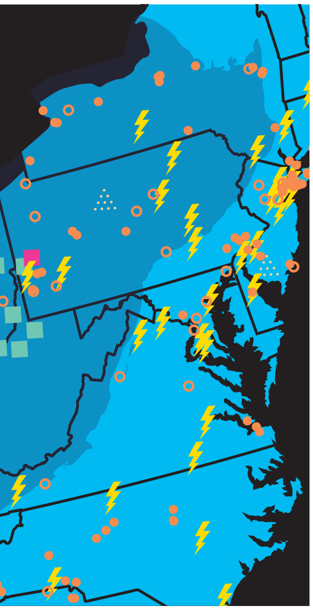
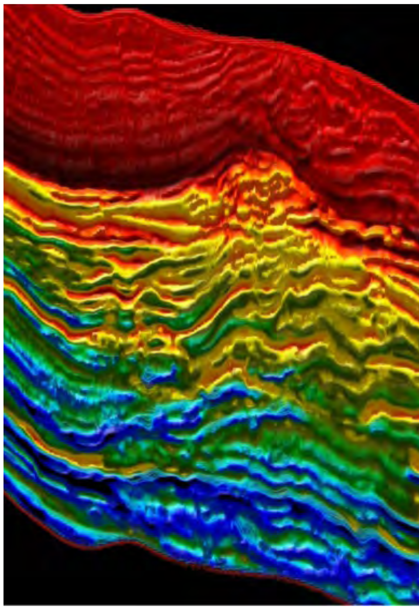
AMERICAN CLEAN SKIES FOUNDATION

TECH EFFECT:

HOW INNOVATION IN OIL AND GAS EXPLORATION IS SPURRING THE U.S. ECONOMY





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BASED ON ANALYSIS CONDUCTED BY

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Acknowledgements

This report was prepared by the American Clean Skies Foundation based on analysis conducted by Harry Vidas and his team at ICF International including William Pepper, Robert H. Hugman, Warren Wilczewski and Briana Adams. Vidas is vice president of the Oil and Gas Division at ICF.

Vidas has directed work in the areas of oil and gas supply, markets and infrastructure since the 1980s. He has directed projects related to international oil and natural gas supply, gas processing, LNG production and shipping, pipeline transmission, underground storage, gas-to-liquids processes, biofuels, synthetic fuels and end-use markets. He has supervised 10 studies related to North American LNG import terminals, including the analysis of pipeline infrastructure capacity and basis differentials at approximately 30 terminal locations as well as studies of gas supplies at several dozen power plant locations.

ACSF's CEO Gregory C. Staple, Energy Policy Advisor Patrick Bean, and Energy Policy Research Associate Geoff Bromaghim provided guidance on the report.

About American Clean Skies Foundation

Established in 2007, ACSF seeks to advance America's energy independence and a cleaner, low-carbon environment through expanded use of natural gas, renewables, and efficiency. The Foundation is a 501 (c) (3) not-for-profit organization.

Contents

Glossary

Abbreviations

AEO	U.S. Energy Information Administration Annual Energy Outlook
Bcf/day (or Bcf/d)	Billion cubic feet of natural gas per day
BOE	Barrels of crude oil equivalent
Btu	British thermal unit, used to measure fuels by their energy content.
EIA	U.S. Energy Information Administration, a statistical and analytical agency within the U.S. Department of Energy
GDP	Gross Domestic Product
GTL	Gas-to-liquids
LNG	Liquefied Natural Gas
Mcf	Thousand cubic feet, volume measurement for natural gas
MMcf	Million cubic feet (of natural gas)
MMBtu	Million British thermal units, equivalent to approximately one thousand cubic feet of gas
MMBOE	Million barrels of oil equivalent wherein each barrel contains 5.8 million Btus
MMbbl	Million barrels of oil or liquids
NAICS Codes	North American Industrial Classification System Codes
NGL	Natural Gas Liquids
Tcf	Trillion cubic feet of natural gas

Terms Used:

Coalbed methane (CBM): recoverable volumes of gas from development of coal seams (also known as coal seam gas, or CSG).

Counterfactual modeling: this approach, as used here, compares recent history and a current forecast of future oil and gas activity and production to what would have happened without recent upstream technology advancements.

Consumer surplus: an economic concept equal to the area below the demand curve down to a horizontal line drawn at the market price. Used in this report to measure the benefits provided to consumers brought about by lower natural gas prices, lower electricity costs, and lower manufacturing prices.

Conventional gas resources: generally defined as those associated with higher permeability fields and reservoirs. Typically, such as reservoir is characterized by a water zone below the oil and gas. These resources are discrete accumulations, typified by a well-defined field outline.

Direct impacts: immediate impacts (e.g., employment or value added changes) in a sector due to an increase in output in that sector.

Downstream oil and gas activities: activities and expenditures in the areas of refining, distribution and retailing of oil and gas products.

Economically recoverable resources: represent that part of technically recoverable resources that is expected to be economic, given a set of assumptions about current or future prices and market conditions.

Hydraulic fracturing: the process of injecting fluid and proppants under high pressure into a shale gas, tight oil or other formation to stimulate production.

Horizontal drilling: the practice of drilling a horizontal section in a well (used primarily in a shale or tight oil well), typically thousands of feet in length.

Indirect impacts: impacts brought about by changes in direct demand through the inter-linkages of various sectors, attributable to the iteration of goods/services purchased by direct and indirect industries

Induced impacts: impacts on all local and national industries due to consumers' consumption expenditures rising from the new household incomes that are generated by the direct and indirect effects flowing through to the general economy. The term is used in industry-level input-output modeling and is similar to the term Multiplier Effect used in macroeconomics.

Midstream oil and gas activities: consist of activities and expenditures downstream of the wellhead, including gathering, gas and liquids processing, and pipeline transportation.

Multiplier effect: describes how an increase in some economic activity produces a cascading effect through the economy by producing "induced" economic activity. The multiplier is applied to the total of direct and indirect impacts to estimate the total impact on the economy. The term is used in macroeconomics and is similar to the term Induced Impacts as used in industry-level input-output modeling.

Natural gas liquids: components of natural gas that are in gaseous form in the reservoir, but can be separated from the natural gas at the wellhead or in a gas processing plant in liquid form. NGLs include ethane, propane, butane, and pentane.

Original gas-in-place: industry term that specifies the amount of natural gas in a reservoir (including both recoverable and unrecoverable volumes) before any production takes place.

Original oil-in-place: industry term that specifies the amount of oil in a reservoir (including both recoverable and unrecoverable volumes) before any production takes place.

Proven reserves: the quantities of oil and gas that are expected to be recoverable from the developed portions of known reservoirs under existing economic and operating conditions and with existing technology.

Recent upstream technological advances: defined here as those advances in drilling and completion technology, such as horizontal drilling with multiple stage horizontal fracturing, as applied to shale or other low-permeability formations that have occurred since approximately 2007.

Shale gas and tight oil: recoverable volumes of gas, condensate, and crude oil from development of shale plays. Tight oil plays are those shale plays that are dominated by oil and associated gas, such as the Bakken in North Dakota.

Technically recoverable resources: represent the fraction of gas in place that is expected to be recoverable from oil and gas wells without consideration of economics.

Tight gas: recoverable volumes of gas and condensate from development of very low permeability sandstones.

Unconventional gas resources: defined as those reservoirs in which oil or gas do not flow without the aid of fracturing technology. The main categories are coalbed methane, tight gas, and shale gas, although other categories exist, including methane hydrates and coal gasification.

Upstream oil and gas activities: consist of all activities and expenditures relating to oil and gas extraction, including exploration, leasing, permitting, site preparation, drilling, completion, and long term well operation.

Conversion Factors

Volume of Natural Gas in 2012 (U.S. demand is approximately 24 Tcf per year)

1 Tcf = 1,000 Bcf
1 Bcf = 1,000 MMcf
1 MMcf = 1,000 Mcf

Energy Content of Natural Gas (1 Mcf is one thousand cubic feet)

1 Mcf = 1.025 MMBtu
1 Mcf = 0.177 barrels of oil equivalent (BOE)
1 BOE = 5.8 MMBtu = 5.65 Mcf of gas

Energy Content of Crude Oil

1 barrel = 5.8 MMBtu = 1 BOE
1 MMBOE = 1 million BOE

Energy Content of Other Liquids

Condensate
1 barrel = 5.3 MMBtu = 0.91 BOE
Natural Gas Plant Liquids
1 barrel = 4.0 MMBtu = 0.69 BOE (actual value varies based on component proportions)

List of Exhibits

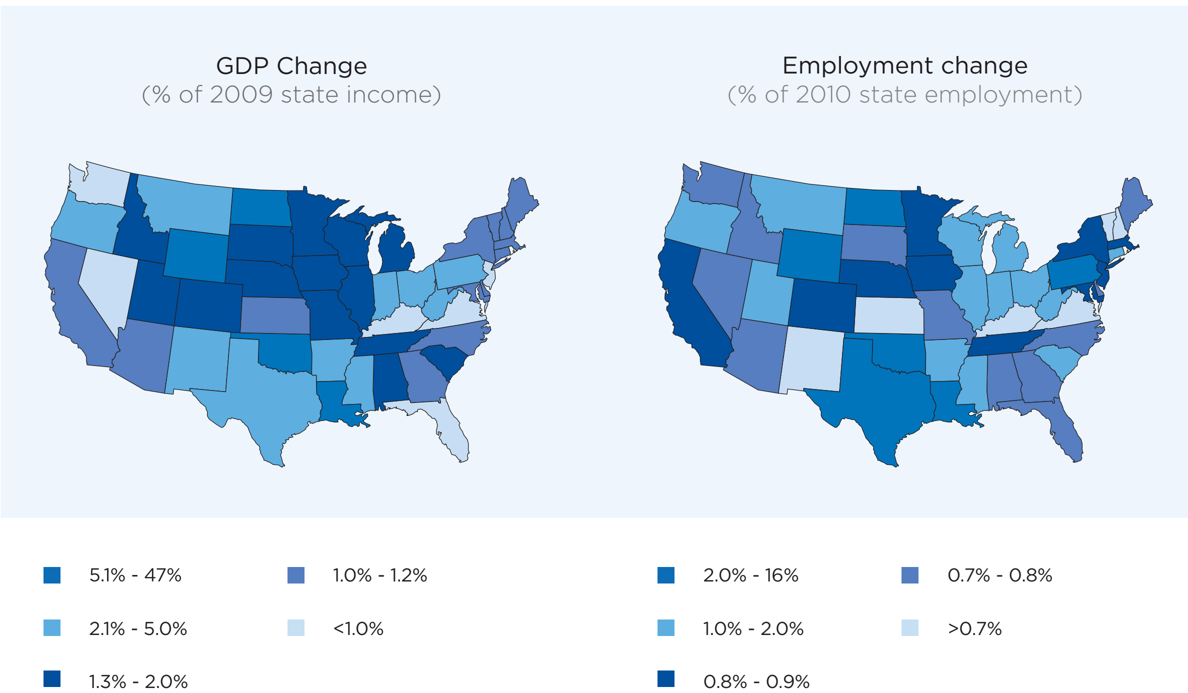
Executive Summary 1

Technology advancement and deployment in the last five years together have revolutionized the U.S. natural gas and oil production industry. This report quantifies the economic impacts of recent upstream technologies, such as hydraulic fracturing and horizontal drilling, which have allowed recovery and production of previously inaccessible domestic resources.

The U.S. has vast reserves of natural gas. ICF estimates that the U.S. Lower-48 has a recoverable gas resource base of over 3,500 trillion cubic feet (Tcf) and 200 billion barrels of crude oil and lease condensate liquids, up from 1,100 Tcf of natural gas and 150 billion barrels of liquids in 2008. The current recoverable gas resource base represents approximately 150 years of U.S. gas demand at current levels. This striking climb in the recoverable resource base of natural gas and crude oil and condensate liquids is already reflected by the production over the past five years, which is, in turn, having a tremendous impact on the overall economy.

The economic benefits include growth in Gross Domestic Product (GDP) and employment gains, lower energy prices, additional tax revenues, and a revival in U.S. production of industrial goods.

Exhibit 1-1
U.S. Map of GDP and Employment Impacts



Major Findings

In a period of just a few years, technological innovations have transformed the U.S. oil and gas industry into a powerhouse that is providing a substantial growth impetus to the national economy and the economies of many states. Among the major findings of this report are:

- **Upstream technology gains will lead to long-term economic growth:** Unconventional activity is underpinned by such a large resource base that expanded production is expected to continue for decades, providing a base for solid growth and long-lasting well-paying jobs.
- **Increasing natural gas production through 2017:** U.S. natural gas production in 2017 will be over 6 trillion cubic feet (Tcf) per year higher due in part to the use of the new technologies and representing a volume that is nearly double U.S. gas imports in 2011 (of 3.5 Tcf).[1] These gains reflect a 30-percent increase over 2017 production projections made in 2008.
- **Added oil production reduces oil imports:** Oil and liquids production is also increasing rapidly, totaling an additional 630 million barrels in 2017, a volume that is nearly equal to total 2011 U.S. crude imports from the Persian Gulf (of 680 million barrels).[2]
- **Industry gains a boon for the U.S. economy:** Upstream technology developments have impacts that affect all sectors of the economy, including the oil and gas service sector, oil and gas material suppliers, oil and gas equipment manufacturers, consumer goods, industries that use natural gas, and the businesses that supply all of these sectors.
- **Significant GDP gains:** The study forecasts a net increase of $167 billion to $245 billion in GDP in 2017 due to recent upstream technology advances, equivalent to between 1.2 percent and 1.7 percent of the 2010 U.S. GDP (of $14.5 trillion).[3,4]
- **Long-term jobs in gas and oil production and related industries:** The modeled incremental production of approximately 1.7 billion barrels of oil equivalent per year by 2017 (including 6.2 trillion cubic feet per year of gas) results in an increase of 330,000 direct and indirect jobs in the upstream and midstream sectors alone. For each one billion cubic feet per day of incremental gas production (or a Btu-equivalent amount of liquids), approximately 13,000 upstream and midstream jobs are added to the economy.
- **Total employment gains exceed the entire U.S. auto manufacturing industry employment:** The study projects significant additional annual employment gains; by 2017, 835,000 to 1.6 million jobs will be created nationwide. That is more than the number of jobs currently in the entire U.S. auto manufacturing industry (including parts suppliers) at the low end.[5] Sectors of the economy experiencing the greatest employment gains include the service sector, manufacturing, wholesale and retail trade, and the oil and gas sector itself.
- **Large positive job impacts at the state level:** For example, in the year 2017, Texas should see a gain of up to 236,000 jobs and Pennsylvania up to 145,000 jobs. States that do not have significant shale gas resources are also expected to gain tens of thousands of jobs, due largely to supply chain businesses. Examples include Florida (59,000 jobs), New Jersey (36,000 jobs), and Missouri (21,000 jobs).
- **Far-reaching midstream and downstream impacts:** Evaluation of the entire impact of shale development on the U.S. economy shows that the effects go far beyond local areas and regions with drilling. Industrial expansion involves facilities such as gas and liquids pipelines, gas processing plants, petrochemical plants, steel manufacturing, sand mining, ammonia production, methanol production, and LNG export terminals.

1. U.S. Energy Information Administration (EIA). "U.S. Natural Gas Imports by Country." EIA, July 2012: Washington, D.C. Available at: http://www.eia.gov/dnav/ng/ng_move_impc_s1_a.htm
2. U.S. Energy Information Administration (EIA). "U.S. Imports by Country of Origin." EIA, July 2012: Washington, D.C. Avaialble at: http://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbl_a.htm
3. All dollar figures are in 2010 real dollars unless otherwise specified.
4. U.S. Bureau of Economic Analysis. "Gross Domestic Product (GDP): Current-Dollar and 'Real' GDP." U.S. Department of Commerce Bureau of Economic Analysis, 2012: Washington, D.C. Available at: http://www.bea.gov/national/index.htm#gdp
5. 789,500 "motor vehicle and parts manufacturing" seasonally adjusted employment as of July 2012. U.S. Bureau of Labor Statistics (BLS). "Automotive Industry: Employment, Earnings, and Hours." BLS, July 2012: Washington, D.C. Available at: http://www.bls.gov/iag/tgs/iagauto.htm

- **Billions of dollars in consumer gains:** The rise in natural gas production has resulted in large price reductions to both direct and indirect end-users. This results in direct savings to natural gas consumers, and indirect savings through lower electricity prices and lower prices for industrial products. Consumers are expected to experience a net benefit of $41 billion in 2017, enough to cover the electricity bill on 30 million homes.[6]
- **GDP gains occur in every state:** The economic impact is widely distributed across the U.S. and has already had very large positive GDP impacts in major production growth areas. Additionally, energy-consuming states without production gain substantially from lower energy prices that free up family budgets for consumer spending for non-energy goods and services.
- **Tax revenues increased at all levels of government:** State, federal, and local governments are experiencing increased revenues resulting from both receipts from the oil and gas industry, as well as from related economic activity flowing through their economies. Incremental tax receipts from all sources of government taxes are expected to be up to $85 billion per year by 2017. In addition, increases in royalty payments to individuals/governments should reach $12 billion annually in 2017.
- **Growing net exports help realign the U.S. trade balance:** The GDP gains are associated with roughly $120 billion additional net exports annually by 2017, which equates to nearly one-quarter of the U.S. 2010 international trade deficit (of nearly $500 billion).[7]

State Impacts

Economic gains are widely distributed across all states (Exhibit 1-1). The largest GDP and employment impacts are seen in production areas, such as North Dakota, Texas, Oklahoma, and Louisiana, among others, while states such as Wisconsin and Ohio also benefit from the production side in the form of the goods and services (e.g., steel, sand) they provide to the upstream and midstream sectors. Downstream activities, such as manufacturing, which benefit from lower natural gas fuel and feedstock prices, further promote GDP and employment growth in states such as California (high-tech manufacturing) and Iowa (fertilizer plants). States that use natural gas for power generation, or see new construction of gas-fired power plants, such as Alabama and Georgia, will benefit from lower natural gas prices. Overall, the economy will benefit from the GDP and employment gains produced through induced economic activity as the impacts generated by more production make their way through the rest of the economy.

Industrial Sector Impact

This study evaluated the impacts of increased natural gas production and lower prices on a range of industries.

- Demand for steel tubular goods has soared, contributing to a revitalization of the domestic steel industry. Steel demand from the oil and gas industry is expected to total over 66 million tons between 2008 and 2017. For comparison, current annualized U.S. steel production is 89 million tons. Low energy prices are also helping to make the steel sector more competitive internationally.
- Ammonia is the basic material for nitrogen-based fertilizer. Natural gas is used both as a feedstock and a fuel in ammonia production. Low gas prices are bringing about a turnaround in the fortunes of U.S. ammonia producers. With natural gas prices under $4 per MMBtu, U.S. producers are becoming internationally price competitive, thereby creating U.S. jobs and reducing the need for imports.
- Natural gas liquids are used as feedstocks to produce certain chemicals. Rapidly increasing production of ethane, a component of natural gas, is creating a transformation of the U.S. petrochemical sector. Ethane is used in the production of ethylene, a building block for plastics. U.S. manufacturers have a large

6. Assumes 11,500 kilowatt-hours (kWh) per home and a residential electricity price of $0.118/kWh. Sources: U.S. Energy Information Administration (EIA). “How much electricity does an American home use.” EIA, 2010: Washington D.C. Available at: http://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3. EIA. “Electricity Explained.” EIA, 2011: Washington, D.C. Available at: http://www.eia.gov/energyexplained/index.cfm?page=electricity_factors_affecting_prices
7. U.S. Census Bureau. “Historical Series: U.S. International Trade in Goods and Services.” U.S. Census Bureau, June 2012: Washington, D.C. Available at: http://www.census.gov/foreign-trade/statistics/historical/

advantage over European and Asian firms, who must use higher cost feedstocks.

- Methanol has many industrial uses and is used as a transportation fuel through blending or the manufacture of biodiesel. The economics of methanol production are highly dependent upon the price and availability of natural gas. Low U.S. natural gas prices have incentivized methanol producers to expand operations or move their operations to the United States.
- Increased volumes of shale gas are expected to result in large volumes of exports of liquefied natural gas, likely beginning around 2016. LNG import facilities are being converted to allow for LNG exports and new facilities may be built. These are capital intensive projects that generate large direct and indirect impacts on the economy.

The impact on U.S. jobs through 2017 can be viewed in terms of number of jobs per billion cubic feet per day (Bcf/day) of natural gas production. This study finds that approximately 13,000 upstream and midstream jobs are created for each incremental Bcf/day of gas production. Also, additional jobs are created downstream in the general categories of construction and operations. The (Exhibit 1-2) diagram shows the jobs generated for four major categories of industrial gas use that are experiencing increases due to the additional gas production. For example, a gas to liquids plant would represent 18,000 direct and indirect jobs per Bcf/day, consisting of 13,000 from the upstream and midstream, 4,000 from construction (annualized), and 900 from operations. Including multiplier effect jobs, the total for gas to liquids ranges from 30,000 to 53,000 jobs per Bcf/d.

Exhibit 1-2

Domestic Job Impacts of Alternative Uses of Natural Gas (Per Bcf/d of Production)

	UPSTREAM & MIDSTREAM JOBS	CONSTRUCTION JOBS	OPERATIONS JOBS	TOTAL
Gas to Liquids Plants	13,000 Jobs	4,000 Jobs	900 Jobs	**Direct & Indirect** 18,000 Jobs **All Jobs** 30,000 - 53,000
Liquefied Natural Gas Plants	13,000 Jobs	1,700 Jobs	200 Jobs	**Direct & Indirect** 15,000 Jobs **All Jobs** 25,000 - 44,000
Methanol Plants	13,000 Jobs	3,000 Jobs	1,800 Jobs	**Direct & Indirect** 18,000 Jobs **All Jobs** 30,000 - 52,000
Ammonia Plants	13,000 Jobs	4,200 Jobs	3,400 Jobs	**Direct & Indirect** 21,000 Jobs **All Jobs** 34,000 - 62,000

Note: Construction-period jobs include jobs associated with production of construction materials and plant equipment and would last for a period of approximately four years. Total jobs are computed by spreading construction jobs over a 20 year plant operating period. The term "D&I Jobs" refers to direct and indirect jobs and "All Jobs" refers to direct, indirect and induced jobs.

Exhibit 1-3 How This Study is Different

To better measure and document the economic transformation spurred by expanded oil and gas technology innovation, ICF International dug deep, studying business plans, expert forecasts and both state and federal government reports.

Building on this growing body of research using various assumptions and methodologies, this study quantifies the economic impacts attributable to recent upstream technological improvements, rather than the total impacts (based on the entire oil and gas industry or a particular resource type such as shale gas). A comparison of our report with three recent studies highlights some key differences (see Exhibit 1-4).

To estimate the impacts of these upstream technology changes, this study compares a forecast preceding the revolutionary deployment of U.S. unconventional natural gas and oil drilling technologies to a current outlook. The difference between these two outlooks illuminates economic impact from the recent technology and production gains.

Specifically, this study quantifies the net impact on GDP, employment by state and industry group, consumer benefits, government revenues, and international trade from 2008 through 2017. The current study:

- Includes the impacts on the economy of oil, gas, and coal.
- Looks at the entire value chain of the oil and gas industry from upstream and its suppliers to end use of oil and gas.
- Evaluates specific impacts for major sectors.
- Employs a comparison between recent history and a current forecast of likely production and prices, and an analysis of what would have occurred without upstream technological advances since 2007.
- Evaluates the impact on GDP in terms of the price and quantity of increased gas and oil supplies with and without the technology advances.

This report develops supply and demand curves for the two scenarios and the comparison of various areas (expenditures, revenues and surpluses) defined by those curves. Other studies primarily rely on estimation of economic impacts of capital and operating expenditures estimated through drilling forecasts. This study and the other approaches rely, in part, on use of the IMPLAN model to determine the flow of effects through the economy.

Overall the report depicts a more complete economic picture of the growing impact of the industry. See Appendices A and C for this study's methodology and other details.

2 U.S. Natural Gas Resurgence

The surge in unconventional gas and tight oil has come about because of the United States' world-class natural gas and oil resource base, technological ingenuity, and readily adaptive markets. This production increase is resulting in a number of benefits, including support of hundreds of thousands of direct and indirect jobs, tens of billions of dollars in annual capital expenditures, expansion of state and federal tax receipts, and increased royalties to mineral rights owners.

The increasing production reduces consumer and industrial energy outlays and helps to realign the international balance of trade, as growing domestic oil and gas production reduces imports. Additionally, lower natural gas prices result in a natural gas and electricity cost advantage to U.S. manufacturing industries relative to prices seen by our trade partners. Also, reduced net energy imports and foreign investment in the U.S. oil and gas industry help support the value of the U.S. dollar. Because of the large unconventional gas and oil resource base in the U.S., there is a growing awareness that current activity represents only a portion of the future potential. This awareness generates confidence in the private sector for long-term investments in upstream assets, midstream infrastructure, and gas-consuming power plants and industrial facilities.

2.1 The Technology Revolution

In a period of just a few years, technological innovations have transformed the U.S. oil and gas industry into a powerhouse that is providing a substantial growth impetus to the national economy and the economies of many states. Based on announced business plans and expert forecasts for the relevant industries, this economic resurgence is expected to continue, providing a bright spot in an otherwise modestly performing economy.

Natural gas production has climbed to record levels and continues to increase. Oil and liquids production is also increasing as a result of industry targeting so-called "tight oil" plays. Prior to the shale gas revolution, there was a consensus that imports of liquefied natural gas (LNG) would have to increase greatly to meet anticipated demand in coming decades. Today, there is significant interest in exporting natural gas and recognition that the U.S. will be a major player in world gas markets in the future.

The gas industry has produced natural gas from shale formations for many decades. In fact, some of the earliest producing gas wells extracted gas from the Devonian shale of the Appalachian Basin.[8] These were long-lived but generally low rate wells that produced for decades. They were drilled vertically and either produced naturally or stimulated using explosives.

Starting in the 1980s, a large effort was expended to obtain commercial gas production from the Barnett Shale of the Fort Worth Basin in North Texas. This effort was carried out by Mitchell Energy and eventually proved very successful. The initial wells were drilled vertically, and various methods were used to stimulate them, including so-called slickwater hydraulic fracturing. Hydraulic fracturing involves pumping

8. The Marcellus is one Devonian-age shale in this basin.

thousands of barrels of water and sand or other "proppants" into the well under high pressure until the formation fractures. The proppant remains in the fractures and props them open to allow the gas or oil to flow. The slickwater method includes components that reduce friction and enhance the fracture network.

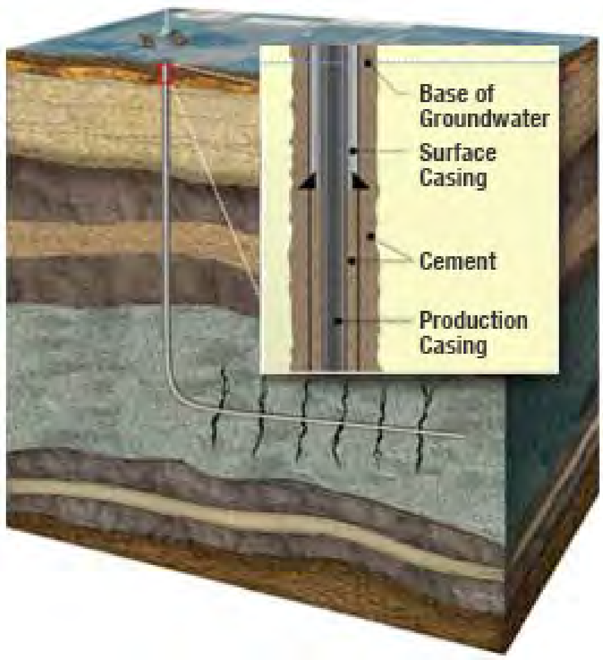
After the initial Barnett shale development, it was determined that the wells could be drilled with a horizontal section through the shale layer thousands of feet in length, then fracture-stimulated in multiple stages. These wells flowed at very high rates, and gas production from the Barnett shale rose considerably. See Exhibit 2-1 for a visual of horizontal drilling and fracture stimulation processes. This was the beginning of the U.S. shale gas revolution.

By drilling a horizontal well section up to 5,000-8,000 feet or more in length and by fracturing the well in as many as 10-20 stages, the well comes in contact with a tremendous volume of shale rock through the fracture network. This is a much more effective way of producing gas in tight formations than vertical drilling.

Highly productive shale gas formations have certain characteristics that promote commercial production. These include high organic content, adequate thermal maturity or "cooking," adequate thickness, high pressure, effective porosity and a brittle nature to allow fracturing. Fortunately, the U.S. has a wide range of plays that meet these criteria. The gas exists in three forms: as adsorbed gas (bound to the organic molecules), free gas (present in porous space), and gas dissolved in water or oil.

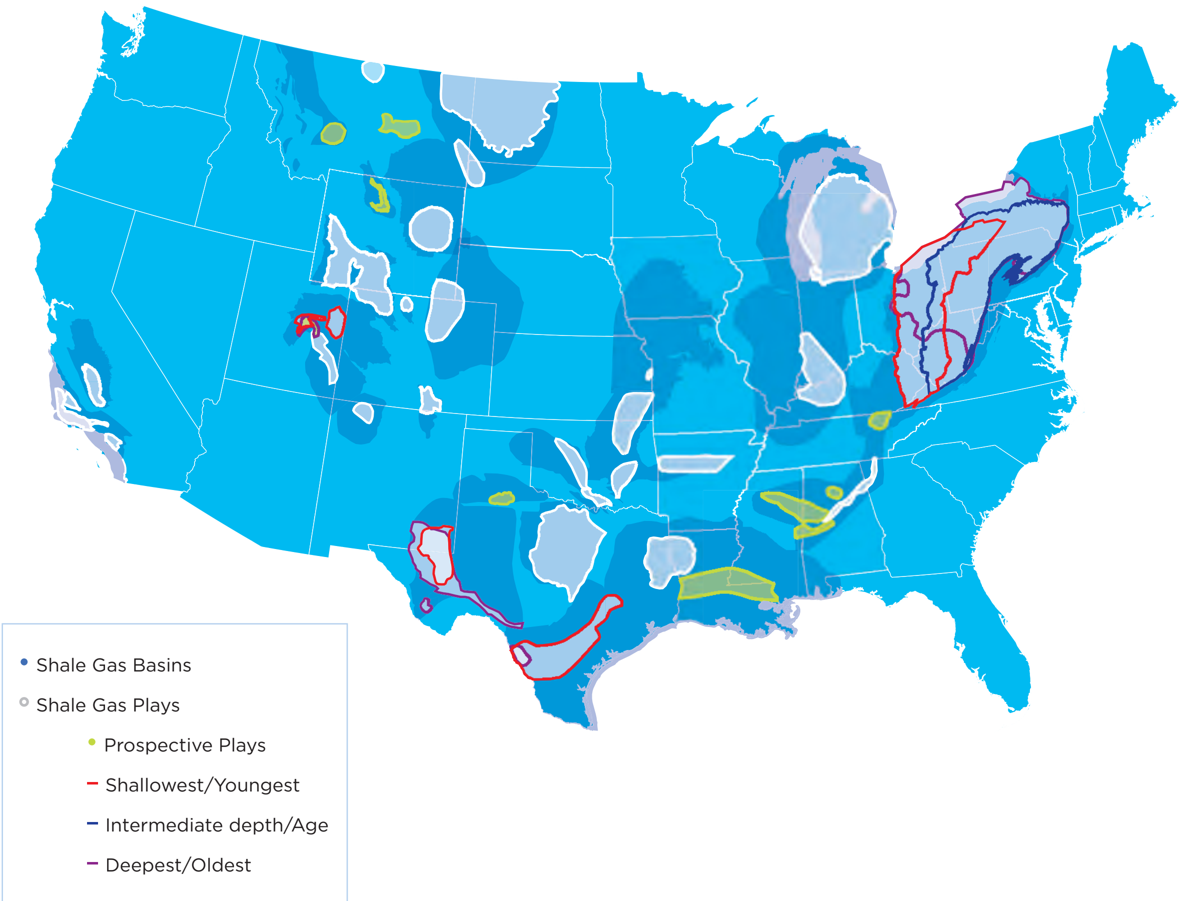
In the mid-2000s, gas producers soon began evaluating a wide range of shale plays across North America and realized that horizontal drilling was widely applicable in many geologic settings. Today, shale gas plays are being developed in most of the major oil and gas provinces of the Lower-48, as well as in Western Canada (see Exhibit 2-2).

Exhibit 2-1
Horizontal Drilling
and Fracture Stimulation



Source: Encana

Exhibit 2-2 Map of U.S. Lower-48 Shale Plays



Source: U.S. Energy Information Administration

2.2 Resource Assessments

The issue of how much recoverable shale gas and tight oil is present in the United States has received a great deal of attention in recent years. Prior to 2000, U.S. assessment groups believed that shale gas potential was limited to a few specific producing areas or plays and would not contribute a significant portion of overall production. This is understandable: At the time, there was no way to tap the shales, though it was known that a large volume of gas was present.

There are several methods of assessing remaining unconventional gas potential. The primary methods are as follows:

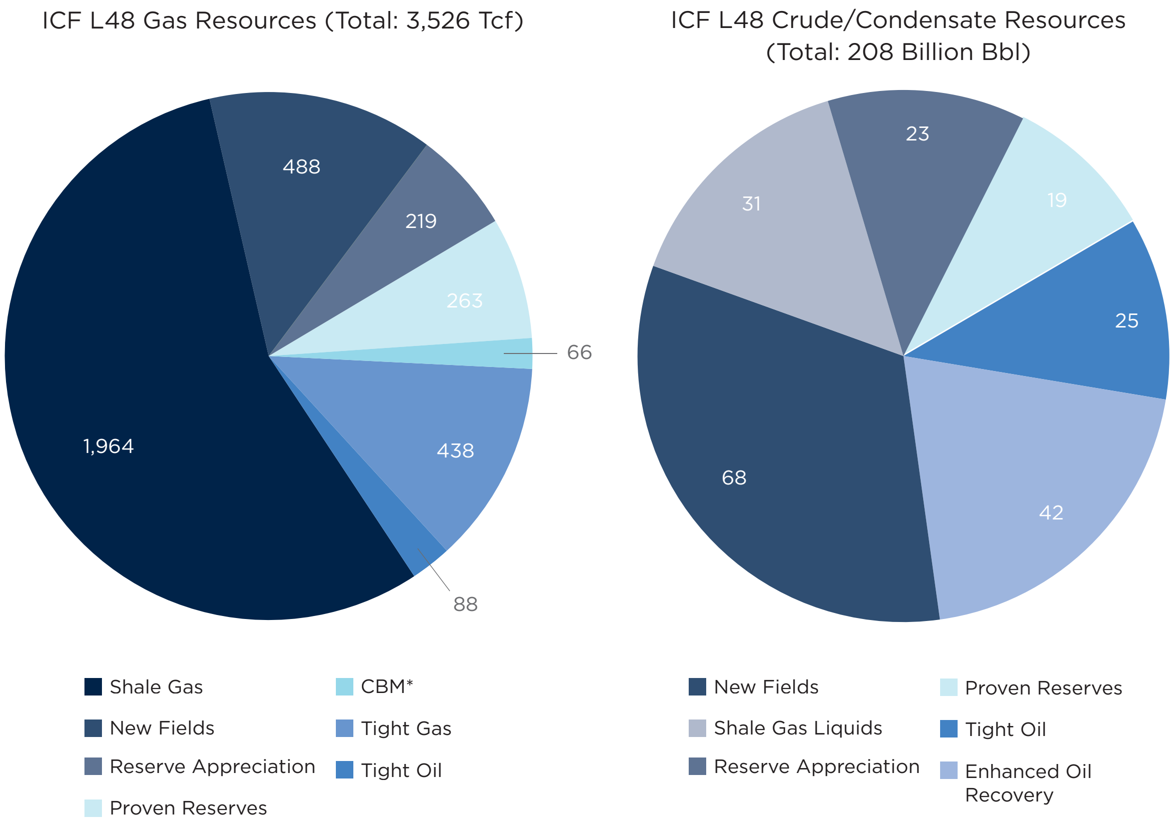
- Gas-in-place determination and engineering determination of per-well recovery, combined with number of potential drill sites
- Gas-in-place estimation and general recovery factor and number of potential well sites
- Estimated recovery per well and number of potential drill sites

The most reliable method is the first method, which estimates the volume of original gas-in-place, then determines the technically recoverable resource per well using engineering methods. The number of potential wells is determined through assumptions about well spacing and risk factors.

Original gas-in-place[9] is estimated by mapping of characteristics such as shale thickness, organic content, depth, pressure, and thermal maturity. Estimates are made of porosity and water saturation (the amount of water in the pores). These data are fed into models to estimate recovery per well, which is the amount of gas that a new well in an area is expected to recover. The estimated well recovery can be calibrated or confirmed by historical well production from nearby wells. This is the "ground-truthing" of well recovery and validates the assessment and the overall approach.

Exhibit 2-3 shows the current ICF North America oil and gas resource base assessment. The volumes are shown in trillion cubic feet of gas and billion barrels of liquids. The exhibit shows that the Lower-48 has a recoverable gas resource base of 3,526 trillion cubic feet (Tcf) and 208 billion barrels of liquids. This recoverable gas resource base represents approximately 150 years of U.S. gas demand at current levels. These volumes are based on conservative estimates using the assumption of current technology. Canada is assessed to have an additional 1,133 Tcf of gas and 35 billion barrels of liquids.

Exhibit 2-3 ICF Lower-48 Oil and Gas Resources



Source: ICF estimates
* Coalbed methane

9. Original gas-in-place and original oil-in-place are industry terms that specify the amount of natural gas and oil, respectively, in a reservoir (including both recoverable and unrecoverable volumes) before any production takes place.

It is also important to look at the changes in resource base assessments since the advent of horizontal shale gas. The current analysis seeks to determine the impact of the new shale gas itself, above and beyond what would have occurred with the gas resource base that was previously envisioned. Exhibit 2-4 shows the difference between the current ICF assessment and the 2003 National Petroleum Council assessment. The 2003 NPC study included a large resource assessment effort, and the study was carried out before significant horizontal shale drilling took place. The exhibit below shows that the current gas resource base assessment is 2,379 Tcf higher, or three times the size of the 2003 resource base. The ICF crude oil and condensate resource base assessment is at least 50 billion barrels larger than ICF's interpretation of NPC's 2003 assessment because of the addition of tight oil and shale gas liquids. If one includes the natural gas plant liquids that can be separated from the wet gas obtained from shale plays, additional tens of billions of barrels of liquids are in the current assessment.

2.3 Drilling and Production

In recent years, U.S. natural gas production has risen by 5 Tcf per year as a result of shale gas development (Exhibit 2-5). Prior to this increase, U.S. gas production had been relatively flat for years and had been declining in many onshore areas. U.S. gas production is now at record levels, surpassing the previous record production rates of the 1970s.

Exhibit 2-4 Differences in Lower-48 Natural Gas Resources Assessments

Resource	Assessment Source (Tcf)		
	2003 NPC	2012 ICF	Difference (Tcf)
Proven Reserves	175	263	88
Reserve Appreciation/Low Btu	218	219	1
New Fields	486	488	2
Shale Gas	35	1,964	1,929
Tight Oil	-	88	88
Tight Gas	175	438	263
CBM	58	66	8
Total	**1,147**	**3,526**	**2,379**
Total Minus Proven	**972**	**3,263**	**2,291**

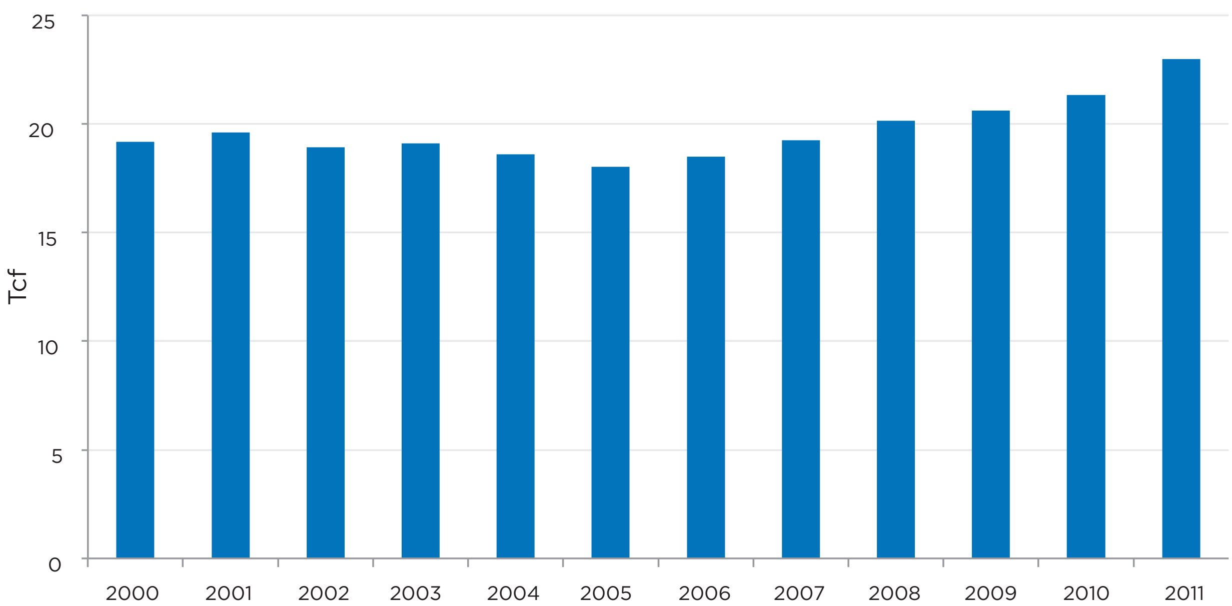
Source: ICF estimates and the 2003 National Petroleum Council (NPC) study, Balancing Natural Gas Policy: Fueling the Demands of a Growing Economy." NPC study available at http://www.npc.org/reports/Vol_5-final.pdf

The traditional indicator of U.S. drilling is the number of active rigs targeting oil or gas. Shale activity resulted in a large increase in gas-directed rig activity that continued through 2010. Exhibit 2-6 shows historical annual U.S. oil and gas well completions in recent years. The peak number of annual wells occurred in 2008. Since 2009, activity has been dominated by horizontal shale gas drilling, with the initial increase in gas drilling followed by a rise in tight oil drilling.

New activity is increasingly dominated by deep, high-cost horizontal wells. While horizontal drilling has been increasing, shallow vertical drilling has been declining. Prior years were dominated by these shallower, less expensive wells. However, the declining drilling activity since 2008 is somewhat misleading because of the large changes in the nature of gas and oil wells being drilled, as a typical horizontal shale well is 10 times more productive than a comparable vertical shale well (4 bcf versus 0.4 bcf per well, respectively). Moreover, a horizontal shale well is roughly 5 times more productive than a comparable conventional gas well, drilled vertically (4 bcf versus 0.8 bcf per well, respectively).[10] This disparity between horizontal and vertical well production underscores that the lower well counts are a function of upstream technology improvements, rather than actual declining activity.

The success of shale drilling resulted in declining natural gas prices and reduced gas-directed drilling activity in 2011 and 2012. At the same time, oil-directed rig activity rose in response to higher oil prices. The change was brought about by moving to the oil portion of shale plays and to tight oil plays. Tight oil drilling activity has increased, but midstream issues related to gas processing and liquids transport have become a major constraint in some areas, as infrastructure investments (needed to process and transport associated liquids) lag behind the increase in drilling activity. This will necessitate large-scale expenditures for new infrastructure.

