The Dow Chemical Company

STATEMENT FOR THE RECORD

COMMITTEE ON ENERGY AND NATURAL RESOURCES

UNITED STATES SENATE

HEARING ON

The Future of Natural Gas

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Submitted by:

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Vice President, Energy and Climate Change

Introduction

The Dow Chemical Company appreciates the opportunity to submit these written comments to the Committee on Energy and Natural Resources.

Dow was founded in Michigan in 1897 and is one of the world's leading manufacturers of chemicals, plastics and advanced materials. We supply more than 3,300 products to customers in approximately 160 countries, connecting chemistry and innovation with the principles of sustainability to help provide everything from fresh water, food, and pharmaceuticals to insulation, paints, packaging, and personal care products. About 21,000 of Dow's 46,000 employees are in the US, and Dow helps provide health benefits to more than 34,000 retirees in the U.S.

Dow is committed to sustainability. We have improved our environmental performance (including on greenhouse gas emissions), and we are committed to do even better in the future. Our ambitious 2015 sustainability goals (http://www.dow.com/sustainability/) underscore this commitment.

Dow is an energy-intensive company. We use energy, primarily naphtha, natural gas and natural gas liquids (such as ethane), as feedstock materials to make a wide array of products essential to our economy and quality of life. We also use energy to drive the chemical reactions necessary to turn our feedstocks into useful products, many of which lead to net energy savings. Dow's global hydrocarbon and energy use amounts to the oil equivalent of 850,000 barrels per day, approximately the daily energy use of Australia.

This testimony describes our views on natural gas supply and demand, and the value-add created by U.S. manufacturers who use natural gas.

Dow believes that natural gas will play a critical role in US energy policy. Because US manufacturing jobs are dependent on the US natural gas market, policies that impact natural gas will have a direct impact on jobs in the US manufacturing sector. We recommend that any natural gas policies carefully consider the need to preserve and enhance the competitiveness of U.S. manufacturers.

Natural Gas Fuels US Manufacturing

Major sectors that use natural gas include the power, manufacturing, residential, commercial, and transportation sectors.

US manufacturers provide the highest value-add of any sector. Using natural gas to make petrochemicals results in *eight times the value* over simply combusting it. This productivity stems from the fact that the chemical industry uses natural gas not just for fuel and power, but also as a raw material or "feedstock."

When natural gas prices are low relative to oil, US chemical manufacturers have a competitive advantage. Recent market activity underscores the favourable climate for US petrochemical industry. When the ratio of oil to gas price is above 7:1, Gulf-Coast-based petrochemicals are more competitive versus the world's other major chemical-producing regions. The current oil-to-gas ratio is very favourable for US competitiveness and increases the exports of petrochemicals, plastics, and other products.

Not only do manufacturers provide the greatest value-add, they are also the most price sensitive. Those sectors in which demand is most sensitive to natural gas prices are termed "price elastic". The more elastic the demand, the more quickly a sector will change its demand for natural gas after a change in price. Inelastic demand occurs when a change in price results in little change in demand.

The industrial sector has the most elastic demand for natural gas. From 1997 to 2008, US industrial gas demand fell 22% as average annual prices rose 167%. Over the same time, demand for power rose 64% (EIA data). The loss in US manufacturing jobs was significant. Indeed, government data show that more than six (6) million jobs were lost in the US manufacturing sector since 1997, and volatile natural gas prices were a significant factor. Change in natural gas price will impact industrial sector demand before that in other sectors. For this reason, we sometimes say that US manufacturers are the "shock absorber" for the US natural gas market. The maintenance of a strong presence of price-sensitive users will help to minimize price volatility in the natural gas market. Government must exercise caution to avoid policies that grow inelastic demand to the detriment of price-sensitive users.

Both price volatility and the "average" price over time have an impact on the industrial sector. Therefore, policymakers should carefully consider the impact of proposed policies on natural gas price and the competitiveness of the US manufacturing sector.

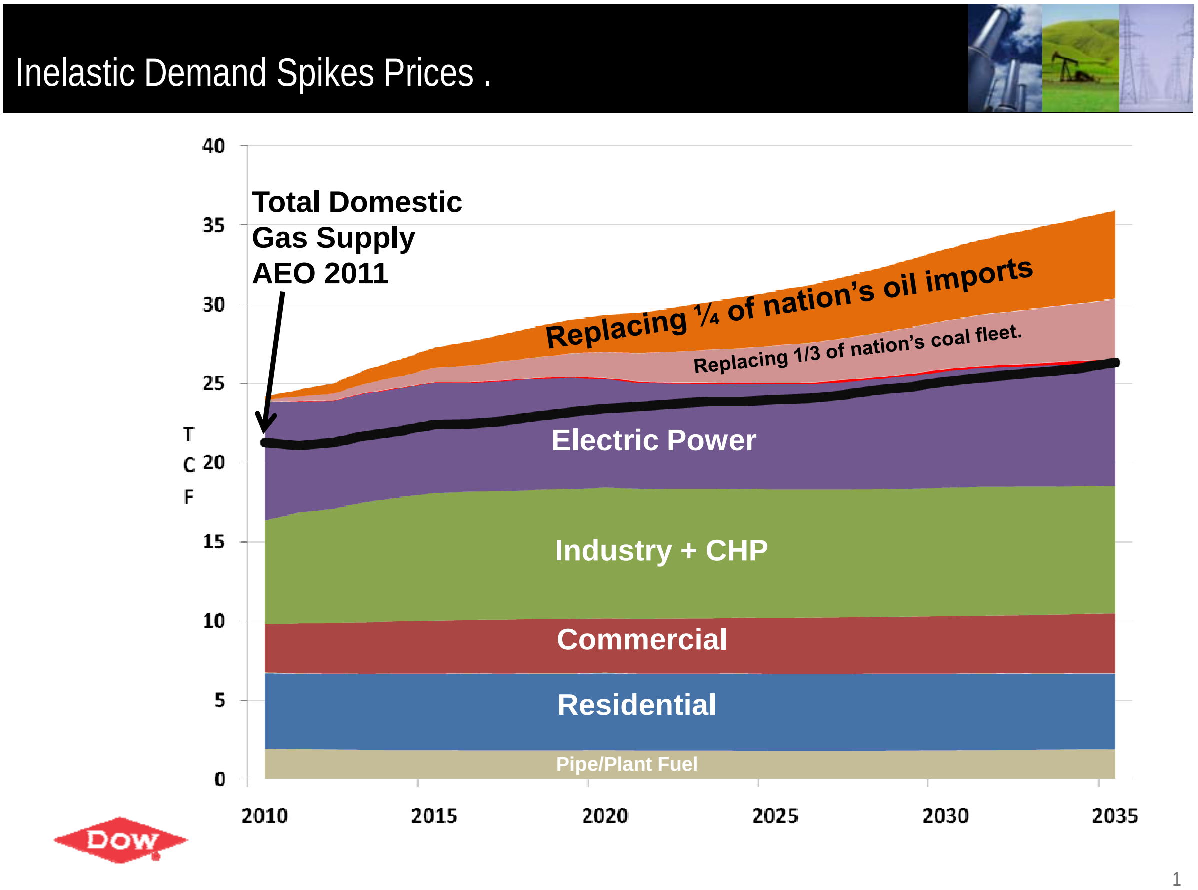
As the figure illustrates, the potential exists for demand to outstrip supply, assuming that fuel switching from coal to gas continues to accelerate and factoring in the proposals by some to displace 25% of our oil imports with natural gas.

Unconventional Natural Gas

The recent MIT report, *The Future of Natural Gas*, confirms that the US has an abundant supply of natural gas, much of it available at an affordable price.

According to this report, the supply of natural gas is changing, as new production of unconventional gas compensate for declining reserves of conventional gas (e.g., five shale plays in the US could see a five-fold growth in production). New supplies are critical as demand for natural gas is growing in every sector of the economy, especially power generation.

The report also concludes that the current supply outlook will contribute to greater competitiveness of US manufacturing, and specifically describes how new sources of natural gas and natural gas liquids are changing the economic competitiveness of the chemical industry, leading to new investments (and job creation).



Dow is in general agreement with the report. For example, the report portrays an appropriate level of cautious optimism. It says: "While the pace of shale technology development has been very rapid over the past few years, there are still many scientific and technological challenges to overcome before we can be confident that this very large resource base is being developed in an optimal manner."

Dow has concerns, however, with two of the report's recommendations. While the study does not openly call for government subsidies for natural gas vehicles, it does call for the government to revise its policies related to CNG vehicles in order to lower up-front costs of such vehicles and the necessary infrastructure. The study also does not recognize another fact: Electric vehicles are three times more efficient than natural gas vehicles. In addition, the infrastructure for an overnight, low-voltage charging infrastructure already exists – our power grid – and it is cheaper to scale up.

The second disagreement relates to the development of an efficient and integrated global gas market. It states, "Greater international market liquidity would be beneficial to U.S. interests. U.S. prices for natural gas would be lower than under current regional markets, leading to more gas use in the U.S." It is hard to understand how this can be. The U.S. has very competitive natural gas prices and exposing it to the rest of the world, where prices are linked to oil price, will not lower domestic prices. In our view, a global market will raise US prices which will be bad for competitiveness of all US energy intensive industries including chemicals. If the US were to begin exporting natural gas, the world market would equilibrate to one world price (with transportation cost differences) which would bring lower prices outside the US and higher prices for US consumers.

The study also offers some acceptable recommendations but in doing so calls for unacceptable policy. One recommendation reads, "In the absence of such policy, interim energy policies should attempt to replicate as closely as possible the major consequences of a 'level playing field' approach to carbon-emission reduction. At least for the near term, that would entail facilitating energy demand reduction and displacement of some coal generation with natural gas." We would have no problem with the first part of that statement, but do not see the need for facilitating displacement of coal with natural gas. It is our belief that market and regulatory forces will naturally move it in that direction.

