY INVESTMENT 2010-2020

	Total Jobs 2010-2020	Average Jobs Added per Year	Payroll ($ Billion)	Output ($ Billion)
Direct	485,054	44,096	$30.7	$71.7
Indirect	258,039	23,458	$16.4	$55.9
Induced	442,233	40,203	$20.8	$66.2
Total Effect	1,185,326	107,757	$67.9	$193.9

Tax Revenues

ACC estimated the additional tax revenues that would be generated across all sectors as the result of increased economic activity resulting from shale-advantaged chemical production. Table 5 details the federal and the state and local tax revenues that will be generated from the expansion in the chemical industry in 2020. The additional jobs created and added output will lead to a gain in taxes receipts. Federal taxes on payrolls, households, and corporations would yield $7.7 billion per year. On a state and local level, an additional $5.4 billion per year would be generated.

[4] Because the investment occurs over a multi-year period, total jobs should be interpreted as *work-year* jobs. This is done to avoid double counting the same job in multiple years.

TABLE 5
TAX IMPACT FROM EXPANDED PRODUCTION OF THE US CHEMICAL INDUSTRY FROM RENEWED COMPETITIVENESS ARISING FROM SHALE GAS, 2020 ($ BILLION)

	Payroll	Households and Proprietors	Corporations and Indirect Business Taxes	Total
Federal	$3.0	$2.5	$2.1	**$7.7**
State & Local	$0.1	$1.0	$5.1	**$6.2**

There are also considerable tax revenues generated from the $71.7 billion investment in new plant and equipment. Table 6 details the federal and the state and local tax revenues that would be generated from the economic impact accrued during the ten-year investment phase. Over the ten-year investment period, federal tax receipts would total $13.0 billion, while state and local receipts would be $7.0 billion. While the impact from the new plant and equipment investment fades as new factories are brought online, the revenues and jobs it creates would, nonetheless, be welcomed during these times of fiscal imbalances.

TABLE 6
TAX IMPACT FROM SHALE-RELATED CHEMICAL INVESTMENT 2012-2020 ($ BILLION)

	Payroll	Households and Proprietors	Corporations and Indirect Business Taxes	Total	*Average per Year*
Federal	$5.8	$5.1	$2.1	**$13.0**	*$1.6*
State & Local	$0.1	$1.7	$5.2	**$7.0**	*$0.9*

Post-2020 US Chemical Industry Capital Spending and Output

For this analysis, ACC examined the economic effects of new investments by the chemical industry through 2020. However, many of the recent project announcements feature a 2018 or later start-up date. As a result, the wave of investment arising from the renewed competitiveness of the industry (due to shale gas) will continue well past 2020 and even 2025. The pace will likely taper off.

We estimate that an additional $24.5 billion to $29.5 billion in chemical industry investment could occur in the period between 2020 and 2025. This conjecture is based on previous cycles associated with positive shock events similar to the availability of shale gas, as well as previous chemical industry cycles. A lot depends upon the state of the global economy and the policy environment. These additional investments could occur in bulk petrochemicals and fertilizers but will also likely be more geared towards plastics resins, synthetic rubber and other downstream activities. In addition, it is possible that a larger share of these investments could occur outside the Gulf Coast. As production from these investments comes on-stream the gains over baseline

production will be maintained. The potential cumulative investments arising from the renewed industry competitiveness due to shale gas could reach between $96 billion and $112 billion by 2025.

Conclusion

The economic effects of new investment by the chemical industry in the United States are overwhelmingly positive. Recent breakthroughs in technology have made it productive and profitable to tap into the vast amount of shale gas resources that are here, in the United States. Barring ill-conceived policies that restrict access to this supply, further development of our nation's shale gas resources will lead to a significant expansion in domestic chemical manufacturing capacity. And this opportunity comes at no better time. The United States is facing persistent high unemployment and the loss of high paying manufacturing jobs. Access to these new resources, building new manufacturing capacity, and the additional production of manufactured products will provide an opportunity for more than 46,000 direct jobs in the chemical industry. A large private investment initiative would enable a renaissance of US manufacturing and in this environment, a reasonable regulatory regime will be key to making this possible.

In addition to those in the chemical industry, other manufacturing investments are being made in areas of the country that have been hardest-hit by industrial sector declines. These investments improve the outlook in these economically depressed areas. Further development of the nation's shale gas and ethane can drive an even greater expansion in domestic manufacturing capacity, provided that policymakers develop balanced regulatory policies and permitting practices.

As US manufacturing is set to gain substantially, due in large part to shale gas development, government and industry need to work together to ensure that the American workforce is prepared for the jobs building and working in the emerging manufacturing renaissance. Between a graying manufacturing workforce and decades of young people turning away from careers in manufacturing and the trades, there is concern about the quality and quantity of workers available for the diverse portfolio of skilled manufacturing and construction occupations that will be required in the coming years. As a result, productivity may be restrained.

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.