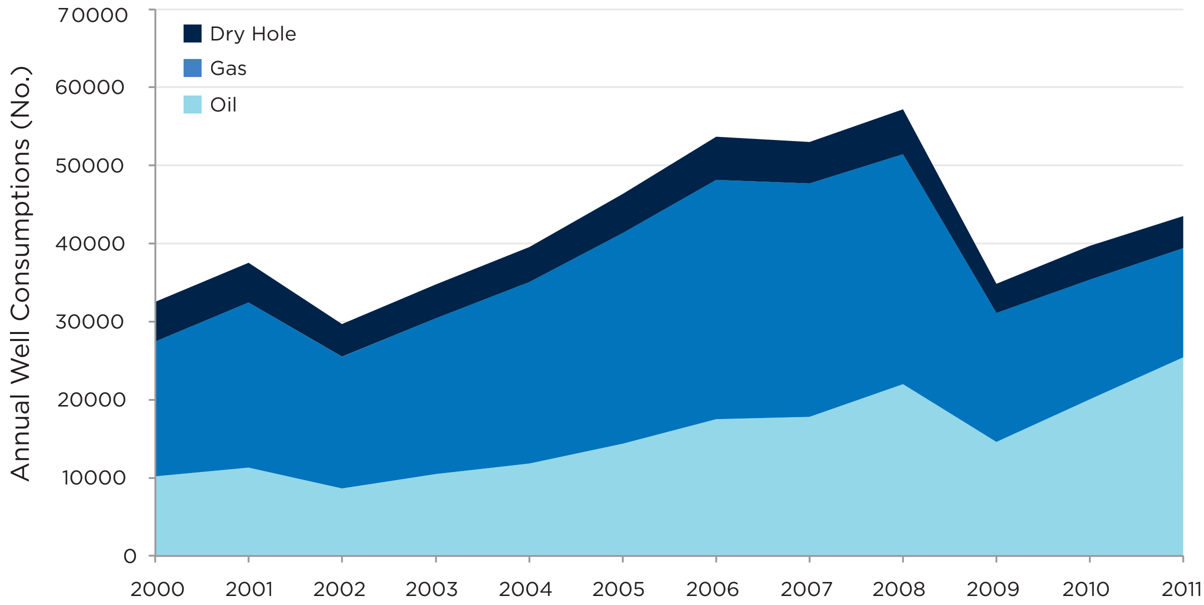
Exhibit 2-5 U.S. Dry Natural Gas Production



Source: U.S. Energy Information Administration (EIA). "U.S. Dry Natural Gas Production." EIA, June 2012: Washington, D.C. Available at: http://www.eia.gov/dnav/ng/hist/n9070us2A.htm

10. Based on ICF decline curve analysis of HPDI database offered by DrillingInfo Inc. and state historical production data.

Exhibit 2-6 Annual U.S. Oil and Gas Completions



Source: API Quarterly Completion, July 2012.

The near-term outlook for U.S. drilling is expected to reflect recent trends, with a continued decline in gas-directed activity and increasing oil activity, primarily in the unconventional oil and wet gas plays. Overall rig activity is not expected to increase significantly until there is an upturn in natural gas prices, although liquids-rich areas such as in the southwestern Pennsylvania portion of the Marcellus will continue to see drilling activity, as liquids prices are tied to crude prices. The growth in gas production of recent years is expected to level off, due to a sharp reduction in dry gas drilling for shale gas since 2010.

In terms of NGLs, liquids are a valuable byproduct of natural gas production. NGLs are hydrocarbons that are produced with natural gas in most areas. NGLs are in gaseous form at the wellhead and must be processed out of the gas. Components of NGLs include ethane, propane, butanes, and pentanes-plus.

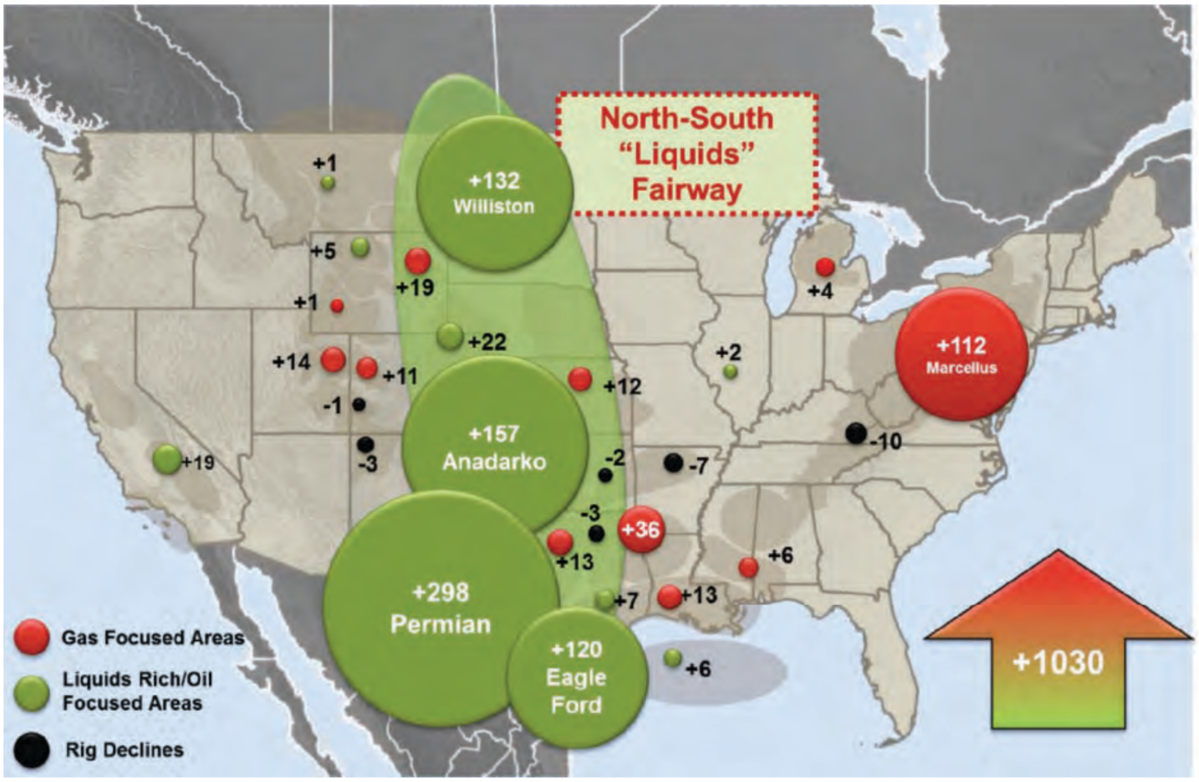
About 75 percent of NGLs in the U.S. come from gas processing plants, while the remainder comes from oil refining. As gas production from shale has increased, the output of U.S. NGLs has grown in parallel and is expected to increase in the future with shale gas production.

NGLs are used in a wide range of applications, including petrochemical plants, space heating, motor fuels, and gasoline blending. Exports of NGLs are expected to become significant in the future. Ethane, which represents the highest volume NGL component, is a key feedstock for the production of ethylene, which is used to manufacture a wide range of commercial and consumer plastic products. Propane is used in the petrochemical industry, as well as for heating and as a motor fuel.

An important aspect of NGL production from shale gas is that on a heating value basis, NGLs are currently much more valuable than natural gas. This is because of the relatively high international oil prices and lower natural gas prices due to the current oversupplied gas market. The difference in price is significant enough to drive drilling activity toward so-called wet gas and tight oil plays.

Different shale plays have varying levels of natural gas liquids content and composition. Exhibit 2-7 illustrates the location of the major liquids rich areas of the U.S. Major shale plays with high liquids content include the Eagle Ford in South Texas, the Granite Wash in western Oklahoma, the Bakken tight oil play in North Dakota, parts of the Marcellus shale in Pennsylvania, and the Utica shale in Ohio. The Permian Basin of West Texas and southeastern New Mexico is emerging as a major player in tight oil and NGL production. The Monterey shale of southern California also has significant potential for liquids.

Exhibit 2-7 Location of Liquids-Rich Areas of the U.S. as Illustrated by Rig Activity[11]



Source: National Petroleum Council (NPC), 2011, "Liquids (NGLs)," working document of the NPC North American Resource Development Study, Washington DC, September 2011. Available at: http://www.npc.org/Prudent_Development-Topic_Papers/1-13_NGL_Paper.pdf

11. Rig additions between May 2009 and March 2011

3 Natural Gas Production and Investment Trends

This section includes a discussion of well drilling operations, requisite capital expenditures, current investment trends, and selected state case studies.

3.1 Gas Well Drilling and Operations

There are many aspects to the drilling and operation of a gas well. Each aspect involves outlays and has an impact on the economy. The basic activities can be categorized as follows:[12]

- Leasing
- Exploration
- Drilling and Completion
- Transporting, Processing and Sales

3.1.1 Leasing

Before drilling a well, the operator must obtain a lease from the mineral interest owner. In a large unconventional gas play on largely private lands, there are typically thousands of small interest owners, so the process of obtaining and managing leases can be a major effort, especially for the larger producers. There are also plays that are located on either federal or state lands, and, in such cases, leasing is carried out by the government agencies. Operators negotiate terms with each leaseholder, typically on the basis of an up-front bonus payment and royalties paid as a percentage of the sales value. Once the lease is arranged, the operator has a certain amount of time to drill a well on the lease.

3.1.2 Exploration

Exploration encompasses various activities aimed at targeting the drilling in specific areas to achieve commercial production. These include regional and local geologic studies, seismic data acquisition and processing. The exploration effort results in a drilling plan that narrows the zone of interest in an area.

3.1.3 Drilling and Completion

Once the site is chosen for drilling a gas well, a drilling and completion plan is developed and implemented. A drilling permit must be obtained from the state or federal agency. The well site or pad is prepared by clearing the land and building a gravel access road. The drilling rig is brought in and drilling begins. The well may be planned as a vertical well or a horizontal well. The drilling and completion of horizontal wells, however, require specialized equipment and procedures.

A typical well design consists of telescoping strings of casing from the surface to total depth. The wellbore is large at the surface, and becomes smaller with depth. Each segment of the well, once drilled, is lined with steel casing that is cemented in place. In a horizontal well, a specialized downhole assembly is used to drill a horizontal section up to 10,000 feet long. This section is then stimulated through hydraulic fracturing in multiple stages.

The drilling and completion of a horizontal gas well can cost from $3 million to $8 million and represents most of the capital outlays. Large cost components include rig rentals, tubular goods,

12. Considine, T., et al, 2009, “An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play,” Penn State College of Earth and Mineral Sciences, July, 2009.

cement, stimulation services, and wellhead equipment. Transportation of materials to the well site is also very significant. Exhibit 3-1 shows a drilling rig used for horizontal well drilling.

3.1.4 Transporting, Processing, and Sales

After the well is completed the necessary processing and transportation infrastructure must be in place to produce the oil and gas. With existing producing basins or areas, such infrastructure is already in place. However, infrastructure in the new shale gas and tight oil plays can be sparse to non-existent. Dry gas plays require minimal processing, so only a gathering and pipeline system are necessary. In a wet gas or oil play, even larger outlays may be required to separate the gas from the oil, process water and liquids from the gas, and transport the dry gas and liquids to market.

Producing, processing, and transporting NGLs from the shale and tight oil plays will result in billions of dollars of expenditures for midstream infrastructure in coming decades. Recently, the Interstate Natural Gas Association of America sponsored a study of future U.S. midstream infrastructure needs, which will be primarily driven by unconventional gas and liquids plays.[13] As shown in Exhibit 3-2, the study projected that between 2011 and 2035 approximately $42 billion dollars of expenditures will be required for gathering lines, $9 billion for pipeline compression, and $22 billion for gas processing. Total outlays including gas transmission lines and other components will be $205 billion.

Exhibit 3-1 Marcellus Shale Drilling Rig

Source: Considine, et al. 2009.

13. The INGAA Foundation, 2011, "North American Natural Gas Mid-Stream Infrastructure Through 2035- A Secure Energy Future, June 28, 2011. http://www.ingaa.org/Foundation/Foundation-Reports/Studies/14904/14889.aspx

Exhibit 3-2 Natural Gas Infrastructure Capital Requirements

Natural Gas Infrastructure Capital Requirements	2010$ Billion		
	2011-2020	2011-2035	Avg. Annual Expenditures
Gas Transmission Mainline	$46.2	$97.7	$3.9
Laterals to/from Power Plants, Gas Storage, Processing Plants	$14.0	$29.8	$1.2
Gathering Line	$16.3	$41.7	$1.7
Gas Pipeline Compression	$5.6	$9.1	$0.3
Gas Storage Fields	$3.6	$4.8	$0.2
Gas Processing Capacity	$12.4	$22.1	$0.9
Total Gas Capital Requirements	**$98.1**	**$205.2**	**$8.2**

Source: The INGAA Foundation, 2011

Exhibit 3-3 Employee Compensation in the Natural Gas Industry is Relatively High

Wages within the oil and gas sector are roughly 40 percent higher than the U.S. average, according to the U.S. Bureau of Labor Statistics. Jobs in the manufacturing sector, an industry that directly benefits from the success of recent upstream technology advancements in North America, typically see annual wages nearly 25 percent higher than the national average. In an economy that continues to languish in many areas of the country, job growth in a high-compensation industry such as oil and gas proves to be a significant economic growth driver. This point is evidenced in the significantly lower unemployment rates seen in gas-producing states such as Pennsylvania and Ohio, which both saw unemployment rates of 7.4 percent in April 2012, compared with 8.1 percent seen nationwide.[14] As gas production in these and other states continues to grow, it will continue to be an economic driver for producing states.

3.2 Value Added by Sector from U.S. Shale Development

Most of the expenditures incurred by natural gas and oil producers are the capital costs to acquire leases and to drill and complete wells. After the well goes into commercial production, there are continuing costs to operate the well. These include the operation of liquids separation, gathering, and compression. Exhibit 3-4 and Exhibit 3-5 are two examples from a recent ICF study of the distribution of GDP additions (i.e., value added) and employment, respectively, by category that result from shale gas development in the U.S.[15] The tables on the following pages show the total share of direct and indirect value added for each category. The data are sorted on the basis of direct and indirect impacts as a proportion of total direct plus indirect impacts. The categories experiencing the largest impact include support activities for oil and gas operations, truck transportation, steel product manufacturing, oil and gas drilling, and non-residential construction.

14. U.S. Bureau of Labor Statistics (BLS). "Regional and State Employment and Unemployment." BLS, June 2012: Washington, D.C. Available at: http://www.bls.gov/news.release/pdf/laus.pdf
15. ICF International. "Economic Impact Study of Construction and Operations." Dominion Cove Point LNG, LP, October 2011: Lusby, MD.

Exhibit 3-4 Example of Direct and Indirect Value Added Share by Sector for U.S. Shale Development

2007 NAICS	IMPLAN Description	IMPLAN Sector	Direct Value Added	Indirect Value Added	Direct and Indirect Value Added
213111	Drilling oil and gas wells	28	17.2%	0.0%	17.2%
213112	Support activities for oil and gas operations	29	12.5%	0.6%	13.1%
484	Truck transportation	335	6.1%	1.1%	7.2%
33121, 33122	Steel product manufacturing from purchased steel	171	4.9%	0.5%	5.4%
211	Oil and gas extraction	20	4.1%	1.3%	5.4%
42	Wholesale trade	319	0.2%	3.0%	3.2%
23	Construction of other new nonresidential structures	36	2.8%	0.0%	2.8%
21232	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	26	2.7%	0.1%	2.7%
55	Management of companies and enterprises	381	0.0%	2.2%	2.2%
5413	Architectural, engineering, and related services	369	0.0%	1.8%	1.8%
531	Real estate	360	0.0%	1.7%	1.7%
3311	Iron and steel mills and ferroalloy manufacturing	170	0.0%	1.3%	1.3%
5411	Legal services	367	0.0%	1.2%	1.2%
32731	Cement manufacturing	160	1.1%	0.1%	1.2%
722	Food services and drinking places	413	0.4%	0.4%	0.8%
5613	Employment services	382	0.0%	0.7%	0.7%
5412	Accounting, tax preparation, bookkeeping, and payroll services	368	0.0%	0.7%	0.7%
523	Securities, commodity contracts, investments, and related activities	356	0.0%	0.7%	0.7%
5222-3	Nondepository credit intermediation and related activities	355	0.0%	0.7%	0.7%
23	Maintenance and repair construction of nonresidential maintenance and repair	39	0.0%	0.7%	0.7%
54161, 5613	Management, scientific, and technical consulting services	374	0.0%	0.6%	0.6%
492	Couriers and messengers	339	0.0%	0.5%	0.5%
5617	Services to buildings and dwellings	388	0.0%	0.5%	0.5%
72111-2	Hotels and motels, including casino hotels	411	0.2%	0.2%	0.4%
5614	Business support services	386	0.0%	0.2%	0.2%
Others			**4.7%**	**22.3%**	**27.0%**
Total			**56.7%**	**43.3%**	**100.0%**

Source: ICF estimates made using IMPLAN model
Note: This table shows approximate percent of capital costs for horizontal shale or tight gas wells (excluding lease acquisition costs) that are represented by value added in each domestic sector. Typical capital costs are in the range of $3 to $8 million per well. Value added for imported goods (about 14% of capital costs) are not in this table.

Exhibit 3-5 Example of Direct and Indirect Employment Share by Sector for U.S. Shale Development

2007 NAICS	IMPLAN Description	IMPLAN Sector	Direct Employment	Indirect Employment	Direct and Indirect Employment
213112	Support activities for oil and gas operations	29	14.2%	0.7%	14.9%
484	Truck transportation	335	10.3%	1.8%	12.1%
33121, 33122	Steel product manufacturing from purchased steel	171	5.5%	0.6%	6.1%
213111	Drilling oil and gas wells	28	5.4%	0.0%	5.4%
23	Construction of other new nonresidential structures	36	4.8%	0.0%	4.8%
21232	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	26	3.4%	0.1%	3.5%
211	Oil and gas extraction	20	2.3%	0.7%	3.0%
722	Food services and drinking places	413	1.5%	1.4%	2.9%
5413	Architectural, engineering, and related services	369	0.0%	2.6%	2.6%
42	Wholesale trade	319	0.1%	2.4%	2.5%
5613	Employment services	382	0.0%	2.5%	2.5%
55	Management of companies and enterprises	381	0.0%	1.8%	1.8%
5617	Services to buildings and dwellings	388	0.0%	1.6%	1.6%
531	Real estate	360	0.0%	1.4%	1.4%
523	Securities, commodity contracts, investments, and related activities	356	0.0%	1.4%	1.4%
23	Maintenance and repair construction of nonresidential maintenance and repair	39	0.0%	1.1%	1.1%
5411	Legal services	367	0.0%	1.0%	1.0%
3311	Iron and steel mills and ferroalloy manufacturing	170	0.0%	1.0%	1.0%
5412	Accounting, tax preparation, bookkeeping, and payroll services	368	0.0%	0.9%	0.9%
5222-3	Nondepository credit intermediation and related activities	355	0.0%	0.9%	0.9%
72111-2	Hotels and motels, including casino hotels	411	0.4%	0.4%	0.8%
492	Couriers and messengers	339	0.0%	0.8%	0.8%
5614	Business support services	386	0.0%	0.8%	0.8%
32731	Cement manufacturing	160	0.6%	0.1%	0.7%
54161, 5613	Management, scientific, and technical consulting services	374	0.0%	0.7%	0.7%
Others			**6.2%**	**18.7%**	**24.9%**
Total			**54.6%**	**45.4%**	**100.0%**

Source: ICF estimates made using IMPLAN model
Note: Total direct and indirect employment can be approximated as roughly 200 person-years per 1 MMBOE (5.67 Bcf dry gas) of incremental annual production.

3.3 Economic Activity of Oil and Gas Services Industries

This section presents a discussion of several service industries related to shale gas development. The discussion shows the wide-ranging nature of economic and job impacts that are related to exploration and drilling activity.

3.3.1 Sand and Other Proppants

The hydraulic fracturing of a gas well requires a combination of water, guar gum, trace amounts of various chemicals, and proppants. Sand, the most frequently used proppant, can come in many forms, including (from lowest to highest quality) brown or white sand, resin-coated sand, or ceramic "sand." The proppant plays a vital role in the hydraulic fracturing process – it is the material that "props" open the fissures in shale rock created by the injection of water into the well. The harder the sand, the more likely it is that the fissures stay open and allow the gas and oil to move out of the rock and into the well.

Growth in the number of hydraulically fractured wells, and the increasing length of horizontal well sections, directly drives increasing proppant demand. A typical well in the Marcellus requires approximately 5 million pounds of proppant (enough to fill about 1,500 children's sand boxes), worth about $175,000.[16] Between 2000 and 2010, as gas drilling activity migrated to shale plays, and the use of hydraulic fracturing took off, the use of sand increased tenfold, to approximately 30 billion pounds per year in 2010 (the annual equivalent to the weight of two Great Pyramids of Giza).[17,18]

The U.S. Geological Survey notes that in 2010 the production value of the sand mining industry exceeded $1 billion for the first time, with growth driven primarily by demand from the oil and gas sector.[19] In 2010, hydraulic fracturing accounted for over 41 percent of all sand consumed in the United States by volume, and over 53 percent by value. This was nearly double the figures for 2009.

Until recently, most of the proppant supplied to oil and gas producers came along with completion services supplied by such companies as Halliburton and Schlumberger. In the past few years, however, as demand and prices for proppants of all grades skyrocketed, E&P companies have begun to seek their own suppliers and supplies. Pioneer Natural Resources, one such company, agreed to buy Carmeuse Industrial Sands (CIS) in March 2012. CIS was already Pioneer's largest sand supplier, and through the acquisition Pioneer hopes to realize $65 million to $70 million in savings, as it both expands output at the brown sand mine in Texas, and starts up production at a white sand mine in Wisconsin.[20]

EOG Resources, another oil and gas producer, recently started operations at its own mine in Chippewa Falls, Wisconsin, from where it ships the sand to its sand processing facility in Refugio, Texas, by rail.[21] EOG employs 38 people at the mine, with another 95 jobs created by trucking companies and subcontractors working with the company. EOG also owns a sand mine in Cooke County, Texas, which is expected to create 40 full-time positions once in operation, with a similar number of associated jobs as in Chippewa Falls.[22]

In 2010, the U.S. oil and gas industry used enough sand to build two Great Pyramids of Giza.

EOG's arrival in Wisconsin is part of a wider boom, with 16 mines in operation and 25 sites in the permitting process.[23] Wisconsin sand, prized for its uniform shape and hardness, can sell for as much as $200 a ton – six times what the USGS reports as the average price of a ton of sand in the U.S. in 2010.[24]

16. Oil and Gas Investments Bulletin (OGIB) Research Team. "US Silica: The First IPO in the "Fracking Sand" Industry." OGIB, 17 February 2012. Available at: http://oilandgas-investments.com/2012/stock-market/us-silica-ipo-fracking-sand/
17. U.S. Geological Survey (USGS). "2010 Minerals Yearbook: Silica [Advance Release]." USGS, February 2012. Available at: http://minerals.usgs.gov/minerals/pubs/commodity/silica/myb1-2010-silic.pdf
18. Deschamps, Jean-François. "Measurements of the Great Pyramid." Deschamps, Jean-François, 1999. Available at: http://www.repertorium.net/rostau/measures.html
19. U.S. Geological Survey (USGS). "2010 Minerals Yearbook: Silica [Advance Release]."
20. "Pioneer Natural Resources Announces Acquisition of Carmeuse Industrial Sands". Business Wire, March 5, 2012. Available at: http://www.businesswire.com/news/home/20120305005402/en/Pioneer-Natural-Resources-Announces-Acquisition-Carmeuse-Industrial
21. The Chippewa Herald. "EOG sand operation underway." The Chippewa Herald, 8 January 2012. Available at: http://chippewa.com/news/local/eog-sand-operation-underway/article_8f360c64-398f-11e1-91cf-001871e3ce6c.html
22. EOG Resources, Inc. "The Facts." EOG Resources, accessed 31 July 2012. Available at: http://www.eogresources.com/operations/cooke_mine.html
23. Smathers, Jason. "Sand mining surges in Wisconsin." Wisconsin Center for Investigative Journalism, 31 July 2011. Available at: http://www.wisconsinwatch.org/2011/07/31/sand-mining-surges-in-wisconsin/
24. Prengaman, Kate., "Frac sand boom creates thousands of jobs." WisconsinWatch. Org, Aug. 19, 2012, Available at: http://www.wisconsin-watch.org/2012/08/19/sand-boom-creates-jobs/

Arkansas, which is in close proximity to a number of shale plays and is also endowed with quality sand deposits, is also seeing a rise in sand-mining activity. Southwestern Energy, the largest natural gas producer in the Fayetteville shale play, operates a sand mining operation in a former channel of the Arkansas River. Its dredging operation is capable of producing about a million tons of sand a year, directly employing 53 people.[25] Since the start of activity in the Fayetteville shale, Arkansas has seen sand mining activity boom, increasing from one company with a license in 2004 to 15 at the end of 2011 – with 10 licenses granted just since 2010.

With demand for natural sand outstripping supply and demand increasing for ever-harder proppants as the industry drills deeper, into harder rock, demand for man-made proppants is also on the increase. Resin-coated sand and ceramics – harder and of more uniform size than silica, fill that need. U.S.-based CARBO, the largest manufacturer of ceramic proppants in the world,[26] recently announced plans for a new plant in Millen, Georgia.[27] Initially designed to hold one production line, with 70 full-time employment positions, the plant could be expanded to four lines. This comes on top of the two plants and 200 employees CARBO currently has in Georgia.

Ceramic proppants are a premium product, and are expected to play a growing role in hydraulic fracturing due to their better performance, and due to recent spikes in guar gum prices.[28,29] In the high-temperature, high-pressure Bakken shale play, ceramic proppants now hold approximately 40 percent of the market.[30] In fact, initial studies are under way to evaluate the potential for a ceramic proppant manufacturing facility to be located in North Dakota, which would turn North Dakota clay into the essential ingredient needed for hydraulic fracturing.

Whether sand, resin-coated sand, or ceramic, the proppant industry's output has been growing by leaps and bounds over the past few years. And with that growth, it has brought jobs and economic growth to communities around the country, including those, like Izard County in Arkansas, where the recession hit particularly hard. And unlike many types of mining, the USGS considers sand mining to have a "limited environmental impact."

3.3.2 Water Use, Treatment, and Disposal

A large component of the economic activity attributable to incremental gas and oil supplies is related to water use, treatment, and disposal. A typical horizontal shale gas well requires 3-9 million gallons of water for hydraulic stimulation.[31,32] The water is typically trucked to the well site, mixed with proppants, and injected into the well during fracturing operations. Much of the water is returned during well cleanout and is available for treatment and re-use. After treatment to separate freshwater from concentrated brine, the freshwater component is re-used and the concentrated brine is typically trucked to an injection well location, where it is injected into a deep formation. Jobs involve truck transportation, truck sales, water treatment facility sales and operation, and water well disposal. Jobs are also generated for environmental monitoring services.

3.3.3 Iron and Steel Products

Steel, and particularly steel tubing, is an essential element of natural gas production and transport. From the drill pipe itself, through to the well casing and well tubing, and out to the gathering, lateral, and transmission lines, the natural gas industry is a major consumer of steel pipe.

25. Quinn, Paul. "Demand from drillers drives Ark. sand mine permits." Arkansas Democrat-Gazette, 13 October 2011. Available at: http://www.alaskajournal.com/Alaska-Journal-of-Commerce/October-2011/Demand-from-drillers-drives-Ark-sand-mine-permits/
26. Seeking Alpha. "CARBO Ceramics Inc." Seeking Alpha, 2012. Available at: http://seekingalpha.com/symbol/crr/description
27. CARBO Ceramics Inc. "CARBO to build new manufacturing plant in Georgia." CARBO Ceramics Inc, 3 May 2012: Houston, TX. Available at: http://www.carboceramics.com/en/rel/39/
28. Wethe, David and Dreibus, Tony. "Guar At Record May Fail To Boost U.S. Output, Help Halliburton." Bloomberg, 19 April 2012. Available at: http://www.bloomberg.com/news/2012-04-20/guar-at-record-may-fail-to-boost-u-s-output-help-halliburton.html
29. CARBO Ceramics Inc. "Guar gum shortage: Proppant misconceptions." CARBO Ceramics Inc, 10 May 2012: Houston, TX. Available at: http://www.carboceramics.com/en/rel/41/
30. Donovan, Lauren. "Is clay the next Bakken play? Ceramic sand could be made in N.D." The Bismarck Tribune, 27 October 2011: Bismarck, ND. Available at: http://bismarcktribune.com/news/state-and-regional/is-clay-the-next-bakken-play-ceramic-sand-could-be/article_3496c950-0051-11e1-9456-001cc4c03286.html
31. Xinhua. "New technologies help save water in US oil industry." Xinhua, 23 June 2012. Available at: http://www.china.org.cn/environment/2012-06/23/content_25715645.htm
32. Susquehanna River Basin Commission. "Gas Well Drilling and Development Marcellus Shale." Susquehanna River Basin Commission Meeting, 12 June 2008: Elmira, NY. P. 19. Available at: http://www.srbc.net/whatsnew/docs/Marcellusshale61208ppt.PDF

A typical shale gas well requires 10,000 feet of steel casing or liner, weighing approximately 130 tons and 8,000 feet of well tubing, weighing 22 tons. Add in an average of a quarter-mile of gathering lines per well, and the sum could easily exceed 160 tons. The increase of natural gas and oil production to the Lower-48, and the associated increase in demand for steel, is therefore contributing to the revitalization of the steel industry.

As shown in Exhibit 3-6: Steel Tubing and Line Pipe Demand Estimates and Projections (rounded), ICF projects steel demand from the natural gas and oil industry to total over 66 million tons between 2008 and 2017. For comparison, current annualized (as of July 2012) steel production in the United States totals 89 million tons.[33] U.S. steel mills are expected to produce a vast majority of this new material, in the process creating new jobs, and spurring additional economic activity.

Traditionally, 55 percent of finished steel products find their way into the construction industry.[34] With that sector just starting to recover, the oil and gas industry has stepped in to bring total U.S. steel demand up to near its pre-2009 peak.[35] Output is ramping up on new tubular steel production lines in Loraine[36] and Youngstown, Ohio,[37] and on new raw steel production lines in Monroe, Michigan,[38] Columbus, Mississippi,[39] and Burns Harbor, Indiana,[40] which provide the feed material used in tubular steel manufacturing.

The change in steel demand coming from the oil and gas industry, in addition to the low energy prices enjoyed by U.S. steel manufacturers as a result of recent growth in natural gas output, have combined to make the American steel industry competitive again and an engine of economic revival.

Exhibit 3-6 Steel Tubing and Line Pipe Demand Estimates and Projections (rounded)

Sector	Tons		
	2008-2012	2013-2017	Total
Drilling Pipe	305,000	356,000	661,000
Well Tubing	3,930,000	4,420,000	8,350,000
Well Casing	14,910,000	18,790,000	33,700,000
Gathering Lines	1,930,000	1,930,000	3,860,000
Gas Plant Lateral	440,000	270,000	710,000
Gas Transmission	8,200,000	4,230,000	12,430,000
Oil Transmission	2,160,000	2,330,000	4,490,000
NGL Transmission	220,000	960,000	1,180,000
Power Lateral	200,000	365,000	568,000
Storage Lateral	286,000	97,000	383,000
All Pipe Types	32,590,000	33,740,000	66,330,000

Source: ICF estimates

33. "Crude steel production", World Steel Association, July 2012. Available at: http://www.worldsteel.org/statistics/crude-steel-production.html
34. Outlook for U.S. Steel Industry & Stocks, SeekingAlpha, Accessed 29 May 2012, Available at: http://seekingalpha.com/instablog/1111501-marketwizard/251529-outlook-for-u-s-steel-industry-stocks
35. Schneider, Keith. "As Demand Rises, Ohio's Steel Mills Shake Off the Rust and Expand." The New York Times, April 24, 2012. Available at: http://www.nytimes.com/2012/04/25/business/energy-environment/ohio-steel-mills-expand-to-meet-demand-in-energy-and-auto-industries.html
36. Miller, Chelsea. "Senator tours U.S. Steel's expanded operations." The Chronicle & Telegram, April 4, 2012. Available at: http://chronicle.northcoastnow.com/2012/04/04/senator-tours-u-s-steel%E2%80%99s-expanded-operations/
37. Ansberry, Clare. "Left for Extinct, a Steel Plant Rises in Ohio." Wall Street Journal, August 2, 2011. Available at: http://online.wsj.com/article/SB10001424053111904233404576462562705511704.html
38. Gerdau Macsteel. "Gerdau Macsteel Approves $67 Million Capital Investment For Monroe, Michigan Plant." Gerdau Macsteel, 9 September 2010: Jackson, MI. Available at: http://www.gerdaumacsteel.com/media-center/releases/GMPressReleaseCapitalProject_20100909.pdf
39. Severstal. "Severstal Columbus." Severstal, accessed 31 July 2012. Available at: http://severstal.com/eng/businesses/international/north_american/columbus/
40. Miller, John. "Indiana Steel Mill Revived With Lessons From Abroad." Wall Street Journal, 21 May 2012: Burns Harbor, IN. Available at: http://online.wsj.com/article/SB10001424052702304444604577340053191940814.html?mod=googlenews_wsj

3.3.4 Trucking

The Great Recession hit the trucking industry particularly hard. Road haulage accounts for about two-thirds of freight tons carried across America, so truckers feel the impact when the economy slows and business activity declines.[41] After peaking in January 2007–almost a year before the recession hit–employment in the industry declined nearly every month until February 2011. In that time, truck transportation shed 169,200 jobs, bottoming out at 1.3 million–a 12 percent drop from the January 2007 peak of 1.5 million.[42] Since then, recovery has been tepid.[43] Current employment levels (as of May 2012) are just above those last seen in April 2004–near the bottom of the last decline.[44]

While the economy is still building momentum, activity in the oil and gas sector has been driving job creation for American truckers. Each well drilled in unconventional formations, which are now responsible for supplying over one-third of natural gas produced, requires approximately 660 truck trips. Exhibit 3-7 shows drilling materials requiring the most truck trips per well.

Besides the drilling rig and attendant infrastructure, a typical shale gas drilling operation requires aggregate material, usually gravel, for the construction of the drilling pad and access roads, the water and sand used for fracturing, steel drilling and casing pipe, casing cement, the transport out of water for treatment, and a variety of other material used in the construction, drilling, and completion of a well.

With activity on the rise, the oil and gas industry has become a jobs driver for American truckers. The Bureau of Labor Statistics reports an average wage of just below $40,000 for a heavy or tractor-trailer truck driver in 2011.[51] For a truck driver in the oil and gas industry, the annual wage ranges between $50,000 and $90,000.[52] What's more, the oil and gas industry is hiring while elsewhere, demand is flat, suggesting a good part of the 200,000 positions the road haulage industry needs to fill may be drilling-related.[53]

Exhibit 3-7 Major Loads Carried by Truck to/from Drill Site (per-well)

Material Transported	Quantity	Truck-trips required
Aggregate (gravel)	5,000 tons[45]	210
Treated water	6 million gallons[46,47,48]	325
Proppant (sand)	2,500 tons[49]	50
Removal of drill cuttings	1,000 tons[50]	75

Sources: Various (see footnotes)

41. Twiddy, David. "U.S. Freight Levels Decline For Second Month." Kansas City Business Journal, 19 June 2012. Available at: http://www.bizjournals.com/kansascity/news/2012/06/19/us-freight-levels-decline-for-second.html
42. Bureau of Labor Statistics. Employment, Hours, and Earnings from the Current Employment Statistics survey (National), Series Id: CES4348400001. Available at: http://data.bls.gov/timeseries/CES4348400001?data_tool=XGtable
43. U.S. Bureau of Labor Statistics (BLS). "Recession leads to lackluster employment in the trucking industry." BLS, February 2010: Washington, D.C. Available at: http://www.bls.gov/opub/ils/trucking.htm
44. U.S. Bureau of Labor Statistics. Employment, Hours, and Earnings from the Current Employment Statistics survey (National), Series Id: CES4348400001. Available at: http://data.bls.gov/timeseries/CES4348400001?data_tool=XGtable
45. Chesapeake Energy. "Shale Operations Overview." County Engineers Association of Ohio Conference, 11-13 December 2011: Columbus, OH. Available at: http://www.ceao.org/e_conferences/winter/2011/2011%20Winter%20Conference%20Packet.pdf
46. Xinhua. "New technologies help save water in US oil industry." Xinhua, 23 June 2012. Available at: http://www.china.org.cn/environment/2012-06/23/content_25715645.htm
47. Susquehanna River Basin Commission. "Gas Well Drilling and Development Marcellus Shale." Susquehanna River Basin Commission Meeting, 12 June 2008: Elmira, NY. P. 19. Available at: http://www.srbc.net/whatsnew/docs/Marcellusshale61208ppt.PDF
48. Treated water means water used for hydraulic fracturing, rather than brine wastewater taken away for treatment.
49. Wethe, David and Klump, Edward. "Mining Sand to Get More Oil." Bloomberg Businessweek, 28 July 2011. Available at: http://www.businessweek.com/magazine/mining-sand-to-get-more-oil-07282011.html
50. Maykuth, Andrew. "Closed-loop systems: Innovative way to dispose of Marcellus drilling debris." The Philadelphia Inquirer, 13 February 2011: Lucullus, PA. http://articles.philly.com/2011-02-13/business/28532329_1_marcellus-shale-drilling-high-pressure-injection
51. U.S. Bureau of Labor Statistics (BLS). "Occupational Employment and Wages, May 2011: 53-3032 Heavy and Tractor-Trailer Truck Drivers." BLS, May 2011: Washington, D.C. Available at: http://www.bls.gov/news.release/archives/empsit_06012012.htm
52. Just Trucking Jobs. "200,000 drivers wanted – The trucking industry desperately seeks quality drivers, and CareerTech hits the road running." Just Trucking Jobs, 7 June 2012. Available at: http://blog.justtruckingjobs.com/truck-driving-job/200000-drivers-wanted-trucking-industry-desperately-seeks-quality-drivers-careertech-hits-road-running/
53. Ibid.

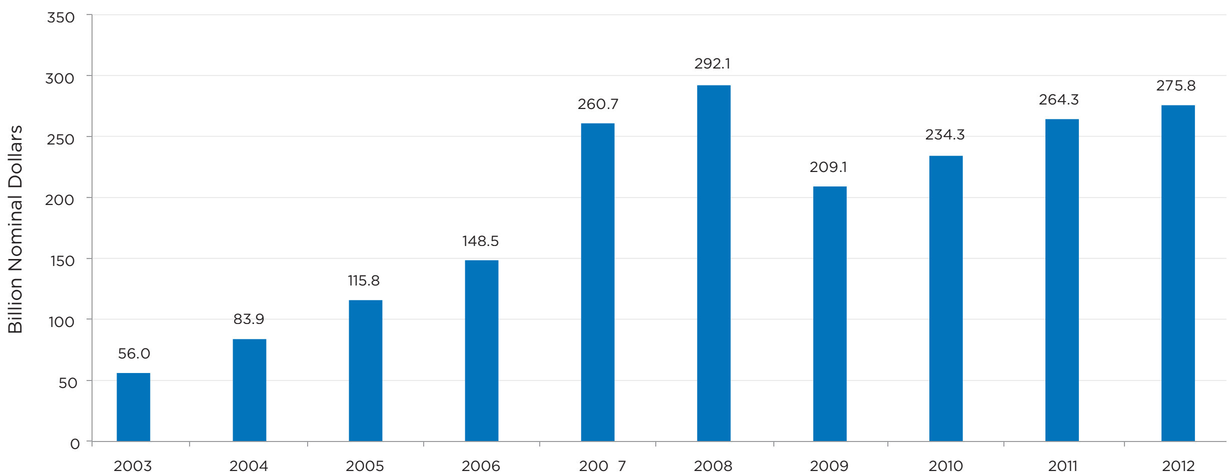
3.4 Investment Sources

Tens of billions of dollars per year in capital outlays will be necessary to develop the U.S. gas resource base in coming decades. Exhibit 3-8 below presents the annual U.S. upstream capital expenditures (all upstream expenditures, such as conventional, unconventional, onshore, offshore, and land acquisitions) between 2003 and 2012 (partial year). Unconventional gas development is very capital intensive and has characteristics that differ greatly from past conventional resource development. For example, large initial outlays are needed for lease acquisition, and once leases are obtained, they must be drilled within a certain time period. Most U.S. unconventional plays were initiated by independent producers rather than major companies. In some cases this has resulted in the independents agreeing to joint ventures with companies with access to more capital to develop their acreage.

Investment capital comes from both domestic and international sources. Domestic producers finance their activity through both debt and equity sources. International funding has come from joint ventures between international oil companies and large domestic independents. In other cases, domestic and international oil companies have purchased U.S. independents to gain access to their acreage.

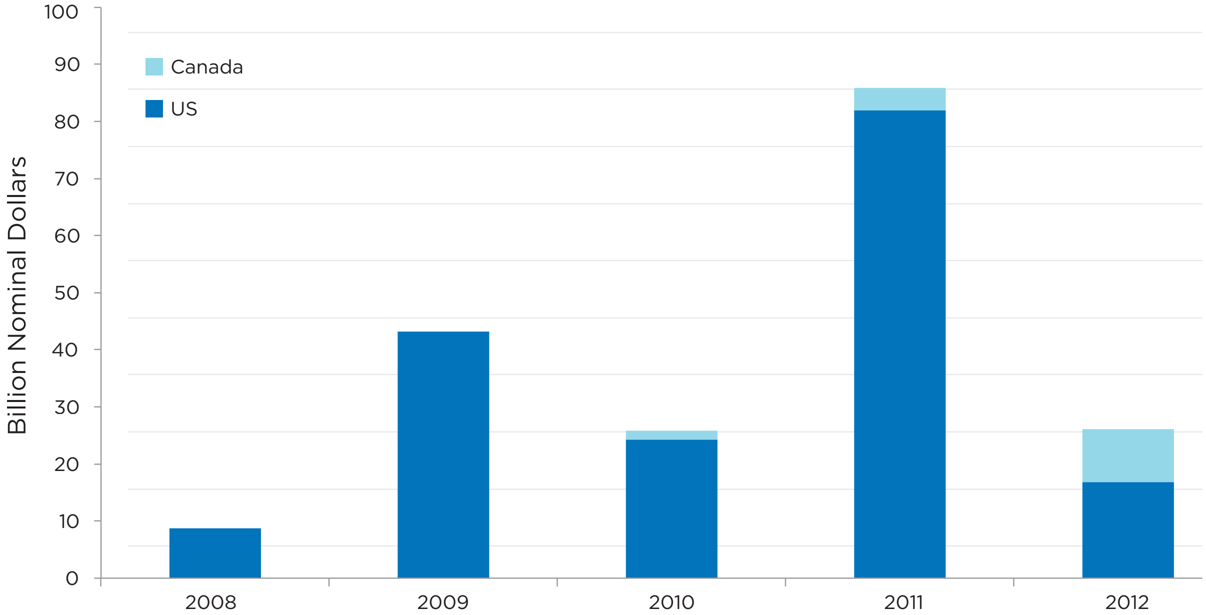
Exhibit 3-9 presents the annual shale-gas related merger and acquisition activity totals for the U.S. and Canada, with partial year data for 2012. These totals are based upon an ICF analysis of 88 deals from 2008 through May 2012. The total value of U.S. deals was $175 billion (nominal) and Canadian deals total $15 billion (nominal).