EIA data shows that since 2000, the vast majority of new power plants constructed use natural gas. When setting policy, it is important to note that homeowners, farmers, and the industrial sector are all dependent upon the use of natural gas, and do not have economic alternatives. At the same time, the electric power generation and transportation markets do have alternative sources of energy. Policy that increases demand for natural gas without ensuring that there is available supply can increase the price of natural gas and electricity for all home-owners, farmers and the industrial sector.

In the recommendation to "set a CO_2 price for all fuels," there is no discussion about the negative impact on energy-intensive trade exposed industries. These increased energy costs would not be absorbed by offshore competitors and thus would give them a competitive advantage, endangering U.S. jobs.

Another claim of the report is questionable: "Displacement of coal-fired power by gas-fired power over the next 25 to 30 years is the most cost-effective way of reducing CO_2 emissions in the power sector." We would argue that demand reduction via energy efficiency is at least as important in cost effectively reducing CO_2 emissions in the power sector and should preferably be pursued prior to any effort to displace coal-fired power by gas. While the study considers the impact of natural gas on the government objective of environmental protection, it also needs to consider the impact that any policies will have on the equally important objectives of economic growth and national security. The above recommendation will likely increase natural gas prices, which will reduce the competitiveness of U.S. industries.

Finally, the study noticeably lacks any recommendations for a streamlined, timely process for exploration and production permitting to ensure access to supply despite the report stating "a robust domestic market for natural gas and NGLs will improve competitiveness of manufacturing industries dependent on these inputs." In our view, it is imperative that increased demand not precede increased supply. Access to offshore natural gas and crude oil is essential for U.S. energy security. Political and regulatory uncertainty threatens to significantly reduce the amount of natural gas that can be extracted. These issues, including regulations around the use of hydraulic fracturing, must be resolved for companies to invest capital in the U.S. based on the new natural gas discoveries.

A Potential Renaissance for US Chemical Manufacturers

What does the promise of increased domestic supply of natural gas mean to US manufacturers? We believe an increase in the natural gas resource base, especially ethane-rich gas such as that in the Marcellus and Eagle Ford regions, could be a "game changer" for US manufacturers.

The American Chemistry Council (ACC) recently evaluated the impact of a 25% increase in the US ethane supply from shale gas. Such an increase in ethane supply would generate

- 17,000 new jobs in the US chemical industry
- $32 billion increase in US chemical production,
- $16 billion in new capital investment in the chemical industry,
- 395,000 new jobs outside the chemical industry, including 165,000 jobs in supplier industries, and 230,000 jobs from new capital investment by the chemical industry.

This would generate an increase in US economic output of $132 billion per year, and raise $4.5 billion per year in additional annual tax revenue for federal, state, and local governments.

ACC is careful to acknowledge that a reasonable regulatory regime will facilitate shale gas development, but the wrong policy initiatives (e.g., state moratoria on shale gas development, and other policies that artificially increase demand) could derail recovery, economic expansion, and job creation.

The full ACC report is contained in the Appendix to this testimony.

Environmental Issues

Legitimate concerns have been raised about the use of hydraulic fracturing (also known as hydrofracking or fracking) to access unconventional gas reserves.

Dow believes that, if done in a safe and effective manner, hydraulic fracturing poses little threat to the environment and is essential for the production of natural gas from shale formations.

As conventional sources of natural gas in the US decline, shale gas will play a vital role in the nation's energy demand over the next decades.

Dow produces products used in association with hydraulic fracturing, such as biocides for microbial control to ensure gas can escape through the fractures. Our biocide products are registered with EPA and with each state where the material will be used. The stringent regulatory requirements are supported by detailed toxicological and environmental fate data which allows selection of proper materials for the given application and region.

In addition to biocides, Dow also produces other products used in hydraulic fracturing. Dow has committed to publishing health information for all of our products and to make this information available on our public website.

Chemicals in the hydrofracking process make up less than 1% of the fluids used. Federal law currently requires companies to report the hazards of components present in formulations >0.1% or >1% depending on the nature of the hazards. The law further requires that this hazard information is available to employees via Material Safety Data Sheets at all worksites.

Dow supports transparency with respect to chemical hazards as a principal component to ensure worker and environmental safety. We promote progressive chemicals management policies and best practices worldwide through voluntary standards such as Responsible Care®. We believe that disclosure of chemical identity should be pursued to the extent possible without compromising true trade secret information, while fully characterizing the hazards of the individual components or formulated product to alleviate concerns about the risk to human health and the environment.

As this debate further develops, we will share chemicals management best practices and provide our feedback on targeted regulations in development to preserve the economical production of energy from unconventional gas resources. Domestic oil and gas production is a necessary part of a balanced energy policy.

U.S. Energy Policy and Natural Gas

Dow has developed an advanced manufacturing plan to promote a competitive manufacturing sector. The plan includes policy recommendations in eight areas, ranging from trade and education to health care and tax policy. It also calls for a comprehensive energy policy, which has four pillars: (1) aggressive pursuit of energy efficiency and conservation; (2) increasing, diversifying, and optimizing domestic hydrocarbon energy and feedstock supply; (3) accelerating development of alternative and renewable energy and feedstock sources; and (4) transitioning to a low-carbon economy.

Natural gas plays a key role in these recommendations. In particular, Dow supports policies to increase domestic production of natural gas in an environmentally responsible manner, including conventional and unconventional natural gas.

According to the Department of the Interior, there are 93 million barrels of oil and 456 trillion cubic feet of natural gas offshore on our nation's Outer Continental Shelf (OCS). These are domestic supplies that can be produced with state-of-the-art techniques that ensure environmentally responsible production, while greatly enhancing our nation's energy and feedstock security. Dow has consistently and persistently supported expanded access to OCS resources.

One way to maximize the transformational value of increased oil and gas production in the OCS is to share the royalty revenue with coastal states and use the federal share to help fund research, development and deployment in such areas as energy efficiency and renewable energy**.** Production of oil and gas on federal lands has brought billions of dollars of revenue into state and federal treasuries. Expanding access could put billions of additional dollars into state and federal budgets.

Dow also believes natural gas can play a role in transitioning to a low-carbon economy. In a much-cited study, Princeton scientists Socolow and Pacala identified 14 specific solutions, each with the potential to reduce one (1) gigaton of carbon dioxide. One of these solutions was fuel switching from coal to natural gas in the generation of electricity. Such fuel switching has been an ongoing trend in recent years, due in part to a downward trend in the price of natural gas. For several reasons, this trend is likely to continue, especially as pressure builds to retire the oldest coal-fired power plants. However, great caution must be taken if the government advances policies to make this transition more abrupt.

Natural gas – including unconventional gas – is a critical component of a balanced US energy policy. The key is to ensure alignment between supply and demand, and to avoid shocks to the market from unwise government policy. The remainder of this section addresses some of these important policy issues: inclusion of natural gas through imposition of a federal Clean Energy Standard (CES), EPA regulations affecting coal-fired power, and tax incentives for natural gas vehicles. Each poses a challenge to US manufacturing.

<u>Clean Energy Standard (CES)</u>

In his last State of the Union address, the President has called for "efficient natural gas" to be included in the mix of clean energy technologies that would receive credit under a clean energy standard (CES). We recommend a significant and critical review of such a proposal.

Dow remains concerned about the potential for natural gas volatility that is damaging to the manufacturing sector. At a time when there continues to be debate about access to domestic natural gas supplies, Congress and the Administration must exercise extreme caution in pursing policies that encourage fuel switching from coal to natural gas in the power sector, which is already happening in the absence of government incentives. In this regard, we note that the Bipartisan Policy Center, in a landmark study of natural gas volatility, has made the same recommendation:

> Government policy at the federal, state and municipal level should encourage and facilitate the development of domestic natural gas resources, subject to appropriate environmental safeguards. Balanced fiscal and regulatory policies will enable an increased supply of natural gas to be brought to market at more stable prices. Conversely, policies that discourage the development of domestic natural gas resources, that discourage demand, or that drive or mandate inelastic demand will disrupt the supply-demand balance, with adverse effects on the stability of natural gas prices and investment decisions by energy-intensive manufacturers.

<u>EPA Regulations Affecting Coal-Fired Power</u>

The government-imposed shocks we worry about most relate to fuel switching: (1) from coal to natural gas in the power sector due to EPA regulation and (2) from gasoline to natural gas in the transportation sector due to government incentives for natural gas vehicles.

EPA is developing several major regulations (e.g., the recently finalized "transport" rule and the proposed utility MACT) that will increase the cost of operating coal-fired power plants, thus providing an added incentive for the retirement of such plants and the construction of replacement generation capacity. This replacement generation is likely to come from natural gas. Dow believes it would be most prudent to ensure a reasonable transition time for the retirement of the oldest coal-fired power plants. The more uncertain the regulatory environment, the more likely the transition will be abrupt, which could alter the demand-supply balance so critical to US manufacturers.

<u>Incentives for Natural Gas Vehicles</u>

Congress is contemplating tax incentives for natural gas vehicles. The goal, as noted by proponent T. Boone Pickens, is to replace 25% of our oil-based transportation fuel with domestically produced natural gas.

Dow and the chemical industry are opposed to such incentives because of the upward pressure they will impose on natural gas demand. Data from the Energy Information Agency suggests such a move, in combination with expected fuel switching in the power sector, will most certainly lead to a situation where demand will outpace supply, with a detrimental effect on US manufacturing. History suggests that such supply-demand imbalances result in demand destruction for US manufacturers.

This latest push to promote natural gas vehicles raises legitimate questions about the incoherent signals that policymakers are sending to the transportation sector. Daniel Yergin recently described the situation. "Could natural gas also be a game changer for transportation? That is much more of a challenge. Automakers and the fuel-supply industry are already dealing with a multitude of imperatives—more fuel efficient cars, more bio-fuels, plug-in hybrid electric vehicles, pure electric vehicles. Making a push for natural gas vehicles would add yet another set of mandates and incentives, including the creation of a costly new fueling infrastructure." As Congress considers the appropriate incentives to advance energy security, it should keep in mind that electric vehicles are 3X more efficient than natural gas vehicles.