ACC Economics & Statistics

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 primary researchers and authors of this project were Martha Gilchrist Moore and Thomas Kevin Swift. The Economics & Statistics Department of ACC consists of:

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Appendix 1: Methodology and Assumptions

The developments in shale gas will engender the wider availability of low cost, domestic energy. For trade-exposed gas-intensive manufacturing industries, lower costs for key inputs improve competitiveness in those industries. The chemical industry is a major consumer of natural gas and/or natural gas liquids. The chemical industry uses large quantities of natural gas for fuel and power. In addition, the chemical industry uses natural gas liquids as a feedstock for petrochemicals and natural gas as the feedstock for nitrogenous fertilizer and carbon black. All of these industries compete in global markets and are sensitive to natural gas costs. Economic theory and empirical evidence suggest that technological innovations and lower input costs will shift the supply curve to the right, engendering additional industry output.

The objective of ACC's research was to quantify the effects of lower-priced and abundant shale gas on the output of the US chemical industry as well as identify the indirect and induced effects on other sectors of the economy. That is, the supply responses.

From a policy viewpoint, it was assumed that there are no barriers to the development of oil and gas. In particular, a policy environment amenable to further expansion of shale gas extraction and related pipeline and other infrastructure development is assumed. Furthermore, it is assumed that there are no barriers (e.g., permits) to private sector development. The scope of the analysis was limited to the chemical industry and did not include the investment or business activity generated by the extraction, recovery or infrastructure related to delivery of the natural gas to manufacturing.

Assumption Development - The research methodology was quantitative in nature and employed a triangulating approach, which aids validity. A comprehensive and exhaustive search of the trade literature on chemical industry project announcements was conducted. Project announcements were confirmed by examining company press releases and annual reports, security analyst reports, consultant reports, and other publications. Using this body of literature, each of the projects announced was thus examined separately.

TABLE 1
CAPITAL EXPENDITURE BY ASSET TYPE

Asset Type	% of Total
Major Process Equipment (pumps, pressure vessels, heat exchangers, etc.)	26%
Piping and Valves	5%
Process Instrumentation	8%
Electrical (switchgear, conduit, wire and cable, etc.)	4%
Building Construction	10%
Other Non-Residential Construction (erection of equipment, piping, etc.)	38%
Engineering Services	9%
Total	**100%**

A number of these project announcements featured data on plant capacity and the intended capital investment. These were taken at face value. Some announcements featured data on plant capacity but no cost information. In such cases, we used standard cost engineering methodology and data (based on the IHS Chemical Process Economics Program Yearbook and other sources) to estimate the capital investments for the remaining projects. These investments are a combination of plant restarts, debottlenecking, brownfield, and greenfield projects. All together, these projects represent a $71.7 billion capital investment by the US chemical

industry. These capital investments provided the "order of magnitude" assumptions used to drive subsequent modeling.

The composition by asset type for these capital investments were derived using the average historical mix for each of the chemical industry's fixed assets for new projects. About half of the investment would be for major process equipment, piping and valves, instrumentation, electrical, and structures. The rest would be for construction activities and engineering services.

The start-up dates for each project was identified and using historical spending patterns for capital projects, we were able to gauge the year-by-year expected incremental value of US chemical industry capital spending arising from this renewed competitiveness induced by shale gas. All estimates on US chemical industry capital investment are expressed in 2012 constant dollars.

Various changes in the long-term price of natural gas were also assessed within the context of industry consumption patterns and industry dynamics. The various scenarios suggested declines (from the most recent EIA *Annual Energy Outlook's* reference case scenario) in long-term natural gas prices in the 15-23% range during the period to 2020 compared to the average during the 2000-2008 period. Various combinations of price and industry responsiveness were evaluated and then using a probabilistic approach, expected value of the change in long-term industry output was assessed.

The expected change in the US chemical industry's output (from a baseline projection) resulting from lower natural gas prices reflects the period through 2020. The baseline forecast represents a consensus forecast, an average of forecaster's projection of industry growth. The most recent industry forecasts of IHS Global Insight and Oxford Economics were averaged to provide this baseline forecast. The output of the announced projects was evaluated and the value of the output was estimated and compared against the baseline. All estimates of changes in output are expressed in 2012 constant dollars.

The assumptions in ACC's analysis were based on actual projects. At the time of the writing of this report, some 97 chemical industry projects have been announced, with an estimated cumulative capital investment totaling $71.7 billion (in 2012 dollars) through 2020. This provides the order of magnitude assumptions and it is assumed that the composition (by product and segment) of the projects will evolve. Examining the capital and output of the projects led to broad assumptions on the impact on the industry. These assumptions about size and nature of impact were used to drive subsequent analysis of the likely effects.

To the extent that additional project announcements will be forthcoming, based on historical cycles in chemical industry investment, we assumed that an additional $10.7 billion (in 2012 dollars) in projects will be announced and started up by 2020. As a result, we developed a high investment case that includes these as yet unannounced capacity additions. Combined with our base case assumptions, this represents estimated cumulative capital investment totaling $82.4 billion (in 2012 dollars) through 2020. It should be noted that the composition (by product or segment) of the US chemical industry's capital investment will evolve.