Exhibit 3-8 U.S. Upstream Capital Expenditures, 2003-2012



Source: Oil and Gas Journal from March 2012 and prior issues.
Note: 2012 is a partial year

Exhibit 3-9 U.S. and Canadian Shale-Related M&A Activity, 2008-2012



Source: ICF estimates
Note: 2012 is a partial year

3.4.1 Foreign and Domestic Investment in U.S. Natural Gas

Since the discovery of the recent upstream technology advancements, independent oil and gas companies have been at the forefront of development. And for most of that time, they were backed by a financial system that supported their investment—granting high-risk loans to an industry that promised high returns. The 2008 financial turmoil led to a breakdown of this relationship, forcing independents to seek investment funding from other sources, both foreign and domestic.

Large or small, "independents" are responsible for drilling 95 percent of wells in the U.S., and for producing 68 percent of domestic oil and 82 percent of domestic natural gas.[54] Some of these companies, such as Chesapeake Energy and Devon Energy, have grown into large industry players over the past 15 years, while others have remained close to their wildcatter roots. The recent financial crisis has had a profound effect on all these companies.

Unlike larger industry participants, which are present along the entire value chain in countries around the globe and hold lines of credit with the world's largest banks, independents, in some cases, have seen their access to credit diminish over the past four years. With a business model built around using current cash flows to finance ongoing exploration and development activity, credit for independent producers is the lifeblood that makes expansion and innovation possible.

54. About IPAA. Independent Petroleum Association of America website. Available at: http://www.ipaa.org/about-ipaa/

Approximately half of the transactions between 2009 and 2011 involved investment by domestic companies. Such was the case with the acquisition of XTO Energy by ExxonMobil in 2009. At $41 billion, it is the largest transaction to date involving a shale development company and announced the return of America's leading O&G company to U.S. onshore development.[55]

At just over $65 billion, transactions involving foreign companies account for the other half of activity (by value). The largest foreign-funded transaction to date has been BHP Billiton's acquisition of Petrohawk Energy, which is active in Eagle Ford and Haynesville shales, as well the Permian basin.[56] The Anglo-Australian company spent approximately $12.1 billion for the opportunity to participate in the development of America's oil and gas resources.[57] The list of foreign companies entering the unconventional gas business also includes BP (UK), Royal Dutch Shell (UK/Netherlands), Statoil (Norway), Repsol (Spain), and even Sinopec and CNOOC (China) and Reliance (India).

The transactions are seen in the industry as a win-win for all sides. For the independents, the deals serve as a source of funding, allowing the companies to continue acquiring acreage and developing new technology at a time when other sources of finance are closed to them. For the investors, it is a chance to gain a foothold in U.S. gas and oil development. A number of financial investors see the industry as a stable, long-term investment in a country with an established rule of law, and thus, no potential for nationalization of property or mineral rights. The "majors," large integrated oil and gas companies such as ExxonMobil and Chevron, see these investments as an opportunity to get back into domestic energy production after drilling wells and building infrastructure overseas. The foreign companies see their joint ventures and mergers (with very few acquisitions) as an opportunity to learn from the companies that invented the industry. And consumers get a continuing supply of natural gas at prices far below what their peers in nearly every other country are paying.

3.5 Natural Gas Production Case Studies: Selected States

An important aspect of recent upstream technology advancements is the geographic diversity of the impact on jobs and economic activity. Current large-scale activity is taking place in Pennsylvania, West Virginia, Ohio, Texas, Louisiana, Oklahoma, Arkansas, Colorado, New Mexico, and North Dakota. Emerging activity is taking place in Kansas, Wyoming, and Montana. Numerous other states have large, undeveloped resources of both oil and gas. The Interstate Natural Gas Association of America (INGAA) predicts that the U.S. and Canada will need to spend $205 billion (2010$) total between 2011 and 2035 on natural gas infrastructure capital investments to support the onshore production of natural gas occurring, largely as a result of the recent upstream technology advancements.[58]

The Marcellus shale formation is one of the largest shale gas formations in the United States. The great majority of Marcellus production is taking place in Pennsylvania, though the formation is located in New York, Pennsylvania, West Virginia, and Ohio. The Utica formation, located in Ohio, Pennsylvania, New York, and parts of Canada, is another large shale formation that is quite active.

While a typical conventional gas well in the Appalachian Basin produces between 100-500 Mcf per day of gas (200-500 million cubic feet [MMcf] over the lifetime of the well), a typical horizontal Marcellus (or Utica) well produces roughly 2-10 MMcf of gas per day, and is projected to average roughly 4 Bcf of gas over the life of each well.[59]

The following sections summarize the current status of shale gas development and economic impact in Pennsylvania, New York, and Ohio, three states that have the potential to see dramatic

55. Gelsi, Steve. "Exxon Mobil to buy XTO Energy in $41 billion deal." MarketWatch, 14 December 2009: New York, NY. Available at: http://articles.marketwatch.com/2009-12-14/industries/30684475_1_xto-energy-natural-gas-southwestern-energy

56. BHP Billion. "BHP Billion and Petrohawk Energy Corporation Announce Merger Agreement." BHP Billion, accessed 31 July 2012. http://www.bhpbilliton.com/home/investors/news/Pages/Articles/BHP-Billiton-and-Petrohawk-Energy-Corporation-Announce-Merger-Agreement.aspx

57. De La Merced, Michael. "BHP Billiton to Buy Petrohawk for $12.1 Billion." The New York Times, 14 July 2011. Available at: http://dealbook.nytimes.com/2011/07/14/bhp-billiton-to-buy-petrohawk-for-12-1-billion/

58. The INGAA Foundation, 2011, "North American Natural Gas MidStream Infrastructure Through 2035- A Secure Energy Future, June 28, 2011. P. 8. http://www.ingaa.org/File.aspx?id=14911

59. Wickstrom, Larry; Chris Perry, Matthew Erenpreiss, and Ron Riley. "The Marcellus and Utica Shale Plays in Ohio." Ohio Department of Natural Resources, Division of Geological Survey, 11 March 2011: Columbus, OH. P. 23. Available at: http://www.dnr.state.oh.us/portals/10/energy/Marcellus_Utica_presentation_OOGAL.pdf economic gains from the recent upstream technology advancements employed in the Marcellus and Utica shales. See Exhibit 3-10 for data on resources, gas production, and examples of investments.

Pennsylvania

The Marcellus shale formation covers roughly 31 million acres and holds several hundred Tcf of recoverable gas, according to some estimates.[60] Pennsylvania has been at the forefront of Marcellus exploration and production, and has experienced an economic revival on a large scale as a result. By the end of 2011, Marcellus production reached approximately 4.5 billion cubic feet per day (Bcf/d), up from only minor output in the mid-2000s.[61]

A 2011 study by Pennsylvania State University estimated that investment in Marcellus natural gas extraction more than doubled between 2009 and 2010 to $11.5 billion, the largest part of which came from expenditures on exploration, drilling, pipeline, and processing plant investments.[62] Of the $11.5 billion, $7.4 billion was for drilling and completion, $2.1 billion was for leasing, and $1.3 billion was for midstream infrastructure. The study concluded that shale gas drilling was responsible for 140,000 jobs in 2010, growing to 216,000 jobs in 2015. (This compares with this ICF study estimate for the state of 86,000 to 145,000 incremental jobs by 2017). The study also estimated that the GDP impact by 2015 would be $17.2 billion and the impact on state and local taxes would be $1.7 billion. (This compares with this ICF study estimates for 2017 of $15.7 to $21.6 billion of incremental growth in GDP and $2.3 to $3.2 billion in additional state and local taxes above the pre-technology baseline).

Recently, drilling and completion activity in Pennsylvania has declined significantly due to low natural gas prices. Gas-directed rig counts have declined while producers are concentrating on liquids-rich areas of the Marcellus located in the southwestern region of the state.[63]

Midstream investment in Pennsylvania, however, has risen greatly, as companies strive to meet the growing infrastructure demands of Marcellus production. Midstream investment provides very positive long term benefits to the state and is generally characterized by much less volatility than upstream investment.

As a result of Pennsylvania's robust gas production, communities where natural gas is produced have directly benefited from the large-scale drilling and production activity. Such indirect impacts include landowner royalty payments, employment in services required for drilling (in addition to direct O&G jobs), increased economic activity in the region, and growing government tax receipts.

One study estimates that consumers saved a total of $650 million in 2011 through lower energy bills as a result of the rise in available gas supplies from the Marcellus.[64] In addition, the industry invested over $400 million in roads and other infrastructure over the past five years.[65] In 2010 alone, companies spent roughly $11.5 billion developing shale in the state, including $346 million in royalty payments to private mineral rights owners.[66]

New York

New York has a state-imposed ban on hydraulic fracturing and hence has no activity in horizontal shale gas. The state imposed the ban several years ago when horizontal drilling first became active in the Marcellus and since then has been studying the issue and attempting to develop a shale gas policy. Recently, the governor of New

60. Picket, Al. "NGLs Present Opportunity to Create Value in Shales with Liquids-rich Gas." The American Oil and Gas Reporter, March 2010: Derby, KS. Available at: http://www.aogr.com/index.php/magazine/cover-story/ngls-present-opportunity-to-create-value-in-shales-with-liquids-rich-gas

61. U.S. Energy Information Administration. "Average monthly natural gas production." U.S. EIA, 30 August 2011: Washington, D.C. Available at: http://www.eia.gov/todayinenergy/detail.cfm?id=2870 and ICF estimate

62. Considine, Timothy; Robert Watson, Seth Blumsack. "The Pennsylvania Marcellus Natural Gas Industry: Status, Economic Impacts, and Future Potential." Pennsylvania State University, 20 July 2011: University Park, PA. Available at: http://marcelluscoalition.org/wp-content/uploads/2011/07/Final-2011-PA-Marcellus-Economic-Impacts.pdf

63. "Liquids" refers to natural gas liquids (NGLs) such as propane, butanes, and ethane, many of which are used in petrochemical processing and fetch much higher prices (based on energy content) than natural gas alone. Shale gas resources containing these liquids are known as "wet gas," while gas-only resources are known as "dry gas."

64. Klaber, Kathryn. "Pennsylvania's Marcellus Shale rules should be fair." The Patriot-News, 20 January 2012. Available at: http://www.pennlive.com/editorials/index.ssf/2012/01/pennsylvanias_marcellus_shale.html

65. Ibid.

66. Efstathiou, Jim Jr. "Gas Price at 10-Year Low Dashes New York Dream of Riches." Bloomberg, 11 April 2012: New York, NY. Available at: http://www.bloomberg.com/news/2012-04-11/gas-price-at-10-year-low-dashes-new-york-dream-of-riches.html

York proposed a plan for limited horizontal shale gas development in certain areas of the state, as discussed below.[67] New York has a long history of low level oil and gas activity and production with roughly 14,000 vintage oil, gas, and salt mining wells.[68] Oil and gas production contributes roughly half a billion dollars to the state economy annually.[69] New York's gas production has been highly dependent upon production in the Black River formation, from which production has been on the decline since 2006, leading to an overall decline in gas production in recent years. In 2011, gas production in the state was 31 Bcf, down 13 percent from 2010.[70]

In terms of potential shale gas development, both the Marcellus and Utica formations extend into southern New York. Some of the best-producing Marcellus wells in Pennsylvania are in the northeastern part of the state adjacent to New York, indicating that New York also has very good potential. New York's Department of Environmental Conservation is expected to propose a plan soon to allow limited development of the Marcellus in a group of counties along the border with Pennsylvania.[71] Permitting could begin later this year for a level of activity in the range of 50 wells per year, initially. Counties under consideration are Broome, Chemung, Chenango, Steuben, and Tioga, all of which border Pennsylvania. The Marcellus is expected to have excellent potential in this area, but the gas is dry, with little liquids. Therefore, due to the decline in dry gas activity in the Marcellus overall, drilling activity would be expected to be moderate over the near term. Long-term production potential could be very large however.

In addition to the statewide ban on horizontal shale gas development, numerous local jurisdictions have also enacted bans. It is unclear how a conflict between local and state governments will be resolved over the long term. One possible approach to alleviate some of the concerns in New York about hydraulic fracturing is the possibility of using propane (in place of water) as a fracking agent. For example, mineral rights owners in Tioga County, NY are in talks with gas producers to develop the area's Marcellus shale using gelled propane.[72]

Despite the current lack of shale activity in New York, the Manhattan Institute, an economic policy think tank, asserts that New York could see $1.9 billion in gas investment, including $152 million paid in royalties in 2015,assuming gas prices rise to $4.52/MMBtu.[73]

In contrast to the $1 billion in state and local taxes generated in Pennsylvania, New York's current oil and gas tax receipts are very small. For example, in 2009 conventional oil and gas operations contributed only $1.4 million in revenues, in addition to local government taxes and landowner royalties of $6.2 million and $25.9 million, respectively.[74] New York collected nearly $640,000 in government royalties in 2009, and received another $790,000 for state land leased for oil and gas production and gas storage.[75]

Ohio

Ohio has extensive shale gas resources in the Marcellus and Utica formations. Shale gas and liquids potential is present across much of the eastern half of the state.[76] Ohio's Utica formation is currently seeing a large amount

67. http://tomwilber.blogspot.com/2012/08/shale-gas-exclusve-cuomos-fracking-plan.html
68. New York State (NYS) Department of Environmental Conservation (DEC). "Oil and Gas." NYS DEC, 2012: Albany, NY. Available at: http://www.dec.ny.gov/energy/205.html
69. Ibid.
70. New York State (NYS) Department of Environmental Conservation (DEC). "Annual Oil and Gas Production Data." NYS DEC, 2012: Albany, NY. Available at: http://www.dec.ny.gov/energy/36159.html
71. http://www.nytimes.com/2012/06/14/nyregion/hydrofracking-under-cuomo-plan-would-be-restricted-to-a-few-counties.html?_r=1
72. Wilber, Tom. "Propane fracking deal reached in NY; Plan would open 130,000 acres in Tioga County for drilling." Star Gazette (Gannett), 29 March 2012. Available at: https://secure.cnynewspapers.com/webbaseELM/en/std/jsp/WebBaseMain.do;jsessionid=59888551E90A5085C0151732741ECA07
73. Efstathiou, Jim. "Gas Price At 10-Year Low Dashes New York Dream Of Riches." Bloomberg News, 11 April 2012: New York, NY. Available at: http://www.bloomberg.com/news/2012-04-11/gas-price-at-10-year-low-dashes-new-york-dream-of-riches.html
74. New York State (NYS) Department of Environmental Conservation (DEC). "New York State Oil, Gas, and Mineral Resources 2009." NYS DEC, 2009: Albany, NY. P. 5. Available at: http://www.dec.ny.gov/docs/materials_minerals_pdf/09anrpt1.pdf
75. New York State (NYS) Department of Environmental Conservation (DEC). "New York State Oil, Gas, and Mineral Resources 2009." NYS DEC, 2009: Albany, NY. P. 5. Available at: http://www.dec.ny.gov/docs/materials_minerals_pdf/09anrpt1.pdf
76. Wickstrom, Larry; Chris Perry, Ron Riley, and Matthew Erenpreiss. "The Utica-Point Pleasant Shale Play of Ohio." Ohio Department of Natural Resources, Division of Geological Survey, 2012: Columbus, OH. P. 19. Available at: http://www.dnr.state.oh.us/portals/10/energy/Utica-PointPleasant_presentation.pdf

of drilling and permitting activity, which is primarily targeting wet gas. The wet gas portion of the Marcellus, which is experiencing a large amount of activity in southwestern Pennsylvania, also extends somewhat into Ohio. The Utica shale is characterized by dry gas production in Pennsylvania and far eastern Ohio, wet gas production in eastern Ohio, and potential oil production in central Ohio.

Companies such as Chesapeake Energy, Anadarko Petroleum, Devon Energy, Chevron, and ExxonMobil are active in Ohio's Utica shale, with Chesapeake the most active.[77] In addition, Williams Partners and Caiman Energy, plan to develop joint ventures in the Utica shale.[78]

A significant amount of drilling activity has occurred in the Utica play, although to date the number of drilled and completed wells has been less than may have been anticipated. As of July of 2012, 14 wells were producing and a total of 129 additional wells were in some stage of drilling and completion, according to Ohio's Department of Natural Resources.

The Ohio Shale Coalition (OSC) estimates that Utica development will support 65,680 incremental jobs annually and add $4.9 billion to Ohio's economic output in 2014.[79] (This compares with 21,000 to 40,000 incremental jobs and $4.6 to $6.5 billion incremental increase in GDP for Ohio in this ICF study). In the same study, industry spending for Utica Shale development was projected to increase from $229 million in 2011 to $6.4 billion in 2014. About 74 percent of expenditures in 2014 are for drilling and completions and about 18 percent are for midstream infrastructure. Well completion activity was assumed to increase to 1,075 wells per year in 2014. In the downstream sector, the OSC study took a conservative approach by not including new petrochemical facilities in the state in their calculations.

In addition to the expenditures on drilling and completions in the Utica, there is widespread expansion of midstream infrastructure, including gathering, processing, and gas and liquids pipelines. Additional gas processing capacity close to the Utica production will be in high demand.

In an effort to meet gas transport and infrastructure needs, Access Midstream Partners LP, Momentum/M3 Midstream LLC, and EnerVest Inc. announced plans in April 2012 to invest $900 million to develop a pipeline and midstream system to gather and transport natural gas to a new processing and compressor plant in Kensington, Columbiana County, as well as a fractionation plant in Harrison County. Over the next two years, the group plans to develop facilities geared toward wet gas, with an estimated $1 billion investment associated with payroll expenses alone, and total midstream pipeline and wet gas development investment is expected to reach $10 billion.[80] Range Resources and MarkWest (a Denver-based midstream company that built processing plants in Houston, PA, and Majorsville, PA) will jointly invest $1 billion to build natural gas processing plants in Harrison and Monroe counties in Ohio.[81] Development of the Utica shale has boosted demand for industries such as steel manufacturing, service industries, and petrochemical facilities. In an effort to meet demand for drilling materials such as steel pipe, Youngstown V&M Star (casing and tubing), U.S. Steel, and Timken announced expansions in Ohio (together totaling $1.1b).[82] Halliburton, Baker Hughes, and Select Energy Services, all O&G service companies, have announced construction of facilities within Ohio to meet the needs of drillers in Ohio's Utica plays; investments total $224 million, and are expected to create 1,185 jobs.

The following exhibit highlights the resource base potential, production, and key investments for the three states discussed above.

77. Efstathiou, Jim. "Gas Price At 10-Year Low Dashes New York Dream Of Riches." Bloomberg News, 11 April 2012: New York, NY. Available at: http://www.bloomberg.com/news/2012-04-11/gas-price-at-10-year-low-dashes-new-york-dream-of-riches.html

78. Staas, Peter. "Let's Make a Deal: Marcellus Shale." Investing Daily, 11 April 2012. Available at: http://www.investingdaily.com/15109/lets-make-a-deal-marcellus-shale-edition

79. Thomas, Andrew R., Iryna Lendel, Edward W. Dill, Douglas Southgate, and Robert Chase, 2012, "An Analysis of the Economic Potential for Shale Formations in Ohio," Cleveland State University Energy Policy Center. Available at: http://ohshalecoalition.com/study/study.pdf

80. O'Brien, Dan. "Energy Giants Bringing Billions to Utica Shale." The Business Journal, 21 March 2012: Pittsburgh, PA. Available at: http://businessjournaldaily.com/drilling-down/energy-giants-bringing-billions-utica-shale-2012-3-21

81. Ibid.

82. Wickstrom, Larry; Matt Erenpreiss, Ron Riley, Chris Perry, and Dean Martin. "Geology and Activity Update of the Ohio Utica-Point Pleasant Play." Ohio Department of Natural Resources, Division of Geological Survey, 2012: Columbus, OH. P. 38. Available at: http://www.dnr.state.oh.us/portals/10/energy/Utica/Utica-PointPleasantPlay.pdf

Exhibit 3-10 Case Study Comparisons

Metric	Pennsylvania	New York	Ohio
Resource Base			
Technically Recoverable Dry Gas (Tcf)[83]	481 (Marcellus: 433, Utica: 48)	137 (Marcellus: 78, Utica: 60)	50 (Marcellus: 0.4, Utica: 50)
Annual Gas Production (Bcf)	1,643 (Marcellus only 2011 est.)[84]	31 (2011)[85]	78 (2010)[86]
Investment Activity			
Geographical Concentration of Investment	• Upstream: SW PA (due to liquids content) and NW PA (due to dry gas) • Midstream: NE PA and SW PA	• Current proposal to allow limited Marcellus development in Broome, Chemung, Chenango, Steuben, and Tioga Counties • Potential investment in Tioga County (south-central) for liquid propane fracking	Central and eastern OH
Upstream Highlights	• Chevron acquisition of Atlas Energy and land purchase from Chief Oil and Gas and Tug Hill (land purchase worth $3.2b)[87,88]	N/A	• Ongoing drilling in the Utica by Chesapeake Energy, Devon Energy, Exxon Mobil, and a Williams Partners and Caiman Energy JV • Halliburton facility construction ($150mm, 300 jobs)[89] • Baker Hughes to invest $64mm and employ 700 in a services-related facility[90] • Select Energy Services invested $10mm in moving its headquarters to Carroll County, requiring 185 jobs[91]
Midstream Highlights	• PA VA Resource Partners (PVR) acquisition of Chief Gathering for $1b[92] • Chief Gathering pipeline construction in NE PA[93] • PVR gathering system construction in NE PA[94] • Williams Partners $2.5b acquisition of Caiman Eastern Midstream[95] • Kinder Morgan acquisition (pending) of El Paso Corp. for $24.4b[96] • First Reserve investment of $100mm for 50% ownership in JV for two pipeline gathering systems in SW PA[97]	N/A	• $900mm investment in a pipeline and midstream system by Access Midstream, Momentum/M3 Midstream, and EnerVest to convey gas to a new processing plant and fractionation plant (eastern OH) • Range Resources and MarkWest investment of $1b to build a gas processing plant in eastern OH • Dominion and NiSource investment in gas processing and fractionation plant • Exterran investment of $13mm for a gas processing facility

83. ICF estimates
84. U.S. Energy Information Administration. "Average monthly natural gas production." U.S. EIA, 30 August 2011: Washington, D.C. Available at: http://www.eia.gov/todayinenergy/detail.cfm?id=2870 and ICF estimate
85. New York State (NYS) Department of Environmental Conservation (DEC). "Annual Oil and Gas Production Data." NYS DEC, 2012: Albany, NY. Available at: http://www.dec.ny.gov/energy/36159.html
86. Ohio Oil and Gas Association (OOGA). "Ohio Oil and Gas Activity." OOGA, 2011: Granville, Ohio. Available at: http://ooga.org/our-industry/ohio-oil-gas-activity/
87. Detrow, Scott. "Chevron Invests in Marcellus Drilling." National Public Radio (NPR), 12 March 2012: Washington, D.C. Available at: http://stateimpact.npr.org/pennsylvania/2012/03/12/chevron-invests-in-marcellus-drilling/
88. Reuters. "Chevron to buy new stakes in Marcellus shale." Townhall.com, 2012: New York, NY:. Available at: http://finance.townhall.com/news/investment/2011/05/04/chevron_to_buy_new_stakes_in_marcellus_shale
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90. Wickstrom, Larry; Matt Erenpreiss, Ron Riley, Chris Perry, and Dean Martin. "Geology and Activity Update of the Ohio Utica-Point Pleasant Play." Ohio Department of Natural Resources, Division of Geological Survey, 2012: Columbus, OH. P. 38. Available at: http://www.dnr.state.oh.us/portals/10/energy/Utica/Utica-PointPleasantPlay.pdf
91. Ibid.
92. Penn Virginia Resource Partners, L.P. "PVR Partners Announces $1 Billion Acquisition of Marcellus Shale Midstream Pipeline Systems from Chief." MarketWatch, 10 April 2012. Available at: http://www.marketwatch.com/story/pvr-partners-announces-1-billion-acquisition-of-marcellus-shale-midstream-pipeline-systems-from-chief-2012-04-10
93. Staas, Peter. "Let's Make a Deal: Marcellus Shale." Investing Daily, 11 April 2012. Available at: http://www.investingdaily.com/15109/lets-make-a-deal-marcellus-shale-edition
94. Penn Virginia Resource Partners, L.P. "PVR Partners Announces $1 Billion Acquisition of Marcellus Shale Midstream Pipeline Systems from Chief." MarketWatch, 10 April 2012. Available at: http://www.marketwatch.com/story/pvr-partners-announces-1-billion-acquisition-of-marcellus-shale-midstream-pipeline-systems-from-chief-2012-04-10
95. Staas, Peter. "Let's Make a Deal: Marcellus Shale." Investing Daily, 11 April 2012. Available at: http://www.investingdaily.com/15109/lets-make-a-deal-marcellus-shale-edition
96. Ibid.
97. Marcellus Drilling News. "First Reserve Invests in Two PA Marcellus Gas Pipelines." Marcellus Drilling News, October 2011. Available at: http://marcellusdrilling.com/2011/10/first-reserve-invests-in-two-pa-marcellus-gas-pipelines/

Exhibit 3-10 Continued Case Study Comparisons

Metric (cont.)	Pennsylvania	New York	Ohio
Investment Activity (cont.)			
Downstream Highlights	· Shell considering $3b-$4b ethane cracking facility in SW PA, estimated to result in $132b in GDP gains and 10,000 jobs[98]	· N/A	· Steel plant expansions: Youngstown V&M Star ($650mm), U.S. Steel ($240mm), Timken-Canton ($225mm)[99]
Indirect Impact			
Impact on Communities	· $650mm in consumer savings from lower energy bills in 2011[100] · $400mm in construction of roads and other infrastructure over the past 5 years[101] · $1b in state and local taxes[102] · 230,000 direct jobs in PA[103] · $11.5b investment in PA shale gas[104] · $346mm in royalty payments to private mineral rights owners in 2010[105]	· NYS could see shale gas investment of $1.9b, including $152mm in royalties in 2015, according to some estimates[106]	· The Ohio Shale Coalition estimates that Utica development will support 65,680 jobs and add $4.9 billion to the state economy by 2014[107] · $1 billion in wages over the next two years, associated with Chesapeake Energy's midstream and downstream activities[108]
ICF Findings (direct, indirect, and induced impacts)[1]			
GDP Additions	$15.7 billion to $21.6 billion annually by 2017	$5.6 billion to $9.2 billion annually by 2017	$10.4 billion to $14.5 billion annually by 2017
Employment	86,000 to 145,000 annual jobs by 2017	41,000 to 76,000 annual jobs by 2017	43,000 to 84,000 annual jobs by 2017
State and Local Taxes (on GDP Additions)	$2.3 billion to $3.2 billion annually by 2017	$1.1 billion to $1.8 billion annually by 2017	$1.7 billion to $2.3 billion annually by 2017

[1] See Chapter 5 and Appendix B for more details on these economic impacts.

98. Klaber, Kathryn. "Pennsylvania's Marcellus Shale rules should be fair." The Patriot-News, 20 January 2012. Available at: http://www.pennlive.com/editorials/index.ssf/2012/01/pennsylvanias_marcellus_shale.html
99. Wickstrom, Larry; Matt Erenpreiss, Ron Riley, Chris Perry, and Dean Martin. "Geology and Activity Update of the Ohio Utica-Point Pleasant Play." Ohio Department of Natural Resources, Division of Geological Survey, 2012: Columbus, OH. P. 38. Available at: http://www.dnr.state.oh.us/portals/10/energy/Utica/Utica-PointPleasantPlay.pdf
100. Ibid.
101. Efstathiou, Jim. "Gas Price At 10-Year Low Dashes New York Dream Of Riches." Bloomberg News, 11 April 2012: New York, NY. Available at: http://www.bloomberg.com/news/2012-04-11/gas-price-at-10-year-low-dashes-new-york-dream-of-riches.html
102. Ibid.
103. Ibid.
104. Ibid.
105. Ibid.
106. Ibid.
107. Ibid.
108. O'Brien, Dan. "Energy Giants Bringing Billions to Utica Shale." The Business Journal, 21 March 2012: Pittsburgh, PA. Available at: http://businessjournaldaily.com/drilling-down/energy-giants-bringing-billions-utica-shale-2012-3-21

Trends in Natural Gas Use and Consumer Impacts 4

4.1 U.S. Natural Gas Utilization

With a sophisticated production, processing, and transportation system, the United States is the world's largest consumer of natural gas. In 2011, total consumption exceeded 24 Tcf for the first time ever. By comparison, Russia, the world's second largest natural gas user, consumed less than 18 Tcf, according to EIA.

Also according to the EIA, in 2011, 2 Tcf, or 8.5 percent of total consumption, was used in the processing and transportation of natural gas. This figure includes natural gas used in the field to power and heat production equipment, at the processing plants to generate the power necessary to separate liquids out of the gas stream and to purify the gas, and by the compressors in pipelines that move gas around the country. The remainder–over 22 Tcf in 2011 (also an all-time high)–was delivered to consumers.

In 2011, electric power generation was the largest consumer of delivered gas, accounting for 34 percent of delivered natural gas used in the U.S. Industrial use (excluding lease and plant use) was second, with 30 percent of consumption, followed by the residential sector, which consumed 21 percent, and the commercial sector, at 14 percent. Vehicle fuel, an emerging area of natural gas consumption, was responsible for just 0.1 percent of gas use.[109]

Just 15 years ago, in 1997, industrial users drew the largest share of delivered gas, accounting for 41 percent of consumption. A variety of projects currently in development (Exhibit 4-3) are expected to further increase the industrial sector's consumption. The share of residential consumption was also higher, at 24 percent. Electricity generation, on the other hand, accounted for less than 20 percent of 1997 consumption (Exhibit 4-2).

A combination of improved technologies and conservation measures have made the residential, commercial, and industrial sectors much more efficient in their energy use, causing a decline in their share of delivered gas consumption. In fact, although population growth has increased the number of households and the square footage of commercial space, both sectors, where gas is used primarily for space and water heating, have seen declining natural gas use over the past 15 years in absolute terms. Residential consumption declined by 5 percent and commercial by 2 percent.

In the industrial sector, natural gas is used as both a source of process heat and as a feedstock. Industries accounting for the majority of natural gas consumption include petrochemicals and refining, pulp and paper, clay and glass, metals, plastics, and food processing. During the past 15 years, as manufacturers have either shifted production overseas or moved toward lighter manufacturing techniques, the industrial sector saw consumption decline by 20 percent. This has freed gas for other applications, such as vehicle use, which, while still a minor share of natural gas consumption, has in fact quadrupled since 1997, and power generation, which saw its consumption nearly double.

The build-out in gas-fired generation capacity, more stringent environmental standards, changing demands on the power grid, and the retirement of older, polluting coal-fired plants have all led to power plants becoming the largest users of natural gas, overtaking industry in 2007. Gas-fired power plants have also become much more efficient, with some facilities now capable of converting upwards of 63 percent of the energy in natural gas into electricity (compared to approximately 35 percent efficiencies achieved by coal plants). These efficiencies, and the dropping cost of generating electricity with gas, have for the first time ever allowed natural gas to achieve parity with coal, as both fuels accounted for 32.4 percent of electricity produced in the U.S. in April 2012.[110]

109. Hence, given the comparatively low level of demand from the transport sector—and notwithstanding a forecast expansion of natural gas vehicles over the next decade, the report does not include detailed assessment of the economic potential of natural gas used in transportation. See, however, the discussion of methanol products—section 4.2.4.

110. "July 2012 Monthly Energy Review: Table 7.2a. Electricity Net Generation: Total (All Sectors)." Energy Information Administration, July 27, 2012. Available at [Excel file]: http://www.eia.gov/totalenergy/data/monthly/query/mer_data_excel.asp?table=T07.02A

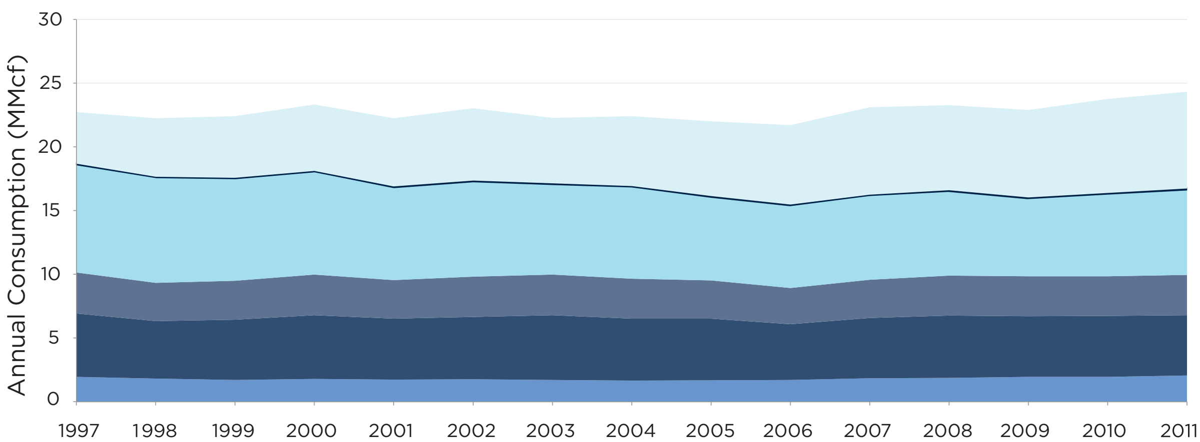
Exhibit 4-1 Gas Use in Power Plants

Gas-fired power plants constitute the majority of new-generation facilities being planned in the U.S. A combination of abundant natural gas supply and low prices means 39.9 gigawatts (GW) of gas-fired generation has been built between 2008 and 2011, and another 16.4 is currently under construction, for completion between 2012 and 2017 (with another 16.4 GW already permitted, and another 19.5 GW in application pending status).[111] Aside from their capital and operating cost advantages, modern combined-cycle gas turbine (CCGT) power plants have a clean profile and relatively small footprint, and are particularly favored in nonattainment[112] or densely-populated urban areas.

The build-out in natural gas generation should help maintain a more robust and resilient power grid. Gas power plants have the ability to ramp generation up and down to help respond to the peaks and troughs associated with sudden power outages, grid failures, or the intermittency of renewables coming onto and off of the grid. In addition, their ability to modulate voltage and frequency make them ideal for correcting imbalances in electric current. Thus, gas-fired power generation can help reduce the frequency of power outages and industrial-plant shutdowns – a major issue for sophisticated manufacturing operations where, for example, each hour of lost power supply can cost as much as $2 million for a single semiconductor plant.[113]

With natural gas supply at record highs, and prices at such lows, the U.S. is going through a CCGT build-out, with 79 plants at various stages of construction and another 42 approved for construction by 2017.[114] This translates into an investment of over $30 billion between 2011 and 2017 in natural-gas fueled power generation alone.[115]

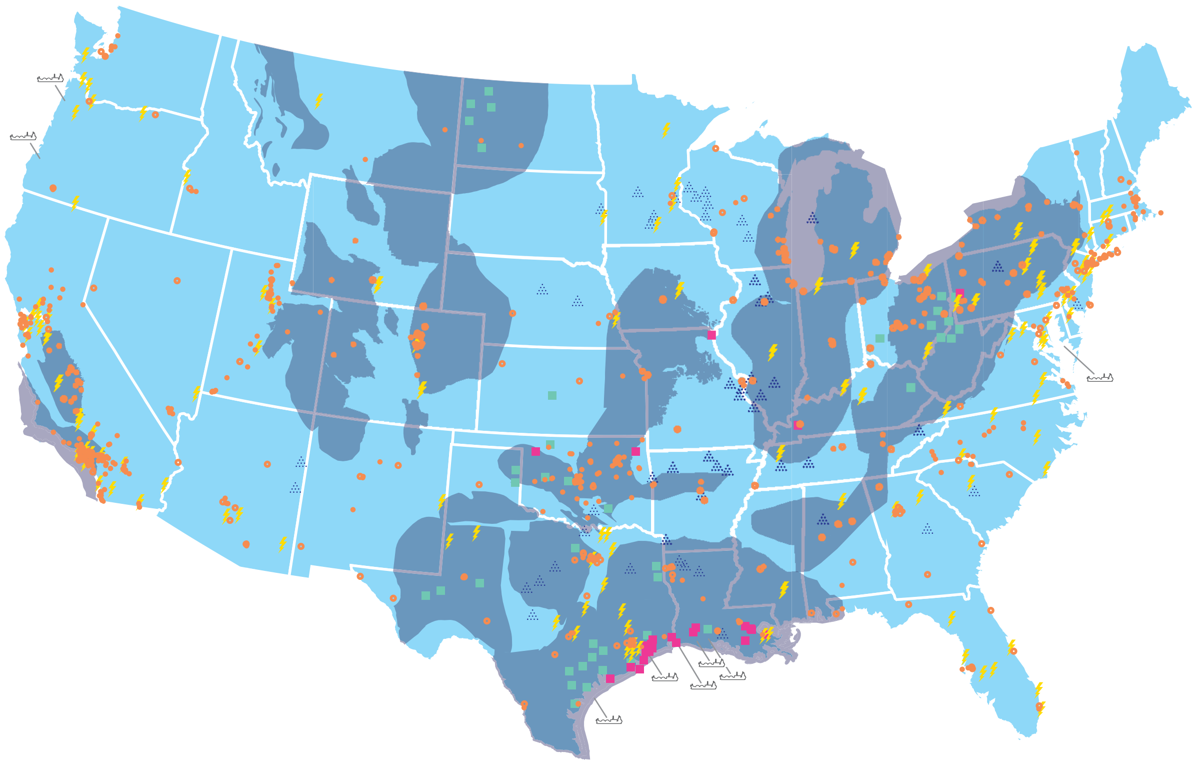
Exhibit 4-2 Natural Gas Consumption by End Use



Source: Energy Information Administration

111. Plants that are either: permitted, where site preparation has begun, under construction, in testing, or completed; according to Ventyx as of July 25, 2012.
112. Nonattainment areas are defined as areas of the country in which air pollution levels persistently exceed the EPA's National Ambient Air Quality Standards (NAAQS).
113. The Electric Power System is Unreliable. Galvin Electricity Initiative. Available at: http://galvinpower.org/resources/library/fact-sheets-faqs/electric-power-system-unreliable
114. Ventyx VSO Database (or Ventyx Velocity Database), accessed July 25, 2012.
115. ICF Estimates based on Ventyx data and cost estimates derived from "Updated Capital Cost Estimates for Electricity Generation Plants." Energy Information Administration, Washington, DC, November 2010.

Exhibit 4-3 Shale Gas and U.S. Economic Development



- Shale Gas Basins
- Frac Sand Production
- New Major Gas-Fired Power Plants
- New Gas Processing and Fractionator Plants
- New Petrochemical & Other Plants
- Planned LNG Export Terminals
- Public LNG/CNG Filling Stations
- Planned Public LNG/CNG Filling Stations Are Along U.S. Interstate Highways

Sources:
Shale Gas Basins: Energy Information Administration, May 9, 2011, http://www.eia.gov/oil_gas/rpd/shale_gas.pdf
Frac Sand Production: ICF International.
New Major Gas-Fired Power Plants: SNL Financial, accessed June 12, 2012.
Included are all planned natural gas-fired power plants with construction costs estimated to exceed $100,000,000.
New Gas Processing and Fractionation Plants: Oil and Gas Journal, May 7, 2012.
New Petrochemical and Other Plants: ICF International
Existing and Planned Public LNG/CNG Filing Stations: Department of Energy, Alternative Fuels and Advanced Vehicles Data Center, accessed June 1, 2012, http://www.afdc.energy.gov/afdc/fuels/stations.html
Included are all existing and planned public CNG and LNG fueling stations (no private/fleet only fueling stations).
Planned LNG Export Terminals: Federal Energy Regulatory Commission, July 17, 2012, http://ferc.gov/industries/gas/indus-act/lng/LNG-proposed-potential.pdf and http://www.ferc.gov/industries/gas/indus-act/lng/LNG-approved.pdf
Included are all export terminals that are either approved and under construction or proposed to the FERC.

4.2 Potential Future Demand for Natural Gas

The U.S. industrial sector consists of all agricultural farms, mining, construction and manufacturing establishments (see text box). Agriculture, construction and mining are categorized as the non-manufacturing industries while the remaining industries are the manufacturing industries. The industrial sector is the second-largest user of delivered natural gas in the U.S., accounting for 6,731 Bcf or 30.2 percent of delivered natural gas use in the U.S. in 2011. If natural gas lease and plant fuel consumption is included in the industrial total (within a broader definition of mining), the industrial sector becomes the largest consumer of total natural gas used in the U.S., accounting for 8,113 Bcf, or 33.4 percent of total U.S. natural gas consumption.[116] The discussion below excludes natural gas lease and plant fuel use because it is usually separated from the accounting of gas use in the gas industry.

Within the industrial sector, the largest users of natural gas are the energy-intensive industries: food, paper, chemicals, petroleum refining, non-metallic minerals, and primary metals industries. These industries are considered basic industries since they are involved in converting basic raw materials into more useful intermediate products. These industries require substantial amounts of processing and energy use, and account for 79 percent of total industrial gas consumption (Exhibit 4-4). More importantly, two industries—chemicals and petroleum refining—account for almost half (46 percent) of total industrial gas consumption.

U.S. Industrial Sector
Non-Manufacturing

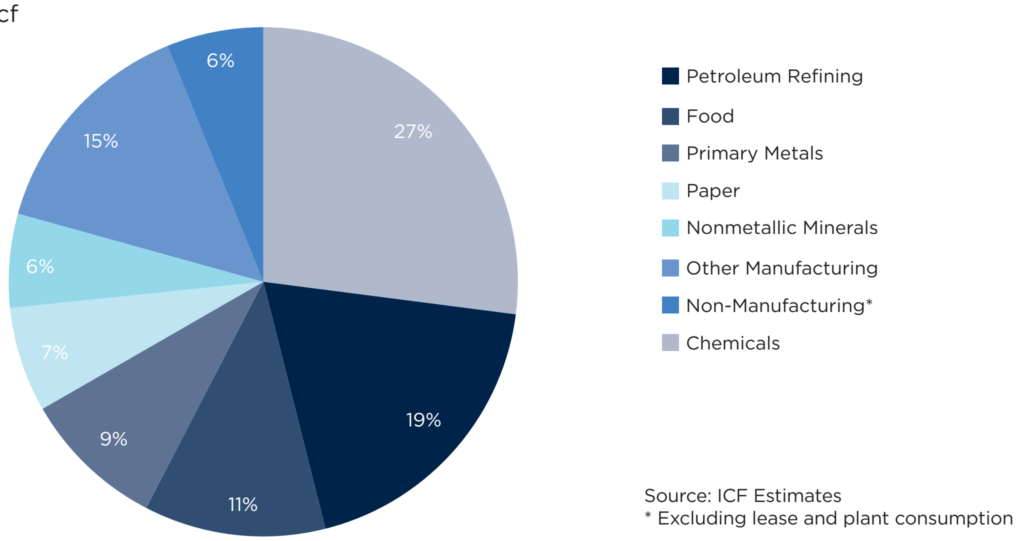
Agriculture	Mining	Construction

Manufacturing

Food & Beverage	Tobacco
Computers & Electronics	Textiles
Electrical Equipment	Apparel
Primary Metals	Wood
Non-Metallic Minerals	Furniture
Rubber & Plastics	Paper
Fabricated Metals	Printing
Chemicals	Oil & Coal
Misc. Manufacturing	Leather
Transportation Equip.	Machinery

Exhibit 4-4 2010 Industrial Natural Gas Consumption by Industry

Total: 6.6 Tcf



Source: ICF Estimates
* Excluding lease and plant consumption

116. Natural gas lease and plant fuel is the natural gas used in gas drilling and field operations and in natural gas processing plants. This consumption was 1,383 Bcf in 2011 and is categorized in the mining industry for overall tracking purposes but is often listed separately in gas industry accounting.