A recent Ernst & Young analysis concluded that H.R.1380, the Natural Gas Act, which would provide tax incentives for natural gas vehicles, would be a costly investment. The budget impact is approximately $3 billion over five years, $10 billion over ten years, and a whopping $135,000 per vehicle, a high figure driven largely by the need for substantial infrastructure to support the natural gas vehicle market.

We would also like to note that substantial investment is being made to promote natural gas vehicles in the absence of additional government incentives. Chesapeake Energy recently announced its intention to invest in natural gas vehicles in the absence of government incentives.

Conclusions

We would like the Members of the Committee to remember five major points from this testimony.

1. US manufacturers provide the highest value-add of any natural gas consumer. Every dollar the U.S. chemical industry spends on natural gas as a raw material creates $8 of added value throughout the economy. This creates a "chain reaction" for our economy and it means jobs.
2. Unconventional gas could be a game-changer for US manufacturers, especially as a source of competitively priced feedstock.
3. Production of unconventional gas, through the technique of hydraulic fracturing can and should be done in an environmentally responsible manner.
4. Natural gas is a critical component of a balanced US energy policy. The key is to ensure alignment between supply and demand, and to avoid shocks to the market from unwise government policy that restricts supply while artificially increasing demand in the power and transportation sectors.
5. A comprehensive and sustainable national energy policy is long overdue. Absent such a policy we are in danger of repeating an over-reliance on natural gas and a return to the price volatility that destroyed American manufacturing jobs in the last decade.

APPENDIX: ACC Study on Shale Gas

Shale Gas and New Petrochemicals Investment: Benefits for the Economy, Jobs, and US Manufacturing

Economics & Statistics
American Chemistry Council

March 2011

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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.

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 a "game changer," creating a competitive advantage for U.S. petrochemical manufacturers, leading to greater U.S. investment and industry growth.

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 U.S. 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 U.S. natural gas prices and create a more stable supply of natural gas and ethane.

In its new report, *Shale Gas and New Petrochemicals Investment: Benefits for the Economy, Jobs and US Manufacturing*, the American Chemistry Council (ACC) uncovered a tremendous opportunity for shale gas to strengthen U.S. manufacturing, boost economic output and create jobs.

ACC analyzed the impact of a hypothetical, but realistic 25 percent increase in ethane supply on growth in the petrochemical sector. It found that the increase would generate:

- 17,000 new knowledge-intensive, high-paying jobs in the U.S. chemical industry
- 395,000 additional jobs outside the chemical industry (165,000 jobs in other industries that are related to the increase in U.S. chemical production and 230,000 jobs from new capital investment by the chemical industry)
- $4.4 billion more in federal, state, and local tax revenue, annually ($43.9 billion over 10 years)
- A $32.8 billion increase in U.S. chemical production
- $16.2 billion in capital investment by the chemical industry to build new petrochemical and derivatives capacity
- $132.4 billion in U.S. economic output ($83.4 billion related to increased chemical production (including additional supplier and induced impacts) plus $49.0 billion related to capital investment by the U.S. chemical industry)

The scenario outlined in ACC's report is corroborated by trends in the chemical industry. ACC member companies, including The Dow Chemical Company, Shell Chemical, LyondellBasell, Bayer MaterialScience and others have announced new investments in U.S. petrochemical capacity to benefit from available resources and grow their chemical businesses. Some of these investments are being made in areas of the country that have been hardest-hit by declines in manufacturing, improving the outlook in economically depressed areas of the country. Further development of the nation's shale gas and ethane can drive an even greater expansion in domestic petrochemical capacity, provided that policymakers avoid unreasonable restrictions on supply.

ACC supports a comprehensive energy policy that promotes energy efficiency and conservation, energy diversity, and expanded domestic oil and natural gas supply, onshore and offshore. 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.

Introduction

This report presents the results of the analysis conducted to quantify the economic impact of the additional production of petrochemicals and downstream chemical products stimulated by an increase in ethane availability. With the development of new shale gas resources, the US petrochemical industry is announcing significant expansions of petrochemical capacity, reversing a decade-long decline. The petrochemical industry is unique in that it consumes energy as a raw material in addition to using energy for fuel and power. With vast new supplies of natural gas liquids from largely untapped shale gas resources, including the Marcellus along the Appalachian mountain chain, a new competitive advantage is emerging for US petrochemical producers. At a time when the United States is facing persistent high unemployment and the loss of high paying manufacturing jobs, these new resources provide an opportunity for new jobs in the petrochemical sector.

This report assumes a one-time $16.2 billion private investment over several years in new plant and equipment for manufacturing petrochemicals[1]. This investment will create jobs and additional output in other sectors of the economy and also will lead to a 25% increase in US petrochemicals capacity and $32.9 billion in additional chemical industry output. In addition to direct effects, indirect and induced effects from these added outputs will lead to an additional $50.6 billion gain elsewhere in the economy. It will create more than 17,000 jobs directly in the chemical industry. These are knowledge-intensive, high-paying jobs, the type of manufacturing jobs that policy-makers would welcome in this economy. In addition to chemical industry jobs, another 165,000 jobs would be created elsewhere in the economy from this chemical industry investment, totaling more than 182,000 jobs. The added jobs created and further output in turn would lead to a gain in federal, state and local tax collections, about $4.4 billion per year, or $43.9 billion over 10 years.

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

The scenario analyzed in this paper that considers a 25% increase in ethane is not merely a thought exercise. New investments in petrochemical capacity to utilize this resource advantage are already being made by chemical companies. The assumptions are reasonable and are consistent with public announcements by companies such as Dow Chemical, Shell Chemical, LyondellBasell and Bayer MaterialScience among others.

In addition to providing a productive and job-creating outlet for increased ethane supplies, the development of additional cracking capacity has the indirect effect of supporting natural gas development. Because of the recent development of gas from shale formations, the

[1] The $16.2 billion capital investment by the chemical industry is based on historical capital-output ratios developed from data from the Census Bureau.

additional supply has pushed down the price of natural gas. Natural gas is an important fuel for home heating and is a vital input to many US manufacturers. Lower natural gas prices, however, also lower the return on investment for shale gas producers. Some shale gas formations, including the Eagle Ford and parts of the Marcellus are rich in natural gas liquids. By providing a market for the co-produced natural gas liquids, ethane in particular, shale gas production remains economic.

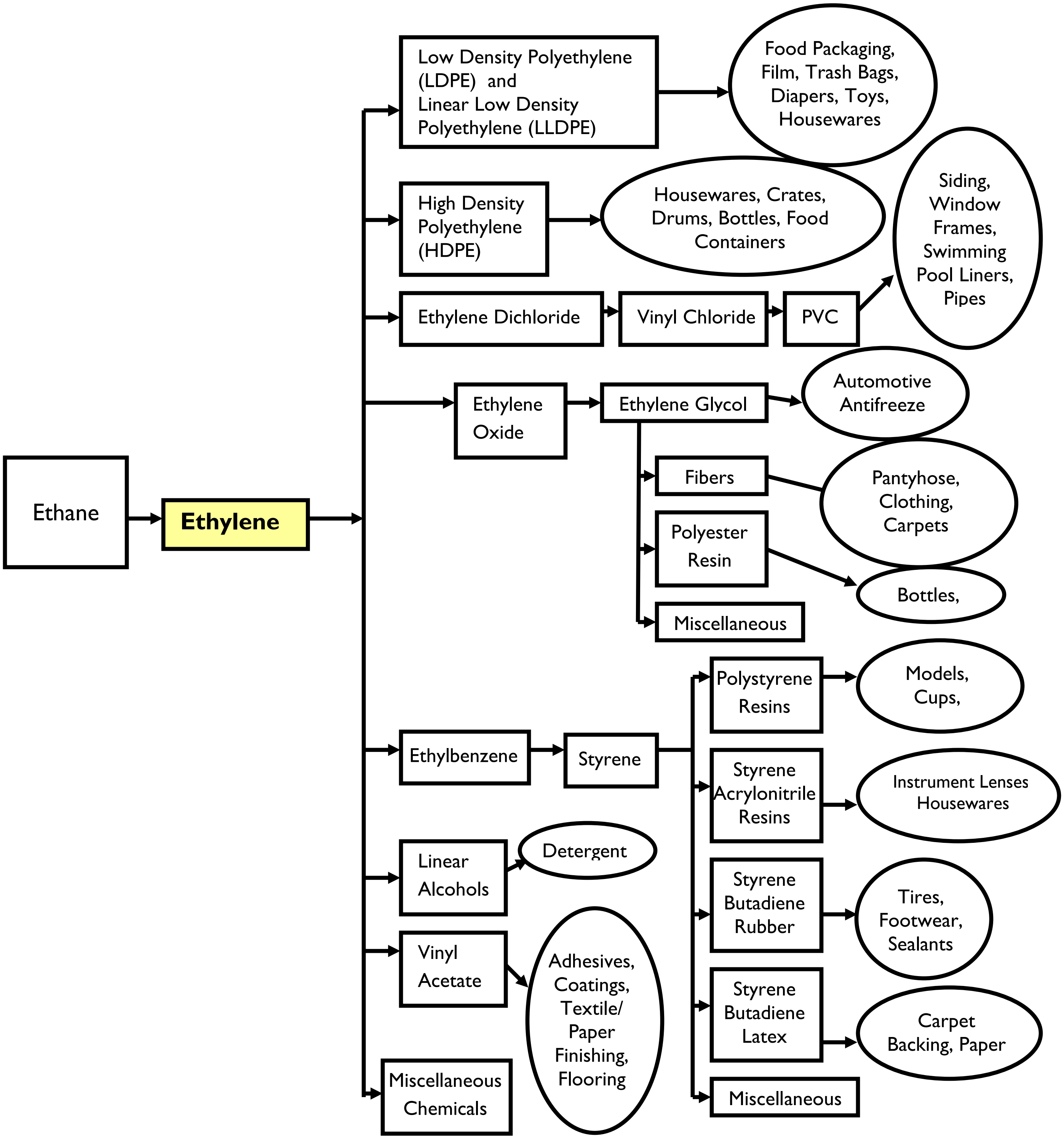
Energy Use and the Chemical Industry

The business of chemistry 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.