Input-Output (I-O) Analysis – To estimate the expected incremental capital investment arising from shale gas-induced competitiveness, the expected change in industry output and the potential effects on job creation, new output, and tax implications for state, local and the Federal government, ACC used a technique called input-output (I-O) analysis. The economic impact of new investment 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

ACC's analysis focused on the first three channels. Spillover (or catalytic) effects would occur from new investment in petrochemicals, but these positive externalities are difficult to quantify and thus were not examined in the analysis. These positive effects could include heightened export demand and the impacts on the industries from renewed activity among domestic end-use customer industries. Due to model limitations, the impact on exports cannot be separately identified, but clearly, increased production is likely to lead to higher exports because of enhanced competitiveness.

The endogenous effects of shale developments by the oil and gas sector itself were not included in the analysis. However, these effects are not insignificant and could generate hundreds of thousands, if not millions of direct, indirect and induced jobs. The scope of this study was limited to the US chemical industry and the economic and employment effects from increased expansion of output and capital spending. To the extent that increased output of the chemical industry does purchase oil and gas products, those effects are captured. For example, the industry uses lubricating oil for moving machinery and the chemical industry's increased output would lead to increased demand for lubricants.

The analysis was broken into two parts: a ten-year change in final demand that occurs during the initial capital investment phase when new plant and equipment are purchased and the ongoing change in final demand (i.e., change in chemical output) that occurs as a result of lower natural gas prices and increased availability of ethane. During the investment phase, the change in final demand occurs in the construction and capital goods manufacturing industries while an examination of the ongoing impact of increased chemical output looks at changes to final demand for several chemical manufacturing industries. The expected changes in these industries' output were then used to drive the modeling of the economic response. The effects on employment and tax revenues also were assessed. To accomplish the goals of the analysis, a robust model of the direct, indirect and other economic effects was employed, as were reasonable assumptions and parameters. To estimate the economic impacts from increasing investment in US petrochemicals production, the IMPLAN model was used. 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.

An input-output model such as IMPLAN is a quantitative economic technique that quantifies the interdependencies between different industries (or sectors) of a national economy. Although first suggested by Francois Quesnay (1694-1774) and by the general equilibrium work of Léon Walras (1834-1910), it was Wassily Leontief (1905-1999) who developed this type of analysis and took the Nobel Prize in Economics for his work on this model. Although complex, the input-output model is fundamentally linear in nature and as a result, facilitates rapid computation as well as flexibility in computing the effects of changes in demand. In addition to studying the structure of national economies, input-output analysis has been used to study regional economies within a nation, and as a tool for national and regional economic planning. A primary use of input-output analysis is for measuring the economic impacts of events, public investments or programs such as base closures, infrastructure development, or the economic footprint of a university or government program. The IMPLAN model is used by the Army Corp of Engineers, Department of Defense, Environmental Protection Agency, and

over 20 other agencies, numerous government agencies in over 40 states, over 250 colleges and universities, local government, non-profits, consulting companies, and other private sector companies.

Because the IMPLAN model does not include the effects of the investment needed to produce the added output of the chemicals industry arising from renewed competitiveness enabled by shale gas, the value of the capital investment was separately estimated.

Effects on added output, jobs, and tax revenues from the new investment spending were assumed to be a one-time impact and were modeled as such. For most projects, the spending would likely occur over the period of five or so years, distinct phases in the project are likely, with engineering and design occurring early, followed by equipment procurement, and then construction and installation. Some overlap of construction activity is possible but assumed to be modest in scope.

Other Assumptions - The results presented in this report are based on the examination of the effects of lower natural gas costs (arising from the revolution in shale gas) on fostering renewed manufacturing competitiveness, output, and investment. The results presented in this report differ from those presented in ACC's March 2011 report. The analysis discussed in the report "*Shale Gas and New Petrochemicals Investment: Benefits for the Economy, Jobs, and US Manufacturing"* focused solely on petrochemicals and products associated with a petrochemical complex (e.g., bulk petrochemicals, and plastic resins). The analysis discussed in this report was expanded in scope and also included fertilizers, carbon black, methanol and other direct consumers of natural gas as well as likely supply responses from producers of other commodity inorganic and organic chemicals, organic intermediates, other downstream petrochemical derivatives, coatings, adhesives, coatings, plastic compounders, other specialty chemicals and additives, pesticides, and other chemistry products.