Natural gas is used for various industrial processes and applications (Exhibit 4-5). The largest application of natural gas is for process heating. This includes direct (non-steam) heating such as cooking, baking, fluid heating, direct drying, and many others. Process heating accounts for 46 percent of total industrial gas use. Steam production (using boilers and onsite combined heat and power (CHP) systems) is the second largest use of natural gas, representing 37 percent of total industrial gas use. Thus, process heating and steam production combined account for 83 percent of total industrial gas consumption. About 10 percent of industrial gas is used as chemical feedstocks to make products such as ammonia, hydrogen and methanol. The other use of gas (at 7 percent) is for buildings (mainly for space heating).

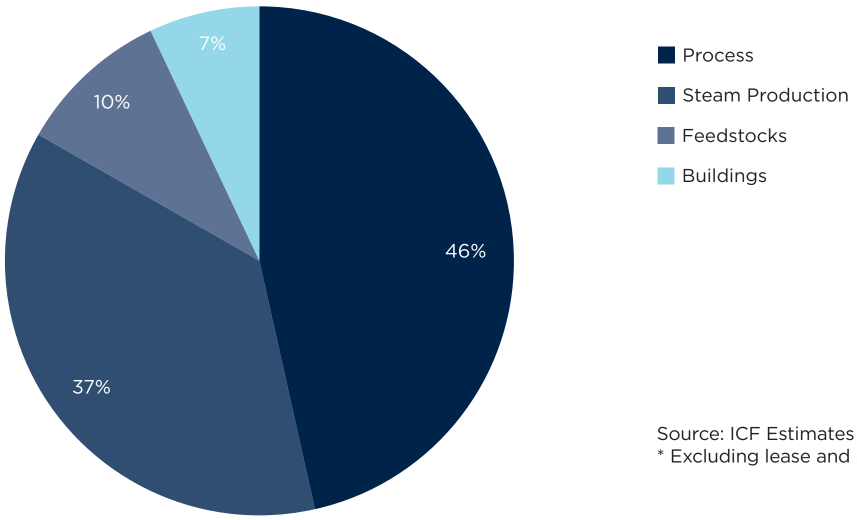
The industrial sector is therefore highly concentrated in its use of natural gas by both industry and application.

One way to measure the impact of natural gas prices on industry is with the cost of natural gas consumed over total production costs by industry. While all costs are important to industries that are facing competitive challenges, the share of production cost is a reasonable first order indicator of the impact of energy prices. On average, energy costs represent less than 4 percent of total production cost in the manufacturing sector. Natural gas costs account for even less, around 1 percent. This means that natural gas and energy costs are small compared to other production costs, such as labor and raw materials. However, a number of industries have very high natural gas expenditures over total production cost, making these industries more sensitive to changes in natural gas prices.

Exhibit 4-6 shows the industry segments with the highest shares of natural gas expenditures over total production costs based on EIA and Census data (only the manufacturing industries are analyzed).[117]

Exhibit 4-5 2010 Industrial Natural Gas Consumption by End-Use Application*

Total: 6.6 Tcf



Source: ICF Estimates
* Excluding lease and plant consumption

117. Natural gas expenditures were taken from the EIA Manufacturing Energy Consumption Survey 2006. In lieu of total production costs, the value of shipments data are used. The shipments data were taken from the Census of Manufactures 2007. The analysis at the 6-digit NAICS Code level industries is limited to the data availability in the MECS, which is not complete but covers major energy consuming industries. The Census of Manufactures 2007 (instead of ASM 2006) is used for Value of Shipments due to data availability at this level.

Exhibit 4-6 Industries with Highest Share of Natural Gas Expenditures of Production Costs (2006)

Rank	Major Industry	NAICS Code	Subsector and Industry	NG + NGL	NG Only
1	Chemical	325311	Nitrogenous Fertilizers	37.65%	37.62%
2	Chemical	325211	Plastics Materials and Resins	15.94%	2.41%
3	Nonmetallic Minerals	327211	Flat Glass	13.26%	13.23%
4	Chemical	325181	Alkalies and Chlorine	12.02%	12.02%
5	Nonmetallic Minerals	327212	Other Pressed and Blown Glass/Glassware	11.81%	11.67%
6	Nonmetallic Minerals	327420	Gypsum	11.23%	11.16%
7	Chemical	325199	Other Basic Organic Chemicals	10.28%	3.56%
8	Nonmetallic Minerals	327213	Glass Containers	8.61%	8.57%
9	Chemical	325110	Petrochemicals	8.57%	0.78%
10	Chemical	325182	Carbon Black	8.47%	8.47%
11	Chemical	325193	Ethyl Alcohol	4.95%	4.89%
12	Nonmetallic Minerals	327993	Mineral Wool	4.65%	4.62%
13	Paper	322130	Paperboard Mills	4.50%	4.46%
14	Chemical	325222	Noncellulosic Organic Fibers	4.49%	4.48%
15	Chemical	325120	Industrial Gases	3.77%	3.77%
16	Food	311221	Wet Corn Milling	3.57%	3.57%
17	Primary Metals	331524	Aluminum Foundries, except Die-Casting	3.35%	3.30%
18	Chemical	325188	Other Basic Inorganic Chemicals	3.12%	2.40%
19	Primary Metals	331111	Iron and Steel Mills	3.06%	3.06%
20	Paper	322121	Paper Mills, except Newsprint	3.01%	2.99%

Source: U.S. Census Bureau. "Manufacturing Energy Consumption Survey (MECS)." U.S. Census Bureau, 2006: Washington, D.C

Aside from natural gas share of total costs, the table also shows the share of natural gas and NGLs over total costs. The inclusion of NGLs provides a more complete evaluation of the importance of natural gas supply (which includes NGLs) on these industries.

The nitrogen fertilizer industry, which manufactures ammonia, tops the list, with natural gas expenditures accounting for almost 40 percent of total production costs. This is primarily because natural gas is a raw material for the fertilizer industry as well as a fuel. The plastic materials and resins industry (rank 2), other basic organic chemicals industry (rank 7), and petrochemicals industry (rank 9), have high natural gas costs because they consume large amounts of NGLs to make olefin products such as ethylene.[118] These industries are of particular interest because the olefin industry relies heavily on natural gas liquids as a raw material. Although natural gas liquids (which include ethane, propane, and other liquids) are not considered natural gas (methane), they are extracted from gas before it is delivered to the consumers, and the price of ethane correlates strongly with the price of natural gas.

The glass industry also has high natural gas expenditures, as it ranks 3rd (flat glass), 5th (other pressed and blown glass), and 8th (glass containers). The glass industry primarily consumes natural gas in its melting furnaces. The flat glass industry reports that natural gas accounts for 13 percent of its total production costs. The chlor-alkali industry ranks 4th with natural gas cost representing 12 percent of total production cost. This industry manufactures

118. The petrochemical, plastic materials and resins, and other basic organic chemical industries are producers of olefin products such as ethylene. The NAICS classification of a chemical plant is based on the product with the largest production. For example, a plastic resin plant could be vertically integrated and so would produce the raw materials such as ethylene and also the intermediate products of these materials, such as polyethylene, and other resins. If the resins are the primary products of the plant, then the plant would be classified under the plastic materials and resins industry.

chlorine and its co-product caustic soda. It is both electricity and steam-intensive. Other industries with significant gas cost shares include other chemical segments (e.g., carbon black, ethyl alcohol), other non-metallic minerals (e.g., gypsum, mineral wool), paper, primary metals, and food.

Methanol production, a subset of Other Basic Organic Chemicals, uses natural gas as both a feedstock and a process fuel, and is therefore highly natural gas intensive. In its pure form, methanol is used as a transportation fuel (along similar lines to ethanol), in biodiesel production, and in wastewater treatment plants. Its primary application, however, is as a feedstock in the manufacture of such varied products as paints, synthetic fibers, plastics, construction materials, and cleaning products. Because the industry is global, with methanol among the most highly-traded commodities, it is also highly susceptible to feedstock costs, and as such plants are usually located where natural gas can be obtained cheaply.

Because the nitrogenous fertilizer (particularly, ammonia), olefin (particularly, ethylene), glass, and methanol industries are those with the highest gas cost share over total production costs, these are discussed further below

4.2.1 Ammonia Production

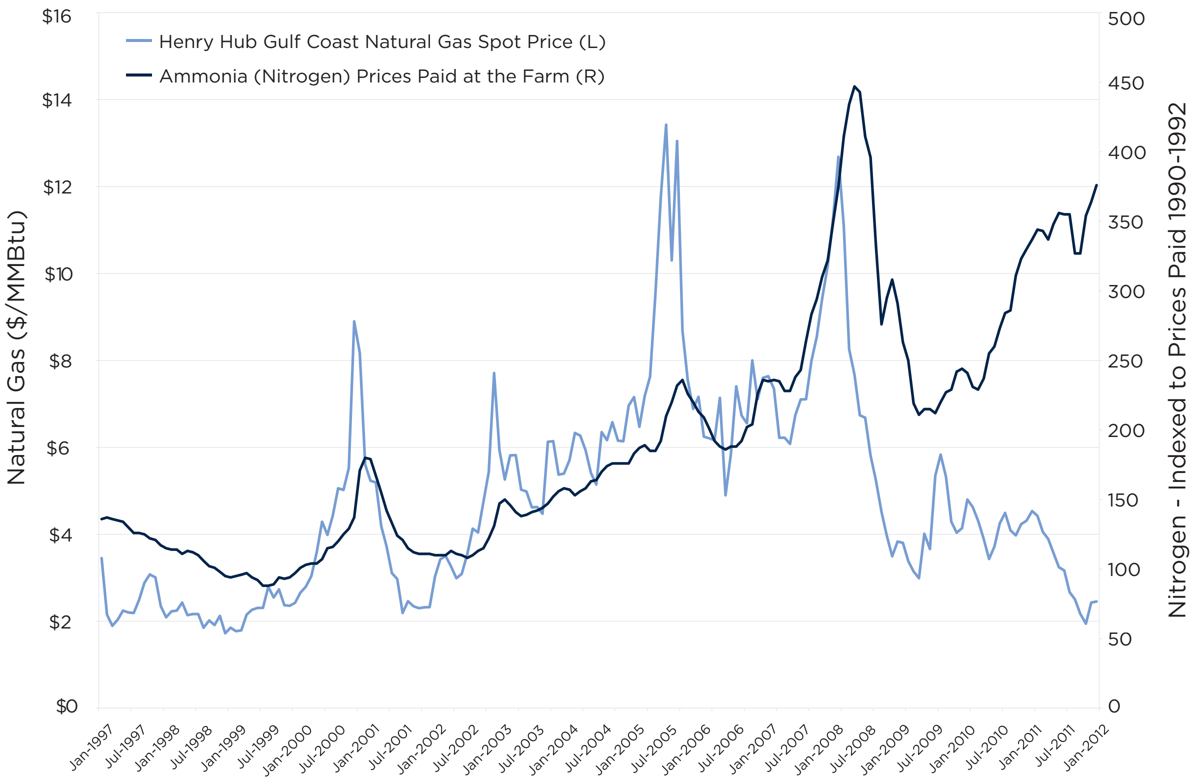
Ammonia is the basic material for all nitrogen-based fertilizer, with fertilizer accounting for about 90 percent of U.S. ammonia consumption. Ammonia can be used directly as a fertilizer or used to make other nitrogen-based fertilizers such as ammonium nitrate, UAN solution and urea. Non-fertilizer applications of ammonia include the production of pharmaceuticals, plastics, explosives, emission control systems, and as a refrigerant.

The production of anhydrous ammonia sources the nitrogen from the air and the hydrogen from natural gas, creating a reaction between the two elements to obtain ammonia. On average, American ammonia producers consume 32.5 MMBtu of natural gas per ton of ammonia, making this the most natural-gas-intensive of all industries. As such, the price of natural gas, used as both a feedstock and for fuel, constitutes a major part of final product cost. At $2/MMBtu, natural gas accounts for 63 percent of the price of anhydrous ammonia production. At the 2004-2008 level of $7/MMBtu, cost of natural gas can constitute as much as 90 percent of anhydrous ammonia production cost.[119]

Exhibit 4-7, showing U.S. nitrogenous fertilizer prices paid by farmers along with U.S. Henry Hub natural gas prices, demonstrates the link between natural gas prices and nitrogenous fertilizer prices, which until 2009 tracked closely. The divergence in prices starting in 2009 indicates the breaking of a linkage between U.S. gas prices and ammonia prices, with the former dictated by growing supplies of natural gas on the U.S. market, and the latter by continuing high demand for fertilizer on the world market. Because ammonia is a tradable product, and because nearly half of all ammonia fertilizer in the U.S. is now sourced from abroad (primarily Trinidad and Tobago, at 55% of imports in 2011, along with Canada, 15%, Ukraine, 9%, and Russia, 8%), American farmers are increasingly exposed to international natural gas prices through the fertilizer they consume.

119. Vroomen, Harry. "Natural Gas and the U.S. Fertilizer Industry." The Fertilizer Institute, Washington, DC, July 15, 2010. p 7. Available at: http://consumerenergyalliance.org/wp/wp-content/uploads/2010/07/Vroomen-CEA-Natural-Gas-Committee-July-15-2010-presentation-at-TFI-hv.pdf

Exhibit 4-7 Monthly Nitrogenous Fertilizer and Natural Gas Prices, 1997-2011



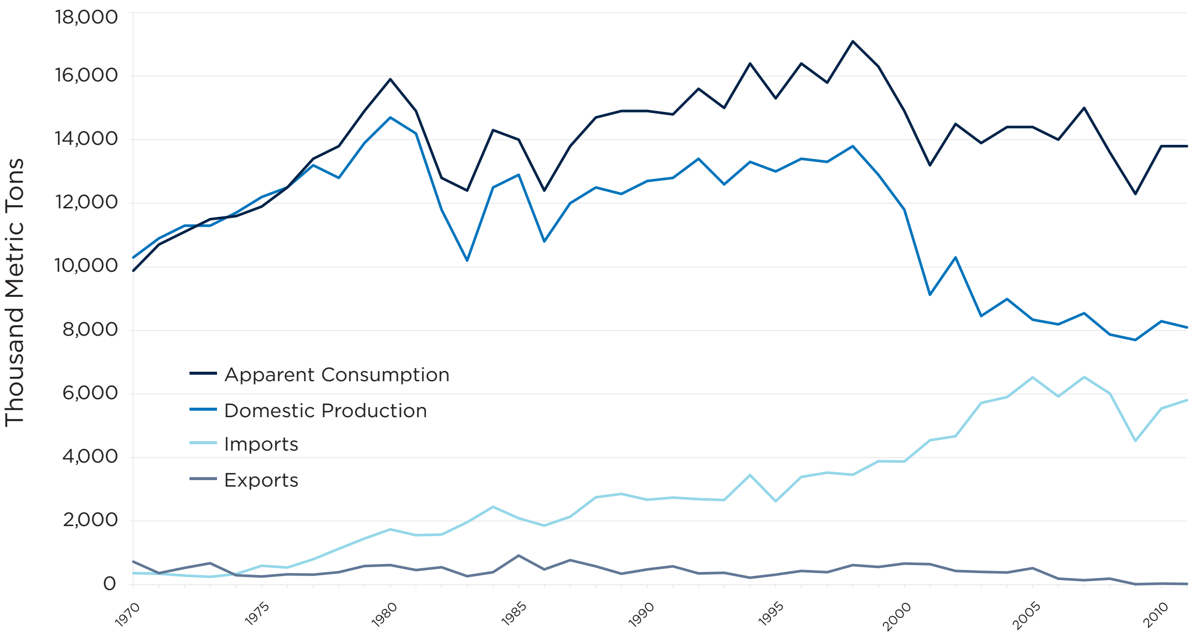
Sources: USDA and EIA.

Because the price of natural gas is such a major determinant of ammonia production economics, the fate of the industry hangs on the price of this commodity. Exhibit 4-8 shows domestic ammonia production and consumption growing steadily until reaching a peak by 1980. Throughout the 1980s and 1990s domestic ammonia production remained fairly flat, hovering between 12-14 million metric tons per year. Production peaked again in 1998 before falling off in 1999 and 2000, prior to the natural gas price increases that occurred in 2001. Between 2000 and 2007, when the price of natural gas slowly ticked up from approximately $2/MMBtu to over $8/MMBtu, the U.S. fertilizer industry shed, in total, 27 ammonia plants,[120] with ammonia capacity declining, from 17,700 to 13,300 thousand metric tons, or a loss of 25 percent of total capacity.

The shutdowns and capacity adjustments in the ammonia industry in part reflect consolidation and evolution in that industry. During periods of high natural gas prices, the plants with higher-cost margins are the most vulnerable to temporary or permanent closure. Some of the U.S. plants were built during a period of much lower gas prices, and proved uncompetitive when feedstock prices rose.

120. Ibid. p 10

Exhibit 4-8 U.S. Ammonia Production, Imports and Exports, 1970-2010



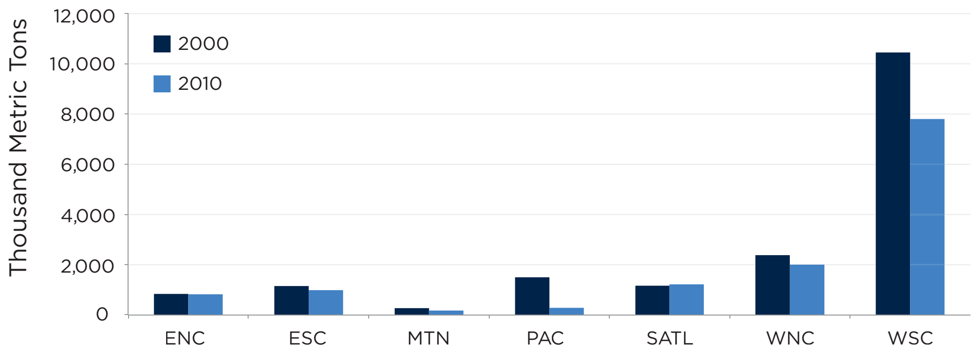
Source: USGS

Geography as well as plant performance and gas price affect the vulnerability of ammonia plants. In the U.S., ammonia producers are located either where the fuel/feedstock supply is inexpensive (near the Gulf) or where the main markets are (in the Midwest). As Exhibit 4-9 shows, the majority of ammonia capacity is located in the West South Central region, which includes Louisiana, Arkansas, Oklahoma and Texas. The region with the second highest capacity is the West North Central region, which includes North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa and Missouri.

In the past, the Gulf Coast ammonia industry has had the advantage of proximity to low cost domestic gas supplies. However, these plants are also close to the seaports through which ammonia from other countries with lower natural gas prices can arrive. As Exhibit 4-9 shows, most of the lost ammonia capacity between 2000 and 2010 has been in the West South Central region, which is most vulnerable to foreign competition when U.S. gas prices are higher. Midwestern ammonia plants are less vulnerable because the imported ammonia must be shipped from seaports, reducing its cost advantage.

Current worldwide capacity of ammonia production is concentrated in Asia (including the Middle East), where ammonia demand is high, and where natural gas is provided to manufacturers at low cost or at subsidized prices (some producers also use coal instead of natural gas). In 2010, the U.S. accounted for only 6 percent of world ammonia production. Nevertheless, domestic producers have some advantage even when gas prices are high, since the current distribution, storage and infrastructure of fertilizer supply in the U.S. is founded on domestic supply. Infrastructure constraints and transportation costs, along with the long lag-times between order and delivery of ammonia from far afield make domestic production attractive.

Exhibit 4-9 Regional Ammonia Capacity Changes from 2000 to 2010



Source: USDA
Note: WSC = West South Central, ENC = East North Central, ESC = East South Central, MTN = Mountain, PAC = Pacific, SATL = South Atlantic, WNC = West North Central

Lower natural gas prices are turning around the fortunes of domestic ammonia producers. At $4/MMBtu – the average price in 2011 - domestic fertilizer production becomes competitive with most Asian and European producers (in general, European producers are at the top of the cost curve, followed by Chinese and Indian plants, as well as Ukrainian plants that receive Russian gas at below-market prices). At $2/MMBtu, U.S. producers become competitive against Russian, African, and Latin American (primarily Trinidad and Tobago) producers, leaving only Middle Eastern producers as a lower-cost source of nitrogen fertilizer.[121] While there is still not enough domestic manufacturing capacity to displace imports, particularly at a time when domestic demand is growing, the current price environment has allowed U.S. producers breathing room they did not enjoy earlier in the last decade.

American fertilizer manufacturers have responded to the opportunity in various ways. Some companies are reopening production facilities mothballed during the last downturn, as PCS Nitrogen Fertilizer is doing with its Geismar, LA plant.[122] Others are planning to open new plants, such as Iowa Fertilizer Company's (a subsidiary of Egypt's Orascom Group) $1.3 billion world-scale facility, planned for Lee County, Iowa.[123]

Most companies, however, are hesitant to again invest billions of dollars in capacity vulnerable to the vagaries of the natural gas price, and have instead opted to expand current production (according to the USDA, between 2001 and 2010, capacity utilization at Ammonia plants hovered around 60%), or to increase value-added in the final product by, for example, producing a urea ammonium nitrate (UAN) blend rather than straight ammonia. This has been the route chosen by LSB, which is adding ammonia production at its Pryor, OK, facility,[124] or by CF Industries, which added UAN production at their Woodward plant.[125]

The conservative approach among U.S.-based nitrogen-based fertilizer producers may be short-lived, however. A number of drivers on the international market, including some marginal production shut-ins in China, and rising natural gas prices elsewhere, have led to significant price

121. "BMO Capital Markets 2012 Farm To Market Conference." CF Industries, May 15, 2012. p 13. Available at: http://phx.corporate-ir.net/External.File?item=UGFyZW50SUQ9NDY3MTM1fENoaWxkSUQ9NDk2OTQ2fFR5cGU9MQ==&t=1
122. Pepperman, Kelly. "Ammonia plant to reopen." WBRZ-TV, 1 February 2011. Available at: http://www.wbrz.com/news/ammonia-plant-to-reopen
123. Area Development Online News Desk. "Iowa Fertilizer Plans $1.3 Billion Manufacturing Plant in Lee County." Area Development Online, 13 March 2012. Available at: http://www.areadevelopment.com/newsItems/3-13-2012/iowa-fertilizer-company-wever-manufacturing-2280090298.shtml
124. LSB Industries, Inc. "LSB Industries, Inc. reports results for the 2012 first quarter." LSB Industries, Inc, 9 May 2012. Available at: http://www.lsb-okc.com/releases/2012/Press_20120509.pdf, p2p2
125. Agrimoney.com. "CF sees rosy outlook, despite corn sowing delays." Agrimoney, 05 June 2011. http://www.agrimoney.com/printnews.php?id=3116&area=n

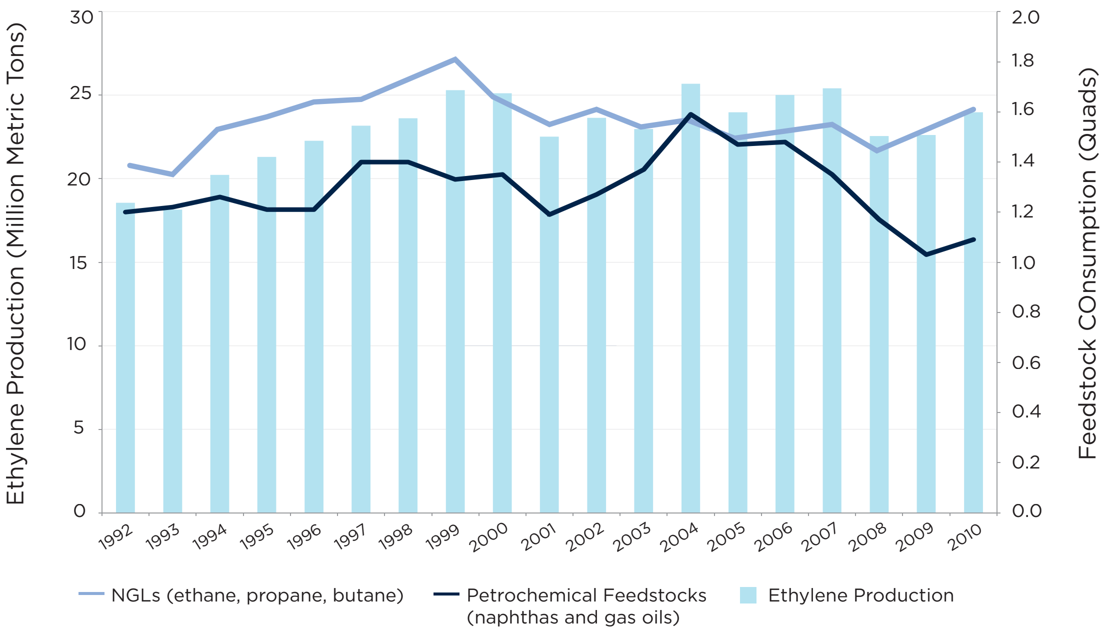
increases for ammonia and urea – the two main sources of nitrogen in fertilizer.[126] Companies around the world are attempting to capitalize on the recent run-up in prices, adding capacity in Africa, Brazil, and throughout Asia,[127] and the deficit should turn into a surplus by 2015.[128] What sets the U.S. market apart is its proximity to customers (U.S. farmers are expected to continue increasing acreage in response to rising commodity prices and demand for biofuel crops), and the availability of a cheap feedstock, as natural gas prices remain 3-7 times lower than prices in Europe and Asia. Even input prices in Trinidad & Tobago are rising, giving pause to manufacturers based in the small Caribbean country.[129]

4.2.2 Ethylene Production

Ethylene is a light, sweet gas that belongs to the olefins group of petrochemicals. Ethylene and its intermediate products are important chemicals in the production of plastics and polymers. Polyethylene, ethylene's major intermediate product, accounts for over half of ethylene use in the U.S. Other major intermediate products made from ethylene include ethylene oxide and ethylene dichloride. Ethylene is produced either by the pyrolysis of NGLs (ethane, propane or butane), or the thermal cracking of naphthas or gas oils.[130] Among all the feedstocks, ethane has the advantage in ethylene production because of its higher ethylene yield combined with minimal co-products. Naphtha crackers generate more co-products and thus require more capital to process.

As Exhibit 4-10 shows, domestic ethylene production grew moderately from 1992 to 1999, but has been fairly flat starting in 2000. The U.S. economic expansion and the high demand for plastic products drove the growth during the 1990s. The flat production since 2000 parallels the slowdown in the U.S. economy as well as declines in demand growth for polyethylene and other ethylene intermediates such as ethylene dichloride and ethylene oxide.

Exhibit 4-10 U.S. Ethylene Production and Feedstock Consumption (1992-2010)

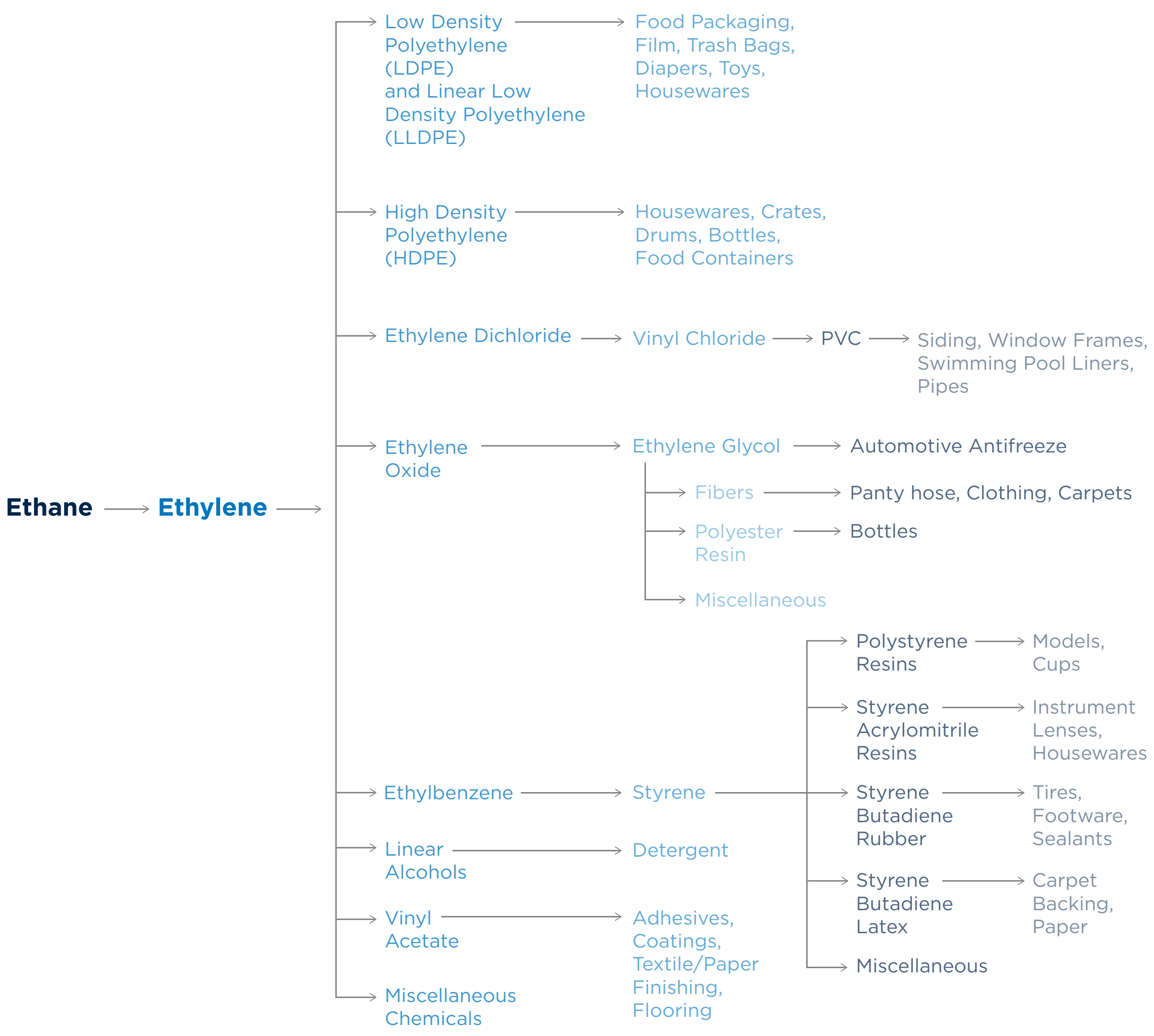


Source: EIA; Chemical and Engineering News; American Chemistry Council; ICIS; Oil & Gas Journal

126. Agrimoney. "Fertilizer Prices May Drag 2012 Farm Profits Lower." No-Till Farmer, 2012. Available at: http://www.no-tillfarmer.com/pages/News---Fertilizer-Prices-May-Drag-2012-Farm-Profits-Lower.php
127. Apodaca, Lori. "Nitrogen (Fixed) – Ammonia." U.S. Geological Survey, 2012. Available at: http://minerals.usgs.gov/minerals/pubs/commodity/nitrogen/mcs-2012-nitro.pdf
128. Terazono, Emiko. "Fertiliser industry warns of surplus." The Financial Times, 13 June 2012: London, UK. Available at: http://www.ft.com/cms/s/0/bae17b7e-b56c-11e1-b8d0-00144feabdc0.html
129. Seay, Stephanie. "Low gas costs may not be enough to spur large fertilizer expansion." Platts, 27 Jan 2012: Knoxville, TN. Available at: http://www.platts.com/RSSFeedDetailedNews/RSSFeed/NaturalGas/3915346
130. Pyrolysis breaks down longer hydrocarbon chains by employing heat in the absence of oxygen. Thermal cracking, in addition to high heat, uses catalysts to obtain lighter hydrocarbon molecules from heavier feedstock.

Ethane is the primary feedstock in U.S. ethylene production, and as such, ethane prices are critical to the overall economic condition of the U.S. ethylene industry (see Exhibit 4-10 for a flow chart of the derivatives of ethylene). The level of ethane demand is influenced by crude oil and natural gas prices. If the crude oil price is high relative to the natural gas price, then the oil-based ethylene feedstock (naphthas and gas oils) price is also relatively higher, and thus ethane becomes a more profitable feedstock choice resulting in high levels of demand for ethane.

Exhibit 4-11 A Simplified Ethylene Flow Chart



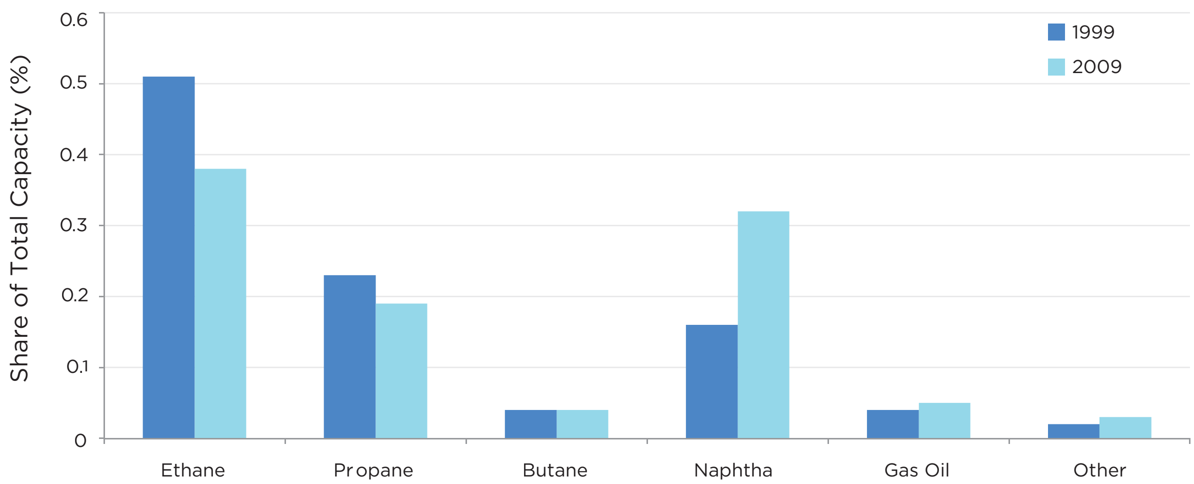
Source: American Chemistry Council

Aside from its relative value to crude oil price, the direct price of natural gas is also critical in ethane pricing and industry profitability. Before natural gas is delivered through the pipelines, raw natural gas is processed to remove the NGL constituents. However, if natural gas prices are high, NGLs can be left in the gas stream to boost pipeline gas heat content. NGL feedstock users (especially ethylene producers) therefore have to offer a premium to the NGL producer to justify removing the NGLs from the gas stream. The price of ethane in particular therefore follows the price of natural gas, providing ethane consumers with an advantage when gas prices are low, and with a disadvantage when gas prices are high.

Over the last decade, the U.S. experienced highly variable gas prices. The response of ethylene producers to changes in relative prices is seen in Exhibit 4-10 above. For example, during 2000 to 2003, when gas prices were relatively high, NGL consumption declined and flattened while consumption of naphthas and gas oils increased. The variability of natural gas prices has also motivated ethylene producers to reduce their reliance on NGLs and increase their naphtha and gas oil capacity. Exhibit 4-12 shows the changes in ethylene capacity by feedstock type.

The run-up in crude oil prices in 2007-2008, and more recently since the start of economic recovery in 2010, has again disadvantaged ethylene producers using naphtha as the feedstock. It has, however, made ethane-consuming crackers much more competitive. Even as U.S. ethane prices hit all-time lows, ethylene and its derivatives continue to sell for a premium. Much of this widening margin is dictated by global commodity prices, and specifically, by the nature of ethylene manufacture facilities around the world – approximately three-quarters of which use naphtha as their primary feedstock.[131] As Exhibit 4-13 shows, feedstock prices are diverging, with the price of naphtha continuing to follow crude oil prices, while discounts for ethane are widening. With approximately half of all U.S. crackers capable of using ethane (many crackers can run on multiple feedstock streams), naphtha is being pushed out, providing American-based petrochemical producers with a tremendous cost advantage over their international peers. This explains the high operating rates North American producers were able to achieve relative to their global peers (91% vs. 85%).[132] With raw materials and utilities accounting for over 75 percent of the cost of producing polyethylene from ethane, and even more when using naphtha feedstock, the widening spread between American and non-American input costs is focusing the industry's attention back on U.S. shores.

Exhibit 4-12 U.S. Ethylene Capacity by Feedstock (1999, 2009)

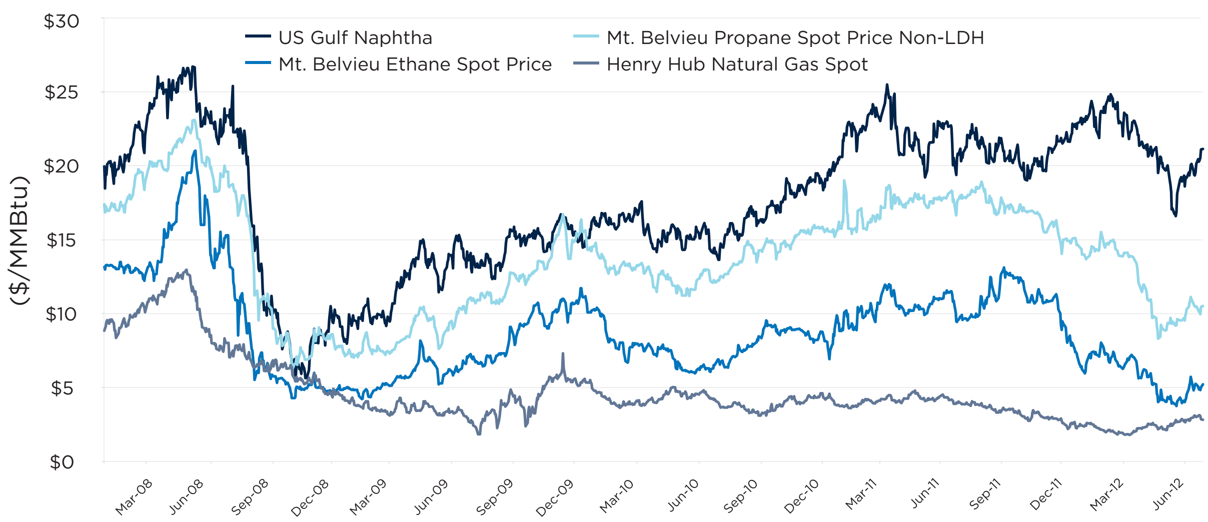


Source: Oil and Gas Journal.

131. Kirkley, Allen. "Ethylene 2008-2028: Feedstock Scenarios." American Institute of Chemical Engineers & American Chemistry's Society Spring Conference & 20th Ethylene Producers' Conference, April 6-10, 2008, New Orleans. Available at: http://www.shell.com/static/chemicals/downloads/aboutshell/allen_kirkley_ethylene_2008_2028_feedstock_scenarios.pdf

132. "Meeting with Investors." Braskem, January 2012. Available at: http://www.braskem-ri.com.br/Download.aspx?Arquivo=umNYwTpGs2H069LrHpi3yQ==&IdCanal=x7SWIN5E/BrOz7EVan4AXQ==

Exhibit 4-13 Petrochemical Feedstock Prices



Source: Bloomberg

Proposed U.S. ethylene capacity would increase U.S. capacity by over 40 percent, from the current 27 million metric tons to 38 million metric tons. Most of the additional capacity will be located in the U.S. Gulf Coast region – a center of petrochemical activity with all the necessary infrastructure and attendant services. Some of the new plants, however, will be located closer to the resource, particularly in states containing Marcellus and Utica shale resources, including Ohio, Pennsylvania, and West Virginia.

A world-class cracker, with total capacity of approximately 1 million metric tons a year of ethylene, consumes around 60,000 bbl/d of ethane.[133] Thus, the proposed plants could bring ethane consumption up by 865,000 bbl/d. The ICF estimates of economic impacts through 2017 presented here are based on an expectation that 6.2 million metric tons of new or converted ethylene capacity coming online by 2017, adding approximately 375,000 bbl/d to U.S. ethane consumption that year.

Neither China, nor any other countries in East Asia, have the low-cost feedstock that the U.S. gas and oil development promises to bring to market. In the Middle East, which to date has enjoyed an advantage over all other regions, fundamentals are also changing. Primarily, this is a result of government policies in countries like Saudi Arabia, where the petrochemical industry is allocated natural gas and NGLs produced in association with crude oil as a matter of economic development policy. With oil production constrained by OPEC quotas, and growing demand for natural gas and NGLs from non-industrial users, supply of feedstock for the Saudi petrochemical industry is being squeezed, forcing some producers to reconsider naphtha and other heavier feeds.[134] Given this situation, even SABIC, Saudi Arabia's petrochemical arm, is looking to invest in U.S. production.

4.2.3 Glass Industry

The U.S. glass and glass products manufacturing industry (NAICS 3272) consists of four major segments:

- Flat glass manufacturing (NAICS 327211)
- Other pressed and blown glass and glassware manufacturing (NAICS 327212)
- Glass container manufacturing (NAICS 327213)
- Glass product manufacturing made from purchased glass (NAICS 327215)

133. Lemos, William. "APLA: Shale gas revolution changes outlook for US ethylene industry." ICIS, 7 November 2011. Available at: http://www.icis.com/Articles/2011/11/07/9505411/apla-shale-gas-revolution-changes-outlook-for-us-ethylene.html
134. "SABIC explores technology to replace gas-based crackers." Platts, Jan 27, 2011. Available at: http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Petrochemicals/7991235

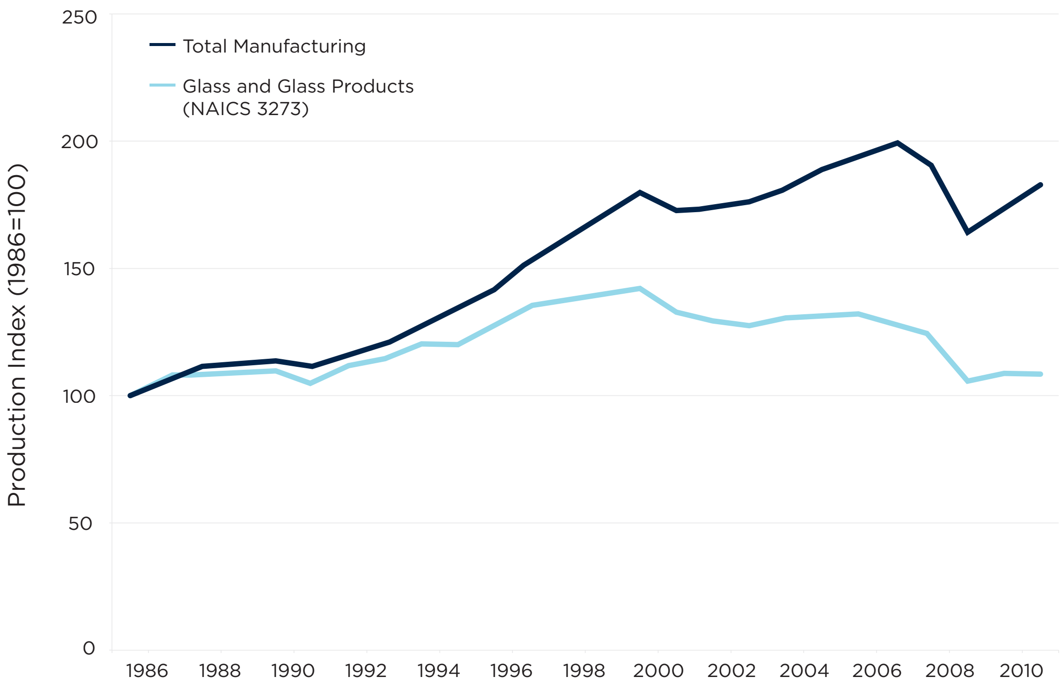
Exhibit 4-14 shows the various markets and applications of the three major glass products. Demand for flat glass is driven by the automotive and construction industries. Glass container production is driven by the food and beverage industries, while the pressed and blown glass industry is dependent on the demands coming from the electronics, kitchenware and tableware industries. Because glass is a very fragile and heavy product, glass manufacturers are usually located near their customers. Thus, for example, flat glass producers would be located near automobile plants and in highly populated areas, and glass container manufacturers would be located near food and beverage plants. Texas, Ohio, California and Pennsylvania have the largest number of glass plants in the U.S.[135]

Exhibit 4-15 shows the production trends of the U.S. glass industry from 1986 to 2011. The figure shows the strong growth of glass production from the 1980s to 2000, but that since 2000, glass production has been fairly flat. The year 2009 saw a precipitous drop in glass production primarily due to the severe decline in vehicle production, construction activity and the overall economy. As seen in Exhibit 4-15, the glass industry has not kept up with the growth of the entire manufacturing sector since the early 1990's. While significant manufacturing growth came from the computer, electronics, and telecommunications equipment sectors, major growth drivers for the glass industry, such as vehicle manufacturing or construction, have grown at a slower rate during the same time period.