Figure 1 illustrates the ethylene supply chain from ethane feedstock through petrochemical intermediates and final end use products.

Figure 1: A Simplified Ethylene Flow Chart



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.

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 more widely used as a fuel. Butane is another NGL feedstock.

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, 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. 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 and ammonia. Olefins, aromatics and methanol are generally referred to as primary petrochemicals, and are the chemical starting point for plastics, pharmaceuticals, electronic materials, fertilizers, and thousands of other products that improve the lives of a growing population.

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. To illustrate how ethylene is used in the economy, a simplified flow chart is presented in Figure 1. While propane has additional non-feedstock uses, the primary use for ethane is to produce petrochemicals;, in particular, ethylene. Thus, if the ethane supply in the US increases by 25%, it is reasonable to assume that, all things being equal, ethylene supply will also increase by 25%.

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.

This report presents the results of an analysis that quantified the economic impact of the additional production of petrochemicals and downstream chemical products. The report also examines the economic impact of the investment in new plant and equipment needed to enable the petrochemical and derivatives sectors to take advantage of the increased ethane supply. Because the focus of this analysis is the impact of a 25% increase in ethane availability, this analysis does not capture any additional activity that could be generated if methanol and ammonia production were to return or increase to prior levels due to the increased availability of natural gas.

Increased ethane production is already occurring as gas processors build the infrastructure to process and distribute production from shale gas formations. According to the Energy Information Administration (EIA), ethane supply has already grown by roughly 20%. 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. In 2010, exports in basic chemicals and plastics were up 28% from 2009. The trade surplus in basic chemicals and plastic surged to a record $16.4 billion.

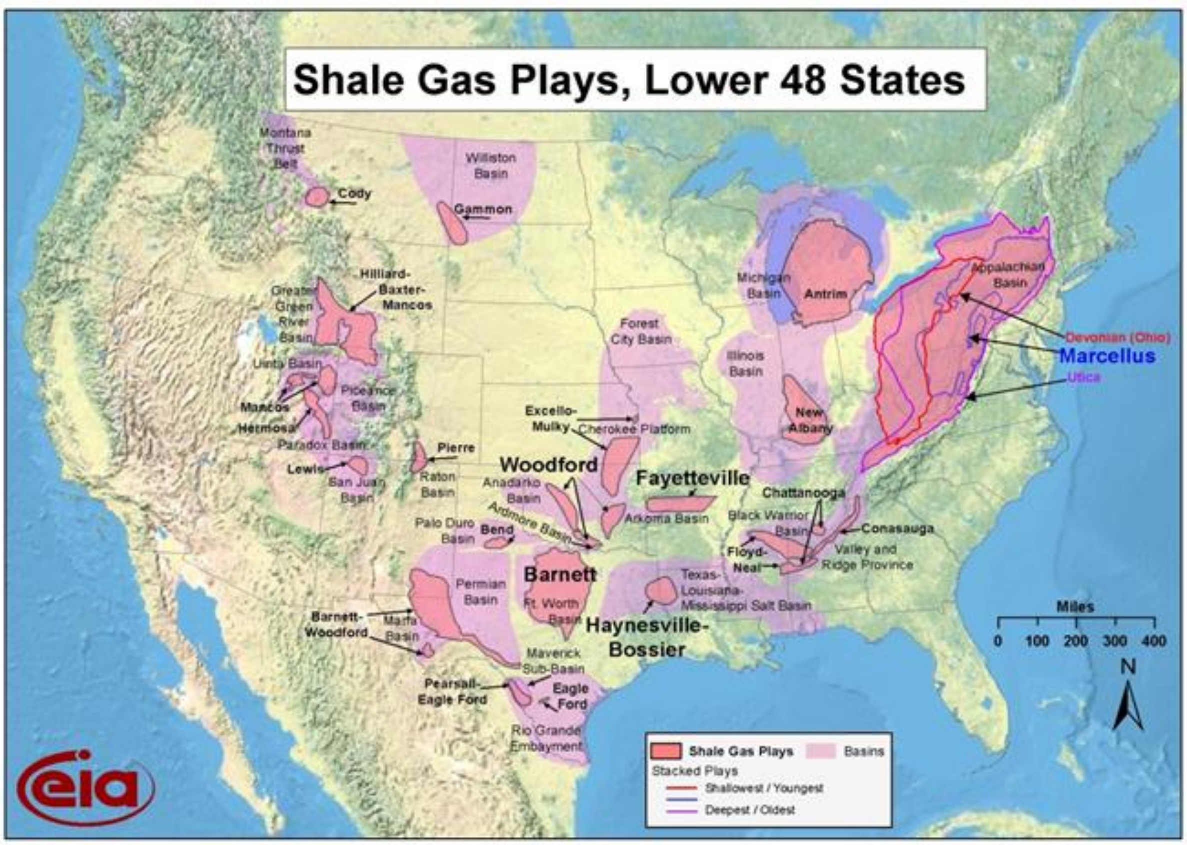
The Development of Shale Gas

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. Rising 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 2 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 existing technology at the time. It should be noted, however, that uneconomic resources often become marketable assets as a result of technological innovation, and shale gas is a prime example.

Figure 2: Shale Gas Resources

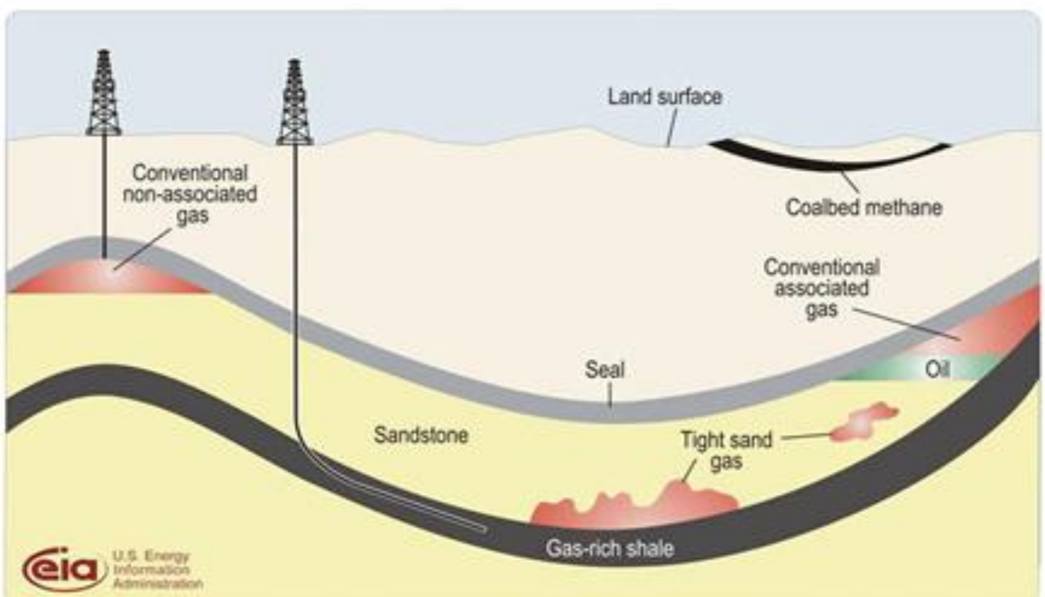


Source: Energy Information Administration based on data from various published studies.
Updated: March 10, 2010

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 2,000-6,000 feet.

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 3 illustrates these technologies. Another important technology is multi-seismology that allows a more accurate view of potential shale gas deposits.

Figure 3: Geology of Shale Gas and Conventional Natural Gas



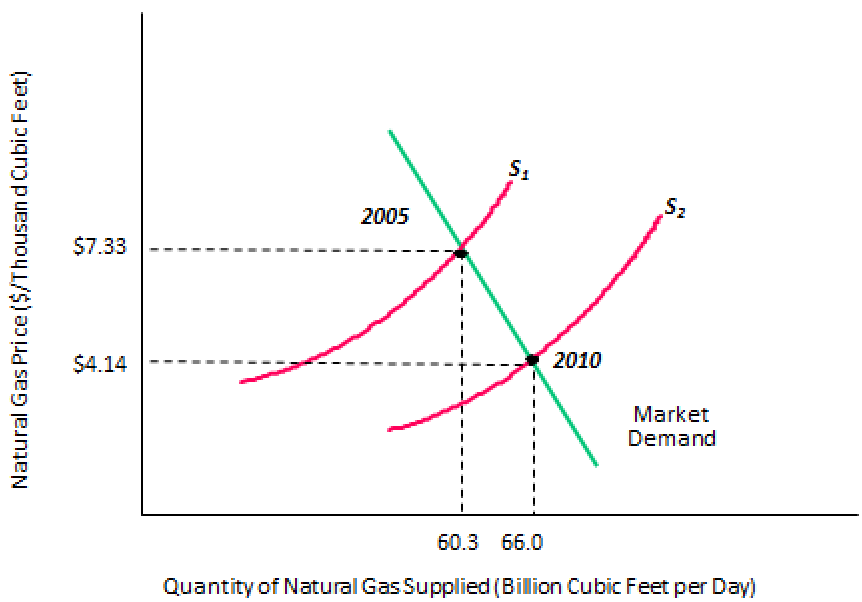
With these innovations in natural gas drilling and production, the productivity and profitability of extracting natural gas from shale deposits became possible. Further, unlike traditional associated and non-associated gas deposits that are discrete in nature, shale gas often occurs in continuous formations. 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 are more closely analogous to manufacturing operations than traditional oil and gas exploration, development and production.

The United States is now estimated to possess 2,552 trillion cubic feet (TCF) of natural gas reserves, 32% of which is shale gas (827 TCF) that no one knew how to extract economically as recently as five years ago. This translates into an additional supply of 36 years at current rates of consumption of about 23 TCF per year. Total US natural gas resources are estimated to be large enough to supply over 100 years of demand. In less than two years, the US has sharply reduced gas imports from Canada and liquefied natural gas (LNG) receipts. These new technical discoveries have vastly expanded reserves and will offset declines in conventional associated natural gas production.