The chemical industry faces a number of challenges and opportunities. Volatile energy costs, other raw material costs and selling prices have a marked effect on industry performance. Demand is dependent upon the health of downstream sectors such as construction, light vehicle, appliance, furniture, electronics, other consumer goods, machinery, textiles, and food industries. In between and along the supply chain are packaging, paper, and other intermediate manufacturing industries. Light vehicles and construction (most notably housing) are the major end-uses, and demand has fallen appreciably in the last five years and has yet to fully recover. Globalization and the movement of customer industries to low-wage nations have adversely affected demand during the past two decades. Nowhere has this been more pronounced than in man-made fibers, where demand from customers is anticipated to fall further as textile mills close or move overseas. A recovery of consumer spending and other economic activity and the downstream customers will determine future demand. In some segments such as printing ink and photographic chemicals, new electronic media and technological developments have resulted in much lower demand. Environmental, energy, and other government policies play a role and in general have raised costs and slowed innovation. On the other hand, environmental policies have been favorable for industrial gases. In addition, plastics, adhesives, and coatings continue to make inroads against competing materials and systems. In recent years, the effect of shale gas has been very pronounced, positively affecting industry competitiveness and boosting exports. Shale gas is also one of the major factors fostering a manufacturing renaissance not just in chemicals but in iron and steel, rubber and plastic products, and other industries.