Exhibit 4-14 U.S. Glass Markets

Major Product Categories	Major Markets
Flat Glass	Automotive and construction (residential, commercial)
Glass Containers	Food and beverage
Pressed and Blown	Tableware, kitchenware, light bulbs, electronics, scientific instruments

Exhibit 4-15 U.S. Glass and Total Manufacturing Production (1986-2011)



Source: Oil and Gas Journal.

135. Worrell, Ernst, et al, Energy Efficiency Improvement and Cost Saving Opportunities for the Glass Industry, An Energy Star® Guide for Energy and Plant Managers, LBNL-57335-Revision, Ernest Orlando Lawrence Berkeley National Laboratory, March 2008.

Glass production is an energy-intensive process. The major processes involved in the production of glass are similar across the major products. There are four major process steps in glass production: batch preparation, melting and refining, forming, and post-forming. Batch preparation involves the mixing of the raw materials including silica, limestone, and soda ash. Other ingredients are added depending on the type of glass being produced.

The melting and refining of the batch is the most energy-intensive step. Depending on the type of glass being produced, the batch is processed in different types of furnaces and at different temperatures. Glass melting furnaces, which are mostly fueled with natural gas, require significant capital and once started, must operate continuously because they are very costly to shut down. Glass melters continuously operate for many years.

Glass companies are susceptible to high energy prices. During the spike in natural gas prices in the early 2000s, glass companies increased the prices of their products (through an energy surcharge) and as such, passed the increased costs to their customers. Aside from natural gas, the industry is also sensitive to high oil prices because of transportation costs. When transportation costs become high, glass companies pass these higher costs to their customers as well. The industry's strategy of adding energy surcharges during periods of high energy prices manifest its inability to switch fuels or to shutdown melters over the short-term.

One important way that the industry saves energy and resources is the use of recycled glass (or "cullet"). About 23 percent of total glass used in the U.S. is recycled.[136] The main sources of cullet are the glass plant's finishing end as well as post-consumer recycling. Most of the cullet used in flat glass production is from the plant's finishing process wastes, while glass container production uses in-plant wastes as well as post-consumer recycled glass. The U.S. recycles about 28 percent of total glass containers and about 90 percent of this goes to the production of new glass containers.[137,138]

The glass industry is highly globalized. The large glass companies operate plants all over the world. For example, PPG Industries, a U.S. glass company, has glass plants in Canada, China, and Europe, aside from several plants in the U.S. Asahi Glass Company, a Japanese glass company has several glass plants all over the world, including in the U.S., Europe and Japan. While the availability of cheaper feedstock at one location may not influence the sighting of a glass plant there, the lower cost of the product may translate into a price advantage for the glass users, such as automobile manufacturers.

4.2.4 Methanol Industry

The methanol industry falls under industrial category Other Basic Organic Chemical, NAICS code 325211. While in some countries, particularly China, methanol is used as a transportation fuel, in the U.S. it is primarily a precursor chemical used in the manufacture of a variety of everyday materials, such as paints, plastics, synthetic fibers (including those used for clothing or carpeting, adhesives, and building materials). In its pure form it is also used in water treatment facilities, in the production of biodiesel, and increasingly, in fuel cells to generate emissions-free electricity.

While natural gas consumption of the "Other Basic Organic Chemical" segment of the U.S. manufacturing industry is reported to account for, on average, 10.28 percent of total product value, methanol production is particularly natural-gas intensive, both for feedstock and process heat use. World-wide, natural gas can account for up to 90 percent of total operating costs in a marginal methanol plant. For plants in regions where natural gas is supplied to the manufacturers at below-market value, and where operating costs are above-average, the

136. U.S. Environmental Protection Agency (EPA). "Glass." EPA, accessed 31 July 2012. Available at: http://www.epa.gov/wastes/conserve/materials/glass.htm
137. Glass Packaging Institute. "Recycling & The Environment." Glass Packaging Institute, accessed 31 July 2012. Available at: http://www.gpi.org/recycle-glass/environment/
138. U.S. Environmental Protection Agency (EPA). "Glass." EPA, accessed 31 July 2012. Available at: http://www.epa.gov/wastes/conserve/materials/glass.htm

share of natural gas cost in total operating cost can be as low as 55 percent.[139] While some countries, particularly China, produce large quantities of methanol from coal, the vast majority of worldwide methanol production capacity is natural-gas based, and therefore highly dependent on natural gas prices.

At the start of 2012, the U.S. has a total of 845,000 metric tons of methanol production capacity – a sharp decline from 1999, when plants located in the country could produce upwards of 7 million tons.[140] Much of the decline was driven by natural gas price increases in the first half of the last decade, which rendered U.S. based production economically marginal, particularly at a time when gas-rich countries such as Egypt and Trinidad & Tobago offered long-term cheap gas supplies to large industrial users as a matter of industrial development policy.

The low natural gas prices, coupled with the promise of solid gas supply for years to come, has incentivized companies to expand, or move their operations to the United States. Such is the case with Methanex; a company that previously disassembled and moved methanol plants out of North America is coming back in a big way – by dismantling and moving one of its methanol plants, now in Punta Arenas, Chile, to Geismar, Louisiana.[141] And for Methanex, this may just be the beginning; with three of its four methanol plants in Chile idled due to a shortage of Argentinean natural gas, the company is already prepping its Geismar site for a possible second plant.

Before the Methanex plant starts up, the Gulf Coast will see the opening of two other facilities. Orascom Construction Industries (OCI) will reopen a long-mothballed Eastman Chemical methanol plant in Beaumont, Texas,[142] that is coupled with an ammonia production line.[143] After changing hands a few times, the facility is being brought back to life, and expected to produce 750 thousand tons of methanol a year, starting in mid-2012.[144]

A second plant being restarted is LyondellBasell's facility in Channelview, Texas. Shuttered in 2003, the plant was initially on the market, but with natural gas prices edging close to $2/MMBtu, LyondellBasell opted to restart production to capture the widening margins between feedstock prices and international product prices. The company plans to begin operations in 2013, and expects to generate EBIDTA upwards of $130 million per year – from a plant requiring little capital expenditure to start.[145]

The announcement by Dallas-based Celanese Corp. of plans to construct a greenfield world-scale plant is a true vote of confidence in the future of American petrochemical industry.[146] The facility, slated for completion in the second half of 2015, will have the capacity to produce 1.3 million tons of methanol a year, and is meant to complement the company's other product lines based at the same Clear Lake, Texas, facility.[147] While the scale of capital outlay has not been announced, plants of its size cost approximately $1 billion to build, and result in the creation of hundreds of full-time jobs. See the exhibit below for a list of planned U.S. methanol capacity additions.

139. CHEMSYSTEMS. "Methanol Strategic Business Analysis." Chemsystems, November 2009: London, UK. Available at: http://www.chemsystems.com/reports/search/docs/prospectus/sba09_methanol_prospectus.pdf

140. Jordan, Jim. "How Methanol Got its Groove Back. The U.S. Methanol Renaissance." RBN Energy, 23 February 2012. Available at: http://www.rbnenergy.com/How-Methanol-Got-its-Groove-Back

141. Kaskey, Jack. "Shale-Gas Boom Spurs Chilean Methanol Plant's Move to U.S." Bloomberg, 18 January 2012: Houston, TX. Available at: http://www.bloomberg.com/news/2012-01-18/shale-gas-boom-spurs-methanex-to-relocate-idled-chilean-plant-to-louisiana.html

142. Kelley, Lane. "US Eastman sells shuttered methanol plant, new owner plans restart." ICIS, 7 January 2011: Houston, TX. Available at: http://www.icis.com/Articles/2011/01/07/9423673/us-eastman-sells-shuttered-methanol-plant-new-owner-plans-restart.html

143. ORASCOM Construction Industries. "OCI Beaumont." ORASCOM Construction Industries, accessed 31 July 2012. Available at: http://www.orascomci.com/index.php?id=pandoramethanolllc

144. Methanex and OCI. "Methanex and OCI Enter Into Methanol Offtake Agreement." Bloomberg, 23 April 2012. Available at: http://www.bloomberg.com/article/2012-04-23/anMlfp7fGWe0.html

145. Kelley, Lane. "LyondellBasell to restart Texas methanol plant in late 2013." ICIS, 8 December 2011: Houston, TX. Available at: http://www.icis.com/Articles/2011/12/08/9515208/lyondellbasell-to-restart-texas-methanol-plant-in-late.html

146. Kaskey, Jack. "Celanese Plans Texas Methanol Plant to Tap Cheap Gas." Bloomberg, 15 June 2012: Houston, TX. Available at: http://www.bloomberg.com/news/2012-06-14/celanese-plans-texas-methanol-plant-to-tap-cheap-gas.html

147. Celanese Corporation. "Celanese Plans Methanol Plant for Houston." Celanese, 14 June 2012: Dallas, TX. Available at: http://www.celanese.com/index/mr_index/mr_news/mr_news_fullpage.htm?id=43443

Exhibit 4-16 Planned Additions to U.S. Methanol Capacity

Company	Methanol Production Capacity (Mt/y)	Natural Gas Consumption (MMBtu/d)	Location	Expected Startup
Celanese Corp.	1,300	124,658	Clear Lake, TX	2015
Methanex	850	81,507	Geismar, LA	2014
Methanex	888	85,103	Geismar, LA	2015+
LyondellBasell	780	74,795	Channelview, TX	2013
Orascom	750	71,918	Beaumont, TX	2012
Total	**4,568**	**437,979**		

Sources: Various

Should all the above-listed projects reach completion, U.S. methanol production will increase more than six-fold in four years, to over 5.4 million metric tons. While still below its 1999 7-million-ton per year peak, this natural-gas fueled renaissance would result in additional natural gas consumption of over 400 Billion Btu/day (at 35 MMBtu of natural gas per metric ton of methanol[148]). Though the U.S. will still be a net importer (2011 methanol imports totaled 8.7 million tons[149]), the expansion of U.S. based methanol production will reduce import dependence by half - a dramatic turnaround for an industry all but written off just a decade ago.

Exhibit 4-17 International Demand and U.S. Export Potential

Overseas Sales of Fuels, Products and Services

An important aspect of the shale revolution is the potential for exporting U.S. fuels, products, and services. Although shale gas production is still new, numerous applications to export liquefied natural gas have been submitted to the U.S. Department of Energy.

Natural gas liquids (NGL) exports are also expected to greatly increase in coming decades. Natural gas liquids are those non-methane components of natural gas that are produced or processed in liquid form. NGL production is growing rapidly because of the gas production growth and a shift to liquids-rich plays. Because of the nature of NGL markets in the U.S., some components of NGLs are expected to see greatly increased exports.

A major source of future exports will be the output products of the growing U.S. petrochemical industry. The growth in this industry will be driven by low cost feedstocks of ethane for ethylene production. Ethylene is a fundamental chemical used in manufacturing plastics.

The other category of future exports are well completion and midstream services. To the extent that international shale gas takes off, the U.S. oil and gas service sector is very well positioned to capture a large component of future international demand for stimulation and other services. Many of these services are highly specialized and take years of development to perfect.

148. Mian, M. A. "Comparison of methods used to calculate netback value." PennEnergy, accessed 31 July 2012. Available at: http://www.pennenergy.com/index/petroleum/display/_printArticle/articles/oil-gas-financial-journal/volume-4/issue-3/features/comparison-of-methods-used-to-calculate-netback-value.html

149. U.S. International Trade Commission, http://dataweb.usitc.gov/scripts/prepro.asp

Economic Impact Findings 5

This section discusses the scope of the economic impact analysis, the inputs and assumptions for modeling, and presents the results of the modeling. The modeling effort attempted to capture the full scope of the impact of the incremental natural gas and liquids drilling throughout the economy resulting from the recent upstream technological advances. The approach to estimate future oil and gas demand using modified EIA forecasts is presented. Assumptions are presented for changes in industries that use natural gas as a feedstock. The approach for modeling manufacturing and power generation impacts is also presented.

5.1 Key Drivers for Economic Impacts

The following section includes a discussion of the main elements that produce the economic impacts including the historical and expected natural gas and liquids production and industrial use of natural gas.

5.1.1 Natural Gas Supply: Growing U.S. Production of Natural Gas and Liquids

Any estimate of how much incremental volumes of natural gas and oil have and will be produced because of recent upstream technological advances involves depicting an "alternative world" in which these advances never occurred and then calculating the differences in energy volumes and prices between that alternative world and what actually happened or what is now projected to happen in the future. There are many ways of estimating this difference that would produce a wide range of results, depending on the specific technology advances that are being considered, the start time from which the volume and price differences are being estimated, and the assumed projections. Because of this potential for a wide range of estimates of the economic impact of upstream technological advances, it is important to consider the results presented here as illustrative rather than definitive. The methodology used here reflects the following elements and conventions:

- The definition of "recent technology advances" is the improvements and wider application in horizontal multi-stage hydraulically fractured wells in gas shales, tight gas and tight oil experienced since approximately 2007 and now expected for the future. These advances have led to larger estimates of technically recoverable resources and expectations for higher gas and oil production rates.
- The EIA Annual Energy Outlook (AEO) for 2012 is the starting point for the calculations regarding future U.S. energy production volumes and prices.[150] However, some amount of demand has been added in the future scenario depicted here to account for more recent announcements and expectations for LNG exports and new petrochemical demands for natural gas and NGLs. For example, the AEO 2012 has 25.3 quadrillion British thermal units (quads) of dry gas demand in 2017, including 1.2 quads of net imports and a market price at Henry Hub of $4.42 per MMBtu. To this AEO demand we added 1.6 quads of incremental natural demand to reflect increased methanol, ammonia, gas-to-liquids (GTL), and LNG production, and have adjusted the gas upward by $0.33/MMBtu (to $4.55/MMBtu) to account for that higher demand.

150. EIA Annual Energy Outlook http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf

- The AEO for 2008, produced by EIA in 2007, is the basis for the prices and U.S. gas and oil supply for the "alternative world" without the incremental low-cost gas and oil supplies. Although the 2008 AEO was the basis, changes to the underlying assumptions and projections were made to reflect the impact of the recession, as well as pricing impacts on volumes consumed. This represents 21.3 quads of domestic production and 3.3 quads of cumulative imports between 2008 and 2017, and a price difference of roughly $1.50/MMBtu (2010 dollars)[151] by 2017.

The net increases in U.S. natural gas, natural liquids, and crude oil and condensate production are shown below in Exhibit 5-1. The impact of these incremental production volumes on total U.S. production is illustrated in Exhibit 5-2. It is important to note that these values represent the net effect on production including reductions in conventional and other kinds of oil and gas investment.

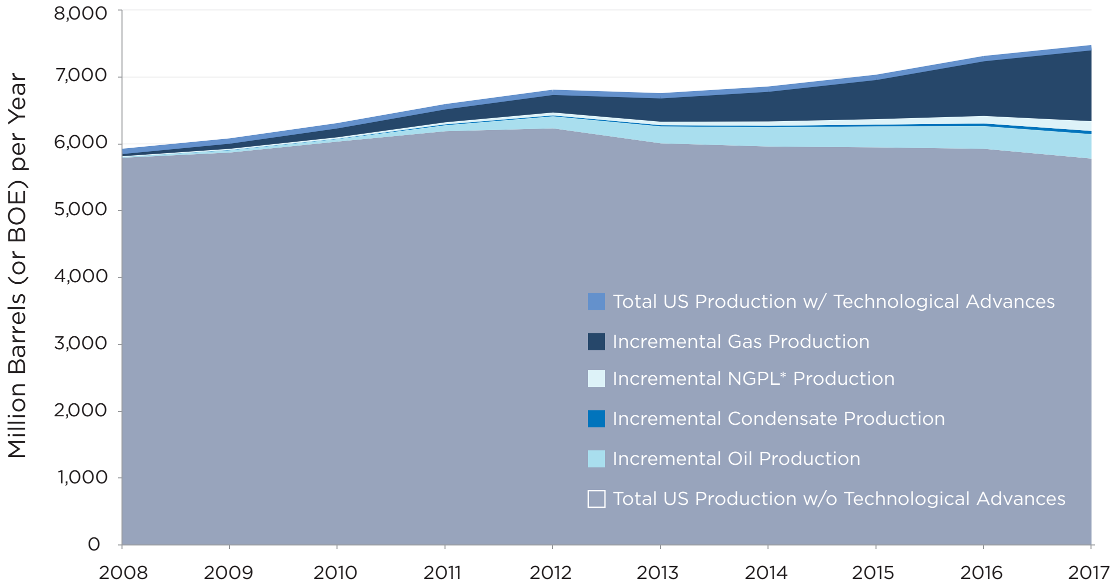
Exhibit 5-1 Incremental Volumes of U.S. Production

Annual Production	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Incremental Gas Production (Bcf)	400	657	951	1,315	1,726	2,193	2,722	3,534	4,848	6,223
Incremental Oil Production (MMbbl)	9	34	38	93	181	256	290	314	341	365
Incremental Condensate Production (MMbbl)	3	6	8	11	14	18	23	30	41	52
Incremental NGPL* Production (MMbbl)	14	22	32	45	59	75	93	121	165	212
Incremental HC Production (MMBOE)[152]	92	171	236	367	539	712	856	1,049	1,349	1,659

Sources: EIA, ICF Estimates

151. Assumes a "without technology advancements" 2017 price of $6.06/MMBtu and a "with technology advancements" 2017 price of $4.55 (2010 dollars)
152. MMBOE defined as million barrels of oil equivalent

Exhibit 5-2 Incremental Volume Impact on Total U.S. Production (attributable to upstream technological advances since 2007)



Source: ICF estimates * Natural gas plant liquids

5.1.2 Natural Gas Demand: Industrial Use and Impact on Coal

The additional production of natural gas and liquids pushes out the supply curve of natural gas, meaning that because there is more supply, every unit of supply is associated with a lower price. In response to this price decline, consumers will demand more units. Thus, our model has assumed a certain level of increased demand in response to the supply-led price decrease. See Exhibit 5-3 for the natural gas price decline associated with the upstream technology changes. Although natural gas has experienced a price decline due to the upstream advances, prices for crude oil and NGLs will not change significantly, as the price of these commodities is dictated by international market supply and demand fundamentals, and expanding total U.S. supply will reduce imports, rather than lower prices. Thus, supply increases for oil and NGLs will not significantly affect their price.

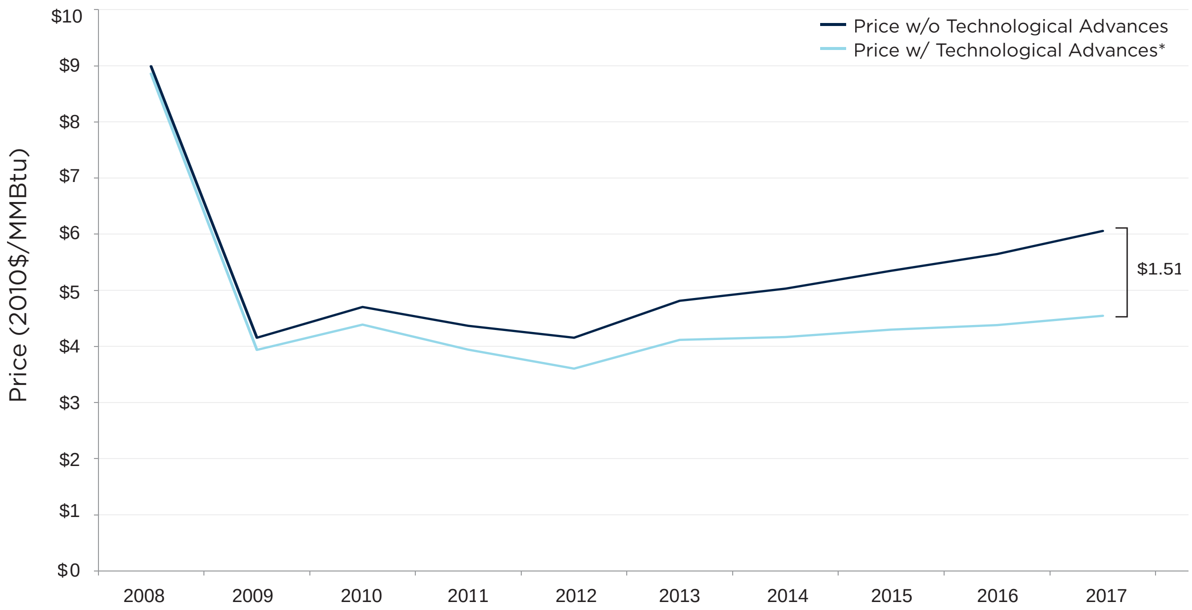
Changes in Industries Using Gas and NGLs as Feedstocks

There are several types of industries whose production might be expected to increase because natural gas and NGLs supplies will go up and prices will come down. These industries include GTLs, LNG, methanol, ammonia and ethylene/polyethylene. Some typical parameters for new plants of these types are shown in Exhibit 5-4.

We also project that by 2017, there will be an incremental 50,000 barrels per day of GTL production (18.3 million barrels annually), 3 billion cubic feet per day (Bcf/d) of LNG exports (1.1 Tcf annually), and 5,500 metric tons per day of reactivated/new methanol production (2 million metric tons annually). Our projections also include 11,000 metric tons per day of reactivated/new ammonia production (4.0 million metric tons annually) and 17,000 metric tons per day of new ethylene/polyethylene production (6.2 million metric tons annually), given the lower prices seen. For the calculation of GDP effects, the assumed value of the products produced is based on the following relationships:

- GTL: $/bbl = AEO wholesale prices for diesel oil in $/bbl
- LNG: $/MMBtu free-on-board (FOB) = (AEO oil $/bbl/5.8*0.75) – 1.50
- Methanol is equal to oil on a Btu basis, or $/metric ton methanol = AEO Oil $/bbl/5.8e6 * 64,600Btu/gallon * 333 gallons/metric ton
- Ammonia (Anhydrous): $/metric ton = AEO WH gas price * 30 + 166
- Ethylene to Polyethylene: polyethylene resin is 70 cents per pound or $1,543 per metric ton.

Exhibit 5-3 Natural Gas Prices (w/ and w/o Upstream Technological Advances)



Source: ICF estimates based on the 2008 and 2012 AEO * Altered to reflect the increasing demand resulting from lower prices

Exhibit 5-4 Characteristics of Industrial Plants Using Natural Gas or NGL Feedstocks

Type of Plant	Feedstock Input	Example Plant Characteristics						
		Output Size	Units for Output	Feedstock Input	Units for Input	Plant Capital Cost (2010$ mm)	Direct Employees for Operation	Direct and Indirect Construction Employment (person-years)
GTL (diesel, waxes, etc.)	Natural Gas	100,000	Barrels per day	947	MMcf/d[153]	$9,750	850	70,000
Liquefied Natural Gas (LNG)[154]	Natural Gas	923	MMcf/d	1,037	MMcf/d	$4,780	200	34,300
Methanol	Natural Gas	2,500	Metric tonnes per day	82	MMcf/d	$680	150	4,900
Ammonia (Anhydrous)	Natural Gas	1,500	Metric tonnes per day	44	MMcf/d	$510	150	3,675
Ethylene to Polyethylene	Ethane, other NGLs	2,740	Metric tonnes per day	60,274	Barrels per day	$2,000	800	14,384

Source: ICF estimates

153. Million cubic feet per day
154. Capital cost given for new greenfield LNG plant. Conversion of an existing import terminal would have approximately 65% of these costs.

Other Manufacturing

Now, we look at the impacts from the manufacturing sector due to the lower natural gas and power prices that result from the recent upstream technological advancements. Our estimates include the representation of 95 sub-sectors, each with data on the electricity and natural gas inputs to the sector including the share of the output that is represented by electricity and natural gas and delivered prices of electricity and natural gas. From these data we estimate the reduced price of the output product (as an index to the base output) and increased output using assumed price elasticities. This then provides us with two points on the supply and demand curves representing the demand, prices and production before and after the lower gas prices. Similar to what was done above, we calculate the increase in the consumer surplus (defined in Appendix C) and output but only include the value added to avoid double counting the consumer surplus already captured in the gas market calculation.

Coal and Power Generation

Next, we address the impacts of the lower natural gas prices on the power generation sector. We represented all fuel types used to produce power based upon the current outlook (after the incremental gas supplies) of the fuel use from the AEO 2012. Average efficiencies of the power generation units by fuel type were based on historical data and adjusted for future years to match power generation with fuel use for the power generation segment fuel use in the AEO 2012. Gas use in the "counterfactual case" (defined as what would have happened without the new technologies) is based on economic dispatch at the higher gas price. The coal use increases by this amount , which is adjusted for the lower efficiencies of the coal units. We also assume that electricity prices change between the two cases by the difference in the cost of gas generation times 0.6, the approximate fraction of time natural gas generation is expected to be at the margin.

These data allow us to compute the increased consumer surplus which duplicates that estimated in the gas sector calculations above and the increase in value added which is the lower electricity prices times the increase in electricity production.

The change in jobs is estimated from the increase in gas generation and reduction in coal generation using 60 jobs per terawatt-hour (TWH)[155] for gas generation and 133 jobs per TWH for coal generation.[156]

Coal Production

We also calculate the loss in GDP from reduced coal production as equal to the reduction in coal use times the delivered price of the coal. The loss in jobs is calculated based on this number and the estimate of 250 jobs per million tons of coal per year.[157]

5.2 Natural Gas and Liquids Production Impacts on the U.S. Economy

This study attempts to quantify all economic impacts of recent technological improvements in the oil and gas industry. The study takes a "counterfactual" approach to the analysis, comparing the difference between the economic impacts of two scenarios:

1. A scenario in which the recent technological improvements in oil and gas production do not exist.
2. Actual history and current projections based on the recent technological improvements.

This section includes a discussion of the main outputs of the model, including the change in GDP, total employment, employment by industry, consumer savings, the U.S. balance of trade, royalty payments and taxes, and state impacts.

155. Defined as 10^12 watts
156. ICF calculations based on: U.S. Energy Information Administration (EIA). "National Energy Modeling System (NEMS) model cost factors." EIA, April 2010: Washington, D.C. Available at: http://www.eia.gov/oiaf/aeo/assumption/pdf/electricity_tbls.pdf
157. ICF estimate of direct and indirect jobs based on: Price WaterhouseCoopers (PwC). "The Economic Contributions of U.S. Mining in 2008." National Mining Association, October 2010: Washington, D.C. Available at: http://www.nma.org/about/info.asp

Two multipliers (used to calculate the multiplier effect impacts on the aggregate economy), 1.3 and 1.9, were used to calculate a range of economic impacts. The lower multiplier, 1.3, indicates that every $1 generated by direct and indirect impacts "induces" an additional $0.30 of economic activity throughout the aggregate economy through the consumer spending of direct and indirect workers in the oil and gas industry. Similarly, the higher multiplier, 1.9, indicates that every $1 in direct and indirect impacts generates an additional $0.90 of economic activity.

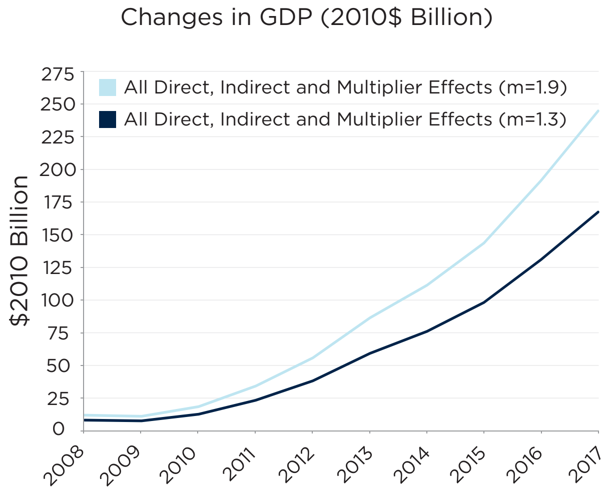
Exhibit 5-5 Impacts Examined

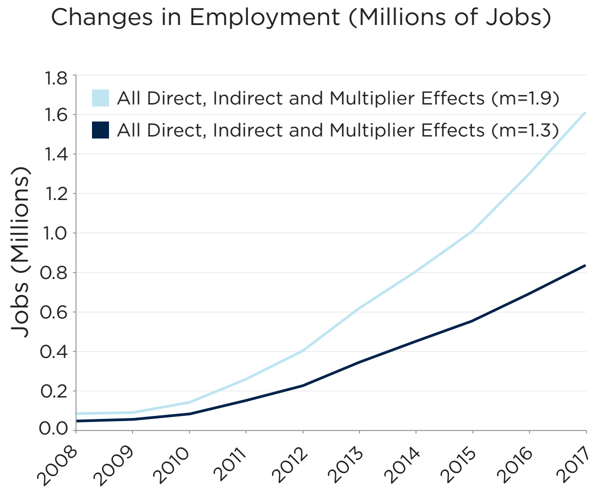
- **Upstream technology advancements lead to a reduction in the per-unit cost** of finding, developing, and producing oil and gas, which, for any given fixed quantity of production, will lower the production-related investment dollars and associated jobs.
- **Increase in production volumes** of oil and gas resulting from lower production costs and a larger technically recoverable resource base. These higher production volumes lead to increases in production-related investment dollars and associated jobs.
- **Reduced cost of natural gas to consumers** resulting from increased production of gas and oil. Some of the dollars thus saved are spent on other domestic goods and services boosting output (such as contributions to GDP) in other sectors.
- **Reduction in electricity prices** coming from lower natural gas prices. As with natural gas consumers, the money saved by electricity consumers is spent on other domestic and imported goods and services boosting GDP.
- **Reduced coal consumption in electric power plants** as more natural gas is used. This reduces jobs in coal mining and transportation and in coal power plant construction and operation.
- The reduction in the prices of natural gas and electricity has resulted in a **lowering of the cost of U.S. manufactured goods** leading to increases in production and a larger contribution to GDP from the manufacturing sector.
- In particular with regard to manufacturing, the increased accessibility and lower price for natural gas and natural gas liquids has stimulated **greater production of certain chemicals and fuels using methane and NGLs as a feedstock.** This will contribute further to U.S. GDP and jobs in terms of both the construction and operation of the facilities.
- The net effects on **U.S. balance of trade** are very positive as net imports of natural gas, oil, manufactured goods and petrochemicals are reduced.
- **Greater foreign investment** in the U.S. upstream and midstream sectors.
- The initial GDP and job effects on the economy of increased U.S. production of energy and goods (also known as direct and indirect activity) produce income that then gets spent leading to further economic output. This "induced activity" is part of the **GDP multiplier effect**. The extent of the multiplier effects will depend on several factors including how much of the additional income is spent on imports and how much "slack" there is in the economy.

5.2.1 GDP and Employment Impacts

GDP and employment impacts from the incremental natural gas and oil are substantial, with somewhere between $167 billion to $245 billion in additional GDP in 2017 and 835,000-1,600,000 jobs (including direct, indirect, and multiplier effects). The largest share of job growth is expected in the "services and all other" category, followed by wholesale and retail trade; manufacturing, oil, gas, coal, and other mining; transportation; construction; and agriculture and forestry. (See Appendix D for a list of NAICS[158] codes included in each sector category). Exhibit 5-6 shows the impact nationally on GDP and employment historically and through 2017.

Exhibit 5-6 Changes in GDP and Employment Impacts





Source: ICF estimates

The effect of a shift in the supply curve on GDP, which, like producers' revenue, can be positive or negative, can be found with the following equation:

$$\Delta GDP = [(P_2 \times Q_2) \times (1\text{-Imports})] - [(P_1 \times Q_1) \times (1\text{-Imports})]$$

Where:

ΔGDP = change in GDP contribution (i.e., change in direct and indirect value added)

Q_1 = original volume of production

Q_2 = new volume of production

P_1 = original selling price

P_2 = new selling price

Imports = ratio of imports to total GDP[159]

158. North American Industry Classification System (NAICS) codes are used to classify industries in order to categorize and analyze statistical data on the U.S. business economy.
159. Estimated at 16 percent of GDP for the U.S. economy

This relationship is used in this report to estimate the primary energy market GDP effects from the production and sale of gas and oil after the supply curve has shifted due to technological advances. As described below, a similar method is used to investigate the change in GDP effects from industries that use natural gas.

The employment and GDP impacts start with natural gas and oil production. The additional production of 1.7 billion BOE of gas, oil, and NGLs in 2017, will add $105 billion in GDP and over 330,000 direct and indirect jobs. The extra natural gas will reduce gas prices by $1.50/MMBtu that year and lead to an increase in manufacturing activity.

The lower prices to the manufacturing sector result in an increase in output and a net increase of $24 billion to this sector and upstream industries (excluding the natural gas sector which is already accounted for), with nearly 70,000 jobs required for the incremental production of industrial goods. This manufacturing includes output for 2017 from 1.5 quads of natural gas and 212 million barrels of NGLs used as feedstocks for GTLs (gas-to-liquids), LNG, ammonia, methanol, and olefins, all of which either are exported or displace imports.

The coal industry will see a reduction of $7 billion in GDP in 2017 and a reduction of 42,300 jobs due to reductions of 2.1 quads of coal use in the power generation sector.[160] Electricity production will have seen GDP additions of nearly $7 billion due to higher demand spurred by reduced electricity prices, though electricity production will see a net decline of 15,800 jobs that year due to the contraction in coal-fired generation (as coal-fired plants require more employees than do gas-fired plants).

Although the U.S. economy overall is expected to see significant GDP gains and employment additions, the impact of lower gas prices will mean reduced producer and royalty revenues from production of conventional and high-cost unconventional natural gas, or a contraction in GDP of $30 billion due to the sustained low gas prices expected through 2017, resulting in job losses of 232,000. However, this upstream contraction in GDP and employment is offset by the $102 billion in GDP and 330,000 employment additions associated with increased production.

In terms of additional consumer spending resulting from lower energy prices, it is assumed that 16 percent of the $34 billion increase in non-energy consumption will be for imported products, thus, increasing domestic consumer spending by $29 billion in 2017. The net impact equates to a $29 billion increase in GDP and nearly 340,400 job additions.

All of the above total to $129 billion in additional GDP with nearly 450,000 additional jobs in 2017, to which we add the multiplier effect for the rest of the economy. We use a range of 1.3 to 1.9 for the multiplier effect and apply these multipliers to the $129 billion to get the range of multiplier effect, or induced, GDP impacts of $39 billion to $116 billion. These multiplier ranges are based on the spread between well-known studies, as well as our own experience in quantifying the economic impacts of the oil and gas industry.[161] Furthermore, the multiplier effect change in GDP is divided by $100,000 to get the multiplier effect change in employment of 386,000-1,160,000.[162] Total impacts (including direct, indirect, and multiplier effect impacts) for 2017 include a range of $167 billion to $245 billion in GDP additions and 835,000 to 1,600,000 jobs. These results are summarized in Exhibit 5-6.

See Appendix C for a detailed explanation of selected other economic impact studies.

160. It is possible that some of these jobs could be regained if the coal not used domestically were to be exported.
161. See Appendix A for a detailed explanation of the multiplier methodology.
162. This $100,000 multiplier effect is calculated as the induced GDP/induced job from the IMPLAN model. This figure is adjusted to exclude imports (estimated at 16%) to arrive at $100,000. These IMPLAN findings were obtained in previous ICF studies, including the Dominion Cove Point LNG export application to the U.S. Department of Energy in late 2011.

Exhibit 5-7 Changes in GDP and Employment Impacts
(attributable to upstream technological advances since 2007)

Economic Impacts	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Change in GDP Impacts (billion 2010 dollars)										
Additional Production of Gas, Oil and NGLs	5.7	5.9	9.5	16.5	28.5	42.6	53.2	66.2	83.1	101.9
Additional Production of Industrial Goods	0.3	0.5	0.8	1.4	1.9	2.6	4.4	8.0	15.8	24.0
Production of Coal	(0.0)	(1.3)	(1.7)	(2.7)	(3.9)	(4.0)	(5.0)	(5.9)	(6.6)	(7.3)
Production of Electricity	0.3	0.7	1.2	2.0	2.6	3.1	3.8	4.6	5.5	6.6
Reduced Cost/Revenues from Production of Base Case Gas, Oil, and NGLs	(2.7)	(4.4)	(6.6)	(9.4)	(12.4)	(14.9)	(18.2)	(22.1)	(26.2)	(30.4)
Additional Consumer Spending from Lower Energy Prices	2.8	4.4	6.6	10.2	12.8	16.1	20.4	24.7	29.2	34.0
(A) All Direct and Indirect Effects	**6.3**	**5.9**	**9.8**	**18.0**	**29.4**	**45.5**	**58.6**	**75.6**	**100.8**	**128.8**
(B) Multiplier Effect (m=1.3)	**1.9**	**1.8**	**2.9**	**5.4**	**8.8**	**13.7**	**17.6**	**22.7**	**30.2**	**38.6**
(C) Multiplier Effect (m=1.9)	**5.7**	**5.3**	**8.8**	**16.2**	**26.5**	**41.0**	**52.8**	**68.0**	**90.7**	**115.9**
All Direct, Indirect and Multiplier Effects (m=1.3) = A + B	**8.2**	**7.6**	**12.7**	**23.4**	**38.2**	**59.2**	**76.2**	**98.2**	**131.0**	**167.4**
All Direct, Indirect and Multiplier Effects (m=1.9) = A + C	**12.0**	**11.1**	**18.5**	**34.3**	**55.9**	**86.5**	**111.4**	**143.6**	**191.5**	**244.6**

Exhibit 5-7 Continued Changes in GDP and Employment Impacts (attributable to upstream technological advances since 2007)

Economic Impacts	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Change in Employment Impacts (Jobs) [Figures rounded]										
Additional Production of Gas, Oil and NGLs	18,300	34,000	46,900	73,000	107,400	141,800	170,500	208,800	268,400	330,100
Additional Production of Industrial Goods	3,400	5,800	8,700	17,800	30,200	52,600	80,900	88,000	82,600	68,900
Production of Coal	(100)	(7,900)	(10,800)	(16,000)	(22,700)	(23,600)	(29,100)	(34,700)	(38,900)	(42,300)
Production of Electricity	100	(3,500)	(4,600)	(6,600)	(9,500)	(9,500)	(11,700)	(13,800)	(15,100)	(15,800)
Reduced Cost/Revenues from Production of Base Case Gas, Oil and NGLs	(20,500)	(33,700)	(50,500)	(71,900)	(94,800)	(113,500)	(139,100)	(168,500)	(200,200)	(232,500)
Additional Spending by Consumers Due to Lower Energy Prices	27,600	44,000	65,900	102,500	127,700	161,400	204,200	247,400	291,600	340,400
(D) All Direct and Indirect Effects	**28,800**	**38,700**	**55,600**	**98,800**	**138,300**	**209,200**	**275,700**	**327,200**	**388,400**	**448,700**
(E) Multiplier Effect (m=1.3)	**19,000**	**17,600**	**29,300**	**54,100**	**88,200**	**136,600**	**175,900**	**226,700**	**302,300**	**386,300**
(F) Multiplier Effect (m=1.9)	**57,000**	**52,800**	**87,800**	**162,300**	**264,700**	**409,800**	**527,600**	**680,100**	**907,000**	**1,158,800**
All Direct, Indirect and Multiplier Effects (m=1.3) = D + E	**47,800**	**56,300**	**84,900**	**152,900**	**226,500**	**345,800**	**451,500**	**553,900**	**690,800**	**835,000**
All Direct, Indirect and Multiplier Effects (m=1.9) = D + F	**85,800**	**91,500**	**143,400**	**261,100**	**403,000**	**619,000**	**803,200**	**1,007,300**	**1,295,500**	**1,607,500**

Source: ICF estimates

5.2.1.1 Future Expenditures and Employment by Industry

ICF has forecast the expenditures and impact on the U.S. economy based upon our understanding of the distribution and economics of the resource base, as well as the evolution of the North American gas and energy market. The capital expenditures were used to estimate jobs per sector required. The upstream analysis forecasts the specific location of drilling and related expenditures by play, and the midstream analysis estimates expenditures by area and transport corridor. Forecasts for other categories shown above, including tax revenues, were developed for the current study, based upon the model activity forecasts.

Exhibit 5-8 shows the net change in jobs (direct, indirect, and multiplier effect) in the U.S. resulting from recent upstream technological advancements. The changes in jobs in 2017 ranges from 835,000 to 1.6 million, depending upon the multiplier effect used (i.e., the larger job figure relates to the higher multiplier effect that might be expected in a slack economy). The largest share of job growth is expected in the "services and all other" category, with between 450,000 and 930,000 net annual job increases in 2017; followed by wholesale and retail trade (110,000-255,000 jobs); manufacturing (120,000-210,000 jobs); oil, gas, and other mining [excluding coal mining] (91,000-96,000); transportation (53,000-75,000); construction (33,000-40,000); and agriculture and forestry (13,000-29,000). The net change in coal mining employment (attributable to upstream oil and gas technology gains) would mean a decline of 24,500-26,000, as demand for coal drops with lower gas prices (relative to those seen without the upstream technology improvements). The electricity sector (contained within the aggregated electricity, gas distribution, water, and sewer sector grouping in Exhibit 5-8) would likely see a decrease in the net change in GDP and jobs, despite a net increase in electricity generation, due to the contraction in coal-fired power generation. A coal-fired power plant employs more operations and maintenance workers than that of a gas-fired plant. On a terawatt-hour (TWH) basis, the average coal power plant requires 133 job-years/TWH, while the average combined-cycle gas-fired plant needs 60 job-years/TWH.