To date, the Barnett, Haynesville, and Woodford basins have received the most attention. But not all shale gas formations are identical: some have little or no NGLs. Haynesville is reported to be mostly dry, while Barnet has dry and rich NGL regions. The Eagle Ford shale formation in Texas is close to the existing petrochemical industry and infrastructure and portions are reported to be rich in ethane and other NGLs. The liquids content adds another layer of complexity and economic attractiveness to the shale gas growth story. More recently, the Marcellus basin (by some estimates the largest known shale deposit in the world) has witnessed significant development. Portions of this formation are rich in NGLs but at a distance from the Gulf Coast where much of the existing petrochemical industry exists. Significant development of infrastructure (pipelines, ethane recovery, etc.) would be needed and could also include investment in petrochemical and derivatives capacity. Thus, areas in western Pennsylvania, New York and/or West Virginia could become the next US petrochemical hub. The governor of West Virginia, for example, has recently formed the Marcellus to Manufacturing Task Force to harness business opportunities surrounding development of the Marcellus basin. In addition, the Eagle Ford shale formation in Texas is close in location to the US petrochemical industry (and infrastructure) in the Gulf Coast and reported to be rich in ethane and other NGLs. Better returns from extracting and marketing liquids could provide an added incentive for shale investment beyond profits arising from the thermal value of natural gas from shale deposits.

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. The latter technologies allowed extraction of shale gas at about $7.00 per thousand cubic feet, which was well below prices of natural gas during the time just after the hurricanes. With new economic viability, natural gas producers responded by drilling, setting off a “shale gas rush”, and 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. 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 shifted to the right, resulting in lower prices and greater availability. During this same time, 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, a recovery of gas-consuming industries and prices occurred. Average daily consumption rose to 66.0 BCF and prices strengthened to $4.14 per thousand cubic feet. Figure 4 illustrates how this new technology's entrance into the market pushed prices lower and expanded supply.

Figure 4: The Advent of Shale Gas Resulted in More, Less Costly Supply of Natural Gas



Source: EIA

The results of the shift in North American natural gas markets have had the positive effect of lowering prices and expanding supply. Shale gas is thus a "game changer". In the decades to come, shale gas could provide 25% of US natural gas needs, compared to 8% in 2008. The availability of this low priced natural gas (and ethane) could improve US chemical and other industry competitiveness. A number of other leading industries, including aluminum, cement, iron and steel, glass, and paper, are large consumers of natural gas that also would benefit from shale gas developments and could conceivably boost capital investments and output.

With rising population and incomes, as well as increased economic activity and regulations, promoting natural gas use in electricity generation would tend to shift the demand curve to the right and move it up along the supply curve. This could partially offset some of the positive gains achieved during the past five years, although further technological developments in drilling and fracturing could spur even more abundant economic resources.

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, but there are some policy risks. Some public concern, however, has been raised regarding hydraulic fracturing due to the large volumes of water and potential contamination of underground aquifers used for drinking water, although fracking 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. We support state-level oversight of hydraulic fracturing, as state governments have the knowledge and experience to oversee hydraulic fracturing in their jurisdictions. We are committed to transparency regarding the disclosure of the chemical ingredients of hydraulic fracturing solutions, subject to the protection of proprietary information.

Shale Gas and Industry Competitiveness

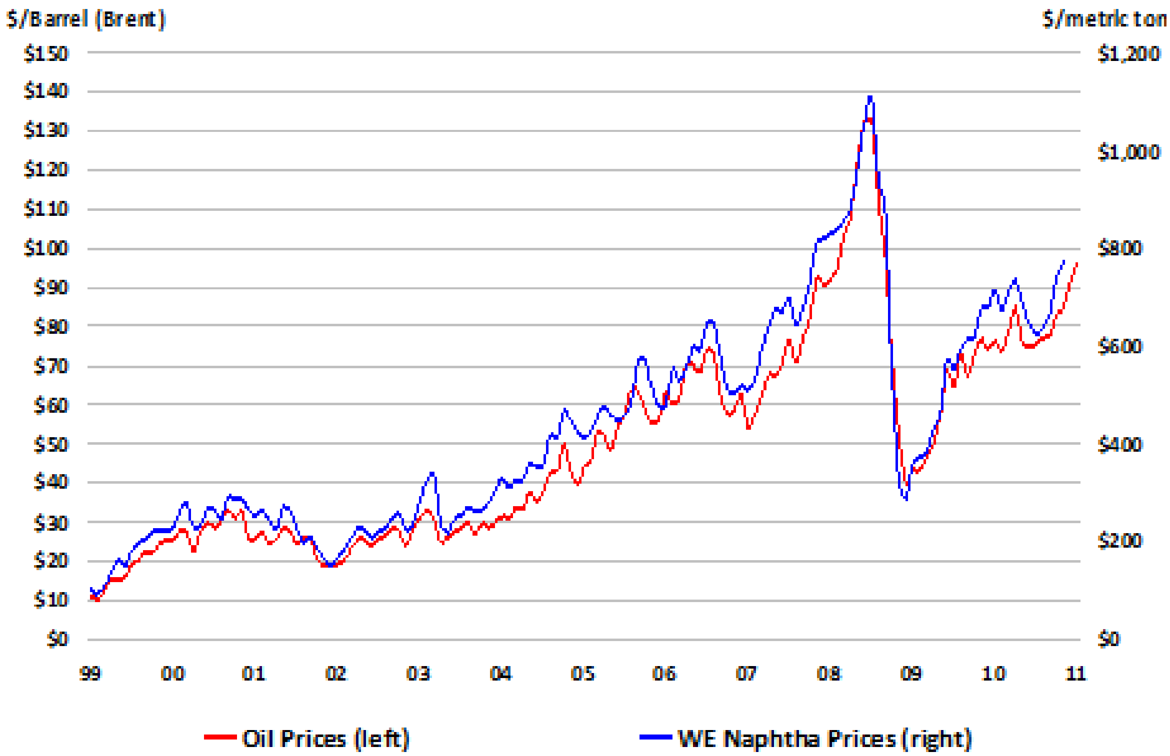
The developments in shale gas will engender the wider availability of low cost, domestic energy. Because US petrochemicals predominantly use ethane and other natural gas liquids, the competitiveness of the industry is heavily dependent upon the price of these liquids and US natural gas, as well as the price of competitive feedstocks.

As a rough rule of thumb, when the ratio of the price of oil to the price of natural gas is more than 7:1, the competitiveness of Gulf Coast-based petrochemicals and derivatives vis-à-vis other major producing regions is enhanced. In the United States, over 85% of ethylene, for example, is derived from natural gas liquids while in Western Europe over 70% is derived from naphtha, gas oil and other light distillate oil-based products.

The price of naphtha, gas oil and other light distillate oil-based products are related to the price of oil, a commodity with prices set by global supply and demand. The price of naphtha (in Western Europe, for example) is highly correlated with the price of oil (Brent) as illustrated in Figure 5. As a result, prices for naphtha will parallel the price for oil.

On the other hand, natural gas markets are regional in nature, with the United States and Canada being an integrated regional market. The price of ethane is correlated with US natural gas prices (Henry Hub). This is illustrated in Figure 6. As a result, prices for ethane will tend to parallel the price for natural gas. The correlation has weakened in recent years and other explanatory variables such as the prices of alternative feedstocks (like propane, butane, and naphtha) are important. The latter tend to be correlated with the price of oil.

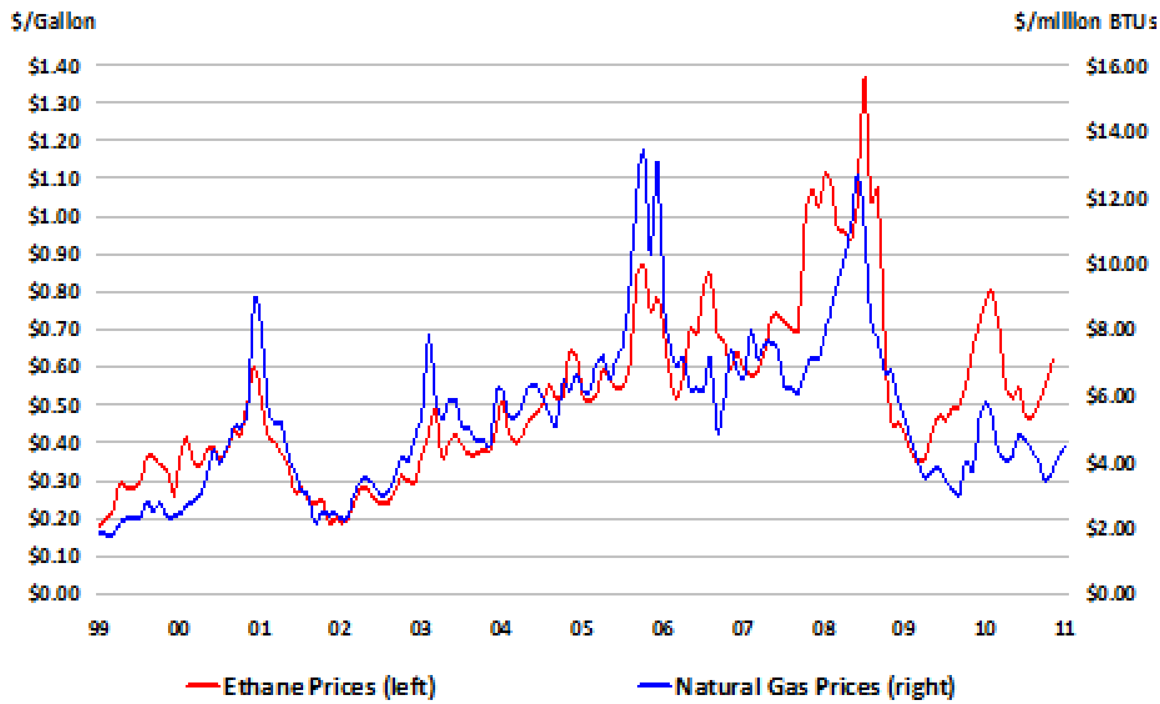
Figure 5: Strong Positive Correlation between the Price of Oil and the Price of Western Europe Naphtha



Source: EIA, Chemical Week Associates, Haver Analytics

Thus, the feedstock costs (and relative competitiveness) of cracking ethane and naphtha will follow the respective costs of natural gas and oil. Historically, other factors (co-product prices, exchange rates, capacity utilization, etc.) have played a role as well. This shift toward more and lower-cost natural gas (and disconnect of its relationship with oil prices) has benefitted the US chemical industry, resulting in greater competitiveness and heightened export demand. This helped offset downward pressures during the recession.