The effect on the industry's output (and jobs) ignores the effects from increased downstream customer industry activity. Lower-cost raw material will foster expansion of this activity. Thus, new investment in the tire, rubber products and plastics products industries (and other industries consumer chemistry) would result in additional demand for chemistry. This would engender chemical industry investment and output in addition to that analyzed in this study. As a result, the likely positive effects on the chemical industry will be much larger.

Appendix 2: List of Companies that have Announced Shale-Related Chemical Industry Investments

The following is a list of chemical companies who have announced projects related to shale gas. We used information from nearly 100 announced projects to drive the analysis in this report. A comprehensive and exhaustive search of the trade literature on chemical industry project announcements was conducted. These were confirmed by examining company press releases and annual reports, security analyst reports, consultant reports, and other publications. The cutoff date was late-March.

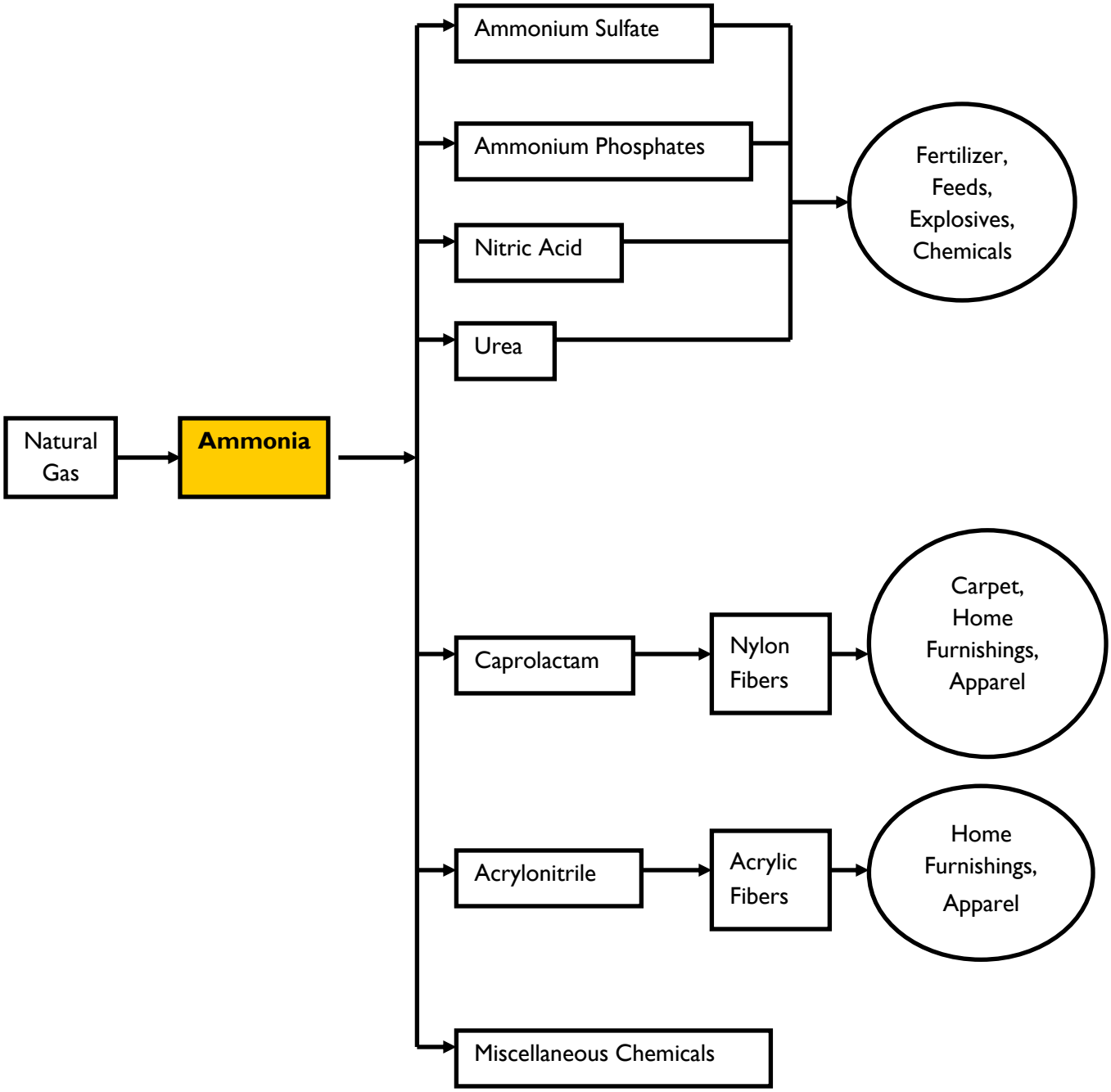
3M
Agrium
Aither Chemicals
Appalachians Resins
Arkema
Ascend Performance Materials
BASF
Bayer Material Science
BioNitrogen
Braskem
C3 Petrochemicals
Celanese
CF Industries
Chevron Phillips
CHS
Cytec Industries
Dow Chemical
Dow/Mitsui JV
DuPont
Dyno Nobel
Eastman Chemical
Enterprise Products
Evonik Industries
ExxonMobil Chemical
Flow Polymers LLC
Formosa
G2X Energy
Georgia Gulf
Grupo Missi & Ghisolfi
Honeywell Specialty Materials
Hanwha Chemical
Huntsman Chemical
ICL Industrial Products
Indorama Ventures
INEOS
Invista
Koch Industries
Kuraray Americas
LANXESS
Lubrizol
LyondellBasell
MEGlobal
Mexichem/Oxychem
Methanex
Mitsui & Co.
Mitsui Chemicals
Mitsui Chemicals Prime Polymer Co. Ltd. JV
Noltex
Occidental Chemical
Ohio Valley Resources
Orascom Construction Industries
PCS Nitrogen
PetroLogistics
PTT Global Chemical
Renetch
SABIC
Sasol
Shell Chemical
Shintech
Solvay
South Louisiana Methanol – a partnership of ZEEP and Todd Corp
US Nitrogen
TPC Group
Westlake Chemical
Williams