Total power generation from natural gas and coal will see a net increase in 2017 of 91 TWH due to an increase in electricity consumption, attributed to lower projected electricity prices. Power generation will experience a net loss in jobs through 2017, given that the coal attrition of 38,800 jobs exceeds job additions associated with additional gas-fired power generation of 23,000 jobs. This equates to 15,800 net job losses, despite a net increase in power generation, though this net loss in power generation jobs is offset by the significant gains elsewhere in the economy.[163]

The net impact of the upstream technology gains on oil, gas, coal, and other mining employment is negative year-on-year from 2008 through 2011 and is forecasted to remain negative through 2012. The decline in net employment (attributable to the upstream technology gains) in the early years is primarily due to a trend of declining net coal mining jobs, while fewer gas wells drilled is a secondary cause for employment attrition between 2008 and 2012, exacerbated by the low gas prices seen in recent years. While absolute coal mining jobs have increased through 2011, according to the U.S. Bureau of Labor Statistics, the ICF model shows that had gas prices stayed high (absent the recent upstream technological improvements), coal mining jobs would have been even higher than current rates, as coal demand would be higher. See Appendix D for a list NAICS[164] codes included in each sector category.

163. 23,000 gas-related job additions minus 38,800 coal-related job losses = 15,800 job losses
164. North American Industry Classification System (NAICS) codes are used to classify industries in order to categorize and analyze statistical data on the U.S. business economy.

Exhibit 5-8 Employment Changes by Sector
(attributable to upstream technological advances since 2007)

Jobs by Sector (m=1.3) [Figures rounded]	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Agriculture and Forestry	700	800	1,300	2,300	3,300	4,900	6,400	8,000	10,200	12,600
Oil, Gas, & Other Mining (excl. coal)	4,600	8,600	11,600	18,600	28,100	38,200	46,000	56,400	73,400	91,000
Coal Mining	(43)	(4,600)	(6,400)	(9,400)	(13,400)	(13,800)	(17,000)	(20,200)	(22,600)	(24,500)
Electricity, Gas Distribution, Water, Sewers	400	(2,700)	(3,500)	(4,900)	(7,100)	(6,400)	(7,800)	(9,100)	(9,400)	(9,100)
Construction	1,700	2,800	4,000	7,200	11,500	18,000	25,000	28,700	31,500	32,900
Manufacturing	6,400	9,100	13,500	24,000	36,000	54,200	72,100	86,600	103,500	120,000
Wholesale and retail trade	6,100	7,300	11,400	20,500	29,300	43,300	56,100	70,400	89,400	110,600
Transportation	3,100	4,000	5,600	9,700	14,700	21,800	27,200	33,400	43,200	53,400
Services & All Other	24,700	31,000	47,300	84,900	124,000	185,600	243,500	299,700	371,500	448,000
Total	**47,800**	**56,300**	**84,900**	**152,900**	**226,500**	**345,800**	**451,500**	**553,900**	**690,800**	**835,000**
Jobs by Sector (m=1.9) [Figures rounded]	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Agriculture and forestry	1,500	1,600	2,500	4,600	7,100	10,700	13,900	17,700	23,100	29,100
Oil, Gas, & Other Mining (excl. coal)	4,800	9,000	12,300	19,700	29,800	40,400	48,700	59,900	77,700	96,300
Coal Mining	(46)	(4,900)	(6,800)	(10,000)	(14,200)	(14,600)	(18,000)	(21,500)	(24,000)	(26,000)
Electricity, Gas Distribution, Water, Sewers	500	(2,600)	(3,300)	(4,500)	(6,400)	(5,300)	(6,400)	(7,300)	(7,000)	(6,100)
Construction	2,000	3,100	4,500	8,200	13,000	20,300	28,100	32,600	36,700	39,600
Manufacturing	10,900	13,200	20,300	36,600	56,700	86,200	113,200	139,600	174,300	210,400
Wholesale and retail trade	13,200	13,900	22,300	40,700	62,200	94,300	121,800	155,000	202,300	254,900
Transportation	4,100	5,000	7,300	12,700	19,600	29,400	37,000	46,000	60,000	74,900
Services & All Other	48,700	53,100	84,100	153,000	235,100	357,600	465,000	585,200	752,300	934,500
Total	**85,800**	**91,500**	**143,400**	**261,100**	**403,000**	**619,000**	**803,200**	**1,007,300**	**1,295,500**	**1,607,500**

5.2.2 Allocation of Impacts among States

ICF's economic impact estimates presented in this report were calculated first at the national level and then allocated among the states using various allocation matrices based on 16 factors, including historical and forecasted oil and gas production, energy consumption, and economic activity by sector. Estimates of which states will experience growth in gas and oil production due to technology advances are based on ICF resource base assessments and production analyses. State-level data such as historical energy production and consumption, coal mining employment allocation, and personal income data came from external sources listed in Appendix A, along with a more detailed explanation of the state allocation methodology.

Overall, all states see an increase in GDP from the boost to consumer surplus through lower gas and electricity prices. Some states also see an increase in manufacturing. Besides the states directly involved in resource production, the most direct impact is felt in states where the oil and gas industry sources its inputs (e.g., Ohio, Indiana, South Carolina, Wisconsin).

States with coal mining activities or those dependent on coal-fired power plants may see a net incremental drop in GDP and employment (relative to that seen without the recent upstream technology improvements), as coal is increasingly replaced with cleaner burning natural gas plants, which require fewer power plant employees. In addition, conventional oil and gas producers (such as in Alaska) will be adversely affected by the technological advances in unconventional production, as gas prices decline with the increased production. Similarly, lower gas prices translate to lower (state) severance taxes and royalties to mineral rights owners, both private and governmental.

As a vote of confidence in the longevity of the technology-driven gas supply growth, Orascom is planning to build the first new nitrogen fertilizer factory in the U.S. in over a decade –a $1.3 billion ammonia plant in Iowa that is expected to create 165 direct jobs and provide farmers in the Midwest with a local source of fertilizer.

Many states providing the services and equipment (e.g., sand, steel) also see strong impacts. All states see an increase in GDP from the boost to consumer surplus attributed to lower natural gas and electricity prices. As discussed in Section 3.3.1, states where proppant sand (sand used to prop open fissures created through the hydraulic fracturing process) is mined have seen activity increase along with demand for sand. Arkansas, Missouri, and a number of other states have seen sand mines open in the past few years, yet the clear leader is Wisconsin, with 16 operational mines and another 25 on the drawing board. Though Wisconsin is not expected to see any oil and gas drilling activity, the knock-on effects from oil and gas activity will be felt there strongly. The growth in natural gas and oil production brought about by new technology is estimated to generate additional growth to Wisconsin's GDP of 1.9 percent in 2017, while growing employment in that state by an additional 1.0 percent in that same year, according to ICF estimates.

Wisconsin is experiencing what could be dubbed a "sand rush." With 16 mines in operation and another 25 in the permitting process, the state has become the preferred source for hard, high-quality white sand used as a proppant in hydraulic fracturing operations. Garnering up to $200/ton, production of white proppant sand in Wisconsin is helping to spread natural-gas driven economic activity to a state not endowed with the resource base of such states as Texas or North Dakota.

Another state benefiting from economic activity generated directly and indirectly by advances in natural gas and oil production is Georgia. The state is now home to two ceramic proppant factories, with plans for more. While no significant oil and gas drilling activity is expected there, a combination of oil-and-gas-associated manufacturing, along with a boost from cheaper natural gas used in newly-built power plants, and a host of other impacts is expected in 2017 to drive growth in the state's economy by up to an additional 1.2 percent, and increase employment by 0.7 percent above the non-technology baseline.

Another input vital to the oil and gas industry is steel, which is used for everything from rig construction to the piping used in drilling and transport of oil and gas throughout the country. As described in detail in Section 3.3.3, the oil and gas industry is expected to consume over 66 million tons of steel for piping alone between 2008 and 2017. A big winner in this industry will be Ohio, which is seeing a renaissance in steel production. The state has already seen the opening of a new tubular steel plant in Lorain, where U.S. Steel employs 788 workers; another plant, Vallourec's $550 million Youngstown tubular steel mill, is expected to employ 350 workers when at full capacity. Along with the economic impacts associated with oil and gas production from the Utica shale basin, and the growth in manufacturing activity both associated with the oil and gas industry and benefiting from the cheaper energy it provides, Ohio's economy is expected to grow by up to an additional 3.6 percent in 2017. Employment in Ohio will increase by up to an additional 1.6 percent that year above the non-technology baseline.

In addition to Texas, Louisiana, and Mississippi, other states with oil-and-gas-related manufacturing industries will see significant additional growth brought about by recent advances in drilling and completion technologies. Among these are the Carolinas. Both states have seen recent growth in manufacturing, with the likes of BMW, Daimler, and Michelin all expecting to expand in-state manufacturing facilities. More directly related to the recent growth in natural gas and oil production are announcements by Siemens and GE to grow natural gas turbine production. While South Carolina boasts GE's giant Greenville facility, which employs over 3,000 in the manufacture of natural gas and steam turbines used in nearly half of all new combined-cycle natural gas power plants in the world, North Carolina is getting a boost from Siemens.[165] The German company, which competes with GE for the gas-fired turbine market, already employs nearly 1,500 people near Charlotte. With the recent build-out in combined-cycle power plants in the U.S., Siemens is planning to expand the facility again. All the additional manufacturing activity, along with a variety of other ancillary impacts brought about by lower natural gas prices and the greater availability of feedstocks, are expected to spur growth in South Carolina by up to an additional 1.9 percent in 2017 and its employment by up to an additional 1.0 percent. While not expected to grow as quickly as its southern neighbor, North Carolina is nevertheless expected to benefit from the technology-led growth in natural gas and oil production, estimated at an additional 1.1 percent of GDP growth in 2017, and an additional 0.7 percent in employment growth for that year.

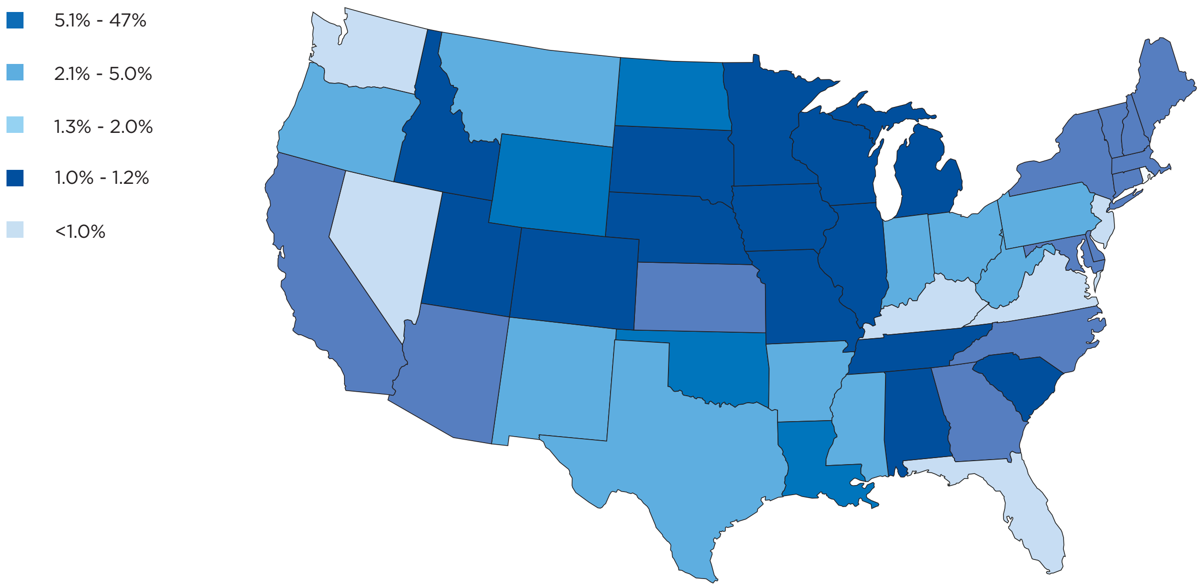
South Carolina boasts the world's largest gas turbine manufacturing facility – GE's Greenville plant, which employs over 3,000 people making a variety of gas and steam turbines used in the most modern natural-gas fired power plants.

Also, North Carolina has seen the grand opening of Siemens' state-of-the-art gas turbine manufacturing facility in 2011, which currently employs 1,500. In anticipation of a build-out in gas-fired power generation capacity in the US and around the world, Siemens is already planning to expand the plant.

165. Weiss, Richard. "Siemens Pumps $1.3 Billion Into Gas Turbines To Fend Off GE." Bloomberg, Jan. 19, 2012. Available at: http://www.bloomberg.com/news/2012-01-19/siemens-to-pump-1-3-billion-into-gas-turbines-to-fend-off-ge.html

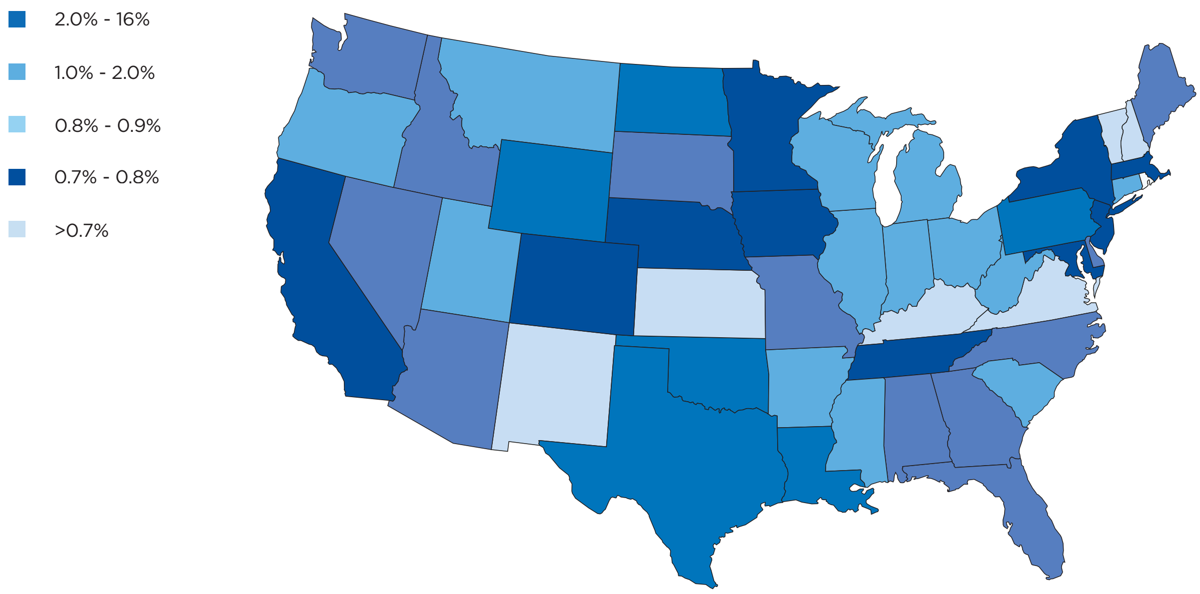
Exhibit 5-9 illustrates the GDP growth impact of recent upstream technology gains by state, while Exhibit 5-10 shows the associated employment growth. Appendix B includes exhibits that show the change in GDP, employment, and taxes from 2008 through 2017 by state and multiplier effect used. Note: All exhibits in this section are based on ICF estimates.

Exhibit 5-9 U.S. Map of GDP Change in 2017 (% of 2009 state income) (attributable to upstream technological advances since 2007)



Sources: ICF estimates based on 2009 state income from the Tax Policy Center for change in GDP impact on state income available at http://www.taxpolicycenter.org/taxfacts/displayafact.cfm?Docid=510, and 2010 state employment (employed population) from the U.S. Bureau of Labor Statistics for employment impact on state employment available at http://www.bls.gov/news.release/srgune.t01.htm.

Exhibit 5-10 U.S. Map of Employment Change in 2017 (% of 2010 state employment) (attributable to upstream technological advances since 2007)



Sources: ICF estimates based on 2009 state income from the Tax Policy Center for change in GDP impact on state income available at http://www.taxpolicycenter.org/taxfacts/displayafact.cfm?Docid=510, and 2010 state employment (employed population) from the U.S. Bureau of Labor Statistics for employment impact on state employment available at http://www.bls.gov/news.release/srgune.t01.htm.

5.2.3 Consumer Savings from Reduced Natural Gas Prices

Consumers stand to benefit considerably from U.S. unconventional oil and gas production, through a combination of:

- **Lower gas prices** (relative to both historical rates and prices seen in other regions such as Europe and East Asia). This study assumes a wholesale gas price of $3.60/MMBtu[166] for 2012 (from the 2012 AEO), down from $8.86 seen in 2008, while countries such as Japan are paying LNG import prices of up to $16/MMBtu.[167]
- **Lower electricity costs** (through lower fuel costs for gas-fired power plants), as natural gas made up 24 percent of the electricity mix in 2010, and is expected to rise to 27 percent by 2035, indicating that benefits to electricity consumers are expected to rise along with natural gas' share of the electricity generation mix.[168]
- **Lower U.S. manufacturing prices**, particularly for industries highly reliant on natural gas as a feedstock, such as petrochemicals and fertilizers.

See Appendix A for additional explanation of the consumer impacts methodology. Exhibit 5-11 below highlights the consumer gains in the form of the direct savings (to residential and commercial users of natural gas) and via secondary uses (e.g., electricity, industrial products).

166. The August 7, 2012 release of EIA's Short-Term Energy Outlook forecasts an average natural gas wholesale price of $2.67/MMBtu for 2012, peaking in December 2012 at $3.27/MMBtu. This lower-than-modeled price will translate to consumer savings above those estimated in the study, with additional benefits for consumers and gas-using industries.
167. U.S. Energy Information Administration (EIA). "Japan." EIA, 4 June 2012: Washington, D.C. Available at: http://205.254.135.7/countries/cab.cfm?fips=JA
168. U.S. Energy Information Administration (EIA). "Today in Energy: Natural gas and renewable shares of electricity generation to grow, coal still large." EIA, 10 February 2012: Washington, D.C. Available at: http://205.254.135.7/todayinenergy/detail.cfm?id=4950

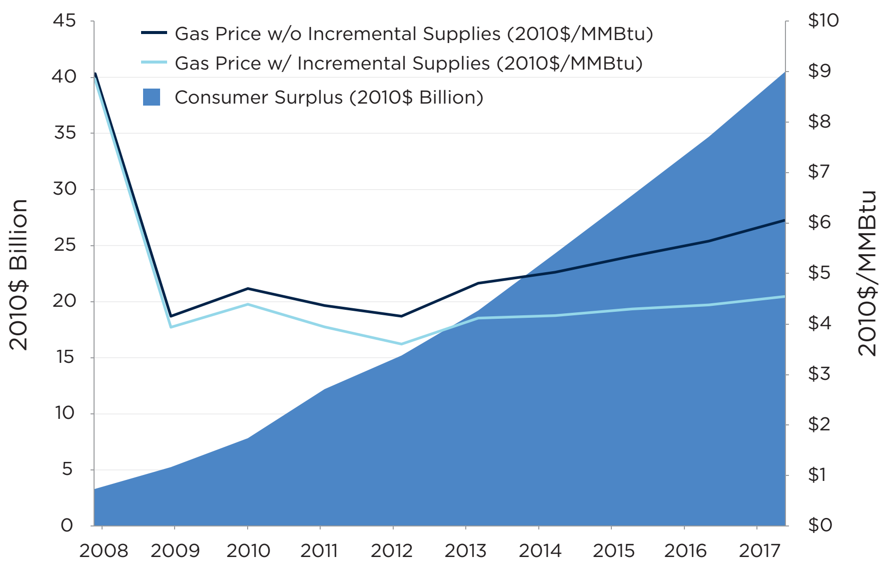
Exhibit 5-11 Changes to Consumer Surplus
(attributable to upstream technological advances since 2007)

Year	Consumer Surplus (2010$ Billion)
2008	3.3
2009	5.2
2010	7.8
2011	12.2
2012	15.2
2013	19.2
2014	24.3
2015	29.5
2016	34.7
2017	40.5

Source: ICF estimates based on the EIA's AEO for 2008 and 2011

Exhibit 5-12 illustrates the consumer surplus, which is expected to reach nearly $41 billion in 2017. Natural gas prices with and without the new shale gas supplies are also shown. The red line in the exhibit represents the prices that were expected in 2008 (absent the significant unconventional production seen since then), while the dashed orange line indicates the current forecasts.

Exhibit 5-12 Change in Consumer Surplus and U.S. Wholesale Gas Prices
(attributable to upstream technological advances since 2007)



Source: ICF estimates

5.2.4 Impacts on U.S. Global Competitiveness and Balance of Trade

With the benefit of ample O&G supplies and lower input costs, the U.S. stands to benefit considerably from the international trade in energy and associated manufacturing output.[169] ICF calculated the change in the balance of trade as the change (decrease) in net import of oil and gas, processed/refined hydrocarbons, and industrial products, estimating that by 2017, the changes in the balance of trade will exceed $120 billion, or a cumulative increase to the balance of trade totaling nearly $500 billion between 2008 and 2017.

The balance of trade calculation included the change in net import (reductions) for dry gas, NGLs, condensate, crude oil, GTLs (e.g., diesel, waxes), LNG, methanol, ammonia (anhydrous), ethylene-to-polyethylene, and industrial products. Exhibit 5-13 shows the balance of trade changes for each affected sector.

As a proportion of the additional industrial goods production will be exported, Exhibit 5-14 shows the change in both the balance of trade and industrial goods production attributable to the recent upstream technological advances.

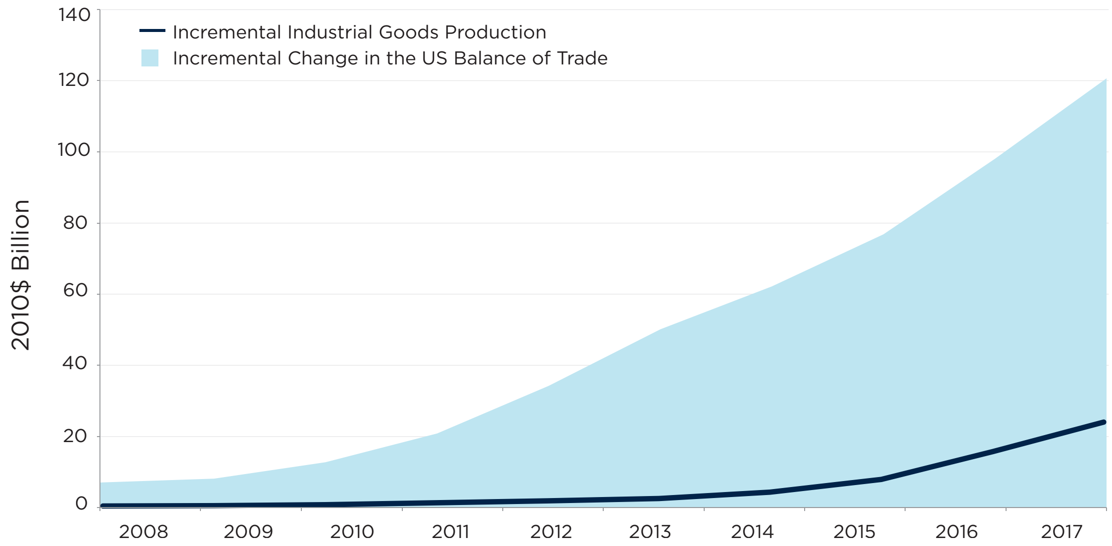
Exhibit 5-13 Changes in Balance of Trade
(attributable to upstream technological advances since 2007)

Type	Change in Balance of Trade (2010$ Billion)									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dry Gas	4.00	3.33	5.31	6.57	8.10	11.70	13.21	14.58	16.60	18.54
NGLs	0.87	0.86	1.60	1.38	3.16	4.12	5.38	7.98	11.92	16.36
Condensate	0.34	0.34	0.63	1.04	1.42	1.97	2.66	3.71	5.33	7.15
Crude	0.90	2.06	2.95	8.64	17.26	26.84	33.03	38.42	43.57	48.80
GTL (diesel, waxes, etc.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85
Liquefied Natural Gas (LNG)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.81	7.72	12.24
Methanol	0.00	0.00	0.00	0.06	0.14	0.23	0.34	0.47	0.59	0.72
Ammonia (Anhydrous)	0.00	0.00	0.00	0.10	0.19	0.29	0.39	0.49	0.58	0.68
Ethylene to Polyethylene	0.00	0.00	0.00	0.00	0.00	0.00	0.97	1.82	2.66	3.42
Industrial	0.95	1.56	2.26	3.05	3.97	5.01	6.21	7.57	9.14	10.93
Total	**7.06**	**8.15**	**12.75**	**20.85**	**34.24**	**50.16**	**62.19**	**76.84**	**98.11**	**120.69**

Source: ICF estimates

169. UBS. "North American energy independence: reenergized." UBS, June 2012: New York, NY. Available at: http://www.static-ubs.com/us/en/wealth/misc/energy/_jcr_content/par/columncontrol_46e8/col2/textimage_bad1.521527600.file/dGV4dD0vY29udGVudC9kYW0vd-WJzX21hbnVhbF9taWcvV01BL2RvY3VtZW50cy9FbmVyZ3lfZnVsbHJlcG9ydC5wZGY=/Energy_fullreport.pdf

Exhibit 5-14 Changes in Balance of Trade and Industrial Goods Production (attributable to upstream technological advances since 2007)



Source: ICF estimates

5.2.5 Royalty Payments and Taxes

This study evaluates the impact of unconventional gas development on federal, state, and local tax revenues, as well as royalty payments to mineral rights owners (including on government lands). It should be noted that taxes and royalties are "carve-outs" of some parts of GDP. They are not separate additions to GDP. Nevertheless, potential tax revenues are a significant factor in policy development, and other aspects of oil and gas development and royalties paid to individuals can have a widespread impact on state economies.

Production of minerals, including oil and natural gas, generates royalty payments to the mineral rights owners. These payments are based on a share of the value of resource produced. Mineral rights owners, including state and federal governments and private individuals, may earn revenues between one-eighth and one-fifth of the wellhead value of the resource produced. Royalties may be paid to the mineral rights owners as frequently as once a month and are generated for as long as production on the property takes place. Oil and gas leases also usually generate one-time "signing bonuses" that are not dependent on the volumes produced.

In 2011, total wellhead revenues generated by production of natural gas, crude oil, lease condensate and natural gas plant liquids was approximately $323 billion. This generated royalty payments of approximately $54 billion. Advances in drilling technology have enabled producers to develop new resources, such as shale gas, which are more widely distributed than conventional gas. This in turn has broadened the amount of land that can be developed, and therefore the pool of royalty recipients.

Exhibit 5-15 shows the impact on royalty payments stemming from recent advances in upstream technologies. Because those advances have caused natural gas prices to fall below what they would have otherwise been (see Exhibit 5-15, second to last row), the net impact on royalties can be negative if the percentage fall in prices exceeds the percent increase in production. Factoring in all changes to oil and gas production, total royalties have gone up due to recent upstream technology advancements and are expected to be $12 billion higher by 2017, while total federal, state, and local tax receipts nationwide are expected to increase by an incremental $58 billion to $85 billion annually by 2017 through upstream technology gains. See Appendix B for the changes in state and local taxes from 2008-2017 by state.

Exhibit 5-15 Change in Taxes and Royalties
(attributable to upstream technological advances since 2007)

Incremental Taxes and Royalties	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Incremental Taxes (2010$ Billion)										
1.3 Mult. Federal Taxes on Incremental GDP Additions	$1.4	$1.2	$1.9	$3.6	$6.0	$10.5	$14.2	$18.7	$25.0	$32.1
1.9 Mult. Federal Taxes on Incremental GDP Additions	$2.1	$1.7	$2.8	$5.3	$8.8	$15.4	$20.8	$27.3	$36.6	$47.0
1.3 Mult. State/Local Taxes on Incremental GDP Additions	$1.2	$1.2	$2.0	$3.6	$5.8	$9.1	$11.7	$15.1	$20.1	$25.8
1.9 Mult. State/Local Taxes on Incremental GDP Additions	$1.8	$1.7	$2.9	$5.3	$8.5	$13.2	$17.1	$22.0	$29.4	$37.7
1.3 Mult. Total Taxes on Incremental GDP Additions	**$2.7**	**$2.3**	**$3.9**	**$7.2**	**$11.9**	**$19.6**	**$25.9**	**$33.7**	**$45.2**	**$57.9**
1.9 Mult. Total Taxes on Incremental GDP Additions	**$3.9**	**$3.4**	**$5.7**	**$10.5**	**$17.4**	**$28.6**	**$37.9**	**$49.3**	**$66.0**	**$84.6**
Federal Tax Rate on GDP (%)	17.6%	15.1%	15.1%	15.4%	15.8%	17.8%	18.7%	19.0%	19.1%	19.2%
1.3 Mult. Weighted State and Local Rate on GDP (%)	15.1%	15.4%	15.4%	15.3%	15.3%	15.3%	15.3%	15.3%	15.4%	15.4%
1.9 Mult. Weighted State and Local Rate on GDP (%)	15.1%	15.4%	15.4%	15.3%	15.3%	15.3%	15.3%	15.4%	15.4%	15.4%
Incremental Royalties (2010$ Billion)										
Change in Royalties (includes change in federal, state, local, and private royalties)	**$0.51**	**$0.26**	**$0.50**	**$1.42**	**$2.81**	**$4.85**	**$6.15**	**$7.72**	**$9.91**	**$12.39**
Incremental Oil, NGL, and Condensate Wellhead Revenues	$2.2	$3.4	$5.4	$12.7	$23.0	$34.9	$43.7	$53.2	$64.4	$76.5
Incremental Natural Gas Wellhead Revenues	$0.9	($1.8)	($2.4)	($4.2)	($6.2)	($5.8)	($6.9)	($6.9)	($5.1)	($2.3)
Incremental Oil, Natural Gas, NGL, and Condensate Wellhead Revenues	**$3.1**	**$1.6**	**$3.0**	**$8.5**	**$16.8**	**$29.0**	**$36.8**	**$46.2**	**$59.3**	**$74.2**

Source: ICF estimates

Conclusion 6

The growth in unconventional natural gas and tight oil is having a large positive effect on the economy. This development supports hundreds of thousands of direct and indirect jobs, generates capital expenditures of tens of billions of dollars per year, greatly expands state and federal tax receipts, increases royalties to both private mineral rights owners and government bodies, and reduces consumer and industrial energy outlays. The unconventional natural gas revolution also improves the international balance of trade, as growing domestic oil and gas production reduces imports, while lower domestic natural gas and electricity prices (relative to prices seen with our trade partners) provide a cost advantage to U.S. manufacturing industries.

There has also been a resurgence in the chemical industry resulting from low prices for both natural gas and NGLs. Exports of liquefied natural gas are planned, as well as expanded exports of chemicals and products produced with low-priced feedstocks. Furthermore, foreign investment in the oil and gas industry is helping to fund the required capital investments and supports the value of the U.S. dollar.

The economic impact of shale development includes much more than the drilling and completion of horizontal wells. Economic impacts come from oil and gas services, product suppliers, manufacturers, and other industries. Expenditures on these sectors flow through the economy multiplier effects, which are widely distributed regionally and among the states. The study forecasts a net increase in GDP of $167 billion to $245 billion in 2017 and an increase of up to 1.6 million jobs.

For each one billion cubic feet of incremental natural gas production, approximately 13,000 upstream and midstream jobs are created. These are high quality, well-paying jobs in the oil and gas upstream and midstream sectors and service sector. In terms of geographic diversity, the shale gas impact goes far beyond the areas of active drilling, such as Pennsylvania, Texas, Oklahoma, and North Dakota. Even states with no current or expected shale drilling will see tens of thousands of new jobs in construction, manufacturing, transportation, and the operation of new plants.

The growth in gas production has resulted in sharp price reductions for end-users of natural gas and electricity. These consumer savings will flow throughout the economy. The new activity has also caused a renaissance in areas such as pipeline and midstream refining infrastructure, petrochemical production, and steel manufacturing. New industries such as high tech sand proppants have emerged. Liquefied natural gas import facilities are being augmented to provided export capacity LNG.

Federal, state, and local government revenues have also experienced a large positive impact. The direct and indirect result of these revenues will increase GDP by up to $85 billion in 2017. Exhibit 6-1 includes a summary of the main economic impacts associated with the incremental production of natural gas and liquids Technological innovations in U.S. oil and gas production have transformed the industry into an engine of growth for the national economy and economies of many states.

Exhibit 6-1 Summary of Changes in Impacts (2008-2017)
(attributable to upstream technological advances since 2007)

Change in Impacts	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Change in Production (MMBOE)										
Incremental Hydrocarbon Production[170]	92	171	236	367	539	712	856	1,049	1,349	1,659
Change in GDP (2010$ Billion)										
All Direct and Indirect Effects	6.3	5.9	9.8	18.0	29.4	45.5	58.6	75.6	100.8	128.8
All Direct, Indirect and Multiplier Effects (m=1.3)	**8.2**	**7.6**	**12.7**	**23.4**	**38.2**	**59.2**	**76.2**	**98.2**	**131.0**	**167.4**
All Direct, Indirect and Multiplier Effects (m=1.9)	**12.0**	**11.1**	**18.5**	**34.3**	**55.9**	**86.5**	**111.4**	**143.6**	**191.5**	**244.6**
Change in Employment (Jobs) [Figures rounded]										
All Direct and Indirect Effects	28,800	38,700	55,600	98,800	138,300	209,200	275,700	327,200	388,400	448,700
All Direct, Indirect and Multiplier Effects (m=1.3)	**47,800**	**56,300**	**84,900**	**152,900**	**226,500**	**345,800**	**451,500**	**553,900**	**690,800**	**835,000**
All Direct, Indirect and Multiplier Effects (m=1.9)	**85,800**	**91,500**	**143,400**	**261,100**	**403,000**	**619,000**	**803,200**	**1,007,300**	**1,295,500**	**1,607,500**
Changes in Other Economic Measures (2010$ Billion)										
Change in Consumer Surplus	3.3	5.2	7.8	12.2	15.2	19.2	24.3	29.5	34.7	40.5
Change in Balance of Trade	7.1	8.1	12.8	20.8	34.2	50.2	62.2	76.8	98.1	120.7
Change in Royalties (includes federal, state, local, and private royalties)	0.5	0.3	0.5	1.4	2.8	4.9	6.2	7.7	9.9	12.4
Change in Total Taxes (m=1.3)	2.7	2.3	3.9	7.2	11.9	19.6	25.9	33.7	45.2	57.9
Change in Total Taxes (m=1.9)	3.9	3.4	5.7	10.5	17.4	28.6	37.9	49.3	66.0	84.6
Changes in Average Impacts (Average % of U.S. Total)										
Change in GDP (as % of 2010 GDP, m=1.3)	0.06%	0.05%	0.09%	0.16%	0.26%	0.41%	0.53%	0.68%	0.90%	1.15%
Change in GDP (as % of 2010 GDP, m=1.9)	0.08%	0.08%	0.13%	0.24%	0.39%	0.60%	0.77%	0.99%	1.32%	1.69%
Change in Employment (as % of 2010 Employment, m=1.3)	0.03%	0.04%	0.06%	0.11%	0.16%	0.25%	0.32%	0.40%	0.50%	0.60%
Change in Employment (as % of 2010 Employment, m=1.9)	0.06%	0.07%	0.10%	0.19%	0.29%	0.45%	0.58%	0.72%	0.93%	1.16%

Source: ICF estimates.
2010 GDP: $14.5 trillion, U.S. Bureau of Economic Analysis. "Gross Domestic Product (GDP): Current-Dollar and 'Real' GDP." U.S. Department of Commerce Bureau of Economic Analysis, 2012: Washington, D.C. Available at: http://www.bea.gov/national/index.htm#gdp

2010 annual average employment: 139.1 million. U.S. Bureau of Labor Statistics (BLS). "Table 1: Employment status of the civilian non-institutional population 16 years of age and over by region, division, and state, 2010-11 annual averages." BLS, 4 April 2012: Washington, D.C. Available at: http://www.bls.gov/news.release/srgune.t01.htm

* Natural gas plant liquids

170. Includes incremental natural gas, oil, condensate, and natural gas plant liquids production

Appendices 7

A. Economic Impact Study Comparisons

Although an increasing number of studies are available on the economic impact of incremental gas and oil production, there are four well known studies used here for comparison purposes. Exhibit 7-1 highlights key differences between this study and a 2011 Price Waterhouse Coopers (PwC) study for the American Petroleum Institute (API); as well as a 2011 study and 2012 follow-on report from IHS Global Insight for America's Natural Gas Alliance (ANGA).[171, 172, 173]

The scope, conventions, and conclusions vary considerably. For example, the initial IHS study for ANGA concentrated on the U.S. shale gas industry and concluded that the existence of shale gas has resulted in $250 billion in savings to consumers over the past three years.[174] On the other hand, the PwC study for API looked at the entire upstream, midstream, and downstream oil and gas industry, and claims that the U.S. oil and gas industry contributed over $1 trillion (or 6 percent of GDP) to the U.S. economy in 2009, including direct, indirect and induced effects.[175] Each study has a different scope, employs its own conventions, uses distinct parameters, and reports different types of results, thus making comparisons difficult. In sum, the studies often diverge on the following key respects:

- **Fuels** examined such as both oil and natural gas, natural gas only, shale gas only, unconventionals only (i.e., shale gas, coalbed methane, and tight gas). This study includes natural gas, oil, and coal.
- **Sectors** along the industry value chain examined. For example, upstream (drilling, well completion, support industries), midstream (gathering, gas processing, pipeline), downstream (refining, distribution, retailing), and end-users (gas consumers). In some cases, such as in this report, value added and employment effects in energy using sectors are also examined.
- **Time period** such as examining a historical period only versus projections into the future. For example, this study includes both historical data (2008-2011) and projections (2012-2017).
- **Types of impact**s quantified can include direct, indirect, and induced impacts. All four studies compared here and this study include all three impacts.
- **Geographic area** in terms of nationwide versus state-by-state analysis. This study assesses both nationwide and state-by-state impacts.
- **Counterfactual scenarios** used for comparison. Some studies look at only a single actual/projected world, while others (including this one) compare the actual/projected world to a counterfactual world.

171. Price Waterhouse Coopers (PwC). "The Economic Impacts of the Oil and Natural Gas Industry on the U.S. Economy in 2009: Employment, Labor Income, and Value Added." American Petroleum Institute (API), May 2011: Washington, D.C.
172. IHS Global Insight. "The Economic and Employment Contributions of Shale Gas in the United States." America's Natural Gas Alliance (ANGA), December 2011: Washington, D.C.
173. IHS Global Insight. "The Economic and Employment Contributions of Unconventional Gas Development in State Economies." America's Natural Gas Alliance (ANGA), June 2012: Washington, D.C.
174. Assumed to include 2009, 2010, and 2011.
175. Price Waterhouse Coopers (PwC). "The Economic Impacts of the Oil and Natural Gas Industry on the U.S. Economy in 2009: Employment, Labor Income, and Value Added." American Petroleum Institute (API), May 2011: Washington, D.C.

Exhibit 7-1 Economic Impact Study Comparison Matrix

Metric	Economic Impact Study			
	(1) ICF	(2) PwC/API	(3) IHS/ANGA 2011	(4) IHS/ANGA 2012
Study Scope				
Sectors (i.e., oil and gas versus gas only)	Oil, gas, and coal	Oil and gas	Shale gas only	Unconventional gas only (i.e., shale + CBM + tight gas)
Area of Industry Quantified (e.g., upstream, support industries, mid-stream, downstream, end-use)	· Upstream (drilling, well completion, support industries) · Midstream (gathering, gas processing, pipeline) · Downstream (refining, distribution) · End-users (gas consumers) · Value added and employment effects in energy-using sectors (power generation, manufacturing)	· O&G extraction · Drilling · Support activities · NG distribution · Pipeline construction · Refineries · Asphalt paving, etc. · Lubricating oil manufacturing · Gasoline stations · Fuel dealers · Pipeline transportation	· Natural gas drilling · Natural gas extraction · Support services · Construction of facilities/machinery for hydraulic fracturing and completions · Construction of gas pipelines	· Natural gas drilling · Natural gas extraction · Support services · Construction of facilities/ machinery for hydraulic fracturing and completions · Construction of gas pipelines
Time Period	2008-2017	2009	2010-2035	2010-2035
Types of Impacts Quantified	Direct, indirect, induced	Direct, indirect, induced	Direct, indirect, induced	Direct, indirect, induced
Point of Comparison				
Outlook (i.e., historical versus projection)	Projections: incremental oil and gas production through 2017.	Historical: Quantification of 2009 O&G industry on the GDP	Projections: Shale gas impacts through 2035	Projections: Unconventional (NG + Oil impacts through 2035
Geographical Area (i.e., nationwide versus state-by-state)	· Nationwide · State-by-state	· Nationwide: operational and capital investment impacts of upstream · State-level: operational impact of upstream	· Nationwide	· Nationwide · State-by-state
Comparison to Counterfactual Scenario[176]	Counterfactual (current outlook vs. outlook assumed in 2008)	No counterfactuals: quantifies 2009 O&G industry impact on the GDP	No counterfactuals: quantifies shale gas impacts through 2035 (except that consumer price impact of having no shale gas is estimated)	No counterfactuals: unconventional impacts through 2035
Multiplier Methodology	ICF-calculated ranges	IMPLAN modeling	IMPLAN modeling	IMPLAN modeling
Economic Impacts Basis	Area under supply and demand curves	Cost/expenditure basis	Cost/expenditure basis	Cost/expenditure basis

176. Each study takes its own approach in describing the scenario to quantify the economic impacts of the industry. This study takes a "counterfactual" approach, which compares the current industry outlook based on current expectations to that assumed in the past (i.e., assumptions on the market before the shale revolution), and makes assumptions for current market conditions based on those past assumptions (e.g., comparison of the state of the industry with shale to market conditions without shale). The study then compares the difference between the current outlook (i.e., shale revolution) and that using past assumptions that no longer apply (i.e., no shale presence).

Exhibit 7-1 Continued Economic Impact Study Comparison Matrix

Metric	Economic Impact Study			
	(1) ICF	(2) PwC/API	(3) IHS/ANGA 2011	(4) IHS/ANGA 2012
Study Findings				
GDP Contributions	Recent technology results in net increase of $167 to $245 billion in 2017.	The oil and gas industry in its entirety contributes $1.1 trillion (6.0% U.S. total) including direct, indirect and induced effects.	Shale gas impacts direct, indirect and induced value added (contribute to GDP) is: • $76b in 2010 • $118b by 2015 • $231b in 2035	Unconventional gas impacts direct, indirect and induced value added (contribute to GDP) is: • $133.4b in 2010 • $196.5b in 2015 • $331.7b in 2035
Employment Impact	Recent technology results in net increase of 835,000 to 1.6 million jobs in 2017.	• The oil and gas industry in its entirety supports 9.2 million jobs (5.3% U.S. total) including direct, indirect and induced effects. • Labor income: $534b (7.7% U.S. total)	Shale gas supports direct, indirect and induced jobs in the amount of: • 600,000 in 2010 • 870,000 in 2015 • 1.6 million by 2035	Unconventional gas supports direct, indirect and induced jobs in the amount of: • 1 million in 2010 • 1.5 million in 2015 • 2.4 million in 2035
Tax Impact (federal, state, local taxes and royalties)	• New technology results in total tax increases on incremental GDP of $58 to $85 billion in 2017. • Royalty increase of $12 billion in 2017.	N/A	The development of shale gas in the U.S. has led or will lead to a gross tax impact of: • $18.6b in 2010 • $57b in 2035 • $933b cumulative for 2010-2035	The development of shale gas in the U.S. has led or will lead to a gross tax impact of: • $33.8b in 2010 • $49.3b in 2015 • $85.1b in 2035 • $1.5 trillion cumulative for 2010-2035
Consumer Savings Impacts	Consumers to experience net benefit of $41 billion in 2017.	N/A	The development of shale gas in the U.S. has led or will lead to: • $926 annually per household savings in lower gas prices for 2012-2015 • $2,000 per household in annual savings in lower gas prices for 2035	N/A
Direct and Indirect Job-years per 1 MMBOE of gas and liquids production	200 jobs/MMBOE incremental production including liquids	N/A	215 jobs/MMBOE including estimated liquids	N/A
Multiplier Effect for Value Added or GDP. Defined as (Direct + Indirect + Induced) / (Direct and Indirect)	1.3 to 1.9	1.41	1.46	N/A
Multiplier Effect for jobs. Defined as (Direct + Indirect + Induced) / (Direct and Indirect).	1.64 to 2.93	1.81	1.82	1.80

Study Sources:
1. This study.
2. Price Waterhouse Coopers (PwC). "The Economic Impacts of the Oil and Natural Gas Industry on the U.S. Economy in 2009: Employment, Labor Income, and Value Added." American Petroleum Institute (API), May 2011: Washington, D.C.
3. IHS Global Insight. "The Economic and Employment Contributions of Shale Gas in the United States." America's Natural Gas Alliance (ANGA), December 2011: Washington, D.C.
4. IHS Global Insight. "The Economic and Employment Contributions of Unconventional Gas Development in State Economies." America's Natural Gas Alliance (ANGA), June 2012: Washington, D.C.