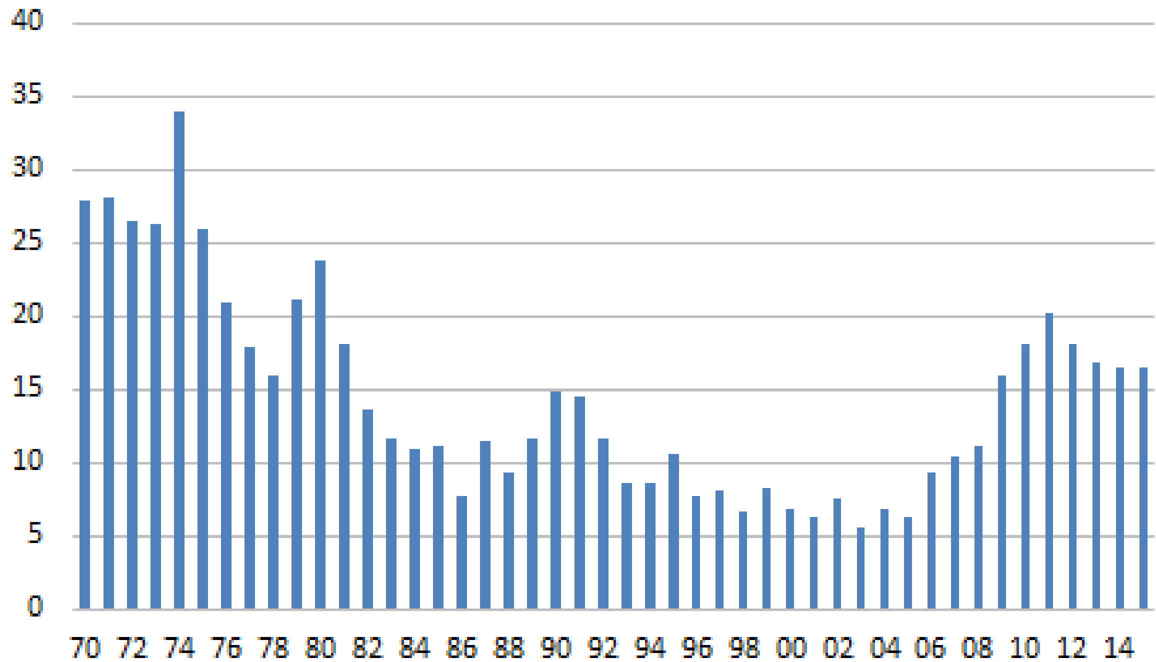
Figure 6: Positive Correlation between the Price of US Ethane and the Price of Natural Gas



Source: EIA, Chemical Week Associates, Haver Analytics

Figure 7 shows the long-term trend in the oil-to-gas ratio, from 1970 through 2015. The early-2000s represent a period in which US petrochemicals were facing competitive challenges. This was in contrast to the 1970s and the period through early-1990s, when US natural gas prices were low and oil prices were high, the latter the result of the Gulf War. In the 1990s, US energy policy favored use of natural gas in electricity generation but did little to address supply. In late-2000, the first of several large price spikes occurred, resulting in higher US natural gas prices as US supply was constrained. This continued during the next five or so years, with subsequent natural gas price spikes pushing the oil-to-gas ratio down to levels associated with non-competitiveness. At that time there were numerous concerns about the long-term viability of the US petrochemical industry. Moreover, a number of plant closures occurred during this period and investment flowed to the Middle East and other "remote gas" locations.

Figure 7: Oil-to-Gas Ratio: A Proxy for US Gulf Coast Competitiveness

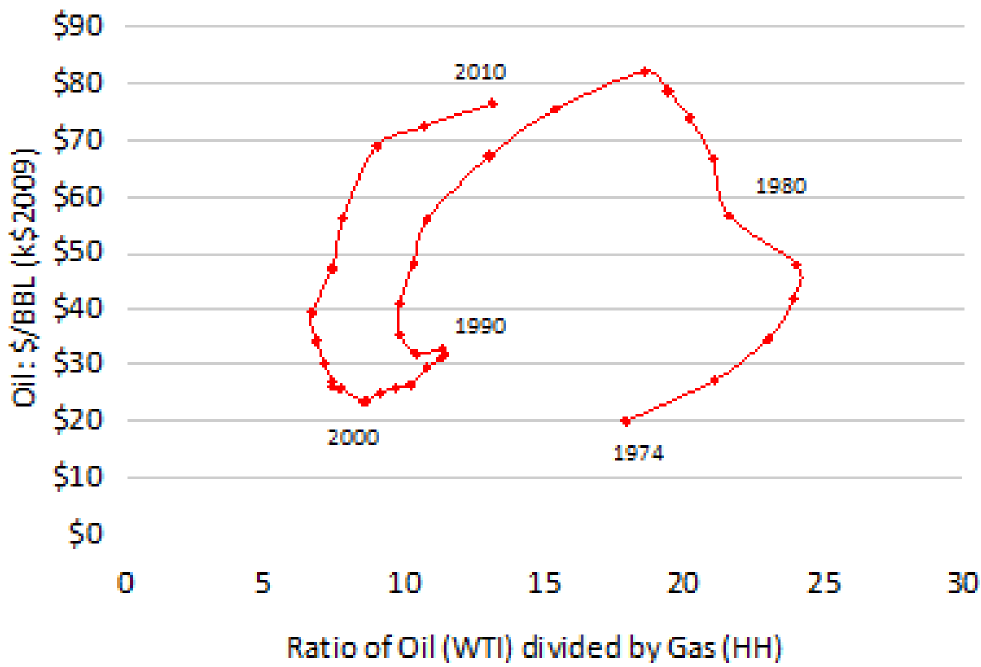


Source: EIA, CMAI, EIU, Global Insight

As noted, with several shale gas technological developments, learning curve effects, and the hurricanes of 2005 (and subsequent spikes in natural gas prices) the oil-to-gas relationship began to change. With the development of low cost shale gas resources in the United States, the oil-to-gas ratio has improved, from a non-competitive ratio of 5.5:1 in 2003 and 6.3:1 in 2005 to 15.9:1 in 2009 and 17.9:1 in 2010. The current ratio is very favorable for US competitiveness and exports of petrochemicals, plastics and other derivatives. Abundant availability and economic viability of shale gas at prices suggests a continued crude oil-natural gas price disconnect. Moreover, forecasters at the EIA and energy consultants expect high oil-to-gas ratios to continue.

Figure 8 illustrates the changing dynamics of natural gas relative to oil from a more long-term perspective. The chart measures the real price of oil (in constant 2009 dollars) relative to this oil-to-gas ratio for the years 1974 through 2010. Five-year moving averages are employed to better illustrate these trends. When the oil-to-gas ratio is high, US Gulf Coast petrochemicals are generally advantaged, as they largely were from 1974 through the late-1990s. But with the promotion of natural gas demand and supply constraints, the situation worsened last decade. Moreover, the real price of oil rose during the past 10 years, which led to advantages among remote locations with abundant natural gas, most notably in the Middle East. With the advent of shale gas, the US petrochemical competitive position is once again evolving, returning closer to the situation which prevailed during the 1980s, when oil prices were relatively high compared to natural gas prices.

Figure 8: Real Price of Oil and Oil-to-Gas Ratio



Note: Used a five-year moving average of prices and ratio to smooth long-term trends

Figure 9 illustrates a global petrochemical cost curve for 2010. Using data for 26 major nations and sub-regions, the curve reflects the differences in plant capacity and feedstock slates and shows how the US has moved to a globally competitive position[2]. The scale is not included in Figure 9 as the figure is only intended to illustrate the short-run supply curve. The cost curve is built on the cumulative petrochemical capacity from the lowest cost producers (in the Middle East) to the highest cost producers (in Northeast Asia). While the Middle Eastern

[2] Petrochemical costs vary depending on historical feedstock costs, by-product credits, cost of fuels and other utilities, hourly wages and staffing levels, other variable operating costs, and fixed costs as well as differences in operating rates. The vertical axis reflects the cash (or variable) costs on a per pound basis while the horizontal axis reflects the corresponding capacity for the country or region.

facilities are substantially advantaged relative to the marginal producers their competitiveness is almost comparable to US ethane-based producers. In the 2010, the Northeast Asian and Western European producers appear to be the least competitive. The latter are not only high-cost producers but also have smaller facilities with an average age of around 35 years resulting in substantially higher maintenance spending relative to their global competitors. As recently as 2005, the United States ranked behind Western Europe. With the revolution in shale gas, US producers have moved down the cost curve and now, rank behind Canada and the Middle East.