Appendix 3: Detailed Results from IMPLAN Modeling of Increased Chemical Industry Output in 2020

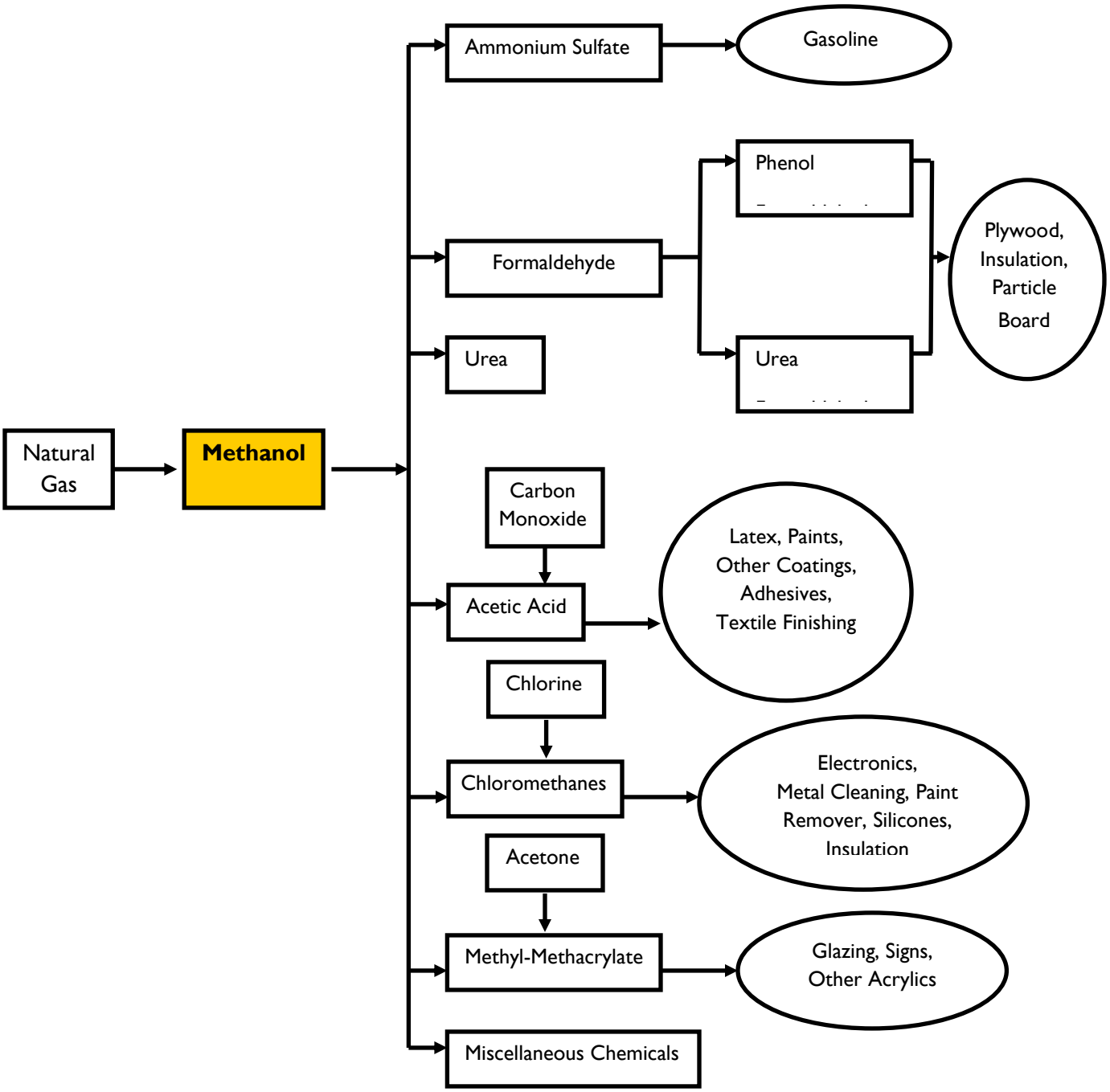
	Direct	Indirect	Payroll-Induced	Total
Agriculture	**-**	**6,011**	**4,325**	**10,336**
Mining & Utilities				
Oil and gas extraction	-	9,768	718	10,486
Natural gas distribution	-	1,743	152	1,895
Electricity generation and distribution	-	2,328	628	2,957
Other mining and utilities	-	3,050	300	3,351
Construction	**-**	**15,005**	**2,831**	**17,837**
Durable Manufacturing				
Primary and fabricated metals	-	7,339	1,041	8,381
Machinery, electrical equipment, and instruments	-	2,802	531	3,333
Computers and electronics	-	1,384	303	1,688
Other durable manufacturing	-	2,390	2,412	4,802
Nondurable Manufacturing				
Petroleum and coal products	-	1,413	118	1,531
Chemicals	46,359	25,902	809	73,070
Other nondurable manufacturing	-	8,931	5,235	14,166
Trade	**-**	**24,866**	**43,670**	**68,536**
Transportation	**-**	**18,546**	**6,575**	**25,121**
Information	**-**	**4,350**	**4,133**	**8,483**
Finance, Insurance and Real Estate	**-**	**16,488**	**29,635**	**46,123**
Services				
Professional and technical services	-	25,737	10,621	36,359
Scientific R&D services	-	15,573	789	16,362
Management of companies	-	19,392	1,908	21,300
Administrative and support services	-	27,039	12,811	39,850
Other services	-	24,052	96,726	120,778
TOTAL JOBS	**46,359**	**264,111**	**226,272**	**536,741**