There are also differences in term of the methodologies used. Estimates of economic effects are often a result of IMPLAN modeling (an input-output model). The input for the model often includes an estimate for the annual capital expenditures and annual operating and maintenance expenditures in upstream production. The expenditures are input into IMPLAN, which then generates direct, indirect, and induced economic impacts such as value added, labor income and jobs. To estimate the economic impacts of upstream expenditures, this study also uses the IMPLAN model to estimate direct and indirect impacts. However, for calculating the multiplier effect (i.e., induced) impacts, this study assumed a range of multipliers from 1.3 to 1.9, which were used to calculate a range of economic impacts. The lower multiplier, 1.3, indicates that every $1 generated by direct and indirect impacts "induces" an additional $0.30 of economic activity throughout the aggregate economy through the consumer spending by direct and indirect workers and business owners. Similarly, the higher multiplier, 1.9, indicates that every $1 in direct and indirect impacts generates an additional $0.90 of induced economic activity.

This study also differs from the other studies examined here in that it assesses the economic impacts of the entire change in producer revenues, including both the portion below the supply curve made up of producer costs and the portion above the supply curve made up of producer surplus. (See Exhibit 7-2). As explained above, the portion below the supply curve is processed through IMPLAN in a manner similar to other studies to produce direct, indirect, and induced effects. The portion above the supply curve is treated as a change in household and government income (royalty income, producers' profits, suppliers' profits, taxes). These impacts are calculated separately for (a) conventional and high cost natural gas whose production is reduced due to lower natural gas prices caused by new technologies and (b) new resources made economic by new technologies. This distinction is import because the states that experience an increase in oil and gas production due to new technologies are not always the same states that would have produced the higher-cost natural gas in the counterfactual world with higher natural gas prices.

Exhibit 7-2 Impact of Upstream Technologies on Producer Revenues and Expenditures

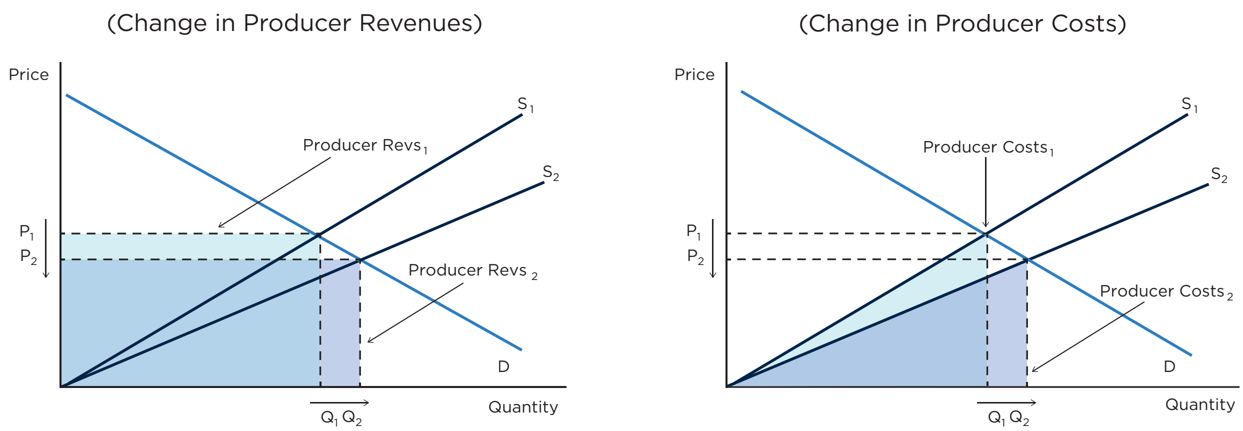


Exhibit 7-13 summarizes some of the key features and finding of related studies. Economic impacts that are quantified include additions to GDP (value added), labor income, taxes (e.g., federal, state, local, royalty payments), and consumer impacts (e.g., lower gas prices). While a large number of studies quantify the *absolute* economic impacts of the oil and gas industry (or a specific segment of the industry, such as shale gas), this study attempts to quantify the change in economic impacts (i.e., the impacts created by the oil and gas industry, rather than a shift from other industries due to the favorable economics). For example, the recent upstream technology advancement has *shifted* investment that would otherwise go to other industries, while lower gas prices associated with the incremental gas and oil supplies has meant consumers spend less on gas costs, essentially *creating* opportunities for consumer spending elsewhere, which is a benefit of the incremental gas and oil supplies.

Because of the different scopes of analysis, very little among the results of the studies can be directly compared. However, it can be noted that there is a reasonable amount of similarity among some important results:

- This study concludes that there are approximately 200 new direct and indirect upstream and midstream jobs created for each 1 MMBOE of incremental natural gas, condensate, crude oil, and NGL produced. The similar value calculated from the ANGA/IHS 2011 study is 215 jobs.
- The range of total GDP (direct, indirect, and induced) resulting in per unit of direct and indirect GDP in this study is 1.3 to 1.9. This compares to a 1.41 and 1.46 calculated from the PwC/API and IHS/ANGA 2011 studies.
- The range of total jobs (direct, indirect, and induced) resulting per direct and indirect job in this study is 1.64 to 2.93. This compares to a 1.81, 1.82, and 1.80 calculated, respectively, from the PwC/API, IHS/ANGA 2011, and IHS/ANGA 2012 studies.

B. Economic Impacts by State

Exhibit 7-3 shows the changes in GDP by state in 2017 as a proportion of state income[177] and the changes in employment by state in 2017 as a proportion of state employment[178]. Exhibit 7-4 through Exhibit 7-5 show the changes GDP, employment, and state and local taxes from 2008 through 2017 by state.

Exhibit 7-3 Changes in GDP and Employment in 2017 (attributable to upstream technological advances since 2007)

State	2017 GDP Change (2010$ bil)		2017 Jobs Change (No.)		Background Statistics					
	Multiplier Effect = 1.3	Multiplier Effect = 1.9	Multiplier Effect = 1.3 [Figures rounded]	Multiplier Effect = 1.9 [Figures rounded]	BLS Employed population (1,000)	As % of 2010 Employment (Multiplier Effect = 1.3)	As % of 2010 Employment (Multiplier Effect = 1.9)	State personal income 2009 (2010$ mm)	As % of 2009 PI (Multiplier Effect = 1.3)	As % of 2009 PI (Multiplier Effect = 1.9)
AL	$1.4	$2.2	8,000	15,700	1,972	0.41%	0.80%	157,324	0.92%	1.41%
AK	($0.1)	($0.0)	100	500	335	0.02%	0.15%	30,182	-0.20%	-0.06%
AZ	$1.7	$2.6	10,900	20,500	2,775	0.39%	0.74%	219,027	0.75%	1.19%
AR	$2.1	$3.0	11,900	20,400	1,249	0.95%	1.63%	93,374	2.25%	3.16%
CA	$11.0	$17.6	74,500	140,700	16,052	0.46%	0.88%	1,566,999	0.70%	1.13%
CO	$2.3	$3.4	8,700	20,100	2,481	0.35%	0.81%	210,513	1.08%	1.62%
CT	$1.4	$2.3	9,200	17,600	1,738	0.53%	1.02%	194,547	0.74%	1.17%
DE	$0.2	$0.4	1,700	3,100	402	0.42%	0.77%	35,048	0.64%	1.05%
DC	$0.2	$0.3	1,500	2,800	309	0.47%	0.90%	41,282	0.37%	0.69%
FL	$4.1	$6.8	32,100	59,400	8,102	0.40%	0.73%	722,328	0.56%	0.94%
GA	$2.5	$4.0	16,800	31,500	4,214	0.40%	0.75%	335,466	0.75%	1.19%
HI	$0.2	$0.3	1,500	3,100	605	0.24%	0.51%	54,594	0.29%	0.58%
ID	$0.4	$0.6	2,700	4,900	697	0.39%	0.71%	49,245	0.80%	1.25%
IL	$5.1	$7.8	29,400	56,400	5,911	0.50%	0.95%	540,380	0.95%	1.45%
IN	$4.6	$6.5	19,600	38,500	2,856	0.69%	1.35%	218,527	2.10%	2.97%
IA	$1.2	$1.8	7,400	13,300	1,565	0.47%	0.85%	113,236	1.02%	1.55%
KS	$0.8	$1.2	4,500	9,200	1,397	0.32%	0.66%	110,418	0.71%	1.13%
KY	$0.7	$1.3	2,400	7,500	1,849	0.13%	0.41%	139,166	0.53%	0.90%
LA	$8.9	$12.1	40,700	72,200	1,915	2.13%	3.77%	169,046	5.27%	7.13%
ME	$0.4	$0.6	2,600	4,700	643	0.40%	0.73%	48,180	0.76%	1.21%
MD	$1.9	$3.0	11,900	23,400	2,818	0.42%	0.83%	274,980	0.69%	1.11%
MA	$2.2	$3.5	15,200	28,700	3,181	0.48%	0.90%	327,395	0.67%	1.08%
MI	$4.0	$6.0	22,000	41,500	4,147	0.53%	1.00%	342,114	1.17%	1.74%
MN	$1.9	$3.0	12,500	23,000	2,742	0.45%	0.84%	220,413	0.87%	1.35%
MS	$1.5	$2.2	7,800	14,500	1,179	0.67%	1.23%	89,743	1.70%	2.43%

177. Based on 2009 state income
178. Based on 2010 employment

Exhibit 7-3 Continued Changes in GDP and Employment in 2017 (attributable to upstream technological advances since 2007)

State	2017 GDP Change (2010$ bil)		2017 Jobs Change (No.)		Background Statistics					
	Multiplier Effect = 1.3	Multiplier Effect = 1.9	Multiplier Effect = 1.3 [Figures rounded]	Multiplier Effect = 1.9 [Figures rounded]	BLS Employed population (1,000)	As % of 2010 Employment (Multiplier Effect = 1.3)	As % of 2010 Employment (Multiplier Effect = 1.9)	State personal income 2009 (2010$ mm)	As % of 2009 PI (Multiplier Effect = 1.3)	As % of 2009 PI (Multiplier Effect = 1.9)
MO	$1.8	$2.8	10,800	20,700	2,767	0.39%	0.75%	216,637	0.81%	1.27%
MT	$0.8	$1.1	2,700	5,900	466	0.58%	1.26%	33,957	2.32%	3.25%
NE	$0.6	$1.0	4,200	7,600	942	0.44%	0.81%	70,665	0.91%	1.39%
NV	$0.6	$0.9	4,900	8,700	1,195	0.41%	0.73%	99,566	0.57%	0.95%
NH	$0.3	$0.6	2,500	4,700	694	0.36%	0.68%	56,488	0.61%	1.00%
NJ	$2.6	$4.3	19,600	36,500	4,117	0.48%	0.89%	435,217	0.60%	0.98%
NM	$1.2	$1.7	-600	4,400	860	-0.07%	0.51%	66,856	1.75%	2.51%
NY	$5.6	$9.2	40,600	76,400	8,762	0.46%	0.87%	908,997	0.61%	1.01%
NC	$2.3	$3.7	15,500	29,500	4,112	0.38%	0.72%	327,199	0.72%	1.14%
ND	$9.4	$12.4	27,500	57,700	361	7.63%	15.99%	26,393	35.59%	47.02%
OH	$10.4	$14.5	42,900	84,000	5,279	0.81%	1.59%	408,707	2.55%	3.56%
OK	$5.2	$7.0	18,400	37,300	1,649	1.12%	2.26%	132,132	3.90%	5.33%
OR	$2.1	$3.0	9,700	19,000	1,772	0.55%	1.07%	138,453	1.49%	2.16%
PA	$15.7	$21.6	85,800	145,400	5,849	1.47%	2.49%	506,397	3.09%	4.27%
RI	$0.3	$0.5	2,300	4,100	504	0.45%	0.82%	43,594	0.70%	1.13%
SC	$2.0	$2.9	10,600	19,800	1,909	0.55%	1.03%	148,265	1.33%	1.95%
SD	$0.3	$0.4	1,800	3,200	421	0.43%	0.77%	31,174	0.81%	1.26%
TN	$2.3	$3.5	12,500	24,100	2,783	0.45%	0.87%	215,819	1.06%	1.60%
TX	$32.4	$44.5	114,900	236,300	11,265	1.02%	2.10%	956,808	3.38%	4.65%
UT	$1.1	$1.7	6,700	12,100	1,253	0.54%	0.96%	87,947	1.28%	1.89%
VT	$0.2	$0.3	1,100	2,100	337	0.31%	0.61%	24,376	0.67%	1.09%
VA	$1.6	$2.8	11,400	23,400	3,960	0.29%	0.59%	347,284	0.45%	0.80%
WA	$1.6	$2.7	12,400	23,300	3,167	0.39%	0.74%	285,696	0.57%	0.96%
WV	$1.2	$1.7	3,800	8,700	734	0.52%	1.19%	58,378	2.04%	2.88%
WI	$2.7	$4.0	14,100	26,900	2,822	0.50%	0.95%	211,337	1.28%	1.88%
WY	$2.7	$3.6	3,600	12,700	282	1.27%	4.52%	26,289	10.39%	13.88%
U.S.	**$167.4**	**$244.6**	**835,000**	**1,607,500**	**139,396**	**0.60%**	**1.15%**	**12,168,161**	**1.38%**	**2.01%**

Source: ICF estimates

Exhibit 7-4 (Multiplier Effect = 1.3) Changes in GDP (2010$ Billion) (attributable to upstream technological advances since 2007)

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
AL	$0.1	$0.1	$0.1	$0.2	$0.3	$0.5	$0.6	$0.8	$1.1	$1.4
AK	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.1)	($0.1)	($0.1)
AZ	$0.1	$0.1	$0.2	$0.3	$0.4	$0.6	$0.8	$1.0	$1.3	$1.7
AR	$0.5	$0.5	$0.8	$0.8	$0.9	$1.1	$1.2	$1.4	$1.7	$2.1
CA	$0.5	$0.7	$1.1	$1.9	$2.7	$4.1	$5.3	$6.8	$8.8	$11.0
CO	($0.0)	($0.1)	($0.1)	($0.1)	($0.0)	$0.4	$0.5	$0.9	$1.5	$2.3
CT	$0.1	$0.1	$0.1	$0.2	$0.4	$0.5	$0.7	$0.9	$1.1	$1.4
DE	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2
DC	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2
FL	$0.3	$0.3	$0.5	$0.9	$1.2	$1.7	$2.1	$2.6	$3.3	$4.1
GA	$0.1	$0.2	$0.3	$0.5	$0.7	$0.9	$1.2	$1.5	$2.0	$2.5
HI	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2
ID	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4
IL	$0.3	$0.3	$0.5	$0.8	$1.2	$1.9	$2.4	$3.1	$4.0	$5.1
IN	$0.2	$0.2	$0.3	$0.6	$1.0	$1.6	$2.1	$2.7	$3.6	$4.6
IA	$0.1	$0.1	$0.1	$0.2	$0.3	$0.5	$0.6	$0.7	$0.9	$1.2
KS	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.5	$0.8
KY	$0.1	($0.1)	($0.0)	($0.0)	($0.0)	$0.1	$0.2	$0.3	$0.5	$0.7
LA	$0.1	$0.1	$0.5	$0.6	$0.6	$0.9	$1.2	$2.6	$5.3	$8.9
ME	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4
MD	$0.1	$0.1	$0.2	$0.3	$0.4	$0.6	$0.7	$1.0	$1.5	$1.9
MA	$0.1	$0.1	$0.2	$0.4	$0.6	$0.8	$1.0	$1.3	$1.7	$2.2
MI	$0.2	$0.2	$0.4	$0.6	$1.0	$1.4	$1.8	$2.4	$3.1	$4.0
MN	$0.1	$0.1	$0.2	$0.4	$0.5	$0.7	$0.9	$1.2	$1.5	$1.9
MS	$0.1	$0.1	$0.2	$0.3	$0.3	$0.4	$0.5	$0.7	$1.2	$1.5
MO	$0.1	$0.1	$0.2	$0.3	$0.5	$0.7	$0.9	$1.1	$1.4	$1.8
MT	$0.0	$0.0	$0.0	$0.0	$0.1	$0.2	$0.3	$0.4	$0.6	$0.8
NE	$0.0	$0.1	$0.1	$0.1	$0.2	$0.3	$0.3	$0.4	$0.5	$0.6
NV	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.5	$0.6
NH	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.3
NJ	$0.2	$0.2	$0.3	$0.5	$0.7	$1.0	$1.3	$1.6	$2.1	$2.6
NM	($0.1)	($0.1)	($0.1)	$0.0	$0.0	$0.2	$0.4	$0.5	$0.8	$1.2
NY	$0.3	$0.4	$0.6	$1.0	$1.4	$2.1	$2.7	$3.4	$4.4	$5.6
NC	$0.1	$0.2	$0.3	$0.5	$0.6	$0.9	$1.1	$1.4	$1.9	$2.3
ND	$0.9	$1.3	$1.9	$3.1	$4.8	$6.0	$7.1	$7.9	$8.6	$9.4
OH	$0.4	$0.3	$0.6	$1.1	$2.0	$3.5	$4.6	$6.1	$8.1	$10.4
OK	$0.3	$0.2	$0.2	$0.4	$0.7	$1.2	$1.6	$2.4	$3.7	$5.2

Exhibit 7-4 Continued (Multiplier Effect = 1.3) Changes in GDP (2010$ Billion) (attributable to upstream technological advances since 2007)

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
OR	$0.1	$0.1	$0.1	$0.2	$0.3	$0.5	$0.6	$0.9	$1.5	$2.1
PA	$0.4	$0.3	$0.8	$1.5	$2.9	$5.6	$7.5	$9.5	$12.4	$15.7
RI	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3
SC	$0.1	$0.1	$0.2	$0.3	$0.5	$0.6	$0.8	$1.1	$1.5	$2.0
SD	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3
TN	$0.1	$0.1	$0.2	$0.4	$0.6	$0.9	$1.1	$1.4	$1.8	$2.3
TX	$2.0	$1.0	$1.4	$4.1	$8.8	$13.4	$16.8	$20.9	$26.6	$32.4
UT	$0.0	($0.0)	($0.0)	($0.0)	$0.0	$0.1	$0.2	$0.4	$0.7	$1.1
VT	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2
VA	$0.1	$0.1	$0.1	$0.2	$0.3	$0.5	$0.7	$0.9	$1.2	$1.6
WA	$0.1	$0.1	$0.2	$0.3	$0.5	$0.6	$0.8	$1.0	$1.3	$1.6
WV	$0.0	($0.1)	($0.2)	($0.2)	($0.2)	$0.2	$0.3	$0.4	$0.8	$1.2
WI	$0.1	$0.1	$0.2	$0.4	$0.7	$1.0	$1.3	$1.6	$2.1	$2.7
WY	($0.2)	($0.3)	($0.4)	($0.6)	($0.6)	($0.2)	$0.1	$0.7	$1.6	$2.7
U.S.	**$8.2**	**$7.6**	**$12.7**	**$23.4**	**$38.2**	**$59.2**	**$76.2**	**$98.2**	**$131.0**	**$167.4**

Exhibit 7-5 (Multiplier Effect = 1.9) Changes in GDP (2010$ Billion) (attributable to upstream technological advances since 2007)

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
AL	$0.1	$0.1	$0.2	$0.3	$0.4	$0.7	$1.0	$1.2	$1.7	$2.2
AK	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)
AZ	$0.1	$0.2	$0.3	$0.5	$0.7	$1.0	$1.3	$1.6	$2.1	$2.6
AR	$0.7	$0.6	$1.0	$1.1	$1.2	$1.5	$1.7	$2.0	$2.4	$3.0
CA	$0.9	$1.0	$1.6	$2.9	$4.3	$6.4	$8.4	$10.8	$14.0	$17.6
CO	($0.0)	($0.1)	($0.1)	($0.0)	$0.1	$0.7	$0.9	$1.4	$2.4	$3.4
CT	$0.1	$0.1	$0.2	$0.4	$0.6	$0.8	$1.1	$1.4	$1.8	$2.3
DE	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4
DC	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3
FL	$0.4	$0.5	$0.8	$1.4	$1.9	$2.7	$3.4	$4.3	$5.5	$6.8
GA	$0.2	$0.3	$0.4	$0.7	$1.0	$1.5	$1.9	$2.4	$3.2	$4.0
HI	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.3
ID	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.5	$0.6
IL	$0.4	$0.4	$0.7	$1.2	$1.9	$2.9	$3.7	$4.7	$6.2	$7.8
IN	$0.3	$0.3	$0.5	$0.9	$1.4	$2.3	$2.9	$3.8	$5.1	$6.5
IA	$0.1	$0.1	$0.2	$0.3	$0.5	$0.7	$0.9	$1.1	$1.4	$1.8
KS	$0.0	$0.1	$0.1	$0.2	$0.3	$0.4	$0.5	$0.6	$0.9	$1.2
KY	$0.1	($0.1)	($0.0)	$0.0	$0.0	$0.3	$0.4	$0.5	$0.9	$1.3
LA	$0.2	$0.2	$0.7	$0.8	$0.9	$1.3	$1.8	$3.6	$7.2	$12.1
ME	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.3	$0.3	$0.5	$0.6
MD	$0.1	$0.2	$0.3	$0.5	$0.7	$1.0	$1.2	$1.6	$2.3	$3.0
MA	$0.2	$0.2	$0.4	$0.6	$0.9	$1.3	$1.7	$2.1	$2.8	$3.5
MI	$0.3	$0.3	$0.5	$0.9	$1.4	$2.1	$2.7	$3.5	$4.7	$6.0

Exhibit 7-5 Continued (Multiplier Effect = 1.9) Changes in GDP (2010$ Billion) (attributable to upstream technological advances since 2007)

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
MN	$0.2	$0.2	$0.3	$0.5	$0.8	$1.1	$1.4	$1.8	$2.4	$3.0
MS	$0.1	$0.2	$0.3	$0.4	$0.5	$0.7	$0.8	$1.1	$1.7	$2.2
MO	$0.2	$0.2	$0.3	$0.5	$0.7	$1.0	$1.3	$1.7	$2.2	$2.8
MT	$0.0	$0.0	$0.0	$0.0	$0.1	$0.3	$0.4	$0.6	$0.8	$1.1
NE	$0.1	$0.1	$0.1	$0.2	$0.3	$0.4	$0.5	$0.6	$0.8	$1.0
NV	$0.1	$0.1	$0.1	$0.2	$0.3	$0.4	$0.5	$0.6	$0.8	$0.9
NH	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.3	$0.3	$0.4	$0.6
NJ	$0.2	$0.3	$0.5	$0.8	$1.1	$1.6	$2.1	$2.7	$3.4	$4.3
NM	($0.1)	($0.1)	($0.1)	$0.0	$0.1	$0.4	$0.5	$0.8	$1.2	$1.7
NY	$0.5	$0.6	$0.9	$1.6	$2.3	$3.4	$4.3	$5.5	$7.3	$9.2
NC	$0.2	$0.3	$0.4	$0.7	$1.0	$1.4	$1.8	$2.3	$3.0	$3.7
ND	$1.2	$1.7	$2.4	$4.1	$6.3	$8.0	$9.3	$10.4	$11.4	$12.4
OH	$0.6	$0.5	$0.8	$1.5	$2.8	$4.8	$6.5	$8.5	$11.3	$14.5
OK	$0.4	$0.3	$0.3	$0.6	$1.0	$1.7	$2.3	$3.4	$5.1	$7.0
OR	$0.1	$0.1	$0.2	$0.3	$0.5	$0.7	$0.9	$1.3	$2.2	$3.0
PA	$0.5	$0.4	$1.1	$2.1	$4.1	$7.8	$10.4	$13.1	$17.1	$21.6
RI	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.5
SC	$0.1	$0.2	$0.3	$0.5	$0.7	$1.0	$1.3	$1.6	$2.2	$2.9
SD	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4
TN	$0.2	$0.2	$0.3	$0.6	$0.9	$1.3	$1.6	$2.1	$2.7	$3.5
TX	$2.8	$1.4	$2.0	$5.7	$12.0	$18.4	$23.0	$28.6	$36.5	$44.5
UT	$0.0	($0.0)	($0.0)	$0.0	$0.1	$0.2	$0.3	$0.6	$1.1	$1.7
VT	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3
VA	$0.2	$0.1	$0.2	$0.4	$0.5	$0.9	$1.2	$1.6	$2.1	$2.8
WA	$0.2	$0.2	$0.3	$0.5	$0.7	$1.0	$1.3	$1.7	$2.2	$2.7
WV	$0.0	($0.2)	($0.2)	($0.3)	($0.2)	$0.2	$0.4	$0.6	$1.1	$1.7
WI	$0.2	$0.2	$0.3	$0.6	$1.0	$1.5	$1.9	$2.4	$3.1	$4.0
WY	($0.2)	($0.3)	($0.5)	($0.7)	($0.7)	($0.2)	$0.1	$0.9	$2.2	$3.6
U.S.	**$12.0**	**$11.1**	**$18.5**	**$34.3**	**$55.9**	**$86.5**	**$111.4**	**$143.6**	**$191.5**	**$244.6**

Exhibit 7-6 (Multiplier Effect = 1.3) Changes in Employment (No.)
(attributable to upstream technological advances since 2007)

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
AL	700	400	700	1,300	1,800	3,100	4,100	5,100	6,500	8,000
AK	0	0	(100)	(100)	(100)	0	0	0	0	100
AZ	700	900	1,400	2,400	3,300	4,700	6,000	7,400	9,100	10,900
AR	2,200	3,900	5,700	6,700	6,900	7,400	8,200	9,000	10,300	11,900
CA	4,500	6,100	9,300	16,000	21,800	31,100	40,300	49,800	61,600	74,500
CO	(300)	(900)	(700)	(600)	(600)	800	1,100	2,500	5,400	8,700
CT	500	700	1,100	2,000	2,700	3,900	5,100	6,200	7,700	9,200
DE	100	200	200	400	500	700	900	1,100	1,400	1,700
DC	100	100	200	400	500	600	800	1,000	1,200	1,500
FL	2,300	3,000	4,600	7,600	10,000	13,800	17,700	21,800	26,700	32,100
GA	1,200	1,500	2,400	3,900	5,100	7,300	9,500	11,600	14,100	16,800
HI	100	100	200	300	400	600	800	1,000	1,200	1,500
ID	200	200	400	600	800	1,200	1,500	1,900	2,300	2,700
IL	1,900	2,200	3,300	5,800	8,100	12,200	15,800	19,400	24,200	29,400
IN	1,100	1,100	1,700	3,100	4,800	7,800	10,200	12,600	16,000	19,600
IA	500	700	1,100	1,800	2,400	3,300	4,200	5,100	6,200	7,400
KS	300	300	500	900	1,200	1,800	2,300	2,800	3,400	4,500
KY	500	(600)	(500)	(500)	(800)	200	400	700	1,400	2,400
LA	300	2,000	4,800	6,500	7,100	10,300	17,600	26,000	33,300	40,700
ME	200	200	300	600	800	1,100	1,500	1,800	2,200	2,600
MD	700	900	1,400	2,500	3,400	5,200	6,800	8,300	10,100	11,900
MA	1,000	1,300	2,000	3,400	4,600	6,600	8,600	10,500	12,800	15,200
MI	1,300	1,700	2,500	4,400	6,300	9,200	12,100	14,700	18,200	22,000
MN	800	1,100	1,700	2,800	3,800	5,400	7,000	8,500	10,400	12,500
MS	500	900	1,300	1,800	2,500	3,900	5,000	5,900	7,100	7,800
MO	700	900	1,400	2,300	3,100	4,500	5,900	7,300	8,900	10,800
MT	100	0	0	100	300	700	1,000	1,400	2,000	2,700
NE	300	400	600	1,000	1,300	1,800	2,400	2,900	3,500	4,200
NV	400	500	800	1,200	1,600	2,200	2,800	3,400	4,100	4,900
NH	200	200	300	600	700	1,100	1,400	1,700	2,100	2,500
NJ	1,300	1,800	2,700	4,500	6,100	8,400	10,900	13,300	16,300	19,600
NM	(600)	(800)	(1,200)	(1,300)	(1,700)	(1,300)	(1,400)	(1,600)	(1,100)	(600)
NY	2,600	3,500	5,400	9,100	12,300	17,400	22,600	27,700	33,900	40,600
NC	1,000	1,300	2,100	3,500	4,700	6,700	8,800	10,800	13,100	15,500
ND	2,600	5,300	6,600	10,500	16,000	19,600	22,200	24,100	25,800	27,500
OH	1,800	2,000	2,900	5,600	9,300	15,700	21,100	26,700	34,400	42,900
OK	1,100	1,100	900	1,700	2,100	3,700	4,800	7,800	12,900	18,400
OR	500	700	1,000	1,700	2,600	4,400	6,000	7,100	8,700	9,700
PA	1,800	2,000	5,000	10,800	20,600	37,500	49,500	58,200	71,600	85,800
RI	200	200	300	500	700	1,000	1,300	1,600	1,900	2,300
SC	600	800	1,300	2,200	3,100	4,600	6,200	7,500	9,000	10,600

Exhibit 7-6 Continued (Multiplier Effect = 1.3) Changes in Employment (No.) (attributable to upstream technological advances since 2007)

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
SD	100	200	300	400	600	800	1,000	1,200	1,500	1,800
TN	800	1,000	1,500	2,500	3,600	5,300	6,800	8,400	10,400	12,500
TX	9,400	7,500	7,900	20,600	38,600	58,300	73,500	84,400	100,300	114,900
UT	100	(100)	(200)	(100)	200	500	1,300	2,600	4,500	6,700
VT	100	100	100	200	300	400	600	700	900	1,100
VA	1,000	700	1,100	2,100	2,700	4,500	5,900	7,400	9,300	11,400
WA	800	1,100	1,700	2,900	3,900	5,400	7,000	8,500	10,400	12,400
WV	100	(1,000)	(1,400)	(2,000)	(1,900)	100	700	900	2,000	3,800
WI	800	1,100	1,600	2,800	4,000	5,900	7,700	9,400	11,700	14,100
WY	(1,400)	(2,100)	(3,300)	(4,800)	(5,800)	(5,400)	(5,700)	(4,100)	(400)	3,600
U.S.	**47,800**	**56,300**	**84,900**	**152,900**	**226,500**	**345,800**	**451,500**	**553,900**	**690,800**	**835,000**

Exhibit 7-7 (Multiplier Effect = 1.9) Changes in Employment (No.) (attributable to upstream technological advances since 2007) [Figures rounded]

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
AL	1,100	700	1,300	2,400	3,400	5,700	7,500	9,500	12,500	15,700
AK	0	(100)	(100)	(100)	(100)	0	100	200	300	500
AZ	1,200	1,500	2,400	4,100	5,700	8,200	10,600	13,200	16,700	20,500
AR	3,800	5,500	8,200	9,600	10,100	11,400	12,900	14,600	17,300	20,400
CA	7,800	9,600	15,100	26,400	37,700	55,000	71,400	89,700	113,900	140,700
CO	(200)	(1,100)	(700)	(200)	300	3,500	4,800	7,700	13,600	20,100
CT	1,000	1,200	1,800	3,300	4,700	6,900	9,000	11,300	14,300	17,600
DE	200	200	400	600	900	1,200	1,600	2,000	2,500	3,100
DC	200	200	300	600	800	1,100	1,400	1,800	2,300	2,800
FL	3,900	4,700	7,400	12,500	17,100	24,200	31,000	38,600	48,500	59,400
GA	2,000	2,400	3,800	6,400	8,800	12,600	16,300	20,300	25,800	31,500
HI	200	200	300	600	800	1,200	1,500	1,900	2,500	3,100
ID	300	400	600	1,000	1,400	2,000	2,600	3,200	4,000	4,900
IL	3,400	3,500	5,600	9,900	14,500	21,900	28,300	35,500	45,500	56,400
IN	2,100	1,900	3,000	5,600	9,000	14,500	18,800	23,700	30,800	38,500
IA	900	1,100	1,700	2,800	3,900	5,500	7,100	8,700	10,900	13,300
KS	500	500	800	1,600	2,200	3,300	4,300	5,300	6,800	9,200
KY	900	(600)	(400)	(200)	(300)	1,600	2,300	3,200	5,100	7,500
LA	800	2,600	6,800	8,900	9,800	14,300	23,000	36,200	52,600	72,200
ME	300	400	500	900	1,300	1,900	2,400	3,100	3,800	4,700
MD	1,300	1,500	2,400	4,200	6,000	8,900	11,600	14,700	19,100	23,400
MA	1,700	2,100	3,200	5,600	7,900	11,400	14,800	18,500	23,400	28,700
MI	2,200	2,700	4,200	7,400	10,900	16,100	21,000	26,200	33,500	41,500
MN	1,400	1,700	2,700	4,500	6,400	9,200	11,900	14,800	18,700	23,000
MS	700	1,400	2,000	2,900	4,000	5,900	7,500	9,300	12,100	14,500

Exhibit 7-7 Continued (Multiplier Effect = 1.9) Changes in Employment (No.) (attributable to upstream technological advances since 2007) [Figures rounded]

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
MO	1,300	1,500	2,300	4,000	5,700	8,200	10,600	13,300	16,800	20,700
MT	100	0	100	200	700	1,400	2,200	3,100	4,400	5,900
NE	500	600	1,000	1,600	2,200	3,100	4,000	5,000	6,300	7,600
NV	600	800	1,200	2,000	2,600	3,600	4,600	5,800	7,200	8,700
NH	300	300	500	900	1,300	1,900	2,400	3,000	3,800	4,700
NJ	2,200	2,800	4,300	7,400	10,300	14,700	18,900	23,600	29,700	36,500
NM	(800)	(900)	(1,300)	(1,100)	(1,300)	(100)	400	800	2,600	4,400
NY	4,500	5,600	8,600	15,000	21,100	30,400	39,300	49,100	62,200	76,400
NC	1,800	2,200	3,400	5,900	8,200	11,700	15,300	19,100	24,100	29,500
ND	5,400	9,300	12,500	20,400	31,100	38,900	44,800	49,300	53,500	57,700
OH	3,400	3,400	5,300	10,100	17,500	29,600	39,500	50,800	66,500	84,000
OK	2,000	1,800	1,900	3,400	4,900	8,500	11,200	17,100	26,800	37,300
OR	800	1,100	1,600	2,800	4,300	6,800	9,100	11,500	15,600	19,000
PA	3,500	3,300	8,100	16,900	32,200	58,900	77,900	94,200	118,800	145,400
RI	300	300	500	800	1,200	1,700	2,200	2,700	3,400	4,100
SC	1,100	1,300	2,100	3,600	5,200	7,700	10,200	12,700	16,100	19,800
SD	200	300	400	700	900	1,300	1,700	2,100	2,600	3,200
TN	1,400	1,600	2,500	4,300	6,400	9,500	12,300	15,300	19,500	24,100
TX	16,700	11,500	13,700	36,300	70,800	107,500	135,400	161,700	199,400	236,300
UT	200	(100)	(100)	100	700	1,400	2,600	4,900	8,100	12,100
VT	100	100	200	400	500	800	1,000	1,300	1,700	2,100
VA	1,700	1,200	2,000	3,800	5,200	8,600	11,300	14,300	18,600	23,400
WA	1,400	1,800	2,800	4,800	6,600	9,400	12,100	15,200	19,100	23,300
WV	200	(1,400)	(1,900)	(2,600)	(2,200)	1,000	2,100	3,000	5,300	8,700
WI	1,400	1,700	2,700	4,700	7,100	10,600	13,700	17,100	21,800	26,900
WY	(1,900)	(2,800)	(4,400)	(6,500)	(7,400)	(5,800)	(5,200)	(1,700)	5,200	12,700
U.S.	**85,800**	**91,500**	**143,400**	**261,100**	**403,000**	**619,000**	**803,200**	**1,007,300**	**1,295,500**	**1,607,500**

Exhibit 7-8 (Multiplier Effect = 1.3) Changes in State and Local Taxes (2010$ Billion) (attributable to upstream technological advances since 2007)

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
AL	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2
AK	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)
AZ	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2
AR	$0.1	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2	$0.2	$0.3	$0.3
CA	$0.1	$0.1	$0.2	$0.3	$0.4	$0.6	$0.8	$1.1	$1.4	$1.8
CO	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	$0.1	$0.1	$0.1	$0.2	$0.3
CT	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2
DE	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
DC	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
FL	$0.0	$0.1	$0.1	$0.1	$0.2	$0.3	$0.3	$0.4	$0.5	$0.6
GA	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4
HI	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
ID	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1
IL	$0.0	$0.0	$0.1	$0.1	$0.2	$0.3	$0.3	$0.4	$0.6	$0.7
IN	$0.0	$0.0	$0.1	$0.1	$0.2	$0.3	$0.3	$0.4	$0.6	$0.8
IA	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2
KS	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1
KY	$0.0	($0.0)	($0.0)	($0.0)	($0.0)	$0.0	$0.0	$0.0	$0.1	$0.1
LA	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.4	$0.8	$1.4
ME	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1
MD	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2
MA	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3
MI	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.5	$0.7
MN	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3
MS	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.3
MO	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2
MT	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1
NE	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1
NV	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1
NH	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
NJ	$0.0	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.3	$0.3	$0.4
NM	($0.0)	($0.0)	($0.0)	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2
NY	$0.1	$0.1	$0.1	$0.2	$0.3	$0.4	$0.5	$0.7	$0.9	$1.1
NC	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.3
ND	$0.2	$0.2	$0.4	$0.6	$0.9	$1.1	$1.3	$1.5	$1.6	$1.8
OH	$0.1	$0.1	$0.1	$0.2	$0.3	$0.6	$0.7	$1.0	$1.3	$1.7
OK	$0.0	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.4	$0.5	$0.8
OR	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.3
PA	$0.1	$0.0	$0.1	$0.2	$0.4	$0.8	$1.1	$1.4	$1.8	$2.3
RI	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
SC	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.3	$0.3

Exhibit 7-8 Continued (Multiplier Effect = 1.3) Changes in State and Local Taxes (2010$ Billion) (attributable to upstream technological advances since 2007)

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
SD	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
TN	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3
TX	$0.3	$0.1	$0.2	$0.6	$1.2	$1.8	$2.3	$2.8	$3.6	$4.4
UT	$0.0	($0.0)	($0.0)	($0.0)	$0.0	$0.0	$0.0	$0.1	$0.1	$0.2
VT	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
VA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2
WA	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.2
WV	$0.0	($0.0)	($0.0)	($0.0)	($0.0)	$0.0	$0.0	$0.1	$0.1	$0.2
WI	$0.0	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.4
WY	($0.0)	($0.1)	($0.1)	($0.1)	($0.1)	($0.0)	$0.0	$0.2	$0.4	$0.7
U.S.	**$1.2**	**$1.2**	**$2.0**	**$3.6**	**$5.8**	**$9.1**	**$11.7**	**$15.1**	**$20.1**	**$25.8**

Exhibit 7-9 (Multiplier Effect = 1.9) Changes in State and Local Taxes (2010$ Billion) (attributable to upstream technological advances since 2007)

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
AL	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.3	$0.3
AK	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)	($0.0)
AZ	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4
AR	$0.1	$0.1	$0.1	$0.2	$0.2	$0.2	$0.2	$0.3	$0.4	$0.4
CA	$0.1	$0.2	$0.3	$0.5	$0.7	$1.0	$1.3	$1.7	$2.2	$2.8
CO	($0.0)	($0.0)	($0.0)	($0.0)	$0.0	$0.1	$0.1	$0.2	$0.3	$0.5
CT	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3
DE	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1
DC	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
FL	$0.1	$0.1	$0.1	$0.2	$0.3	$0.4	$0.5	$0.7	$0.8	$1.0
GA	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.3	$0.3	$0.4	$0.6
HI	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1
ID	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1
IL	$0.1	$0.1	$0.1	$0.2	$0.3	$0.4	$0.5	$0.7	$0.9	$1.1
IN	$0.1	$0.0	$0.1	$0.1	$0.2	$0.4	$0.5	$0.6	$0.8	$1.1
IA	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3
KS	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2
KY	$0.0	($0.0)	($0.0)	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2
LA	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.3	$0.6	$1.1	$1.9
ME	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1
MD	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4
MA	$0.0	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.5
MI	$0.0	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.6	$0.8	$1.0
MN	$0.0	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.5
MS	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2	$0.3	$0.4

Exhibit 7-9 Continued (Multiplier Effect = 1.9) Changes in State and Local Taxes (2010$ Billion) (attributable to upstream technological advances since 2007)

State	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
MO	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4
MT	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2
NE	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.2
NV	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.1	$0.1
NH	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1
NJ	$0.0	$0.0	$0.1	$0.1	$0.2	$0.3	$0.3	$0.4	$0.5	$0.7
NM	($0.0)	($0.0)	($0.0)	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.3
NY	$0.1	$0.1	$0.2	$0.3	$0.5	$0.7	$0.9	$1.1	$1.4	$1.8
NC	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.3	$0.3	$0.4	$0.6
ND	$0.2	$0.3	$0.5	$0.8	$1.2	$1.5	$1.8	$2.0	$2.2	$2.4
OH	$0.1	$0.1	$0.1	$0.2	$0.5	$0.8	$1.0	$1.4	$1.8	$2.3
OK	$0.1	$0.0	$0.0	$0.1	$0.1	$0.2	$0.3	$0.5	$0.7	$1.0
OR	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.3	$0.5
PA	$0.1	$0.1	$0.2	$0.3	$0.6	$1.1	$1.5	$1.9	$2.5	$3.2
RI	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1	$0.1
SC	$0.0	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.5
SD	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1
TN	$0.0	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.5
TX	$0.4	$0.2	$0.3	$0.8	$1.6	$2.5	$3.1	$3.9	$4.9	$6.0
UT	$0.0	($0.0)	($0.0)	$0.0	$0.0	$0.0	$0.1	$0.1	$0.2	$0.3
VT	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
VA	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4
WA	$0.0	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.2	$0.3	$0.4
WV	$0.0	($0.0)	($0.0)	($0.0)	($0.0)	$0.0	$0.1	$0.1	$0.2	$0.3
WI	$0.0	$0.0	$0.1	$0.1	$0.2	$0.2	$0.3	$0.4	$0.5	$0.7
WY	($0.1)	($0.1)	($0.1)	($0.2)	($0.2)	($0.0)	$0.0	$0.2	$0.5	$0.9
U.S.	**$1.8**	**$1.7**	**$2.9**	**$5.3**	**$8.5**	**$13.2**	**$17.1**	**$22.0**	**$29.4**	**$37.7**

C. Economic Impact Study Methodology

Impact Assessment

Numerous economic impact studies have attempted to capture the impact of the increase in natural gas supply (resulting from successful shale gas production) on the U.S. economy. While this study's approach diverges somewhat from the other approaches, all the studies cited previously employ the Impact Analysis for Planning (IMPLAN) input-output model. IMPLAN is based on a social accounting matrix that incorporates all flows within an economy and is used to assess the aggregate economic impact associated with an industry's output. For these economic impact studies, the "inputs" for the model are the direct industry investments made in the industry (e.g., drilling equipment) for each specific oil and gas NAICS[179] code, which together act as the economic stimulant. The model then assesses the "output" on each of the other NAICS codes classified in the business economy (i.e., how the investments in the oil and gas industry affect the economy at large), indicating the macroeconomic impact of the oil and gas industry. While methodologies and underlying assumptions can vary considerably, the economic impact studies typically have the following impacts:

- **Direct Impacts** represent the immediate impacts (e.g., employment or output changes) due to the investments that result in direct demand changes, such as expenditures needed for the drilling and operation of a natural gas well. Examples include higher demand for drilling equipment and production workers.
- **Indirect Impacts** are brought about by changes in direct demand through the inter-linkages of various sectors, attributable to the iteration of goods/services purchased by direct and indirect industries. Direct industry expenditures (e.g., natural gas extraction costs) produce a domino effect on other industries, classified as the "indirect impact," as component industries' revenues (e.g., cement and steel manufacturers needed for well construction) are stimulated along with the direct industry.
- **Induced Impacts** represent the impacts on all local and national industries due to consumers' consumption expenditures rising from the new household incomes that are generated by the direct and indirect effects of the final demand changes. Induced expenditures are generated in the economy at large through the tertiary economic activity created by the direct and indirect industries (e.g., consumer spending of direct and indirect workers).