Figure 9: Typical Petrochemical Cost Curve by Country/Region, 2010

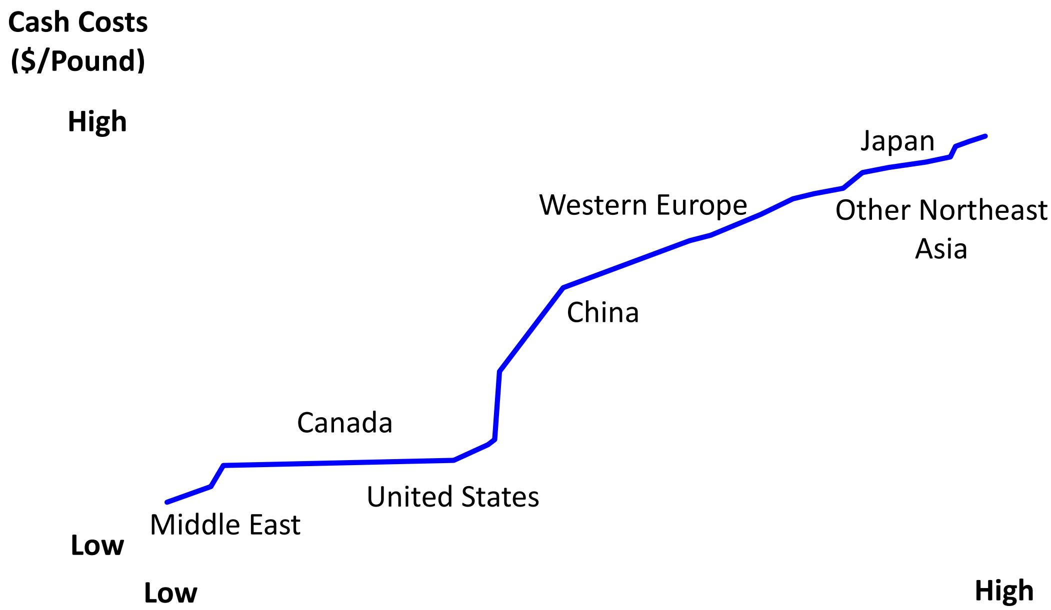
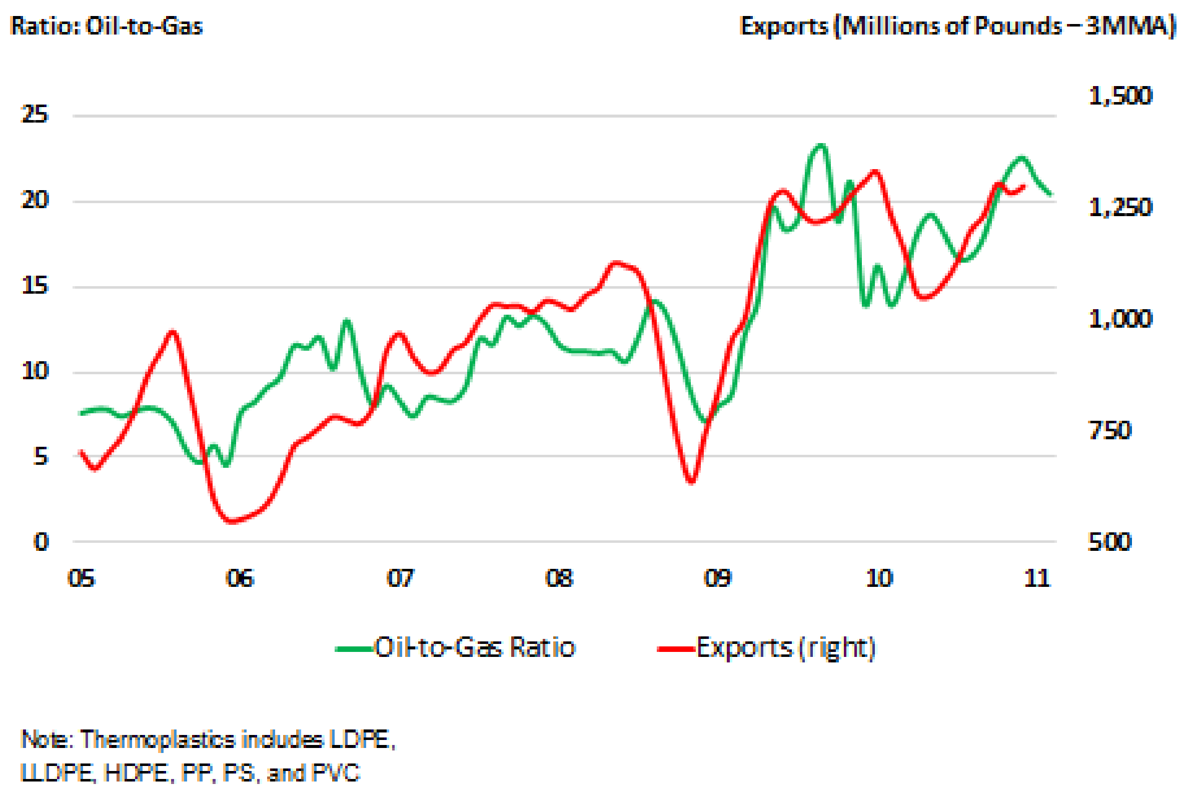


Figure 10 illustrates the competitive dynamics of petrochemicals and derivatives by examining the strong correlation between thermoplastic exports (as measured in millions of pounds) and the oil-to-gas ratio. As a result of shale gas (and weak industrial demand for gas), the US oil-to- gas ratio has been above 7:1 for several years. The ratio of oil prices to natural gas prices has been over 22:1 recently. This position is very favorable for US competitiveness and exports of petrochemicals, plastics and other derivatives. In 2010, the US Gulf Coast cost position improved so much that the region now is second only to the Middle East in terms of competitiveness. As a result, for example, US plastic exports are up nearly 10% due to this improved position. Furthermore, ethane supplies are tightening in the Middle East and are constrained. The era of low-cost feedstocks is over for some producing nations in that region. This will also aid US competitiveness and may induce capital investment in the United States.

Figure 10: Thermoplastic Exports and Oil-to-Gas Ratio



With the further development of shale gas, the oil-to-gas ratio is expected to remain high, and the future for the US petrochemical industry appears positive. This analysis seeks to quantify the economic impact of the additional production of petrochemicals and downstream chemical products.

Methodology and Assumptions

The objective of the research was to quantify the effects of private investment in US petrochemicals and downstream chemical products on additional output of the industry, as well as indirect and induced effects on other sectors of the economy. 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

The 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 chemical industry 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 of petrochemicals would likely lead to higher exports because of enhanced competitiveness.

In addition to added output, 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 is needed, as well as reasonable assumptions and parameters of the analysis. 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.

The analysis was broken into two parts: the one-time 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 that occurs with a 25% increase in ethane production in the United States. It was assumed that production of ethylene and downstream plastics resins would experience a similar increase. Since 99% of all US ethane supply goes into ethylene production, and over 82% of ethylene goes into plastic resins, this linear relationship is a reasonable assumption. Other ethylene derivatives (synthetic rubber, polyolefins, etc.) production is expected to expand as well, but not by as much. Table 1 details the additional chemical industry output generated by a 25% increase in ethane production. The assumption that production of ethylene will increase is reasonable and consistent with public announcements by companies such as Dow Chemical, Shell Chemical, LyondellBasell and Bayer MaterialScience, among others.

- In December 2010, Dow Chemical announced it will increase ethane cracking capability on the US Gulf Coast by 20% to 30% over the next two to three years, and is reviewing options for building a natural gas liquids (NGL) fractionator to secure ethane supplies. The latter provides a new source of NGL supplies, helping to position U.S. petrochemical companies as one of the lowest cost producers of ethylene globally. Both actions are intended to capitalize on the favorable supply dynamics in North America.

- In the Autumn/Winter 2010 issue of *Shell Chemicals Magazine*, the company discussed how its base chemicals operations in the Gulf Coast region have taken advantage of changing hydrocarbon market dynamics to strengthen its feedstock processing capability. The turnaround in competitive positioning achieved was deemed vital to the success of Shell's chemicals business in the United States and for future security of supply to customers in North American heartland markets.

- Bayer MaterialScience has expressed interest in siting an ethane cracker in West Virginia at one of its two manufacturing complexes in the state, according to press reports. There are no ethane crackers in the Marcellus region. A West Virginia ethane cracker would be the first to serve the hub of chemical manufacturing in the western Pennsylvania/West Virginia area.

The IMPLAN model used to analyze this boost of production was adjusted to avoid double counting the impact of increased petrochemical and intermediate organic chemical demand. In addition, spending for oil and gas production and related services was excluded. Thus, the model was tailored to incorporate an annual increase in spending of $32.8 billion from an expansion of petrochemicals and associated downstream chemical manufacturing activity.

Table 1: Additional Chemical Industry Output Generated by a 25% Increase in Ethane Production

	$ Billion
Bulk Petrochemicals and Organic Intermediates	$18.3
Carbon Black	0.2
Plastics Resins	13.1
Synthetic Rubber	1.0
Man-Made Fibers	0.3
Total	**$32.8**

Lower natural gas costs also could engender new carbon black capacity (in line with new synthetic rubber capacity and higher activity in rubber products). Higher activity in downstream plastic products manufacturing (or processing) would lead to higher sales of plastic additives and plastics compounding. Similarly, higher activity in downstream tire and other rubber products manufacturing (or processing) would lead to higher sales of rubber processing chemicals. These effects are not captured in the analysis. Another effect that is not captured in the analysis is the improved competitive position which would result in higher chemical exports.

Because the model does not include the effects of the investment needed to produce the added $32.8 billion output of petrochemicals that would be generated by the 25% increase in ethane supply, the value of the capital investment was separately estimated. Based on the economics and chemical engineering literature, typical capital-output ratios were estimated to range from 0.27:1 to 0.73:1. That is, $1.0 billion in added petrochemical and derivative output could require new capital investment ranging from $270 million to $730 million. Data sources for calculating these capital-output ratios include the *Quarterly Financial Report* prepared by the US Census Bureau, fixed asset and industry data from the Bureau of Economic Analysis (BEA), and the *Corporation Sourcebook* prepared by the Statistics of Income Division of the Internal Revenue Service. The capital-output ratio of 0.49:1 that was used was based on an average of ratios calculated. That is, $1.0 billion in added petrochemical and derivative output would require new capital investment on the order of $490 million. The scope of the analysis was limited to the chemical sector and did not include the investment or business activity generated by the extraction, recovery or infrastructure related to delivery of the ethane to chemical plants. It also did not include the effects from investment in development and production of shale gas nor pipeline and other infrastructure development.