Appendix 4: Simplified Chemical Value Chains

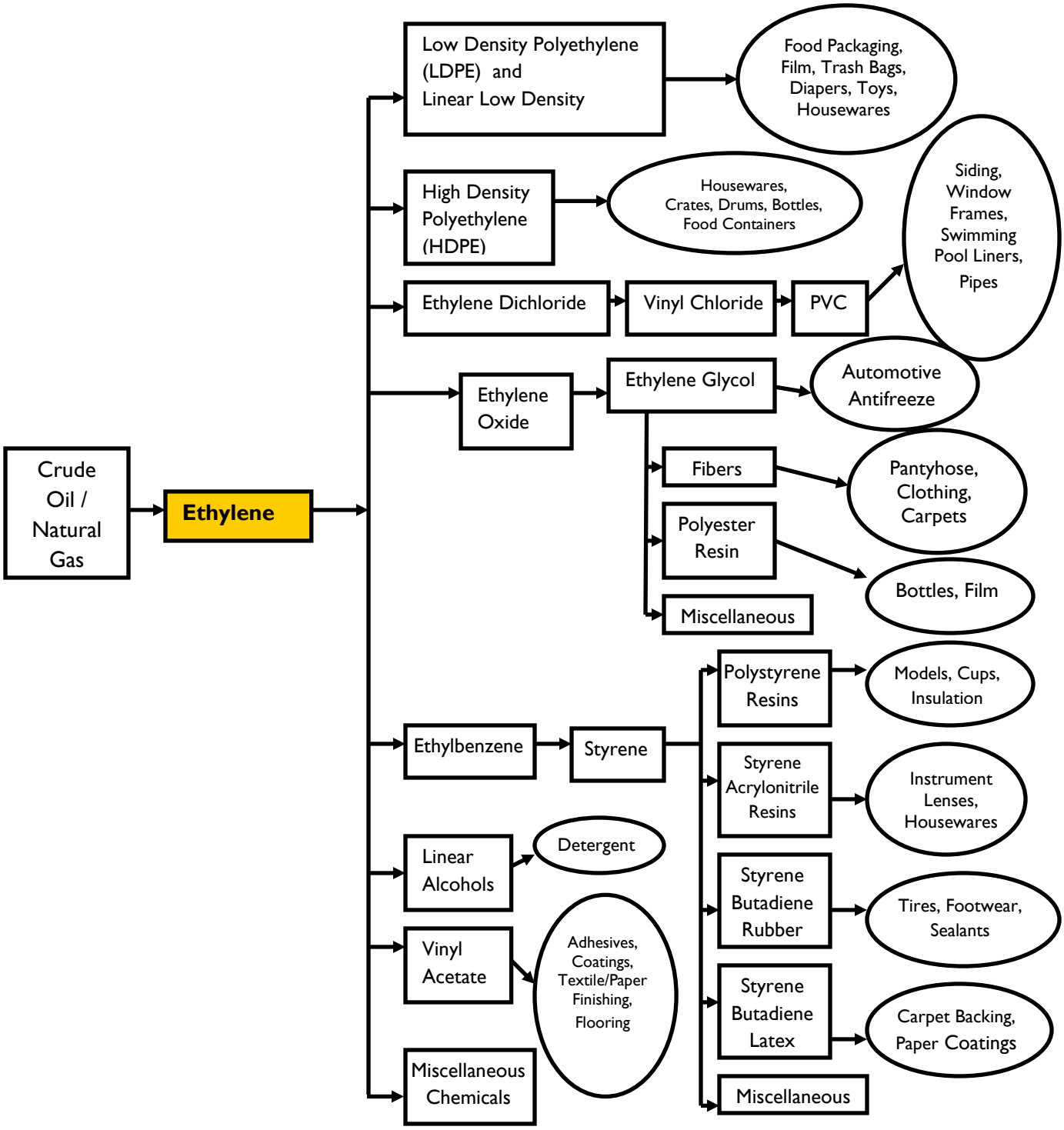
Ammonia



Methanol


Natural Gas
Methanol
Ammonium Sulfate
Gasoline
Formaldehyde
Phenol
Urea
Urea
Plywood, Insulation, Particle Board
Carbon Monoxide
Acetic Acid
Latex, Paints, Other Coatings, Adhesives, Textile Finishing
Chlorine
Chloromethanes
Electronics, Metal Cleaning, Paint Remover, Silicones, Insulation
Acetone
Methyl-Methacrylate
Glazing, Signs, Other Acrylics
Miscellaneous Chemicals

Ethylene


Crude Oil / Natural Gas
Ethylene
Low Density Polyethylene (LDPE) and Linear Low Density
Food Packaging, Film, Trash Bags, Diapers, Toys, Housewares
High Density Polyethylene (HDPE)
Housewares, Crates, Drums, Bottles, Food Containers
Ethylene Dichloride
Vinyl Chloride
PVC
Siding, Window Frames, Swimming Pool Liners, Pipes
Ethylene Oxide
Ethylene Glycol
Automotive Antifreeze
Fibers
Pantyhose, Clothing, Carpets
Polyester Resin
Bottles, Film
Miscellaneous
Ethylbenzene
Styrene
Polystyrene Resins
Models, Cups, Insulation
Styrene Acrylonitrile Resins
Instrument Lenses, Housewares
Styrene Butadiene Rubber
Tires, Footwear, Sealants
Styrene Butadiene Latex
Carpet Backing, Paper Coatings
Miscellaneous
Linear Alcohols
Detergent
Vinyl Acetate
Adhesives, Coatings, Textile/Paper Finishing, Flooring
Miscellaneous Chemicals

Appendix 5: Alternative High Case

The analysis presented above is based on actual projects rather than conjecture. These projects are the direct result of low cost abundant natural gas and NGL feedstocks in the United States. The estimated cumulative capital investment totals $71.7 billion (in 2012 dollars) through 2020. However, there is likely to be additional investment through 2020 that has not yet been announced. To the extent that additional project announcements will be forthcoming, ACC developed a high case scenario where estimated cumulative capital investment totals $82.4 billion (in 2012 dollars) through 2020. As in the base case scenario presented in this report, capital spending also peaks in 2015 but the wave of spending lasts longer.