While induced impacts are included in many of the economic impact studies on shale gas, the inclusion of induced impacts can be quite controversial, for a number of reasons.

1. Induced impacts include aspects of the economy (e.g., retail store economic activity near gas production sites) that are far removed from the direct industries (e.g., gas production).
2. It is nearly impossible to isolate the direct correlation between one industry (e.g., natural gas production) and an economic activity that is often several degrees away from the original activity (e.g., higher demand for workers' housing near the production site). An induced impact may actually be (in whole or in part) the result of another phenomenon, such as an economic stimulus, the opening of a new business nearby, or the phase in the aggregate economy's business cycle, rather than as a sole result of the purported economic stimulant (e.g., gas production).
3. Similarly, induced impacts have a tendency to overestimate the true impact of an industry (particularly when looking at induced impacts in the context of gross impacts). First, an induced impact may be wholly attributed to the economic stimulant, without the ability to segment out confounding variables (e.g., other economic stimuli). Second, an induced impact in one industry may be a direct impact to another.

179. North American Industry Classification System (NAICS) codes are used to classify industries in order to classify and analyze statistical data on the U.S. business economy.

Quantification of Impacts

There are a number of ways to measure the direct, indirect, and induced economic impacts of an industry. The primary measures include the following:

- **Output** represents the value of an industry's total output increase due to the modeled scenario.
- **Employment** represents the jobs created by an industry, based on the output per worker and output impacts for each industry.
- **Value Added (VA)** is the "additional" output created by the industry, or the contribution to Gross Domestic Product (GDP) and is the "catch-all" for payments made by individual industry sectors to workers, interests, profits, and indirect business taxes. VA measures the specific contribution of an individual sector after subtracting out purchases from all suppliers, and includes labor income, property income (e.g., property rents, royalties, corporate profits), and the tax impact (i.e., federal, state, and local taxes).

  VA = Output – Inputs (e.g., intermediate purchases) = "Additional" Output

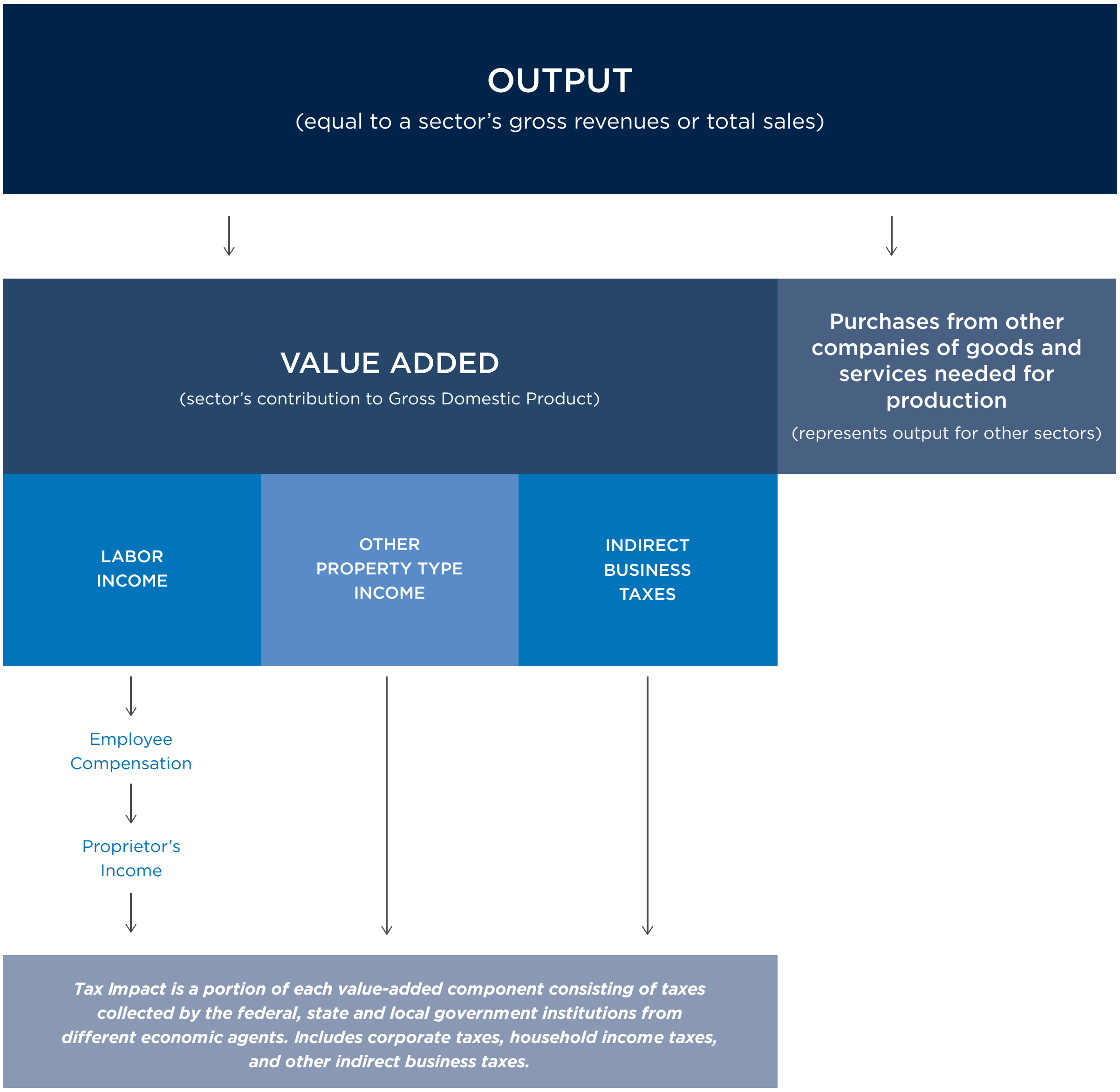
  Ex: If a U.S. industry expands output by $1 billion, and the cost of intermediate goods totals $300 million, the value added (GDP additions) totals $700 million ($1b – $300mm)
- **Macroeconomic GDP Multiplier (MEGM)**, also called the "income multiplier," is the calculated ratio of induced value added as a proportion of the direct and indirect value added. Essentially, this signifies the economic activity in the aggregate economy that was created through the economic activity of the direct and indirect industries.[180]

  MEGM = (Induced VA) / (Indirect VA + Direct VA) = Induced VA / Additional Output

  Ex: The direct and indirect VA for an industry totals $500mm and $600mm, respectively, while the induced VA totals $1.5b. Thus, the MEGM is 1.4 = [$1.5b/($500mm + $600mm]]

180. Other economic impact studies have calculated similar multiplier effects, based on IMPLAN calculations, hereafter referred to as the "IMPLAN multiplier." The IMPLAN multiplier is calculated by taking the total industry spending as the input, and calculating the total indirect and induced output that is generated throughout the aggregate economy based upon the spending inputs. This study differs in that we calculate the GDP multiplier effect (based on the change in volume and pricing of the gas industry), rather than using IMPLAN to generate the multiplier, and include both the direct and indirect GDP value added as the denominator.

Exhibit 7-10 Relationship of Key Accounting Concepts for a Given Industry Sector
(shows the key accounting concepts for the given industry sector)



Methodology for this Study

Recent economic impact studies have typically quantified the impact of shale gas activity on the overall economy by calculating the gross impact of the industry on the overall economy, rather than the net impact (value added of the industry). While the gross impact captures the industry's entire impact on the economy, the net impact isolates out the impact share that would otherwise be allocated to other industries in the absence of the economic stimulant (i.e., shale gas revolution). While most studies assume a certain level of capital and operations and maintenance expenditures to calculate the economic impact of a sector, this study focuses on the impact of changing quantities and pricing and how those factors impact the aggregate economy, rather than assessing the impact based on industry expenditures.

This study attempts to calculate the volume and price of the incremental production of energy or goods in a sector that is associated with the impact of the supplemental gas available (from shale gas production, which increases total volumes, thus lowering the retail price). That price (P) multiplied by quantity (Q) represents the net sales revenue. In the absence of any imported intermediate goods, PxQ would also be the sum of the value added in Sector A plus the value added in all of the industries that sell intermediate goods and services to Sector A plus the value added further down in the value chain. Stated another way, in the absence of any imports, the value added summed over all parts of the value chain equal the sales revenue of the final product. However, since there are imports into the U.S. economy, this study calculates the change in value added from a change in Sector A as:

$$\Delta GDP = P \times \Delta Q \times (1\text{-Imports})$$

Where:

ΔGDP = change in value added in GDP contribution (i.e., direct and indirect value added)

ΔQ = incremental volume of production in Sector A

P = retail natural gas price

Imports = ratio of Imports to GDP in the U.S.[181]

The equation above works well in the absence of feedstock components and when price is not affected by volume changes (i.e., inelastic demand). However, natural gas is commonly used as a feedstock in such industries as power generation, petrochemical processing, and fertilizer manufacturing, among others. Thus, the change in feedstock quantities must be factored in. Likewise, in the case that incremental quantities of gas affect the overall price (as evidenced in the drop in recent natural gas prices), the price change must also be considered. Thus, the equation to quantify the effect on GDP becomes:

$$\Delta GDP = \underbrace{[(P2 \times Q2 - FC2) \times (1 - \text{Imports})]}_{\text{New supply impact}} - \underbrace{[(P1 \times Q1 - FC1) \times (1 - \text{Imports})]}_{\text{Original supply impact}}$$

Where:

ΔGDP = change in value added in GDP contribution (i.e., direct and indirect value added)

Q1 = original volume of production in Sector A

Q2 = incremental volume of production in Sector A

P1 = original retail natural gas price

P2 = new retail natural gas price

FC1 = original feedstock costs

FC2 = new feedstock costs[182]

Imports = ratio of Imports to GDP in the U.S[183]

181. Estimated at 16%
182. Assumes the impact of the new feedstock costs on the GDP has already been accounted for
183. Estimated at 16%

An important component in assessing the impact to GDP is the effect on other industries that further produce a GDP impact. As stated earlier, this impact is called the Macroeconomic GDP Multiplier (MEGM). The GDP multiplier effect is essentially the additional contribution to GDP stemming from the spending of income earned in Sector A and indirect industries, which is then spent further down Sector A's value chain through induced spending (e.g., aggregate consumer spending).

Estimation of Multiplier Effect

The multiplier effect is usually a result of the IMPLAN model, meaning that to estimate the oil and gas production impact on the U.S. economy, some studies will use the assumed capital expenditures (needed to produce the oil and gas) as the input for an input-output model, such as IMPLAN. The model will then generate the direct, indirect, and induced economic activity produced by those oil and gas capital expenditures. Thus, the induced multiplier effect is calculated from those outputs (typically, as a proportion of the total economic impacts divided by induced economic impacts).

This study employed two multiplier effects to estimate the lower-bound and upper-bound estimates for "induced" activities in the U.S. economy, resulting from the spending of personal income generated by the direct and indirect activities of the industry production. The equation below shows the upper-bound GDP multiplier effect from any incremental increase of purchases (from business investment, exports, government spending, etc.) MPC is marginal propensity to consume, and is estimated at 0.900 using a post-World War II average for the U.S.. This means that for every dollar of personal income generated, \$0.90 goes toward consumption, and the remaining \$0.10 is saved. The MPI is the marginal propensity to import, estimated at 0.162, based on the average for recent years. The effective tax rate is assumed at \$0.269 per dollar of income/GDP. Inputting the MPC, MPI, and tax rate into the equation below shows that every dollar of income stemming from direct and indirect activity could produce a total of \$1.984, meaning that \$0.984 is "induced" economic activity, or the amount produced as the multiplier effect.

$$\Delta GDP = \Delta Exports * 1 / (1-MPC*(1-TAX) + MPI)$$

The explanation of the equation starts with the assumption that some policy or event causes a purchase of, say, \$100 million in domestic goods and services. This then produces \$100 million in income (to workers and owners of capital) who save some of their earnings (10%), buy imported goods (16.2%), pay taxes (26.9%), and spend on domestic good and services the rest (the remaining 46.9%, or \$46.9 million). That \$46.9 million is then filtered through the economy further in second-round spending, which leads to another \$46.9 million in income, of which 46.9 percent, or \$22.0

Exhibit 7-11 Multiplier Effect Methodology

Multiplier Effect Input	Value
Marginal Propensity to Consume after Taxes (MPC)	0.900[184]
Marginal Propensity to Import (MPI)	0.162[185]
Tax Rate	0.269[186]
Resulting Multiplier	**1.984**

184. http://frank.mtsu.edu/~jee/2011/5_MS110_pp39to46.pdf
185. http://data.worldbank.org/indicator/NE.IMP.GNFS.ZS
186. http://en.wikipedia.org/wiki/List_of_countries_by_tax_revenue_as_percentage_of_GDP

million is considered third-round spending on domestic goods. This goes on several times. Add up all of the domestic spending/income ($198.4 million) and divide by the original $100 million to get the multiplier of 1.984.

However, economists do not usually believe that the full theoretical multiplier is actually achieved because:

- There can exist an upward sloping aggregate supply curve (especially at times of full employment). This means that the extra spending will lead to an increase in prices, rather than just an increase in real output.
- Some of the added personal income is not considered permanent (e.g., lease bonuses) and so may go disproportionately into savings.
- Iterations of income-consumption-income take time, so the full multiplier may not be felt for some time.

Because of this uncertainty in the multiplier effect, a range is used in this study. In previous studies using the IMPLAN input-output model, ICF found a multiplier of 1.6. Thus, in providing a range for GDP multiplier effects, this study uses 1.9 as the multiplier for the upper-bound limit, and 1.3 [1.6 – (1.9-1.6)] for the lower-bound estimate. This study's employment multipliers range from 1.64 to 2.93. These values result from IMPLAN modeling with the assumed 1.3 to 1.6 GDP multipliers discussed above.

Modeling Approach

There are many complex economic impacts of the technology advances associated with gas production that have decreased the costs of producing oil and gas and have expanded the recoverable oil and gas resource base. The major impacts include:

- The per-unit cost of finding, developing, and producing oil and gas have gone down over the past decade as a result of shale gas production. Therefore, for any given fixed quantity of production, the production-related investment dollars and associated jobs will likely be lower, relative to conventional production.
- The lower cost of production has led to an increase in production volumes of oil and gas. These higher production volumes lead to increases in production-related investment dollars and associated jobs.
- The increase in production of oil and gas has reduced the cost to consumers of natural gas. Some of the dollars thus saved are spent on other domestic goods and services, boosting GDP in other sectors.
- Reduced natural gas prices have led to a reduction in electricity prices. The money saved by electricity consumers is spent on other domestic and imported goods and services, boosting GDP.
- Some of the incremental natural gas production has come about by reducing coal consumption in electric power plants. This reduces jobs in coal mining and transportation and in coal power plant construction and operation.
- The reduction in the prices of gas and electricity has reduced the cost of U.S. manufactured goods leading to increases in production and a larger contribution to GDP from the manufacturing sector.
- In particular with regard to manufacturing, the increased accessibility and lower price for natural gas and natural gas liquids will stimulate greater production of certain chemicals and fuels using methane and NGLs as a feedstock. This will contribute further to U.S. GDP in terms of both the construction and operation of the facilities.
- The net effects on U.S. balance of trade are very positive as net imports of natural gas, oil, and petrochemicals and are reduced.
- The initial GDP and job effects on the economy of increased U.S. production of energy and goods (also known as direct and indirect activity) produce income that then gets spent leading to further economic output. This "induced activity" is part of the GDP multiplier effect. The extent of the multiplier effects will depend on the marginal propensity to import and how much "slack" there is in the economy.

Our approach to modeling these various GDP and employment impacts of the incremental gas and oil supplies contains multiple steps.

Consumer Impacts Methodology

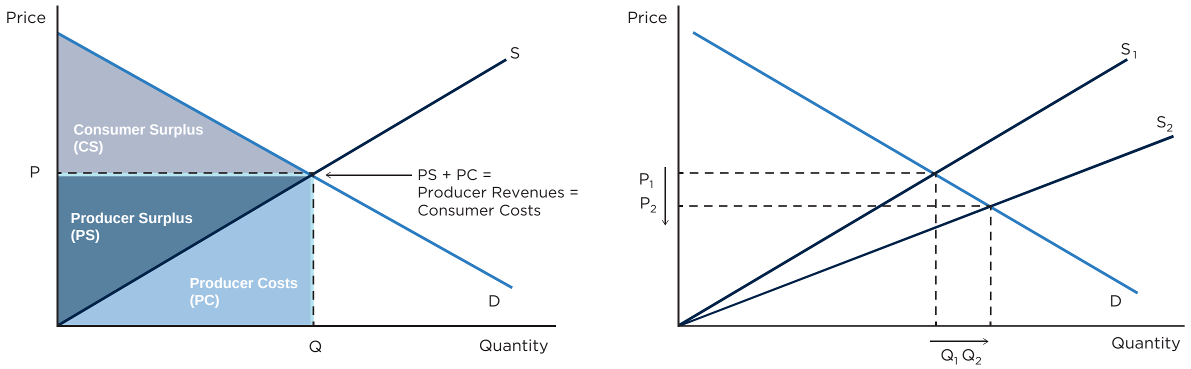
Consumers have benefited from the historic drop in gas prices over the past few years, which is a direct result of supply increases associated with the recent upstream technology advancements in North America. Using the two sets of altered AEO projections as a basis, ICF constructed a primary energy demand curve and supply curves representing supply before and after the addition of the lower cost gas and oil. These curves allow us to estimate various areas within the supply/demand diagrams, including the important economic concepts illustrated in the left-hand chart in Exhibit 7-12:

- **Consumer Surplus:** The blue triangle formed below the demand curve down to a horizontal line drawn at the market price (P). Consumer surplus represents the additional or surplus value of the product to the consumer beyond what the consumer has to pay. That is, the total value to consumers minus the consumers costs. Consumer surplus is one of the measures of the societal benefits from a change in a market.
- **Consumer Costs:** The rectangular area formed below a horizontal line drawn at the market price (P) out to the total quantity consumed (Q). The consumer costs represent the total dollar amount paid by consumers to producers. (In these simplified examples, the term "producer" refers to all parts of the supply value chain including intermediate goods, production, distribution and retailing.)
- **Producer Revenues:** This is also the rectangular area formed below a horizontal line drawn at the market price (P) out to the total quantity consumed (Q). Producer revenues represent the total dollar amount paid by consumers to producers.
- **Producer Costs**: This is the area under the supply curve out to the total quantity consumed (Q). Producer costs represent the dollar amount that producers must spend on labor, materials, capital goods, and services to make the product available to consumers. This is an important item in that it represents the expenditures that will provide jobs along the oil and gas supply chain.
- **Producer Surplus**: The area above the supply and below a horizontal line drawn at the market price (P). The producer surplus is equal to producer revenues minus producer costs. In other words, the producer surplus represents the difference between the market value of the product and what it costs to produce. Along with consumer surplus, producer surplus is one of the measures economists use to gauge the societal benefits from a change in a market.

Exhibit 7-12 Price and Quantity Impact of Increased Gas Supply

Visual of consumer and producer impacts

Visual of the change in impacts from an increase in supply



In the absence of any imported intermediate goods, Producers' Revenue (P x Q) also would be the sum of the value added in this example industry (Sector A) plus the value added in all of the industries that sell intermediate goods and services to Sector A plus the value added further down in the value chain. Stated another way, in the absence of any imports, the value added summed over all parts of the value chain equal the sales revenue of the final product. To incorporate imports, the following equation can be used.

Contribution to GDP = P x Q x (1-Imports)

Where:

Q = volume of production in Sector A

P = selling price to consumers

Imports = ratio of imports (for the U.S. economy as a whole, imports are about 16% of GDP)

The advances in upstream technologies have had the effect of shifting the supply curve for oil and natural gas down and to the right. As shown in the right-hand chart in Exhibit 7-12, such a shift in supply has the effect of dropping the price (from P1 to P2) and increasing consumption (from Q1 to Q2). This increases the consumer surplus and provides a net benefit to consumers. The producer revenues could increase or decrease depending on whether the percentage change in price was greater than the percentage increase in quantity sold. Also, the change in the producer surplus could be positive or negative, depending on the relative changes in price and quantity and the shapes of the old and new supply curves.

The effect of a shift in the supply curve on GDP, which, like producers' revenue, can be positive or negative, can be found with the following equation:

ΔGDP = [(P2 x Q2) x (1-Imports)] - [(P1 x Q1) x (1-Imports)]

Where:

ΔGDP = change in GDP contribution (i.e., change in direct and indirect value added)

Q1 = original volume of production

Q2 = new volume of production

P1 = original selling price

P2 = new selling price

Imports = ratio of imports to total GDP[187]

187. Estimated at 16% of GDP for the U.S. economy

State Allocation Methodology

ICF's economic impact estimates presented in this report were calculated first at the national level and then allocated among the states using various allocation matrices based on factors such as historical and forecasted oil and gas production, energy consumption, and economic activity by sector. There were a total of 16 economic impact variables that were allocated as shown in Exhibit 7-13 below. In some cases, two allocation matrices were employed. For example, the GDP and job effects from greater production of natural gas resulting from technological advances were allocated mostly based the states in which that production is expected to take place and partly based on which states supply the materials, equipment and services needed for drilling and production activities.

The primary source of information for sector-specific economic activity among the states was the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. State-level data on historical energy production and consumption came from Energy Information Administration statistics. The allocation of coal mining and support jobs among states was based on report entitled The Economic Contribution of the U.S. Mining in 2008 prepared for the National Mining Association. Data for personal income came from The Tax Policy Center. Estimates of which states will experience growth in gas and oil production due to technology advances are based on ICF resource base assessments and production analyses.

Exhibit 7-13 Impact Allocation Methodology

Economic Impact Variable to be Allocated	State Allocation Method(s)
GDP Gain from Incremental Crude Oil Production	Forecasted Crude Production Delta by Year & 2010 Indirect Oil/ Gas-Related Sectors
GDP Gain from Incremental Natural Gas Plant Liquids Production	Forecasted NGPL Production Delta by Year & 2010 Indirect Oil/ Gas-Related Sectors
GDP Gain from Incremental Natural Gas Production	Forecasted Gas Production Delta by Year & 2010 Indirect Oil/ Gas-Related Sectors
GDP Loss from Lower Gas Prices for Base Case Production	Gas Production in 2010 & 2010 Indirect Oil/Gas-Related Sectors
GDP Gain from Shifts in Consumer Spending Stemming from Lower Natural Gas Prices	2010 All-sector Gas Consumption & 2010 State Personal Income
GDP Gain from Shifts in Consumer Spending Stemming from Lower Electricity Prices	2010 All-sector Electricity Consumption & 2010 State Personal Income
GDP Gain from Lower Consumers Liquids Prices	2010 State Personal Income
GDP Gain from Increase in General Industrial Activity (that is, other than the specific gas/NGL-feedstock-consuming industries shown below)	2010 Industrial Gas Consumption & 2010 Indirect Industrial-Related Sectors
GDP Gain from GTL	Location of Proposed GTL Plants & 2010 Indirect Industrial-Related Sectors
GDP Gain from LNG	Location of Proposed LNG Plants & 2010 Indirect Industrial-Related Sectors
GDP Gain from Methanol	Location of Proposed Methanol Plants & 2010 Indirect Industrial-Related Sectors
GDP Gain from Ammonia	Location of Proposed Ammonia Plants & 2010 Indirect Industrial-Related Sectors
GDP Gain from Ethylene	Location of Proposed Ethylene Plants & 2010 Indirect Industrial-Related Sectors
GDP Gain/Losses from Power Generation Output	2010 All-sector Electricity Generation & States with Coal to Gas Switching
GDP Loss from Coal Mining & Transportation	2008 Coal Mining and Support Sectors
Multiplier Effect GDP	Calculated Based on Direct + Indirect Effects among States & 2010 State Personal Income

D. NAICS[188] Codes used for the Economic Impact Analysis

2007 NAICS	Sector Description	2007 NAICS	Sector Description
Agriculture and forestry			
11111-2	Oilseed farming	11211, 11213	Cattle ranching and farming
11113-6, 11119	Grain farming	11212	Dairy cattle and milk production
1112	Vegetable and melon farming	1123	Poultry and egg production
11131-2,111331-4, 111336*, 111339	Fruit farming	1122, 1124-5, 1129	Animal production, except cattle and poultry and eggs
111335, 111336*	Tree nut farming	1131-2	Forest nurseries, forest products, and timber tracts
1114	Greenhouse, nursery, and floriculture production	1133	Logging
11191	Tobacco farming	1141	Fishing
11192	Cotton farming	1142	Hunting and trapping
11193, 111991	Sugarcane and sugar beet farming	115	Support activities for agriculture and forestry
11194, 111992, 111998	All other crop farming		
Oil, Gas & Other Mining			
211	Oil and gas extraction	21232	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying
2121	Coal mining	21239	Other nonmetallic mineral mining and quarrying
21221	Iron ore mining	213111	Drilling oil and gas wells
21223	Copper, nickel, lead, and zinc mining	213112	Support activities for oil and gas operations
21222, 21229	Gold, silver, and other metal ore mining	213113-5	Support activities for other mining
21231	Stone mining and quarrying		
Electricity, Gas Distribution, Water, Sewers			
2211	Electric power generation, transmission, and distribution	2213	Water, sewage and other systems
2212	Natural gas distribution		
Construction			
23*	Construction of new nonresidential commercial and health care structures	23*	Construction of other new residential structures
23*	Construction of new nonresidential manufacturing structures	23*	Maintenance and repair construction of nonresidential maintenance and repair
23*	Construction of other new nonresidential structures	23*	Maintenance and repair construction of residential structures
23*	Construction of new residential permanent site single- and multi-family structures		
Manufacturing			
311111	Dog and cat food manufacturing	33152	Nonferrous metal foundries
311119	Other animal food manufacturing	332111-2, 332117	All other forging, stamping, and sintering
31121	Flour milling and malt manufacturing	332114	Custom roll forming

188. North American Industrial Classification System (NAICS)

D. Continued NAICS Codes used for the Economic Impact Analysis

2007 NAICS	Sector Description	2007 NAICS	Sector Description
Manufacturing (Cont.)			
311221	Wet corn milling	332115-6	Crown and closure manufacturing and metal stamping
311222-3	Soybean and other oilseed processing	332211, 332214	Cutlery, utensil, pot, and pan manufacturing
311225	Fats and oils refining and blending	332212-3	Handtool manufacturing
311230	Breakfast cereal manufacturing	33231	Plate work and fabricated structural product manufacturing
311311-2	Sugar cane mills and refining	33232	Ornamental and architectural metal products manufacturing
311313	Beet sugar manufacturing	33241	Power boiler and heat exchanger manufacturing
31132	Chocolate and confectionery manufacturing from cacao beans	33242	Metal tank (heavy gauge) manufacturing
31133	Confectionery manufacturing from purchased chocolate	33243	Metal can, box, and other metal container (light gauge) manufacturing
31134	Nonchocolate confectionery manufacturing	332992-3	Ammunition manufacturing
31141	Frozen food manufacturing	332994-5	Arms, ordnance, and accessories manufacturing
31142	Fruit and vegetable canning, pickling, and drying	3325	Hardware manufacturing
311511-2	Fluid milk and butter manufacturing	3326	Spring and wire product manufacturing
311513	Cheese manufacturing	33271	Machine shops
311514	Dry, condensed, and evaporated dairy product manufacturing	33272	Turned product and screw, nut, and bolt manufacturing
311520	Ice cream and frozen dessert manufacturing	3328	Coating, engraving, heat treating and allied activities
311611-3	Animal (except poultry) slaughtering, rendering, and processing	332911-2, 332919	Valve and fittings other than plumbing
311615	Poultry processing	332913	Plumbing fixture fitting and trim manufacturing
3117	Seafood product preparation and packaging	332991	Ball and roller bearing manufacturing
31181	Bread and bakery product manufacturing	332996	Fabricated pipe and pipe fitting manufacturing
31182	Cookie, cracker, and pasta manufacturing	332997-9	Other fabricated metal manufacturing
31183	Tortilla manufacturing	333111	Farm machinery and equipment manufacturing
31191	Snack food manufacturing	333112	Lawn and garden equipment manufacturing
31192	Coffee and tea manufacturing	33312	Construction machinery manufacturing
31193	Flavoring syrup and concentrate manufacturing	33313	Mining and oil and gas field machinery manufacturing
31194	Seasoning and dressing manufacturing	33321, 333291-4, 333298	Other industrial machinery manufacturing
31199	All other food manufacturing	33322	Plastics and rubber industry machinery manufacturing
31211	Soft drink and ice manufacturing	333295	Semiconductor machinery manufacturing

D. Continued NAICS Codes used for the Economic Impact Analysis

2007 NAICS	Sector Description	2007 NAICS	Sector Description
Manufacturing (Cont.)			
31212	Breweries	333311-3	Vending, commercial, industrial, and office machinery manufacturing
31213	Wineries	333314	Optical instrument and lens manufacturing
31214	Distilleries	333315	Photographic and photocopying equipment manufacturing
3122	Tobacco product manufacturing	333319	Other commercial and service industry machinery manufacturing
3131	Fiber, yarn, and thread mills	333411-2	Air purification and ventilation equipment manufacturing
31321	Broadwoven fabric mills	333414	Heating equipment (except warm air furnaces) manufacturing
31322	Narrow fabric mills and schiffli machine embroidery	333415	Air conditioning, refrigeration, and warm air heating equipment manufacturing
31323	Nonwoven fabric mills	333511	Industrial mold manufacturing
31324	Knit fabric mills	333512-3	Metal cutting and forming machine tool manufacturing
31331	Textile and fabric finishing mills	333514	Special tool, die, jig, and fixture manufacturing
31332	Fabric coating mills	333515	Cutting tool and machine tool accessory manufacturing
31411	Carpet and rug mills	333516, 333518	Rolling mill and other metalworking machinery manufacturing
31412	Curtain and linen mills	333611	Turbine and turbine generator set units manufacturing
31491	Textile bag and canvas mills	333612	Speed changer, industrial high-speed drive, and gear manufacturing
31499	All other textile product mills	333613	Mechanical power transmission equipment manufacturing
31511, 31519	Apparel knitting mills	333618	Other engine equipment manufacturing
31521	Cut and sew apparel contractors	333911, 333913	Pump and pumping equipment manufacturing
31522	Men's and boys' cut and sew apparel manufacturing	333912	Air and gas compressor manufacturing
31523	Women's and girls' cut and sew apparel manufacturing	333921-4	Material handling equipment manufacturing
31529	Other cut and sew apparel manufacturing	333991	Power-driven handtool manufacturing
3159	Apparel accessories and other apparel manufacturing	333992, 333997, 333999	Other general purpose machinery manufacturing
3161	Leather and hide tanning and finishing	333993	Packaging machinery manufacturing
3162	Footwear manufacturing	333994	Industrial process furnace and oven manufacturing
3169	Other leather and allied product manufacturing	333995-6	Fluid power process machinery
3211	Sawmills and wood preservation	334111	Electronic computer manufacturing
321211-2	Veneer and plywood manufacturing	334112	Computer storage device manufacturing

D. Continued NAICS Codes used for the Economic Impact Analysis

2007 NAICS	Sector Description	2007 NAICS	Sector Description
Manufacturing (Cont.)			
321213-4	Engineered wood member and truss manufacturing	334113, 334119	Computer terminals and other computer peripheral equipment manufacturing
321219	Reconstituted wood product manufacturing	33421	Telephone apparatus manufacturing
32191	Wood windows and doors and millwork	33422	Broadcast and wireless communications equipment
32192	Wood container and pallet manufacturing	33429	Other communications equipment manufacturing
321991	Manufactured home (mobile home) manufacturing	3343	Audio and video equipment manufacturing
321992	Prefabricated wood building manufacturing	334411	Electron tube manufacturing
321999	All other miscellaneous wood product manufacturing	334412	Bare printed circuit board manufacturing
32211	Pulp mills	334413	Semiconductor and related device manufacturing
32212	Paper mills	334414-6	Electronic capacitor, resistor, coil, transformer, and other inductor manufacturing
32213	Paperboard Mills	334417	Electronic connector manufacturing
32221	Paperboard container manufacturing	334418	Printed circuit assembly (electronic assembly) manufacturing
322221-2	Coated and laminated paper, packaging paper and plastics film manufacturing	334419	Other electronic component manufacturing
322223-6	All other paper bag and coated and treated paper manufacturing	334510	Electromedical and electrotherapeutic apparatus manufacturing
32223	Stationery product manufacturing	334511	Search, detection, and navigation instruments manufacturing
322291	Sanitary paper product manufacturing	334512	Automatic environmental control manufacturing
322299	All other converted paper product manufacturing	334513	Industrial process variable instruments manufacturing
32311	Printing	334514	Totalizing fluid meters and counting devices manufacturing
32312	Support activities for printing	334515	Electricity and signal testing instruments manufacturing
32411	Petroleum refineries	334516	Analytical laboratory instrument manufacturing
324121	Asphalt paving mixture and block manufacturing	334517	Irradiation apparatus manufacturing
324122	Asphalt shingle and coating materials manufacturing	334518-9	Watch, clock, and other measuring and controlling device manufacturing
324191	Petroleum lubricating oil and grease manufacturing	334611-2	Software, audio, and video media reproducing
324199	All other petroleum and coal products manufacturing	334613	Magnetic and optical recording media manufacturing
32511	Petrochemical manufacturing	33511	Electric lamp bulb and part manufacturing
32512	Industrial gas manufacturing	33512	Lighting fixture manufacturing
32513	Synthetic dye and pigment manufacturing	33521	Small electrical appliance manufacturing

D. Continued NAICS Codes used for the Economic Impact Analysis

2007 NAICS	Sector Description	2007 NAICS	Sector Description
Manufacturing (Cont.)			
325181	Alkalies and chlorine manufacturing	335221	Household cooking appliance manufacturing
325182	Carbon black manufacturing	335222	Household refrigerator and home freezer manufacturing
325188	All other basic inorganic chemical manufacturing	335224	Household laundry equipment manufacturing
32519	Other basic organic chemical manufacturing	335228	Other major household appliance manufacturing
325211	Plastics material and resin manufacturing	335311	Power, distribution, and specialty transformer manufacturing
325212	Synthetic rubber manufacturing	335312	Motor and generator manufacturing
32522	Artificial and synthetic fibers and filaments manufacturing	335313	Switchgear and switchboard apparatus manufacturing
325311-4	Fertilizer manufacturing	335314	Relay and industrial control manufacturing
325320	Pesticide and other agricultural chemical manufacturing	335911	Storage battery manufacturing
325411	Medicinal and botanical manufacturing	335912	Primary battery manufacturing
325412	Pharmaceutical preparation manufacturing	33592	Communication and energy wire and cable manufacturing
325413	In-vitro diagnostic substance manufacturing	33593	Wiring device manufacturing
325414	Biological product (except diagnostic) manufacturing	335991	Carbon and graphite product manufacturing
32551	Paint and coating manufacturing	335999	All other miscellaneous electrical equipment and component manufacturing
32552	Adhesive manufacturing	336111	Automobile manufacturing
32561	Soap and cleaning compound manufacturing	336112	Light truck and utility vehicle manufacturing
32562	Toilet preparation manufacturing	336120	Heavy duty truck manufacturing
32591	Printing ink manufacturing	336211	Motor vehicle body manufacturing
32592, 32599	All other chemical product and preparation manufacturing	336212	Truck trailer manufacturing
32611	Plastics packaging materials and unlaminated film and sheet manufacturing	336213	Motor home manufacturing
326121	Unlaminated plastics profile shape manufacturing	336214	Travel trailer and camper manufacturing
326122	Plastics pipe and pipe fitting manufacturing	3363	Motor vehicle parts manufacturing
32613	Laminated plastics plate, sheet (except packaging), and shape manufacturing	336411	Aircraft manufacturing
32614	Polystyrene foam product manufacturing	336412	Aircraft engine and engine parts manufacturing
32615	Urethane and other foam product (except polystyrene) manufacturing	336413	Other aircraft parts and auxiliary equipment manufacturing
32616	Plastics bottle manufacturing	336414	Guided missile and space vehicle manufacturing
32619	Other plastics product manufacturing	336415, 336419	Propulsion units and parts for space vehicles and guided missiles

D. Continued NAICS Codes used for the Economic Impact Analysis

2007 NAICS	Sector Description	2007 NAICS	Sector Description
Manufacturing (Cont.)			
32621	Tire manufacturing	3365	Railroad rolling stock manufacturing
32622	Rubber and plastics hoses and belting manufacturing	336611	Ship building and repairing
32629	Other rubber product manufacturing	336612	Boat building
32711	Pottery, ceramics, and plumbing fixture manufacturing	336991	Motorcycle, bicycle, and parts manufacturing
327121-3	Brick, tile, and other structural clay product manufacturing	336992	Military armored vehicle, tank, and tank component manufacturing
327124-5	Clay and nonclay refractory manufacturing	336999	All other transportation equipment manufacturing
327211	Flat glass manufacturing	33711	Wood kitchen cabinet and countertop manufacturing
327212	Other pressed and blown glass and glassware manufacturing	337121	Upholstered household furniture manufacturing
327213	Glass container manufacturing	337122	Nonupholstered wood household furniture manufacturing
327215	Glass product manufacturing made of purchased glass	337124-5	Metal and other household furniture (except wood) manufacturing1
32731	Cement manufacturing	337127	Institutional furniture manufacturing
32732	Ready-mix concrete manufacturing	337129	Wood television, radio, and sewing machine cabinet manufacturing1
32733	Concrete pipe, brick, and block manufacturing	337211, 337212, 337214	Office furniture and custom architectural woodwork and millwork manufacturing1
32739	Other concrete product manufacturing	337215	Showcase, partition, shelving, and locker manufacturing
3274	Lime and gypsum product manufacturing	33791	Mattress manufacturing
32791	Abrasive product manufacturing	33792	Blind and shade manufacturing
327991	Cut stone and stone product manufacturing	339112	Surgical and medical instrument manufacturing
327992	Ground or treated mineral and earth manufacturing	339113	Surgical appliance and supplies manufacturing
327993	Mineral wool manufacturing	339114	Dental equipment and supplies manufacturing
327999	Miscellaneous nonmetallic mineral products	339115	Ophthalmic goods manufacturing
3311	Iron and steel mills and ferroalloy manufacturing	339116	Dental laboratories
33121, 33122	Steel product manufacturing from purchased steel	33991	Jewelry and silverware manufacturing
331311-2	Alumina refining and primary aluminum production	33992	Sporting and athletic goods manufacturing
331314	Secondary smelting and alloying of aluminum	33993	Doll, toy, and game manufacturing
331315, 331316, 331319	Aluminum product manufacturing from purchased aluminum	33994	Office supplies (except paper) manufacturing
331411	Primary smelting and refining of copper	33995	Sign manufacturing
331419	Primary smelting and refining of nonferrous metal (except copper and aluminum)	339991	Gasket, packing, and sealing device manufacturing

D. Continued NAICS Codes used for the Economic Impact Analysis

2007 NAICS	Sector Description	2007 NAICS	Sector Description
Manufacturing (Cont.)			
33142	Copper rolling, drawing, extruding and alloying	339992	Musical instrument manufacturing
33149	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying	339993, 339995, 339999	All other miscellaneous manufacturing
33151	Ferrous metal foundries	339994	Broom, brush, and mop manufacturing
Wholesale and retail trade			
42	Wholesale trade	447	Retail - Gasoline stations
441	Retail - Motor vehicle and parts	448	Retail - Clothing and clothing accessories
442	Retail - Furniture and home furnishings	451	Retail - Sporting goods, hobby, book and music
443	Retail - Electronics and appliances	452	Retail - General merchandise
444	Retail - Building material and garden supply	453	Retail - Miscellaneous
445	Retail - Food and beverage	454	Retail - Nonstore
446	Retail - Health and personal care		
Transportation			
481	Air transportation	486	Pipeline transportation
482	Rail transportation	487, 488	Scenic and sightseeing transportation and support activities for transportation
483	Water transportation	492	Couriers and messengers
484	Truck transportation	493	Warehousing and storage
485	Transit and ground passenger transportation		
Services & All Other			
51111	Newspaper publishers	6111	Elementary and secondary schools
51112	Periodical publishers	6112-3	Junior colleges, colleges, universities, and professional schools
51113	Book publishers	6114-7	Other educational services
51114, 51119	Directory, mailing list, and other publishers	6211-3	Offices of physicians, dentists, and other health practitioners
51121	Software publishers	6216	Home health care services
5121	Motion picture and video industries	6214-5, 6219	Medical and diagnostic labs and outpatient and other ambulatory care services
5122	Sound recording industries	622	Hospitals
5151	Radio and television broadcasting	623	Nursing and residential care facilities
5152	Cable and other subscription programming	6244	Child day care services
51913	Internet publishing and broadcasting	6241	Individual and family services
517	Telecommunications	6242-3	Community food, housing, and other relief services, including rehabilitation services
518	Data processing, hosting, and related services	7111	Performing arts companies
51911-2	Other information services	7112	Spectator sports
521, 5221	Monetary authorities and depository credit intermediation	7113-4	Promoters of performing arts and sports and agents for public figures
5222-3	Nondepository credit intermediation and related activities	7115	Independent artists, writers, and performers

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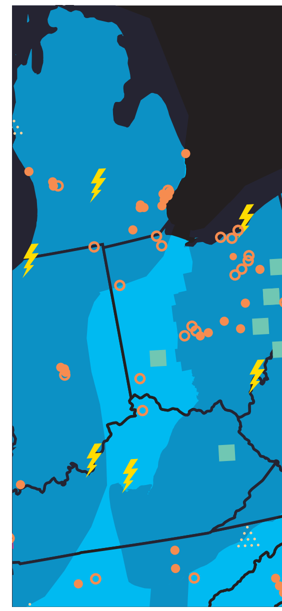

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