The results of the analysis indicate that the added $32.8 billion output of petrochemicals and derivatives would necessitate new capital investment of $16.2 billion. These investments could be a combination of debottlenecking, brownfield and greenfield projects. The composition by asset type for this capital investment was derived using the average historical mix for the chemical industry's expenditures for fixed assets. The fixed asset data from the BEA was used. These assumed spending by asset type were assigned to the appropriate NAICS industry and the IMPLAN model was re-run to incorporate the effects of the new investment. 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. Although the spending would likely occur over the period of three 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.

Added Output and Job Creation

The output and employment generated by additional ethane utilization in the petrochemical and derivative industries is significant. The additional $32.8 billion in chemical industry activity would generate over 17,000 high-paying, desirable jobs in the chemical industry. Innovative, creative and pacesetting, the business of chemistry is one of the most knowledge-intensive industries in the manufacturing sector. "Knowledge worker" is a term that was originally coined by management guru, Peter Drucker, several decades ago. It refers to employees with university degrees/training whose principal tasks involve the development or application of specialized knowledge in the workplace. A study by Industry Canada showed that 38% of all employees in the US business of chemistry have at a minimum, a university degree. This is nearly double the average in US manufacturing.

Table 2: Economic Impact from Expanded Production of Petrochemical and Derivatives from a 25% Increase in Ethane Production

Impact Type	Employment	Payroll ($ Billion)	Output ($ Billion)
Direct Effect	17,017	$2.4	$32.8
Indirect Effect	79,870	6.6	36.9
Induced Effect	85,563	4.1	13.7
Total Effect	**182,450**	**$13.1**	**$83.4**

In addition, the increased use of ethane by the chemical industry would generate purchases of raw materials, services, and other supplies throughout the supply chain. Thus, nearly another 80,000 indirect jobs would be supported by the boost in ethane production. 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 more than 85,000 jobs induced by the response of the economy to changes in household expenditure as a result of labor income generated by the direct and indirect effects. All told, the additional $32.8 billion in chemical industry output from a 25% increase in ethane production would generate $83.4 billion in output to the economy and more than 182,000 new jobs in the United States generating a payroll of $13.1 billion. This comes at a time when 15 million Americans are out of work. Moreover, the new jobs would primarily be in the private sector. A detailed table on jobs created by industry is presented in Appendix Table 1.

Table 3: Economic Impact from New Investment in Plant and Equipment

Impact Type	Employment	Payroll ($ Billion)	Output ($ Billion)
Direct Effect	54,094	$4.3	$16.2
Indirect Effect	74,479	5.1	16.8
Induced Effect	100,549	4.8	16.1
Total Effect	**229,122**	**$14.2**	**$49.0**

Following a decade of contraction in the petrochemical sector, new plant and equipment would be required to use the additional feedstock supplies. A one-time $16.2 billion investment would generate more than 54,000 jobs, mostly in the construction and capital equipment-producing industries. Indirectly, another $16.8 billion in output and more than 74,000 jobs would be generated throughout the supply chain. Finally, a further $16.1 billion in output and more than 100,000 jobs would be created through the household spending of the workers building, making, and installing the new plant and equipment and those throughout the supply chain. All told, a $16.2 billion investment in the chemical industry would support nearly 230,000 jobs and $14.2 billion in payrolls. These impacts would likely be spread over several years. A detailed table on jobs created by industry is presented in Appendix Table 2.

Tax Revenues

The IMPLAN model allows a comprehensive estimation of additional tax revenues that would be generated across all sectors as the result of increased economic activity. Table 4 details the type and amount of tax revenues that would be generated from a boost in ethane production by 25% and its subsequent consumption by the chemical industry. The additional job*s* created and added output in turn would lead to a gain in taxes receipts. Federal taxes on payrolls, households, and corporations would yield about $2.5 billion per year, and assuming historical tax buoyancy, would generate $24.9 billion over 10 years. On a state and local level, an additional $1.9 billion per year would be generated, or $19.0 billion over 10 years.

Table 4: Tax Impact from Expanded Production of Petrochemical and Derivatives from a 25% Increase in Ethane Production ($ Billion)

	Payroll	Households and Proprietors	Corporations and Indirect Business Taxes	Total	*Over 10 Years*
Federal	$1.0	$0.9	$0.6	**$2.5**	***$24.9***
State and Local	$0.02	$0.30	$1.57	**$1.9**	***$19.0***

There are also considerable tax revenues generated from the $16.2 billion investment in new plant and equipment. Federal tax receipts would be $3.1 billion, while state and local receipts would be $1.8 billion. While the impact from the new plant and equipment investment would be short-lived, it would nonetheless be welcomed during these times of fiscal imbalances.

Combining the additional federal tax revenues from the added output with tax revenues associated with this private-sector boost in investment, the 10-year revenue addition to the US Treasury would be at least $25.0 billion. Similar large gains in revenues would accrue to the states and various localities.

Table 5: Tax Impact from New Investment in Plant and Equipment ($ Billion)

	Payroll	Households and Proprietors	Corporations and Indirect Business Taxes	Total
Federal	$1.4	$1.2	$0.5	**$3.1**
State and Local	$0.04	$0.4	$1.3	**$1.8**

Future Research

The economic impact of the additional production of petrochemicals and downstream chemical products was quantified in this report. Added output, jobs and tax revenues were all evaluated based on the additional output in chemicals only. A number of other manufacturing industries, including aluminum, cement, iron and steel, glass, and paper also are large consumers of natural gas that would benefit from shale gas developments and could conceivably boost capital investments and output. In addition, the rubber and plastics products industries could similarly expand. Further analysis could be conducted to incorporate these effects. In addition, the economic effects arising from the development of shale gas for other non-industrial markets and for possible exports could be examined. Finally, the renewed competitiveness arising from shale gas has enhanced -US chemical industry exports, production and jobs. These positive trends will persist and will need to be quantified. Combined, these positive effects could be comparable in scope to the primary findings of this analysis.

Conclusions

The economic effects of new petrochemicals investment 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 petrochemical capacity. Indeed, a new competitive advantage has already emerged for US petrochemical producers. And this 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 petrochemical and derivative capacity, and the additional production of petrochemicals and downstream chemical products will provide an opportunity for more than 400,000 jobs – good jobs. A large private investment initiative would enable a renaissance of the US petrochemical industry and in this environment, a reasonable regulatory regime will be key to making this possible.

ACC's Economics & Statistics Department

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

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Appendix Table 1: Jobs Generated by the Expanded Production of Petrochemical and Derivatives from a 25% Increase in Ethane Production

	Direct	Indirect	Induced	Total
Agriculture	**-**	**1,280**	**1,977**	**3,256**
Mining & Utilities	**-**	**5,319**	**540**	**5,859**
Oil and gas extraction	-	3,072	154	3,226
Natural gas distribution	-	969	52	1,022
Electricity generation and distribution	-	782	232	1,014
Other mining and utilities	-	496	103	599
Construction	**-**	**3,048**	**837**	**3,885**
Durable Manufacturing	**-**	**3,363**	**1,924**	**5,287**
Primary and fabricated metals	-	1,516	425	1,941
Machinery, electrical equipment, and instruments	-	802	230	1,032
Computers and electronics	-	378	143	521
Other durable manufacturing	-	666	1,126	1,792
Nondurable Manufacturing	**17,017**	**6,898**	**2,701**	**26,616**
Petroleum and coal products	-	699	39	738
Chemicals	17,017	4,522	370	21,908
Other nondurable manufacturing	-	1,678	2,293	3,970
Trade	**-**	**11,857**	**17,101**	**28,957**
Transportation	**-**	**5,936**	**2,607**	**8,542**
Information	**-**	**1,627**	**1,845**	**3,472**
Finance, Insurance and Real Estate	**-**	**4,823**	**9,863**	**14,686**
Services	**-**	**35,720**	**46,169**	**81,889**
Professional and technical services	-	8,167	3,965	12,132
Scientific R&D services	-	4,644	216	4,860
Management of companies	-	4,531	734	5,265
Administrative and support services	-	9,127	4,666	13,793
Other services	-	9,252	36,588	45,840
TOTAL JOBS	**17,017**	**79,870**	**85,563**	**182,450**

Appendix Table 2: Jobs Generated from New Investment in Plant and Equipment

	Direct	Indirect	Induced	Total
Agriculture	**-**	**427**	**2,334**	**2,761**
Mining & Utilities	**-**	**833**	**638**	**1,470**
Oil and gas extraction	-	208	181	389
Natural gas distribution	-	86	62	148
Electricity generation and distribution	-	270	274	544
Other mining and utilities	-	269	121	390
Construction	**17,537**	**820**	**983**	**19,339**
Durable Manufacturing	**31,169**	**13,779**	**2,259**	**47,208**
Primary and fabricated metals	3,899	6,895	499	11,293
Machinery, electrical equipment, and instruments	22,304	2,799	271	25,374
Computers and electronics	1,999	1,653	167	3,819
Other durable manufacturing	2,968	2,432	1,322	6,721
Nondurable Manufacturing	**-**	**2,387**	**3,187**	**5,573**
Petroleum and coal products	-	75	46	121
Chemicals	-	401	437	837
Other nondurable manufacturing	-	1,911	2,704	4,615
Trade	**-**	**7,829**	**20,070**	**27,899**
Transportation	**-**	**4,179**	**3,062**	**7,241**
Information	**5,388**	**3,109**	**2,172**	**10,668**
Finance, Insurance and Real Estate	**-**	**5,836**	**11,618**	**17,454**
Services	**-**	**35,281**	**54,228**	**89,509**
Professional and technical services	-	9,984	4,664	14,647
Scientific R&D services	-	1,034	254	1,288
Management of companies	-	3,362	865	4,228
Administrative and support services	-	12,329	5,486	17,815
Other services	-	8,573	42,959	51,532
TOTAL JOBS	**54,094**	**74,479**	**100,549**	**229,122**