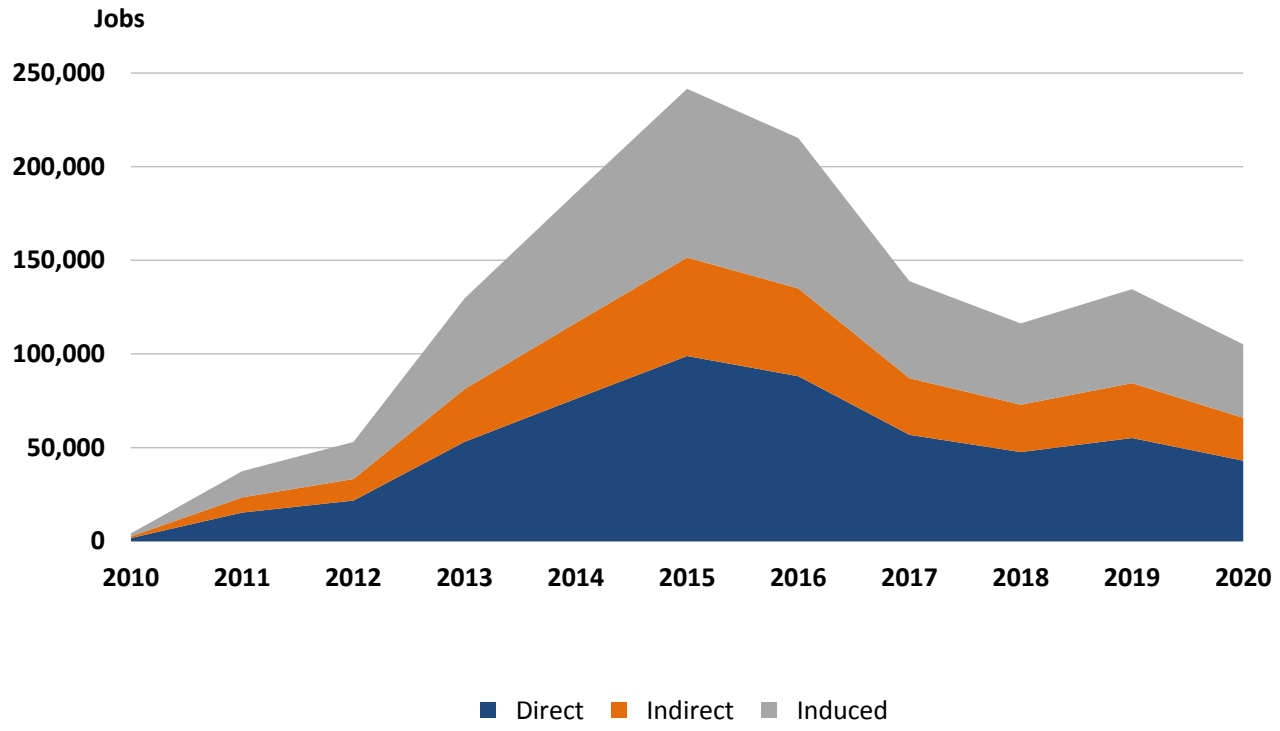
The chemical industry output generated from the $82.4 billion investment will be 10.3% above the baseline in 2020. This represents $76.5 billion (2012 dollars) in additional output at that time. The $76.5 billion in new chemical output would directly generate nearly 53,000 high-paying, desirable jobs in the industry. In addition, the increased competitiveness arising from shale gas and expanded output by the US chemical industry would generate purchases of raw materials, services, and other supplies throughout the supply chain. Thus, through indirect effects, another 302,000 supply chain jobs would be supported by the boost in the output of the chemical industry.

TABLE 1
ECONOMIC IMPACT FROM EXPANDED PRODUCTION OF THE US CHEMICAL INDUSTRY FROM RENEWED COMPETITIVENESS ARISING FROM SHALE GAS, 2020 (HIGH INVESTMENT CASE)

	Employment	Payroll ($ Billion)	Output ($ Billion)
Direct Effect	53,079	$5.6	$76.5
Indirect Effect	302,395	$21.7	$114.9
Induced Effect	259,071	$12.2	$38.8
Total Effect	**614,544**	**$39.4**	**$230.3**

Finally, the wages earned by new workers in the chemical industry and workers throughout the supply chain are spent on household purchases and taxes generating nearly 259,000 payroll-induced jobs generated by the response of the economy to changes in household spending as a result of labor income generated by the direct and indirect effects. All told, the additional $76.5 billion in the output of the chemical industry (from renewed competitiveness of the shale gas revolution) would generate $230 billion in output to the economy and 615,000 jobs in the United States generating a payroll of $39 billion.

FIGURE 1
EMPLOYMENT IMPACT FROM NEW INVESTMENT IN PLANT AND EQUIPMENT BY THE US CHEMICAL INDUSTRY (HIGH INVESTMENT CASE)



In the high case, the $82.4 billion in needed investments would generate an average of 51,000 direct jobs each year, mostly in the construction and capital equipment-producing industries. During 2015, when investment activity is projected to peak, nearly 100,000 direct jobs are created. Over the ten-year period, a total of 557,000 direct jobs are supported by the ethane-advantaged build out of the chemical industry (Appendix Table 2). Further, through supply-chain impacts, chemical industry investment supports an additional 27,000 indirect jobs per year. Thus, a total of 297,000 work-year jobs are supported in supply chain industries. These are jobs in industries that supply materials and services to the companies building new chemical facilities and manufacturing the process equipment. Finally, the payrolls generated by workers throughout the investment supply chain support an additional 46,000 jobs per year on average, largely in local communities. Over the ten-year investment period, a total of 508,000 payroll-induced work-year jobs are supported through the household spending of workers supported directly and indirectly by chemical industry investment. All told, the ten-year $71.7 billion investment in the U.S. chemical industry would support a total of 1.4 million jobs over the ten-year investment wave and $78.0 billion in payrolls.

TABLE 2
ECONOMIC IMPACT FROM CHEMICAL INDUSTRY INVESTMENT 2010-2020 (HIGH INVESTMENT CASE)

	Total Jobs 2010-2020	Average Jobs per Year	Payroll ($ Billion)	Output ($ Billion)
Direct	557,436	50,676	$35.3	$82.4
Indirect	296,547	26,959	$18.8	$64.2
Induced	508,228	46,203	$23.9	$76.1
Total Effect	**1,362,210**	**123,837**	**$78.0**	**$222.8**